ACRP 03-50A
URBAN AIR MOBILITY: USE CASES AND APPLICATIONS

Task 4 Interim Report

Prepared for
Airport Cooperative Research Program
Transportation Research Board
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DISCLAIMER

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LIST OF ACRONYMS AND ABBREVIATIONS

AAM	Advanced Aerial Mobility
ACRP	Airport Cooperative Research Program
AIP	Airport Improvement Plan
ALP	Airport Layout Plan
APM	Automated People Mover
AV	Automated Vehicles
Caltrans	California Department of Transportation
CAMTS	Commission on Accreditation of Medical Transport Systems
CIP	Capital Improvement Program
CMF	Capability Maturity Framework
ConOps	Concept of Operations
CSF	Critical Success Factor
DEP	Distributed Electric Propulsion
DOT	Department of Transportation
EASA	European Union Aviation Safety Agency
eCTOL	Electric Conventional Take-Off and Landing
EPCRA	Emergency Planning and Community Right-To-Know Act
ESA	Endangered and Threatened Species Conservation Act
eVTOL	Electric Vertical Takeoff and Landing
FAA	Federal Aviation Administration
FATO	Final Approach and Takeoff Area
FBO	Fixed-Base Operator
GPS	Global Positioning System
ICAO	International Civil Aviation Organization
INS	Inertial Navigation System
IPP	FAA Integration Pilot Program
LAANC	Low Altitude Authorization and Notification Capability System
M2M	Machine to Machine
mph	miles per hour
MRO	Maintenance, Repair, and Overhaul
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NCDOT	North Carolina Department of Transportation

Next Gen	Next Generation Air Transport
NPIAS	National Plan of Integrated Airport Systems
NYCEDC	New York City Economic Development Corporation
OEM	Original Equipment Manufacturer
RAF	Required Action Framework
RAM	Regional Air Mobility
STOL	short takeoff and landing
sUAS	Small Unmanned Aircraft System
TM	Traffic Management
TNC	Transportation Network Company
TSA	Transportation Security Administration
TWG	Technical Working Group
UAM	Urban Air Mobility
USC	United States Code
UTM	UAS Traffic Management
VALE	Voluntary Airport Low Emissions
VHM	Vehicle Health Management
VTOL	Vertical Takeoff and Landing
WSDOT	Washington State Department of Transportation

CHAPTER 1: INTRODUCTION

This interim report presents combined findings for work performed as part of Tasks 1 through 4 of Airport Cooperative Research Program (ACRP) Project 03-50: *An Airport-Centric Study of the Urban Air Mobility Markets*. The report summarizes the motivations for Urban Air Mobility (UAM) for airports, a market assessment, and emerging use cases with a solid business case for airport applications. It provides assessment tools for airport operators to determine readiness for UAM, multimodal integration, and community outreach. It also describes a strategy for engaging with airport stakeholders to better understand their perspectives and their views of policy and planning considerations with regard to operational integration of UAM.

☛ *In this report, the term UAM is used in deference to the original title of the research project. It is meant to imply both UAM and Advanced Air Mobility (AAM).*

Background and Scope of the Interim Report

This project provides airport industry practitioners with information on the rapidly forming UAM movement and helps advise airports on items essential to preparing for this new industry. UAM, which is a subset of Advanced Air Mobility (AAM), has raised interest worldwide in providing a new mode of transportation that brings urban travel to the skies. The United Nations projects that over 68 percent of the world's population will live in urban areas by 2050 (United Nations, 2018). Concerns regarding climate change, greenhouse gases, traffic congestion, and frustration with current transportation systems have prompted extensive research and funding to help mitigate these issues.

Industry has long sought ways to address the widespread and complex problems of congestion, pollution, and access to efficient, convenient, and affordable transportation options. One such option, UAM, is poised to bring major benefits to the air transport and surface transport sectors. Technological advances in lightweight composites, sensors, microcomputers, advanced battery technologies, and electric motors have ignited a new revolution in UAM-based transportation, with the potential to change the way people live and work.

Because of the nascent and changing environment for UAM technology and the lack of fully implemented UAM use case scenarios, the research team performed an extensive literature research to document emerging technology, promising applications, and projected market opportunities (see the *Annotated Bibliography* section at end of this report). This literature review helped shape the contents of this task report and pointed to knowledge gaps that the team will attempt to fill as the research progresses through subsequent tasks.

Report Organization

The report includes eight chapters, references, and an annotated bibliography.

Chapter 1 (this chapter)—introduces the scope of the report and its organization.

Chapter 2—Discusses a market assessment of the UAM market for 2025 to 2035 and includes an overview of the motivation behind UAM and the proposed business cases.

Chapter 3—Discusses UAM business cases and implications and guidance for UAM integration, including tools for multimodal integration and community engagement.

Chapter 4—Discusses the motivation and primary use cases for UAM: Passenger, Air Metro, and Air Cargo. Applications and UAM aircraft operations for each use case illustrate the state of the industry worldwide. This chapter includes use case considerations for airports to help provide insight and practical guidance to airport industry practitioners.

Chapter 5—Provides a detailed impact assessment and opportunities for UAM at airports, focusing on the use cases for Passenger Air Mobility, Air Cargo, and Air Medevac.

Chapter 6—Provides planning strategies and considerations for integrating UAM into airports.

Chapter 7—Provides an overview of the Assessment Toolkit and instructions for use.

Chapter 8—Discusses future engagement efforts, a stakeholder engagement plan, a questionnaire, interview candidates, and technical working group members.

Annotated Bibliography—Discusses the research performed using existing research literature, generalist UAM papers, and airport-specific documents for this project.

CHAPTER 2: MARKET ASSESSMENT

Methodology

In conducting this market assessment, the WSP team first defined a set of guiding principles to ensure that rigorous methods are applied while reflecting practical considerations for nascent technology with undefined operating models and uncertain regulatory pathways.

The team established the following guiding principles for market sizing from prior case studies in nascent technology, including consumer technology, ridesharing, and mobile telephony:

1. **Markets are defined for use cases:** Market sizing should be informed by specific use cases – there is always a seller (e.g., flight service provider with specific routes) and a buyer (e.g., type of customer). Each market segment is therefore determined by the relationship between buyer and seller for a given use case.
2. **No single view of the world:** The unit of analysis is sized according to individual use cases, and each use case can be sized for multiple scenarios. Depending on customer adoption and other key "swing variables" and sensitivities, each use case can realize a downside, baseline, or upside scenario (as discussed further below). Practical planners will benefit by replacing individual opinion with objectively verifiable market assumptions regarding how the UAM airport market will take shape.
3. **Markets are segmented to provide bottom-up detail**. Each use case scenario is broken down into the most fundamental underlying components to get at the root of who is buying what service or product. To this end, the research team sizes original equipment manufacturer (OEM), operator, developer, security, maintenance, and service supplier segments. Furthermore, every segment is sized by use case for each scenario.
4. There are two inflection points, with pilot flights emerging in approximately 2025, followed by early scaling efforts in the runup to 2030. Every segment is sized by use case for each scenario, i.e., approximately 2025 and 2035. Airport planners can use these inflection points, driven by tangible differences in customer adoption, as real-life markers to prioritize budgets and adjust their operational plans as appropriate.
5. **Real markets have customers who are willing to pay**. The WSP research team avoids using top-down assessments based on aggregate math. All markets (nascent and mature) become tangible and real with volume (*how many customers*) and price (*how much customers might be willing to pay*).
6. **Adjacent industries are proxies**: As a starting point for key assumptions and uncertain variables, the research team seeks a foundational understanding of similar or adjacent industries and related technologies. Future developments in UAM may be uncertain, but related mature markets can provide useful models for study.
7. **Be transparent—if assumptions change, market sizing changes with it**. At its core, the market sizing model is robustly mathematical. All core factors (technology, consumer, regulatory) are shaped into quantifiable, measurable assumptions, each with a magnitude and metric.

Use Cases

Case 1: Air Metro

As the stated focus of ACRP 03-50 is the 2025–2035 period, the research is primarily interested in the Air Metro use case for passenger transport. Air Metro resembles existing public transit options (e.g., subways and buses) in that vehicles follow a predictable schedule of stops along predefined routes. Air Metro is distinguished from air taxis, where passengers hail pick-up services on demand and travel point to point. The air taxi market is briefly addressed later in this section as the literature uniformly views Air Metro as the initial passenger use case, and as a required bridge to air taxi in the longer term (2030–2040+).

To estimate sizes for various segments of the currently small-to-nonexistent Air Metro market, assumptions were required as inputs for rigorous bottom-up calculations. The research team developed the following assumptions for the Air Metro use case by considering existing UAM market literature, available data from industry stakeholders, and existing aviation standards (i.e., regulation and certification):

- Vehicle Assumptions:
  - *Capacity*: Vehicles are assumed to bear one to four passengers, reflecting a majority of existing designs (100+ concepts in development) and the constraints of likely electric propulsion.
  - *Autonomy*: Early vehicles are initially expected to be piloted, then transition to remotely piloted and increasingly autonomous operations, based on the current state of autonomy research and development and nascent certification procedures.
  - *Performance*: OEMs are estimated to target a useful range of 60 miles and cruising speed of 150 miles per hour (mph) for vehicles, citing the specifications desired by early industry conveners of the UAM vision.
  - *Cost*: The upfront cost per vehicle is anticipated to range between $280,000 and $481,000, as indicated by the early market data made available by several vehicle manufacturers.
- Operational Assumptions:
  - *Passenger Load*: Trips are expected to average a passenger load of three riders, as reported by market studies accounting for the shared route model of Air Metro.
  - *Recharging Time*: A battery recharging and or swapping time of 20 minutes is assumed, based on the desired specifications stated by early UAM vehicle operators.
  - *Mission Time*: A single mission is projected to take 64 minutes, calculated by combining estimated time spent in flight, passenger loading/unloading, and charging/battery swap times.
  - *Daily Trips*: Each vehicle is estimated to complete 11 missions per day, calculated by dividing an assumed 12 working hours per day using Visual Flight Rules by the estimated mission time.

- Route and Network Assumptions:
    - *Layout*: Routes for Air Metro are expected to take the form of a distributed hub and spoke model, according to existing UAM market studies.
    - *Scheduling*: Vehicles will operate with predictable service schedules along predetermined routes.
    - *Early Use Case*: A shuttle service between airports and city centers is believed by many industry stakeholders to be an early proving ground for Air Metro prior to reaching scale.
- Infrastructure Assumptions:
    - *Types*: At maturity, a distribution of small, medium, and large skyports with electric vertical takeoff and landing (eVTOL) capacities of one, four, and 12 landing pads, respectively, is assumed to service Air Metro. This understanding is based on current urban heliports.
    - *Components*: A skyport is expected to include concrete vehicle landing pads and charging stations, and, for larger stations, a passenger terminal, based on the current industry vision and existing heliports and small airports.
    - *Locations*: Early skyports may build upon existing infrastructure, such as the tops of parking garages or utilize open land near highway interchanges, according to concepts offered by early conveners of the UAM industry.
    - *Cost*: It is assumed that the cost to develop skyports will be analogous to heliport and industry development in urban areas and airports. This assumption must be modified by the components of skyports, such as all-electric charging stations, that must be appraised individually.

A Note on Air Taxis

The eventual Air Taxi use case will share many similarities with its predecessor, Air Metro. Due to the on-demand nature of air taxi service, the team has identified multiple points of differentiation from Air Metro:

- First, the team assumed a higher passenger load for Air Metro than for Air Taxi (average of three riders versus just one rider).
- Second, the team expects that Air Taxi will require a higher density of skyport infrastructure than will Air Metro, due to its vision of widespread door-to-door service.
- Third, it is anticipated that Air Taxi may only emerge as a viable use case upon the maturity of Air Metro, given the additional complexity of airworthiness certification and safety standards associated with the goal for Air Taxi to be ubiquitous—taking off, landing, and flying over a greater range of regions.

Case 2: Air Cargo

The study's scope for the Air Cargo use case is limited to last-mile delivery, as current industry trends and technological developments do not point toward long-haul cargo or heavy freight delivery being viable in the near term. Last-mile delivery refers to expedited on-demand delivery of a parcel by a small Unmanned Aerial System (sUAS) from a nearby distribution hub to a neighborhood receptacle.

The methodology that the research team used for closely analyzing the Air Cargo use case resembled that used for Air Metro. In conducting the analysis, the team again derived assumptions believed to shape the emerging Air Cargo (last-mile delivery) use case. The following assumptions about Air Cargo were developed from available market research estimates, data released by manufacturers and operators, Unmanned Aerial System (UAS) delivery pilot programs, and the existing Federal Aviation Administration (FAA) regulatory state:

- Vehicle Assumptions:
  - *Capacity*: Delivery payloads for sUAS are expected to be capped at 5 pounds, reflecting the current FAA regulations applied to UASs under Part 107.
  - *Autonomy*: Delivery vehicles are assumed to be remotely piloted or autonomous small unmanned, according to the early industry delivery pilot programs.
  - *Performance*: An average sUAS speed of 43 mph and 30-minute flying time per single charge was calculated by averaging the top speeds and flying times for available systems.
  - *Cost*: The average cost for a new delivery sUAS is assumed to be $3,000, from a source reporting on a major commercial delivery fleet.
- Operational Assumptions:
  - *Recharging Time*: Recharging time following each delivery is anticipated to be 60 minutes, according to commonly available sUAS models on the market.
  - *Delivery Distance*: Door-to-door roundtrip deliveries are assumed to fall within a 9-mile range and take 30 minutes or less, based on current industry estimates.
  - *Mission Time*: Cycle time of 95 minutes per delivery mission was determined by combining maximum delivery time, target recharging time, and loading/unloading time.
  - *Daily Trips*: A single sUAS is projected to complete on average 10 delivery trips per day, calculated by dividing estimated hours of operation (5:00 am to 10:00 pm) by mission time.
- Route and Network Assumptions:
  - *Scheduling*: Last-mile deliveries will be unscheduled, with routes being computed when an order is placed, based on the known plans of commercial sUAS delivery fleets.
  - *Early Use Case*: There is belief across the industry that rural delivery may see faster growth than urban due to a larger relative cost savings and flights over a lower density population.
- Infrastructure Assumptions:
  - *Types*: Delivery requires skyports at distribution hubs for loading and neighborhood receptacles for receiving and securing delivered parcels.
  - *Capacity*: Each skyport is assumed to house an average of 13 cargo pads, with each able to process up to 10 deliveries per hour. Further, it is assumed that each skyport maintains a fleet of 133 drones.

Case 3: Air Medevac

The Air Medevac use case is defined as future medical transport flights using vehicles such as hybrid-electric and electric Vertical Take-off and Landing jets (VTOL). Air Medevac's use of VTOL distinguishes it from the air ambulance market's use of a conventional helicopter to transport patients to the hospital for emergencies and occasional appointments. The team believes that Air Medevac with eVTOLs will be a viable substitute for helicopter services, and that over time the adoption rate of Air Medevac will grow (from 1–10 percent in 2025 to 10–50 percent in 2035).

Assumptions play a critical component in this study's bottom-up market assessment of the Air Medevac use case. Medical transport is held to higher standards than general passenger transport. Given the FAA's strict existing standards for the Commission on Accreditation of Medical Transport Systems (CAMTS) Air Ambulance accreditation, it is likely that Air Medevac will be held to a similar or even higher bar. Many of the following assumptions were derived from the wealth of publicly accessible information available from the mature air ambulance market, which the research team used as a proxy for Air Medevac:

- Vehicle Assumptions:
    - *Capacity*: Seating capacity for Air Medevac vehicles is expected to be larger than Air Metro, to accommodate a single patient, a pilot, multiple medical staff, and the associated patient care equipment.
    - *Autonomy*: Vehicles are expected to transition from being piloted in the beginning to remotely piloted or autonomous as the technology develops, but there will always be personnel in addition to the patient onboard.
    - *Crew Certification*: Based on existing air ambulance standards, it is assumed that each vehicle may require four full-time pilots, four full-time nurses, and four full-time paramedics to be certified annually.
    - *Cost*: The upfront cost per vehicle is anticipated to range between $280,000 and $481,000, as indicated by the early market data made available by several vehicle manufacturers.
- Route and Operational Assumptions
    - *Mission Components*: Air Medevac missions are categorized into three sub-missions: response, transport, and return, mirroring the existing air ambulance mission structure:
        - Response: time between the vehicle's initial dispatch and its arrival on scene
        - Transport: time from the vehicle leaving the scene to dropping off the patient at the medical center
        - Return: time from departing the medical center to arriving back at its station, in many cases including charging time.
    - *Mission Distance*: An average Air Medevac flight distance of 52 miles is used based on existing rotor air ambulance data for relatively shorter medical air transport trips.
    - *Mission Time*: Expected average mission time of 130 minutes, also taken from existing rotor air ambulance data.

    - *Recharging Time*: Projected range of recharging time is between 20 minutes (from research on battery-swapping) and 120 minutes (from available vehicle concept specifications).
- Infrastructure Assumptions
    - *Types*: Air Medevac is expected to utilize bases with terminals, which are expected to include four pads with two charging stations each, according to available market literature.
    - *Cost*: A single Medevac base is forecast to cost between $5.1 million and $10.5 million, based on estimated developmental costs for similarly sized rotor air ambulance operating bases.

Downside, Baseline, and Upside Model Assumptions

The market forecast three foundational scenarios: a downside case, a baseline case, and an upside case. This provides a more thorough market forecast that captures the inherent uncertainty in predicting the future. Each case is predicated on certain assumptions that have downstream effects on conclusions drawn from the model. In the forecast, these cases are used to perform an assessment for each segment of the market for two single-year periods: 2025 and 2035.

Downside Case

In the downside forecast, each segment is sized for every use case with a lower customer adoption or willingness to pay assumption. That is, either the volume or price (and in select cases, both) is more bearish than in the expected baseline or upside scenarios, and it can be assumed that obstacles to the implementation of UAM have been more prohibitive than anticipated. The downside case, therefore, represents the lower bound of the UAM market's potential size.

This has led to one or more several key assumptions:

- Technology has been slow to mature to an acceptable degree, driving up the per-unit price of various UAM services (the use cases) and thereby reducing demand.
- Regulatory groups have been reluctant or unwilling to work with industry and community stakeholders in developing new standards and guidelines, leading to reduced and delayed access to major markets, thereby reducing the volume of services available.
- Operations in 2025 are limited in scope to early-stage pilots in a small number of major cities, leading to low penetration in markets that the UAM industry is working to disrupt (e.g., urban passenger transportation).

Baseline Case

In the baseline case forecast, the research team provides a more realistic estimate of the UAM market volume and willingness to pay, predicated primarily on taking publicly available statements about the state of technology and policy at face value.

Using this model, several assumptions are outlined:

- OEM estimates of the readiness level of their vehicles are more or less accurate. Consequently, it is reasonable to assume that some operations will take place in 2025 and early-stage regulatory policies will be in effect to enable this market.
- Adoption rates of each use case for UAM will be similar to (and calibrated against) other novel technologies and paradigms that have been met with steady and gradual adoption when introduced to new markets.

Upside Case

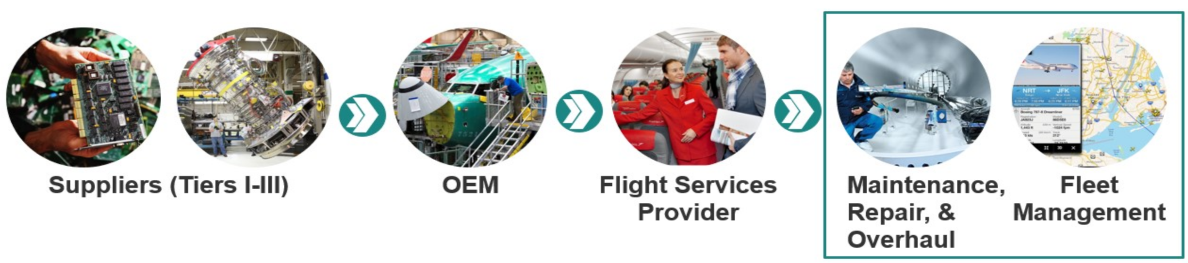
The final forecast scenario for each market segment, called the upside case, is sized to reflect that either the total volume of UAM access is higher than anticipated, the customer's willingness to pay is higher than expected, or both.

Several assumptions follow from this framework:

- UAM implementation begins in the very near term and, by 2025, has matured somewhat into a growing and ground-breaking new industry.
- Regulators, industry partners, community representatives, policymakers, and others have coalesced on a more-or-less shared vision of UAM implementation, and it has therefore enjoyed a smooth and popular rollout.
- Unlike many other nascent industries, major setbacks have been limited in scope or have been resolved quickly enough that neither the public nor regulatory groups have had cause to reduce customer demand (willingness to pay) or government-sanctioned access (volume).

In other words, in the upside case, technological hurdles have been surmounted, robust but fair regulatory policies have been implemented, and the public has been on board with UAM from an early stage. In the upside case, UAM market penetration is strong early on and grows even stronger with time.

The complete market for UAM can be segmented into several categories that, taken together, constitute the complete value chain (see Figure 1)



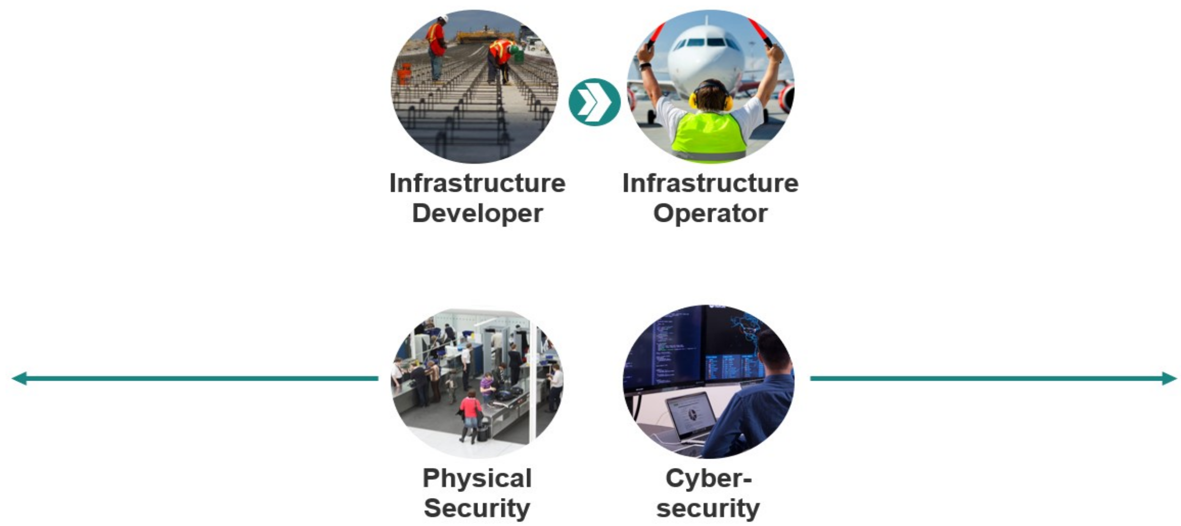


Figure 1. Market segments for the UAM value chain.

Segments are defined based on the value provided, who the customer is, and what each customer is typically willing to pay. For an airport, both the airport operator and the airline earn revenue based on operations conducted at the actual site. However, what distinguishes the operator from the airline is that the airline is a customer of the operator, whereas the airline's customers are the passengers. In this example, airlines are much more willing to pay airports for access than passengers are to pay airlines.

Original Equipment Manufacturers and Suppliers

Original equipment manufacturers, or OEMs, are the stakeholders in UAM responsible for the system integration and assembly of vehicles.

Because vehicle development is a costly and time-consuming process, and owing to the breadth of prospective eVTOL designers, the OEM market segment involves significant assumptions and justifications, such as the following:

- OEMs and suppliers have a limited role as vehicle developers despite some prospective OEMs who have announced interests in also providing flight services directly. The scope of this segment is vehicle sales.
- Because there is currently no high-volume production eVTOL or hybrid vehicle, some speculation is necessary regarding pricing structure. The team used three prices (a downside, baseline, and upside to match the business cases), based on prices of rotor-wing aircraft with comparable characteristics to anticipated VTOLs.
- Because this study examines market sizes across 2025 and 2035, the operating lifespan of VTOLs will be comparable to those of general aviation aircraft; a vehicle produced for 2025, for example, will likely still be in operation in 2035. The team accounted for this in determining the total number of vehicles for each time period.

The size of the OEM market is expected to grow substantially in all cases between 2025 and 2035, with a 2025 base level air passenger (air taxi and metro) market size of 110 million dollars, which is expected to swell to nearly 18 billion dollars by 2035 (Table 1). By contrast, the Air Cargo market is expected to be more substantial in the near term (2025) but grow at a more moderate pace as it assumes a greater share of the parcel delivery market.

Table 1. OEM and supplier market assessment (in millions of USD).

	2025			2035		
	Downside	**Baseline**	**Upside**	**Downside**	**Baseline**	**Upside**
Air Metro	55–60	110–120	275–300	910–940	2,300–2,400	4,500–4,700
Air Cargo	1,000–1,020	1,900–2,000	3,900–4,100	590–600	1,000–1,100	1,700–1,800
Air Medevac	5–7	30–35	95–100	18–22	60–70	290–300

Infrastructure Developers

Necessary infrastructure for vehicles, drones, passenger intake, and support staff consists of a wide variety of buildings servicing mission-specific elements of UAM. Such infrastructure must include, at minimum, the following:

- Skyports, from which passengers will arrive and depart.
- Cargo loading facilities designed for automated missions.
- Terminal buildings for passenger screening and pre-processing.
- Facilities for dedicated traffic monitoring, communications, and navigation equipment.

For infrastructure developers, Air Cargo will be the dominating UAM use case in the next decade, with a downside estimate of $14 billion in 2025 and $32 billion by 2030 (Table 2).Table 2). In contrast, for the same scenarios and years, Air Metro will grow from $100 million to $1.8 billion, and Air Medevac will incrementally grow from $10 million to $36 million.

Table 2. Infrastructure developer market assessment (in millions of USD).

	2025			2035		
	Downside	**Baseline**	**Upside**	**Downside**	**Baseline**	**Upside**
Air Metro	100–150	210–220	560–570	1,800–1,900	4,900–5,000	9,900–11,000
Air Cargo	13,900–14,100	24,000–26,000	50,000–53,000	30,000–33,000	57,000–60,000	125,000–130,000
Air Medevac	10	69	253	36	138	768

What largely drives this marked difference is that Air Cargo, which uses drones rather than human-carrying vehicles, faces far less regulatory uncertainty. Drone cargo delivery pilot programs have already begun in several countries and U.S. states and are much more likely to take over large portions of the cargo delivery model by 2025 than Air Metro is to revolutionize passenger transport. As Air Cargo will likely be a much larger market by 2025, building the necessary support infrastructure will require much more investment.

Although UAM is a novel industry, construction and building for aviation are not. The research team based its assumptions for infrastructure development on the following existing parallels:

- Takeoff/landing pads required for skyports will be functionally analogous to existing helicopter pads, whose dimensions and requirements the FAA specifies and whose construction costs are well established.
- Because UAM will likely be initially limited to specific geographies that are currently unknown, the team used median nationwide construction costs (e.g., materials, labor) that will affect the market pricing scheme.
- The downside, baseline, and upside market scenarios are predicated on determinations of the volume of UAM traffic in each time period, as well as the capacity of vehicle trips each skyport can support. The latter assumption will depend on the recharge time of production vehicles and regulatory requirements.
- Construction costs for UAM infrastructure will be analogous to those associated with current aviation infrastructure. The cost of a terminal building for a small, regional airport (with passenger capacity similar to that of expected UAM skyports) will be comparable to that of a terminal for UAM.

Infrastructure Operators

As in other industries, infrastructure operators for UAM sit at the nexus of public-facing business-to-business and business-to-customer operations. Like airline operators, UAM infrastructure operators are responsible for running and maintaining the facilities from which passenger and cargo operations will be run. Their responsibilities may include:

- Passenger terminal organization, upkeep, and maintenance.
- Management of arrival/drop-off zones and vehicle storage.
- Maintenance and operation of support infrastructure (e.g., surveillance equipment).
- Passenger and cargo security screening.

As with the infrastructure developer segment, the use case for the infrastructure operator segment is consistently the largest in the Air Cargo market. For all scenarios and time periods, the Air Cargo infrastructure operator market is one to several orders of magnitudes larger than Air Metro or Air Medevac.

In the baseline scenario (Table 3), the Air Cargo market will reach nearly $2 billion by 2025 and just over $4.5 billion by 2035. In contrast, Air Metro's and Air Medevac's infrastructure operator sizes at the same two points in time will be $14 million and $33 million in 2025 and $320 million and $65 million, respectively.

Table 3. Infrastructure operator market assessment (in billions of USD).

	2025			2035		
	Downside	**Baseline**	**Upside**	**Downside**	**Baseline**	**Upside**
Air Metro	.0070	.014	.035	.13	.32	.63
Air Cargo	.58	1.96	4.91	1.32	4.62	11.92
Air Medevac	.0059	.033	.098	.021	.065	.30

Air Cargo is forecast to begin and mature earlier than Air Metro and Air Medevac, largely as a response to the lower regulatory barrier for drone package delivery than for passenger-carrying flights. This principal assumption explains the high-level takeaway from Table 3, but several additional assumptions include:

- Passenger skyports will include facilities across a range of sizes and traffic capacities: 30 percent of skyports will be single-pad, 50 percent will have four pads, and 20 percent will have 12 pads.
- Air Metro skyport operator revenue can be triangulated by examining airport revenue per-passenger for various services (e.g., parking, concession, airline fees), airport fees from ridesharing services, and airport customer fees.
- Air Cargo infrastructure operators' share of cargo revenue is similar to distribution hub operators for existing package delivery service.
- The volume of Air Cargo infrastructure operators is based on the forecasted package delivery volume, ignoring specific geographical requirements.
- Air Medevac base operator revenue will be functionally identical to existing air ambulance base operator shares of industry revenue.
- Air Medevac adoption rates are predicated on operational cost savings of VTOL aircraft compared to traditional helicopters.

Flight Service Providers

Flight service providers are responsible for interfacing with revenue-generating customers to service their various transportation needs, including:

- Transporting paying passengers along pre-planned routes (Air Metro).
- Last-mile delivery of small parcels on demand (Air Cargo).
- Emergency medical transport to treatment facilities (Air Medevac).

Given the anticipated growth in volume of online retail sales over the next decade and the forecasted delivery savings that drone delivery offers, the team projects significant revenue and growth for Air Cargo flight service providers. The baseline forecast shown in Table 4 indicates a projected market size of nearly $12 billion in 2025, which will more than double to nearly $28 billion in 2035, as a result both of growth in parcel delivery demand, and of the drone delivery market taking a larger portion of that demand.

Similarly, the team anticipates rapid growth in Air Metro flight service between 2025 and 2035, growing from $110 million to $2.5 billion. The baseline case includes a more modest growth in Air Medevac, from $400 to $800 million. For Air Medevac, the more stable market for air ambulance services in the United States, which are largely a function of population, drives growth.

Table 4. Flight service provider market assessment (in billions of USD).

	2025			2035		
	Downside	**Baseline**	**Upside**	**Downside**	**Baseline**	**Upside**
Air Metro	.054	.11	.27	.97	2.46	4.83
Air Cargo	8.32	11.73	18.54	18.88	27.58	44.98
Air Medevac	.028	.40	1.18	.14	.80	3.53

The following model assumptions, developed through existing research into market trends and underlying market limitations, for each use case's flight service provider market assessment, heavily incorporate expected changes in demand:

- Per-passenger pricing for Air Metro will remain relatively fixed over the examined time period and will be set at rates slightly above existing ridesharing per-mile fares.
- The team calibrated ticket revenue for flight service providers by indexing publicly available ticket revenue data against transportation volume.
- The team based Air Cargo market projections on forecasts by Morgan Stanley regarding differences in expected adoption rates for urban and rural drone-based parcel delivery.
- Conventional air ambulance trip prices are heavily dependent on fluctuations in aviation fuel. The relatively stable price of electricity implies that Air Medevac trip pricing will be more consistent.
- The per-flight cost charged to customers of Air Medevac will depend both on insurance/Medicare reimbursement and on the costs associated with personnel and equipment (e.g., onboard medical staff, consumable medical supplies).

Maintenance, Repair, and Overhaul

Maintenance, repair, and overhaul (MRO) is broken out into its own segment in this report. This segment, which comprises the processes and activities involved in maintaining a fleet of transportation service vehicles, may function differently in a UAM context than in legacy industries. Owing in part to the specialization of technologies developing for UAM, as well as to the forecast "distributed" nature of UAM, MRO services may be fulfilled by third-party service suppliers, thus constituting their own market.

In the baseline scenario for MRO in 2025, shown in Table 5, Air Metro and Air Cargo have markets sized at just over $500 million apiece, compared to Air Medevac, which is expected to be a bit short of $20 million. However, just 10 years later, in 2035, both Air Metro and Air Cargo increase to nearly $2 billion and just over $1 billion, respectively, while Air Medevac will double to around $35 million.

Although Air Cargo will likely be adopted more quickly than passenger-carrying use cases, the significant increase in complexity between vehicles that carry passengers and the drones that carry cargo is the primary driver in per-vehicle MRO costs. As a consequence, despite disparities in their overall market sizes, the Air Metro use case will have a disproportionately large MRO market.

Table 5. Maintenance, repair, and overhaul market assessment (in billions of USD).

	2025			2035		
	Downside	**Baseline**	**Upside**	**Downside**	**Baseline**	**Upside**
Air Metro	.13	.50	.75	1.41	1.98/	2.54
Air Cargo	.36	.51	.81	.82	1.20	1.96
Air Medevac	.0012	.017	.051	.0060	.035	.15

Similar to the discussion of Infrastructure Developers, above, strong real-world parallels exist between the MRO likely required for UAM and that required in adjacent industries such as commercial aviation. Therefore, assumptions for this section heavily leverage publicly available information about these industries, and include:

- Calculate the size of the UAM MRO market by determining the range of MRO costs incurred by major airlines as a percentage of their total revenue and scaling that to the expected overall size of the UAM services market.
- Calibrate the size of the drone cargo market by calculating the percentage of airlines' MRO costs. Also use published estimates of individual drone repair costs and scale them up to the size of the drone cargo delivery market.
- Publicly traded air ambulance corporations have published annual MRO and revenue figures. Compare the airline MRO costs mentioned in the previous two points to triangulate the anticipated Air Medevac MRO costs.

Fleet Management

Fleet management encompasses operational logistics and management of vehicles, excluding procurement and maintenance. The oversight of deployed vehicles is crucial for maintaining safe UAM operations and ensuring mission completion. To ensure that vehicle operators are tracking pertinent vehicle data, it is necessary to have both a robust software system and employees tasked with monitoring operations. Both fleet operators and regulatory entities are involved in this segment of the market. Regulatory bodies must set certification and licensing standards to enable fleet managers to engage in UAM operations. Fleet management includes:

- Ensuring continual airworthiness (all use cases)
- Operator certification and licensing (all use cases)
- Operations management and tracking vehicle data (e.g., monitoring vehicle energy use)
- Vehicle health and safety monitoring
- Fleet logistics

The fleet management market segment is expected to be relatively small due to the smaller staffing requirements and the low cost of management software (see Table 6). Adjacent industries with fleet management and logistics departments show that limited staff is needed to conduct management operations.

Table 6. Fleet management market assessment (in USD).

	2025			2035		
	Downside	**Baseline**	**Upside**	**Downside**	**Baseline**	**Upside**
Air Metro	$104,353	$162,313	$654,193	$404,963	$1,800,766	$9,792,812
Air Cargo	$108,519,000	$190,699,200	$400,229,700	$235,198,500	$434,660,100	$952,443,600
Air Medevac	$471,593.6	$859,487	$1,749,360	$768,218	$1,338,649	$4,533,065

The Air Metro and Air Medevac use cases reflect lower valuation figures than the Air Cargo use case because of the large difference in predicted fleet sizes. Air cargo operations will reach larger adoption rates at earlier stages, so substantial fleet operation and logistics costs are expected:

- Estimated Air Metro fleet management labor costs use employment numbers from the Washington, D.C., public transit system financial records. Labor needs and costs for fleet management for ground-based public transit serve as a proxy for the UAM Air Metro ecosystem.
- UAM Air Metro Fleet Maintenance labor costs can be calculated by determining the range of operational labor costs incurred by a major public transit system (e.g., Washington Metropolitan Area Transit Authority) as a percentage of their total revenue and scaling that to the expected overall size of the UAM Air Metro market.
- After determining the estimated fleet management labor values, the cost of fleet management equipment can be determined by multiplying the cost of fleet management software and hardware per vehicle by the number of vehicles for UAM Air Metro determined in the Air Metro OEM segment analysis.
- The costs of the labor and the fleet management equipment can be added together for each Air Metro case and timeframe to produce the total estimated fleet management segment valuations.
- The value of the fleet management segment for Air Cargo was determined by discussing costs with current fleet management service providers geared toward sUAS operations and multiplying their per-vehicle fleet management cost estimates by the number of Air Cargo vehicles calculated for the given years and cases.
- The WSP team considered the current value of air ambulance services to be similar to the values associated with UAM-conducted Medevac operations, for lack of a better valuation.
- After determining air ambulance logistics and labor costs on a per-trip basis, the team multiplied the per-trip payroll by the number of estimated flights.

Physical Security

Protecting physical technologies and ensuring passenger safety are both involved in establishing comprehensive physical security. The platforms used to operate and monitor physical infrastructure are quite similar across markets. Therefore, it is likely that physical security measures will be adopted from adjacent industries (e.g., general aviation). Physical security includes:

- Passenger screening and ensuring onboard passenger cooperation
- Protecting physical infrastructure from tampering and vandalization
- Having an operating system that monitors physical UAM infrastructure and technologies

After assessing the literature, the team determined that physical security differences between Air Metro, Air Cargo, And Air Medevac could not be distinguished in a meaningful way. The value of the physical security market segment for Air Metro is relatively low due to the estimated number of trips in the early adoption phase (Table 7). Even in the upside case in both 2025 and 2035, the limited number of trips for the Air Metro use case does not provide a clear picture of the amount of physical security and related infrastructure needed.

Table 7. Physical security market assessment (in USD).

	2025			2035		
	Downside	**Baseline**	**Upside**	**Downside**	**Baseline**	**Upside**
Air Metro	$247,358	$494,715	$1,236,788	$4,947,152	$7,420,728	$12,367,880
Air Cargo	--	--	--	--	--	--
Air Medevac	--	--	--	--	--	--

Note: "--" indicates that the field is not applicable.

Physical security does not represent a large portion of the value chain, particularly at early stages of the market. In addition, the role of physical security in the Air Cargo and Air Medevac use cases, in all scenarios, was found to be too low for meaningful analysis. However, the development and implementation of physical security infrastructure and procedures could have a larger impact for airports than for other UAM destinations, given the predicted high traffic volume.

- Estimates for physical security expenses were based on the figures in the Port Authority of New York and New Jersey 2018 budget report, which provided proxies acceptable for UAM Air Metro physical security estimates.
- The total amount spent on physical security by the Port Authority was converted to a cost of security per trip basis.
- The cost of security per trip was then multiplied by the estimated number of UAM trips calculated in the OEM Air Metro sheet.

CHAPTER 3: BUSINESS CASE AND IMPLICATIONS FOR AIRPORTS

The market assessment shows significant potential for UAM to be an economic driver at smaller general aviation and regional airports. UAM could bring back operations these airports may have lost when carriers reduced their flights and routes, and they could once again provide or create new air service to their communities on a larger scale than was possible before. The issue lies in how to facilitate the needed infrastructure to support UAM operations. Key areas that must be addressed are:

- Funding
- Vertiports
- Charging facilities
- Ground support equipment
- Cargo facilitation
- Changes to lease agreements
- Last-mile transportation facilitation
- Weather systems
- Land use
- Noise

Another issue that must be considered in the business case for UAM is that larger airports may not have the capacity to facilitate new operations without innovative solutions. If they are already at capacity with their current operations both for land use and airspace, it may be difficult to bring in additional aircraft with less passenger capacity. Parking facilities may be an untapped resource for creating vertiports to better integrate with other modes of transportation to create a transportation node. OEMs indicate a positive outlook regarding the ability to coexist with and not disrupt current operations. This leaves capability for larger hubs, as well as utilizing reliever airports or nearby vertiports with an efficient means to transport passengers between locations. For UAM to work efficiently, it must be integrated into a multimodal system.

Multimodal Integration

Seamless mobility connections are essential for people arriving at the airport and traveling to their destinations. UAM users will expect airport infrastructure to support and provide multiple mobility options, reduce delays when shifting from one mode to another, and ensure reliable mobility. The mobility options that must be considered are personal transportation, transit, micro-transit, and other shared mobility or automated shared mobility, each with multiple modal connectivity options. The mobility options could include electric vehicles, automated vehicles (AVs), or connected vehicles that are personal or shared. Electric micro-mobility options include e-scooters, e-mopeds, and e-bikes.

Emergency personnel traveling by themselves or with their equipment require different modal choices; their goal is to get their destination quickly and safely, with little or no room for error. The mobility needs of emergency personnel are different. The airport mobility options must support their unique needs. Transit and micro-transit vehicles are typically owned and operated by local transit agencies, while the other shared mobility services are owned and operated by private companies. To provide the users with seamless mobility options, coordination between the airport, transit agencies, and private mobility providers is essential.

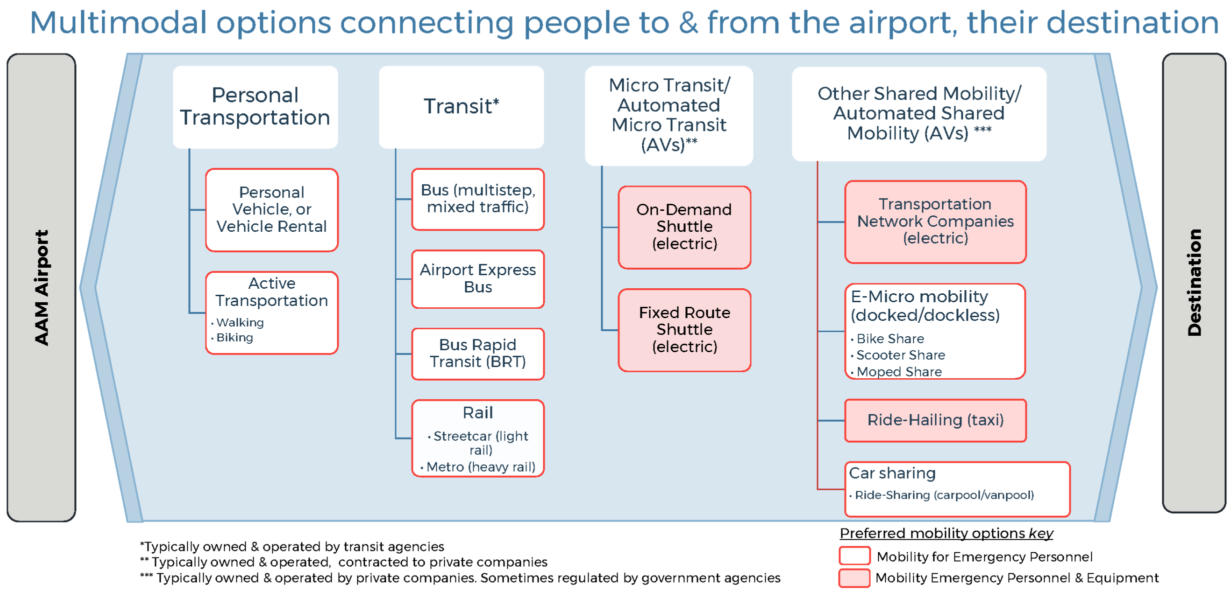


Figure 2. Multimodal options connecting people to and from the airport, their destination.

Planning for Infrastructure to Support Multimodal Options

To identify the appropriate infrastructure necessary to support users' multimodal needs, it is first necessary to understand the larger context of those needs. For example, the importance of time for the user (e.g., are they dealing with an emergency?) and their comfort level in using different mobility options will inform their mobility choices.

Early infrastructure planning should consider the mobility and accessibility needs of people of all ages and abilities. Community input on mobility needs must be solicited during the early mobility planning phases through outreach and engagement. Inclusive design such as multi-lingual mobile application and street signage, accessible application for the cognitively disabled, call-a-ride alternatives to a mobile application, and other accommodations must be incorporated.

Airport infrastructure must support evolving user demand, consumer trends, and expectations and reflect the surrounding context—urban, suburban, or rural. Taking the airport context into consideration will ensure that the planned infrastructure is fiscally sustainable while meeting user demand and needs. The recommended mobility modes based on the airport context (see Figure 3).

Once the appropriate and necessary infrastructure at an airport is identified, the airport must coordinate with transit agencies and private mobility providers. Then, the airport must work to implement both offsite improvements like traffic signals and onsite improvements like dedicated curb space, a multimodal transfer facility, and electric charging facilities for electric micro-mobility and other electric vehicles. Targeted investments in surrounding communities using community feedback as a guide will help achieve equitable outcomes.

Integrated mobility services and payment platforms with the option to reserve or book services ahead of time from the point of origin to destination will provide seamless mobility, which is both expected and desired by both emergency and non-emergency AAM users. Targeted education and outreach to the surrounding community, particularly in low-income and disadvantaged communities, will reduce entry and adoption barriers to new mobility options and integrated technology.

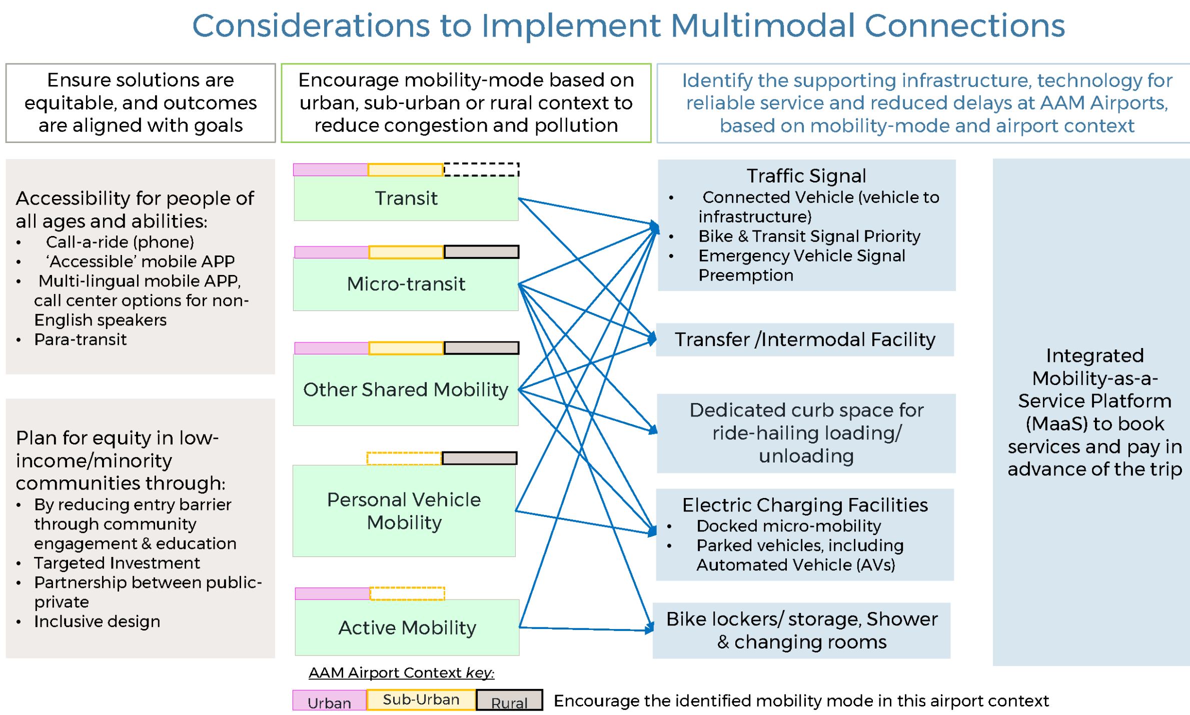


Figure 3. Considerations to implement multimodal connections.

Implications and Guidance for UAM at Airports

Other considerations include planning for UAM package deliveries from both medical and other sources. These may require additional security, storage, and handling procedures. Routing these deliveries on the ground and air on a mass scale without conflicts with other users in the same airspace may also require innovative solutions. The scale of package deliveries, and the size of the system required to support it, could be staggering. It is estimated that a city the size of Los Angeles has approximately 250,000 packages delivered per day. Furthermore, UPS has reported a total package delivery amount of approximately 18.3 million deliveries per day in the US (Lohn, 2017). While not all these packages would be delivered by UAM, it illustrates the scale for potential package delivery and the complexity of integration between all users in the airspace and at airports.

With all the possibilities for UAM at airports, an essential consideration is funding. Many airports struggle to find adequate funding for additional projects beyond pavement maintenance. UAM must include an associated mechanism to capture additional revenue streams to support the needed infrastructure. Additional revenue can come from the increased airport operations, drawing on concessions, charging fees, user fees, and landing fees. Public-private partnerships may be another option. OEMs indicate that fully private funding is a viable option to begin operations for airports that fit their business needs. Many airports have had success with these models. However, it is imperative to fully consider the legal and other implications when entering into these agreements, such as:

- Responsibilities for safety, security, and economic oversight
- Risk evaluation

- Revenues and differing regulations surrounding each
- Increase in user fees
- Environmental issues
- The particular public-private partnerships model for:
    - Management
    - Concession
    - Privatization
    - Developer Financing

Changes to state and federal programs to support UAM may be another viable option for funding. The most likely option for funding infrastructure will be a combination of multiple funding sources. Regardless of funding, the research team identified the following additional considerations that are essential to evaluate in the near term to determine their capabilities to support UAM operations:

- Space constraints and availability to build new facilities
- Long-term lease agreements not favorable to new operations
- Changes in existing lease agreements
- Time and funding to redevelop the property to accommodate the demand for UAM operations
- Land-use analysis based on economic development potential
- Project benefit analysis
- Staffing requirements
- Procurement requirements
- Contractual authority to procure services
- Federal, state, and local regulation review regarding UAM operations
- Business model structure for the airport to support current and future changes

The UAM industry is continually evolving. Changing regulations, vehicles, operational requirements, maintenance, and existing infrastructure create a challenging environment in which to plan and build new infrastructure. Noise, zoning, land use restrictions, and current lease agreements may also slow down progress for airports. Although UAM has a large amount of momentum, airports face a significant risk associated with the loss of revenue from fuel taxes. A self-sustaining airport system requires a revenue collection system. Potential methods to collect such revenue include electrical generation from solar farms or other green technologies, sub-metering electricity, user fees, landing fees, or a combination of those methods. Smaller airports also have the potential to serve as a micro-grid, ground transportation vehicle charging multimodal hub for the community, which could bring jobs and revenue to the airport.

Safety and noise pollution are significant risks for airports. The prospect of manned and unmanned aircraft operating in close proximity raises the risk to safety and hence the demand for an entirely new approach for air traffic management. Noise footprints, even for eVTOL-enabled aircraft, will need to be examined carefully, especially in urban operations.

Other implications include insurance demands for a new industry. Because insurance is risk-averse, and without precedence for UAM, it is hard to determine an appropriate rate to charge for a policy. Lack of precedence will result in higher rates until the industry can determine an appropriate risk model.

Guidance for Operators to Maintain Engagement with Industry and Community Stakeholders, Including Key Messages

Existing UAM literature highlights the importance of community buy-in for successful UAM integration. This includes the public at large, whom the UAM industry must convince of the value of urban air transportation and its safety, as well as the community of aviation stakeholders, who already hold a high degree of public acceptance. Further, the literature suggests that community outreach may be a critical part of near-term UAM planning, as early Air Cargo operations are already underway in the United States. Major community integration issues include noise impact and mitigation, business development opportunities, land use provisioning, potential environmental considerations, and public comfort with UAM vehicles and flights. Disseminating information and managing expectations will engage the public and help to communicate the true aspects and opportunities UAM brings to their community.

Community engagement is a field that is constantly changing. With the rise of digital engagement strategies (as evidenced in 2020 alone) comes new and expanded opportunities to reach populations, raise awareness, and garner feedback. From virtual meetings to online survey software, advanced presentation materials, and many other emerging tools, the opportunities for public engagement are unprecedented. Despite such technological advances, however, the main focus of community engagement remains the same. It is, and has always been, about sitting down at the table (whether in person or virtually) with members in a community, sharing information on an initiative, and listening to how others may be impacted to better mitigate issues and risks, as well as even improve the initiative based on that feedback. Further, community engagement methods are (at the time of this writing), required to be multi-dimensional, combining traditional public outreach e.g., in-person townhalls, newspaper notices, and fliers, with more innovative and emerging outreach efforts (e.g., virtual meeting rooms, online surveys), to best serve all populations regardless of geographic location, culture, background, and technological prowess.

Community engagement should be nimble throughout all phases of UAM development, tailoring the approach to the targeted community, individual airport capabilities (whether hub, reliever, or general aviation), and the proper stage of UAM implementation. In addition, a Community Engagement Plan should be developed that allows for the incorporation of new methods and technologies as the years progress. This concept of "building the airplane as we fly" mirrors the possibility (and the unknowns) surrounding UAM. Various messaging examples are provided in Table 8, Table 9, and Table 10.

General Messaging Examples

Table 8. General messaging examples - community.

Examples of Potential Issues Perceived by the Community	Examples of Key Response Messages
Noise Visual disturbance (e.g., lack of acclimation to seeing increased aircraft overhead) Privacy concerns (e.g., data security, lower-altitude overhead views of properties)	1. The safety and security surrounding UAM is of utmost concern to all parties involved. All aircraft and activities will be regulated and approved for safety, privacy, and security by the FAA, in line with current aviation standards.

Examples of Potential Issues Perceived by the Community	Examples of Key Response Messages
Safety (e.g., passenger safety, crash safety for those on the ground) Environmental (e.g., impacts to wildlife, especially bird and flying insect migration or movement) Equity concerns (e.g., affordability and neighborhood flight patterns) Time-tradeoffs lacking/first- and last-mile issues (e.g., inefficiencies such as long security lines between passenger drop-off and terminal)	2. Accessibility and equity will greatly improve over time. Ensuring the early success of UAM will pave the way for larger-scale aspirations and affordability.

Table 9. General messaging examples - stakeholders

Examples of Potential Issues Perceived by Key Stakeholders	Examples of Key Response Messages
Airports Air congestion concerns Lack of electrical or other infrastructure capabilities/cost to retrofit Security concerns Staffing shortfalls (e.g., new skills, training)	1. UAM operators have no desire to affect current aviation practices, and many opportunities exist for UAM operations on unused or offsite locations. 2. The financial responsibility of upgrading infrastructure will not be solely the airport's responsibility. There is a large role for private investment in the improvements needed for UAM operations and an expectation that operators will contribute to the financial improvements needed.

Examples of Additional Messaging for Specific Use Cases

Table 10. Specific messaging – use cases.

Airport Type	Use Case	Key Messaging
Hub	Air Passenger Mobility	Travelers can reduce their commute times to major airports or activity centers; using UAM can also decrease the risk of missing a flight that can arise when driving the long distances often required to reach a Hub facility.
General Aviation	Emergency Services	UAM allows more remote communities or destinations a much stronger connection to lifesaving resources, whether the quick response UAM offers as an ambulatory service or the ability to quickly get help on the scene of an emergency.

Airport Type	Use Case	Key Messaging
General Aviation	Package Delivery	People living in a more rural community can receive their packages in less time than they have been accustomed to. Instead of days for delivery, it could be 30 minutes to an hour.
General Aviation	Air Passenger Mobility	Living a remote lifestyle should not mean you have to sacrifice quality healthcare. UAM can bring doctors and medical supplies to a community in need with much more frequency and greater ease.
General Aviation	Air Passenger Mobility	For underutilized airports, especially those in more rural or remote settings, a lack of activity is a threat to longevity and prosperity. UAM provides many opportunities for the reinvigoration of existing assets.
Hub	Package Delivery (Medical)	Utilizing UAM for transport of time-sensitive medical cargo that comes off long-haul flights (e.g., organs for transplant) allows a quick departure from a busy hub airport and ensures efficient delivery to the major hospital performing the transplant.
Reliever	Package Delivery	UAM can further the mission of reliever airports in reducing air traffic congestion by easing the distribution of parcels arriving on cargo flights, thereby increasing the number of cargo flights that can land at reliever facilities.

Objective and Strategies To mitigate different types of risk and ensure UAM's success, it is critical that a team comprised of those responsible for implementation and communications (Implementation/Communications Team) proactively update and inform the community and be responsive to stakeholders at every step. The most effective public information program anticipates and responds to stakeholders' information needs, concerns, and desires. Successful execution is critical to establishing credibility and generating public trust. A proactive community engagement effort will ensure that affected communities and stakeholders are provided with the information they need to trust the safety measures, understand the benefits, and accept the presence of UAM in their lives. Strategies to achieve these objectives include:

- Consistent Communication - The Implementation/Communications Team should commit to frequent and honest communication, disseminating accurate and easy-to-understand information in multiple languages through the organization's appropriate channels. Public safety and mitigating impacts are key components of all communication.

- Collaboration - Involving various community groups, Transportation Network Companies (TNCs), elected officials, utility companies, and other key stakeholders with the airport's planning process will foster a partnership mentality and potentially result in increased economic opportunity for the region, making UAM even more viable.
- Leverage Community Connections - The Implementation/Communications Team will reach an expanded audience by communicating UAM messaging through all project partners (e.g., participating federal, state, and local officials, TNCs, and utility companies), community organizations, major employers, the hospitality and tourism community, other elected officials, and the media, as appropriate.
- Active Listening - The Implementation/Communications Team will elicit regular feedback from local community leaders, maintain open communication lines with critical stakeholder groups, and promote that collaboration in UAM messaging.
- Transparency - The project will earn the community's trust through transparency and accountability. The foundation for building that trust will be the communication of clear and consistent messaging, timely and reliable information, and sharing of progress reports to track advancements and results throughout the UAM implementation.
- Issue Resolution- Issues will promptly be addressed before they can escalate. The Implementation/Communications Team will communicate with empathy and positivity to resolve issues where feasible and/or promote the long-term benefits of UAM.

Tactics

Social Media: With social media being the primary source of news for many people, it is essential to utilize this medium in reaching the public in their daily lives. Social media is an opportunity to inform and engage with the public/stakeholders and foster a sense of community surrounding the incorporation of UAM in the region. Messages should be tailored to each audience and for each of the varying platforms. Use of media, such as photos and, especially, video, is typically most effective. Additionally, social media is an optimal vehicle for engagement because strategies and content can easily alter if they do not have the desired outcome.

Stakeholder Meetings/Presentations: Engage with the community early and often regarding UAM efforts. Offer meetings and presentations in both in-person and virtual formats as feasible. Use engagement tools such as Mentimeter, Whiteboards, Poll Everywhere, etc. to transform virtual meetings into a more engaging experience that generates more useful feedback and allows participants to feel heard and to feel that they are a part of the process.

UAM Tours for Key Stakeholders/Elected Officials: Offer tours that provide real-life experiences of the aircraft and/or flight as feasible further into UAM development; these are a valuable tool for gaining the support of key stakeholders such as elected officials, by physically illustrating the benefits of UAM by offering.

Community Events: When feasible, host attractive, and fun community events such as ice cream socials, concerts, carnivals, 5Ks, and more to showcase that the airport is a good partner with the community and are bringing a value-add to your neighbors through UAM that will increase mobility, stimulate the economy, and further environmental benefits, etc.

Phone and/or Email Hotline: Give the public an opportunity to provide comments and ask questions through a "Contact Us" form on a UAM-specific website page and/or general airport website section. Additionally, provide a phone number the public can call with any issues or questions.

Website: Incorporate UAM operations-related content such as project mission, background, FAQs, and other collateral (i.e., infographics, fact sheets, and videos), contact information, etc., on a designated webpage promoted via the airport's main homepage and other advertising materials.

E-newsletters: Include UAM efforts in existing newsletters of the airport organization or offer a spin-off newsletter option for those who are interested.

Media Relations: Engage the media with traditional outreach, i.e., well-crafted press releases, and offer advance access to experiences and information. Further, utilize the media to cover other outreach efforts such as events by offering unique experiences to the community and/or sharing the human impact of the story (e.g., how UAM will affect a specific group or person, the economic benefits, the time saved and so on). Disseminate a unified message about UAM's benefits and objectives and keep the public informed about milestones reached or meetings, community events, or activities related to or sponsored by the UAM-specific airport initiative.

Collateral Materials: Develop maps, fact sheets, infographics, FAQs, fliers or postcards, and other elements utilizing cohesive and visually appealing branding to highlight the goals/benefits of the initiative.

Informational Promo Video: Develop an informational video about the initiative to showcase the benefits of UAM, humanize the effort in the specific community through expert interviews or sharing human experiences, and provide answers to likely questions from the public. Video is the most effective online communication medium.

"UAM is Coming" Advertising Campaign: Prior to operations, make a concentrated effort to inform the community about the initiative via paid media such as social media advertisements, billboards, direct-mail postcards, newspaper ads etc., so the public will know what to expect.

Public Opinion Surveys: Use software such as SurveyMonkey or MetroQuest to keep track of the community's perception of the initiative as UAM unfolds will be valuable in gauging future outreach efforts. The plan must be flexible enough to shift if a message is not resonating or tactic is not effective.

Focus Groups: Create organized focus groups, which can be effective particularly in the early stages, that bring together community leaders and TNCs to prioritize objectives, determine the most effective communications efforts, and further identify the risks specific to each community involved.

CHAPTER 4: USE CASES AND APPLICATIONS FOR URBAN AIR MOBILITY

This chapter discusses the motivation and primary use cases for UAM: Passenger, Air Metro, and Air Cargo. Applications and UAM aircraft operations for each use case illustrate the state of the industry worldwide. Use case considerations for airports help provide insight and practical guidance to airport industry practitioners.

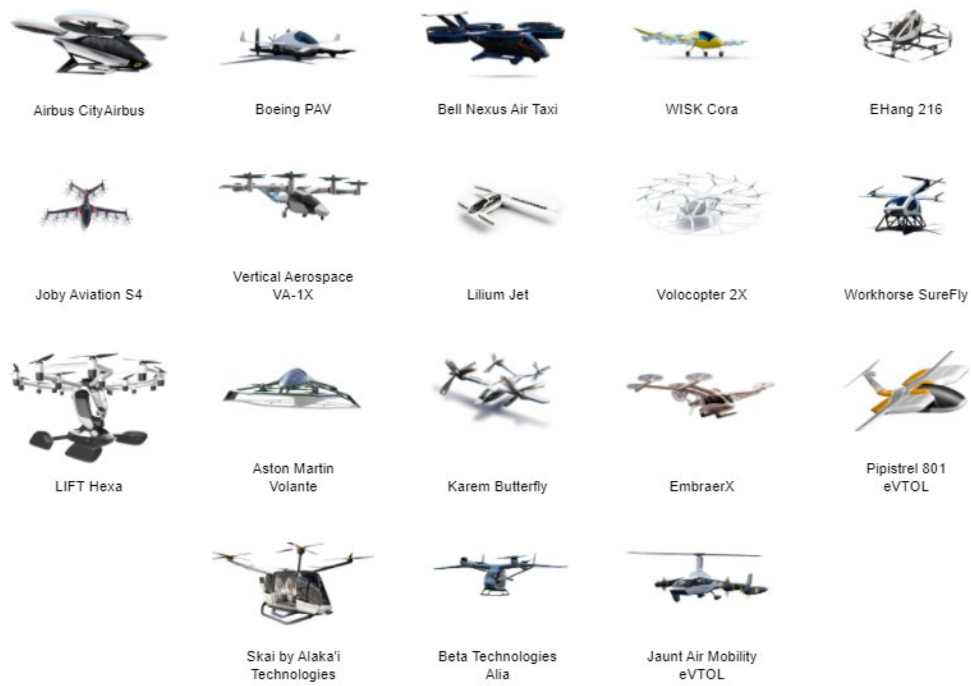
Many similarities exist between the early automotive industry and the emerging UAM industry. UAM has attracted substantial interest from industry stakeholders and investment capital providers worldwide. Within the first six months of 2020, $907 million flowed into the industry from investors (Hader & Baur, 2020). The Uber Elevate conference and resulting white paper inspired many to the possibility of urban air transportation. The possibility of a new generation of aerial transportation that is cost-effective, clean, and widely available has garnered much attention.

Low Hanging Fruit

- *Air Cargo* ***(First Use Cases)***
  - ***Medical***
  - ***Parcel***
- *Air Metro at Airports*

UAM companies are a mix of established players in aviation, major automotive companies, and entirely new players with little experience working with the FAA and airports. Some of the organizations that have advanced are strategically aligning themselves with industry giants such as Airbus, Boeing, and Bell. Although Uber was a primary player initially, it has since sold Uber Air to Joby Aviation. Changes in the industry are happening daily, and cities and states join the effort and partner with companies to bring UAM to their locations. After evaluating parameters relating to transportation habits, infrastructure, airspace regulations, and aviation operations, Foster and Sullivan found that the following cities emerged with top (10) scores (in descending order) in terms of UAM readiness: London, Singapore, Los Angeles, San Francisco, Dubai, Seattle, Paris, Boston, New York, and Vancouver (Foster and Sullivan, 2020). OEMs and service providers have indicated potential for airports to take a lead role in AAM initiatives. They have expressed willingness to partner with airports, but need to be informed regarding an airport's current status with regard to UAM, infrastructure, electrical capacity, and growth potential. Having a clear understanding of the airport's resources will foster productive discussions between airports, OEMs, service providers, and planners to better facilitate multiple options for AAM integration.

At the Vertical Flight Society's 2021 technical meeting on January 26, 2021, Jay Merkle spoke about the possibility of type certification of a handful of aircraft for UAM operations in 2021. At the time of this report, the FAA was working with 30 companies toward certification. TransportUP has compiled a list of 18 leading manufacturers competing for the UAM market (see Figure 4).



Source: TransportUP, n.d.

Figure 4. TransportUP's Watchlist of the world's leading eVTOL, flying car, and flying taxi manufacturers.

Passenger Air Mobility

The research team separated the Passenger Air Mobility use case into Air Metro, Air Taxi, and Regional Air Service. Air Metro resembles existing public transit options such as subways and buses in that vehicles follow a predictable schedule of stops along predefined routes, distinguished from Air Taxi, where passengers hail pick-up services on demand and travel point to point. Regional Air Service or Regional Aerial Mobility can serve regional or rural areas, not only urban areas.

Airports can play a primary role in the passenger use case because their existing infrastructure is already primed for aviation. From the team's market assessment, Air Metro will grow from $100 million to $1.8 billion in revenue between 2025 and 2035 for infrastructure operators. Not all operations will be at airports, however, and other plans for vertiports at off-airport locations may have additional obstacles to overcome before construction can proceed, including:

- Noise considerations
- Zoning restrictions
- Electrical capacity to support new aerial vehicles
- Code updates for existing buildings
- Allocating land in a densely populated area

With already-established aerial operations, airports are a logical place to start for UAM. According to the U.S. Department of Transportation, in 2019, there were approximately 5,080 public-use airports in the US; UAM operations could use many of these. The airports where UAM operations may fit best are those that can handle an additional load of traffic. General aviation and reliever airports may be particularly suited to realize the most significant growth from the influx of expected UAM operations. However, it may not be practical for larger airports to incorporate aircraft with smaller passenger capacity if they are already overloaded with higher-capacity aircraft operations.

As in the Marketing Assessment in Chapter 2, the WSP team makes the following assumptions for most UAM vehicles manufactured in the near term for passenger operations:

- **Vehicle Assumptions:**
  - *Capacity*: Vehicles will bear one to four passengers, reflecting the majority of existing designs (150+ concepts under development) and the constraints of likely electric propulsion.
  - *Autonomy*: Early vehicles will first be piloted and then transition to remotely piloted and increasingly autonomous operations, based on the current state of autonomy research and development and nascent certification procedures.
  - *Performance*: OEMs will target a useful range of 60 miles and cruising speed of 150 mph for vehicles, citing the specifications desired by early industry conveners.
  - *Cost*: The upfront cost per vehicle will range between $280,000 and $481,000, as indicated by the early market data made available by several vehicle manufacturers.
- **Operational Assumptions:**
  - *Passenger Load*: Trips will average a passenger load of three riders, as reported by market studies accounting for the shared route model of Air Metro.
  - *Recharging Time*: Batteries will require 20 minutes to recharge or swap, according to the desired specifications stated by early UAM vehicle operators.
  - *Mission Time*: A single mission will take 64 minutes, calculated by combining estimates for in-flight, passenger loading/unloading, and charging/battery swap times.
  - *Daily Trips*: Each vehicle will complete 11 missions per day, calculated by dividing an assumed 12 working hours per day using Visual Flight Rules by the estimated mission time.
- **Route and Network Assumptions:**
  - *Layout*: Routes for Air Metro will take the form of a distributed hub and spoke model, according to existing UAM market studies.
  - *Scheduling*: Vehicles will operate with predictable service schedules along predetermined routes, a defining characteristic of the Air Metro use case.
  - *Early Use Case*: A shuttle service between airports and city centers will be an early proving ground for Air Metro prior to reaching scale.
- **Infrastructure Assumptions:**

- *Types*: At maturity, a distribution of small, medium, and large skyports with eVTOL capacities of one, four, and 12 landing pads, respectively, will service Air Metro. This understanding is based on current urban heliports.
- *Components*: A skyport will include concrete vehicle landing pads, charging stations, and, for larger stations, a passenger terminal, based on the current industry vision and existing heliports and small airports.
- *Locations*: Early skyports may build on existing infrastructure, such as the tops of parking garages or use open land near highway interchanges, according to concepts offered by the UAM industry's early conveners.
- *Cost*: The cost to develop skyports will be analogous to heliport and industry development in urban areas and airports. This assumption must be modified by the components of skyports, such as all-electric charging stations, that must be appraised individually.

The eventual Air Taxi use case will share many similarities to Air Metro. The WSP team found that the on-demand nature of Air Taxi service results in the following differences:

- Air Taxi will have a smaller passenger load compared to Air Metro (average of one rider versus three riders).
- Air Taxis will require a higher density of skyport infrastructure compared to Air Metro, due to its vision of widespread door-to-door service.
- Air Taxi may only emerge as a viable use case upon Air Metro's maturity, given the additional complexity of airworthiness certification and safety standards associated with the goal for Air Taxi to be ubiquitous—taking off, landing, and flying over a greater range of regions.

Current Use Case Applications

- Los Angeles, California, has created a partnership with the Mayor’s office, Los Angeles Department of Transportation, and Urban Movement labs to make UAM a viable transportation system in the city. They are currently mapping out locations and assessing designs for vertiports. UAM Division of Hyundai Motor Group is providing financial support.
- Lilium announced a partnership in Florida to create the first vertiport network in the United States. The first planned area will be the Lake Nova aerotropolis, contiguous to the Orlando International Airport, with over 75 million visitors annually. The network will connect Florida communities through their Lilium jet, which holds five passengers and is a fully electric eVTOL. Lilium plans to build a $25 million, 56,000-square foot vertiport to facilitate operations. Lilium anticipates generating 100 jobs and $1.7 million in economic activity in a 10-year period (Hawkins, 2020).
- Joby Aviation is a California-headquartered transportation company developing an all-electric vertical takeoff and landing aircraft in UAM operations. Joby works with the Agility Prime program to accelerate development for UAM. The company has been making strides to acquire Uber Air in late 2020 and is advancing its goals for FAA certification. Joby has agreed to a G-1 certification basis for its aircraft with the FAA. It hopes to be certified according to the FAA’s Part 23 requirements for normal category airplanes, with special conditions to address specific

requirements. It has plans to operate as a commercial passenger aircraft by 2024. Joby works with the Agility Prime program to accelerate development for UAM.

- EHang is an autonomous aerial vehicle platform based in Guangzhou, China. EHang has been aggressively performing operations worldwide, and it has been testing its aircraft in multiple use cases, including passenger transport, air ambulance, heavy cargo delivery, medical supply, and firefighting. EHang has agreements with many countries to test their aircraft, including Austria, Canada, China, France, South Korea, Norway, Spain, and the United States. EHang has successfully flown a no-passenger test flight in North Carolina partnered with the North Carolina Department of Transportation. EHang also completed passenger operations with its EHang 216 in China. In Hezhou, there are plans to deploy 20 of its two-seat aircraft and create an airport terminal specifically for UAM services (Shicong, 2020). Of note, a modified version of the 216 has been equipped with firefighting capabilities to assist with the deployment of fire retardant for use on high-rise buildings.
- Volocopter is an autonomous aircraft and vertiport manufacturer based in Bruchsal, Germany. Volocopter was the first air taxi developer to be awarded SC-VTOL Design Organization Approval by the European Aviation Safety Agency. Volocopter has been active in Singapore and aims to have its vertiport, identified as Voloports, across Singapore. It anticipates that each Voloport can handle 10,000 passengers a day.
- FlyOhio has worked extensively to research and implement UAM. FlyOhio has partnered with Ohio State University for a research project along the 33 Smart Mobility Corridor to test a low-altitude air traffic management system. The next goal is to research information on infrastructure for vertiport locations to support eVTOL aircraft.
- XTI aircraft has received orders from an unidentified U.S. operator for 40 hybrid-electric TriFan 600 aircraft revealed at Vertical Flight Society's Forum 77 meeting.
- The U.S. House of Representatives will hold a hearing to examine AAM infrastructure needs (NBAA - National Business Aviation Association 2021).

Air Medical

The WSP team separated Air Medical into two categories: Air Medevac and Medical Cargo delivery. The Cargo Delivery use case covers Medical Cargo delivery, and the following section covers Air Medevac. Per the team's market assessment covered in Chapter 2, Air Medevac will incrementally grow from $10 million to $36 million between 2025 and 2030. Many airports already have existing Air Medevac operations, and, over time, these fleets may transition to UAM vehicles. The changes required to support operations will also benefit other electrification efforts at airports. Air Medevac would have higher electrical demands because of its rapid response rate. To compete with rotor-wing aircraft, Air Medevac would require a battery recharge rate of four times the current rate (Reiche & Cohen, 2018). Significant changes may be necessary to improve the electric infrastructure at some smaller general aviation airports—consideration on the use of existing helipads and their proximity to the required charging infrastructure for eVTOL. The charging infrastructure would need to function without impeding traditional helicopter operations.

The Air Medevac use case includes future medical transport flights using vehicles such as hybrid-electric and electric VTOL jets. Air Medevac's use of VTOL distinguishes it from the air ambulance market's use of a conventional helicopter to transport patients to the hospital for emergencies and occasional appointments. The team believes that Air Medevac with eVTOLs will be a viable substitute for helicopter services and that, over time, the adoption rate of Air Medevac will grow (from 1–10 percent in 2025 to 10–50 percent in 2035).

Assumptions play a critical component in the team's bottom-up market assessment of the Air Medevac use case. The FAA holds medical transport to higher standards than general passenger transport. Given the FAA's strict existing standards for the CAMTS Air Ambulance accreditation, the team finds it likely that the FAA will hold Air Medevac to a similar or even higher bar. The research team derived many of the following assumptions (consistent with the Marketing Assessment in Chapter 2) from the wealth of publicly accessible information available from the mature air ambulance market, which the WSP team used as a proxy for Air Medevac:

- **Vehicle Assumptions:**
    - *Capacity*: Seating capacity for Air Medevac vehicles will be larger than Air Metro vehicles to accommodate a single patient, a pilot, multiple medical staff, and the associated patient care equipment.
    - *Autonomy*: Vehicles will transition from piloted to remotely piloted or autonomous, but always with other personnel in addition to the patient onboard.
    - *Crew Certification*: Based on existing air ambulance standards, each vehicle may require annually certified personnel consisting of four full-time pilots, four full-time nurses, and four full-time paramedics.
    - *Cost*: The upfront cost per vehicle will range between $280,000 and $481,000, as indicated by the early market data made available by several vehicle manufacturers.
- **Route and Operational Assumptions:**
    - *Mission Components*: Air Medevac missions have three sub-missions—response, transport, and return—mirroring the existing air ambulance mission structure:
        - Response: the time between the vehicle's initial dispatch and its arrival on the scene.
        - Transport: time from the vehicle leaving the scene to dropping off the patient at the medical center.
        - Return: time from departing the medical center to arriving back at its station, in many cases including charging time.
    - *Mission Distance*: An average Air Medevac flight distance will be 52 miles, based on existing rotor air ambulance data for relatively shorter medical air transport trips.
    - *Mission Time*: Expected average mission time of 130 minutes, based on existing rotor air ambulance data.
    - *Recharging Time*: Recharging time will be between 20 minutes (from research on battery-swapping) and 120 minutes (from available vehicle concept specifications).
- **Infrastructure Assumptions:**
    - *Types*: Air Medevac will use bases with terminals, expected to include four pads with two charging stations each according to available market literature.

- *Cost:* A single Medevac base will be between $5.1 and $10.5 million, anchored in estimated developmental costs for similarly sized rotor air ambulance operating bases.

Current Use Case Applications

- EHang has joined Ambular to help build multiple eVTOL air ambulance vehicles to assist in medical emergencies. The Ambular aircraft consists of two designs. One is meant to carry two passengers, while the other is a pod to transport a single occupant. The use case for the pod acts as an intensive care unit fully encompassed in an aerial vehicle. It is meant to travel the last-mile (by train or truck) for critical patients.
- Flirtey was the first company in the United States to perform an autonomous delivery of medical equipment to a home in Reno, Nevada. It has worked toward equipping sUAS with defibrillators to help save lives during a cardiac arrest event. It is also delivering saliva-based COVID-19 tests via sUAS to limit exposure to the disease.

Cargo Delivery

The Cargo Delivery use case has the most potential for the early stages of UAM. As determined by the WSP team's market study, the Air Cargo market will reach nearly $2 billion by 2025 and just over $4.5 billion by 2030. Cargo delivery has already become profitable and has provided lifesaving supplies for medical operations worldwide. Air Cargo using an airport as a hub could prove beneficial, as described in Chapter 2. The return on investment could be several orders of magnitudes larger than that of Air Metro or Air Medevac. Due to the scale of operations for UAM cargo delivery, airports will need to assess whether they have the required space for infrastructure to support mass package delivery. Other concerns are security needed for package handling, as well as ground and air capacity to support extensive operations at the airport. A fee-based system will collect revenue from cargo delivery operations because aviation fuel taxes are not applicable for this use case. The WSP team made the following assumptions for the majority of UAM vehicles manufactured for cargo delivery operations.

The methodology used for analyzing the Air Cargo use case closely resembles what the WSP team performed for Air Metro. In conducting the analysis, the team again derived assumptions believed to shape the emerging Air Cargo (last-mile delivery) use case. The team took the following assumptions (consistent with the Marketing Assessment in Chapter 2) about Air Cargo from available market research estimates, data released by manufacturers and operators, UAS delivery pilot programs, and the existing FAA regulatory state:

- **Vehicle Assumptions:**
    - *Capacity*: Delivery payloads for sUAS are capped at 5 pounds, reflecting the current FAA regulations applied to UAS under Part 107.
    - *Autonomy*: Delivery vehicles will be remotely piloted or autonomous small unmanned, according to the early industry delivery pilot programs.
    - *Performance*: The research team calculated an average sUAS speed of 43 mph and 30-minute flying time per single charge by averaging the top speeds and flying times for available systems.
    - *Cost*: The average cost for a new delivery sUAS will be $3,000, from a source reporting on a major commercial delivery fleet.

- **Operational Assumptions:**
    - *Recharging Time*: Recharging time following each delivery will take 60 minutes; the research team estimated this by referencing commonly available sUAS models on the market.
    - *Delivery Distance*: Door-to-door roundtrip deliveries will fall within a 9-mile range and take 30 minutes or less, based on current industry estimates.
    - *Mission Time*: The team determined cycle time of 95 minutes per delivery mission by combining maximum delivery time, target recharging time, and loading/unloading time.
    - *Daily Trips*: A single sUAS will complete on average of 10 delivery trips per day, estimated by dividing estimated hours of operation (5:00 am to 10:00 pm) by mission time.
- **Route and Network Assumptions:**
    - *Scheduling*: Last-mile deliveries will be unscheduled, with routes computed once an order is placed, based on the known plans of commercial sUAS delivery fleets.
    - *Early Use Case*: Rural delivery may see faster growth than urban due to more significant relative cost savings and flights over a lower density population.
- **Infrastructure Assumptions:**
    - *Types*: Delivery requires skyports at distribution hubs for loading, as well as neighborhood receptacles for receiving and securing delivered parcels.
    - *Capacity*: Each skyport will house an average of 13 cargo pads, with each able to process up to 10 deliveries per hour. Further, each skyport will maintain an estimated fleet of 133 drones.

Current Use Case Applications

- Through the FAA's Integration Pilot Program (IPP), North Carolina has performed many operations for WakeMed Health and Hospitals. It has been found that medical cargo delivery with sUAS can address inefficiencies in supply chains, recover costs, and enable a broader healthcare delivery system redesign. UPS Flight Forward, which earned the necessary federal certifications to operate a drone airline, has an ongoing drone delivery service at WakeMed's main campus in Raleigh. UPS Flight Forward and Matternet use sUAS to deliver healthcare equipment, medicine, and personal protective equipment to medical providers in the Charlotte, North Carolina, area. Flytrex is another partner with North Carolina that is testing using sUAS for food delivery services serving multiple restaurants in a nearby neighborhood shopping center.
- Zipline, a California-based sUAS delivery company, has found much success worldwide, delivering lifesaving medical supplies to rural clinics. In Ghana, Zipline delivered more than 170 different vaccines, blood products, and medications to nearly 22 million people (Kolodny, 2019).
- Matternet, partnered with the Swiss Post, has used sUAS to deliver blood samples between hospitals. The Swiss Federal Office for Civil Aviation granted Matternet a certification to allow their sUAS to fly autonomously over cities at any time for this purpose. Their operations were reported to be the first Beyond Visual Line of Sight flights supported by Swiss U-Space, Switzerland's nationwide integrated airspace system (Urban Air Mobility News, 2019).

- Through the FAA IPP, Memphis-Shelby Airport, home to FedEx's largest and busiest hub, has operated a fleet of seven drones to evaluate their use in a dynamic airport environment. Memphis is the only one of the FAA drone pilot programs that performed in a commercial cargo and passenger airport's heavily restricted airspace. (Inside Unmanned Systems 2020) Their goals are to eventually expand operations to other delivery applications. FedEx has used sUAS with success in the following areas:
    - General visual inspection.
    - Security/perimeter surveillance.
    - Foreign object debris detection.
    - Wildlife management.
    - Aircraft parts delivery.
- University of Maryland School of Medicine evaluated using sUAS for the transport of live organs. Time is crucial from the time an organ is removed to the time it is transplanted. Using sUAS can decrease the travel time, which can often extend the useful life of the organ.
- EHang became the world's first UAM company approved by a national aviation authority to carry out a commercial pilot operation for the category of 150 kilograms plus heavy-lift air logistics uses. EHang is evaluating the use case of heavy cargo delivery to transport cargo between the ground and hilltops and shore and islands to assess the potential.

CHAPTER 5: IMPACT ASSESSMENT AND OPPORTUNITIES FOR URBAN AIR MOBILITY

As UAM draws closer to becoming a reality, municipal planners should begin identifying how this new form of urban transportation will impact the lives of their citizens. In particular, transportation and infrastructure planners have an opportunity to not only accommodate UAM systems but also use them to enhance current and future developments in other sectors.

Current work has largely focused on the development of new technologies—vehicles, automated systems, and battery storage—and the magnitude of UAM's likely economic impact. In the current study, the team seeks to leverage that information to better understand how UAM will impact airport developers and operators and their supporting communities. In the following section, these impacts are framed around several variables, each representing a key group, operation, or aspect of the airport ecosystem.

This analysis considers impacts on each variable from three primary standpoints:

1. Economic – How will UAM operations affect financial decision-making for airport planning and operation, and what opportunities exist?
2. Operational – What changes in procedure will need to be made to incorporate UAM most efficiently into the daily activities of airport staff and passengers?
3. Policy/planning – How should incorporating UAM into airports affect the manner in which airports are planned and designed?

Further, efforts have been taken to ensure that impacts addressed account for insights from the UAM market assessment, expert interviews, and best-practice guidance on airport planning and operation.

This impact assessment is structured across two categories—impacts and opportunities—organized by a set of variables that represent specific aspects of airport planning, organizational principles, and stakeholders.

Further, within each sub-category, impacts and opportunities are considered across the three UAM use cases defined explicitly and in greater detail in the market assessment. These three use cases are taken as the base unit of analysis within each variable because their specific operational considerations merit individual analysis.

Where possible, assessment of impacts and opportunities is grounded in existing considerations and requirements for airport planning discussed in sources such as:

- FAA advisory circulars and planning documentation
- Academic research and literature
- Industry/trade publications, working group reports, and presentations
- SDO recommendations and guidelines
- Supplemental analysis of the airport market

In this analysis, the team identifies substantial impacts to airport planning and operation from each use case. Airport planners and municipal transportation authorities should take careful note of the following likely considerations:

- **Air Metro**: As Air Metro operations are expected to center around service to and from major U.S. airports, passenger transportation using this method will likely impact airport operations substantially across each major variable, in the following ways:
    - Increase traffic to and from airports, into spatial requirements and demand for various airport services.
    - Create potential challenges for airport grid maintenance and inspection schedules.
    - Alter commercial aviation flight routes and scheduling to accommodate UAM flight routes to and from airports.
    - Affect share of passengers traveling to/from airports using ground-based ridesharing and taxi services.
    - Change the background noise profile for communities living in close proximity to airports.
- **Air Cargo**: Air Cargo operations are anticipated to serve a significant portion of Americans in the next 5 to 10 years, owing to the increased convenience and speed of rapid, last-mile delivery afforded by drones. It is further anticipated that these operations will be adopted relatively quickly, compared to the other use cases, and are likely to have significant effects on airport stakeholders and operators, such as the following:
    - Increase demand for consumer goods, leading to an increase in general freight shipping such as air freight transport.
    - Increase demand on airport grid infrastructure and facility space.
    - Create security challenges for drone mitigation at U.S. airports.
    - Increase demand on airport flight management infrastructure and personnel.
    - Prompt new regulatory considerations for control and management of large, semi-autonomous fleets.
    - Expand access to rapid retail service for local airport communities.
- **Air Medevac**: In the United States, the air ambulance industry as a whole is anticipated to see significant growth in the near term owing to a combination of rural hospital closings and improvements in the efficacy of emergency trauma care. Air Medevac may be poised to account for some portion of this growth, benefiting from reduced fuel costs over legacy rotorcraft air ambulances. As a result, airport planners should be mindful of potential impacts, including the following:
    - Lead to new considerations for routing/scheduling around emergency response flights.
    - Increase power consumption and pose greater strain on the electrical grid from high-voltage, rapid-charging systems for electric aircraft.
    - Expand capabilities for the handling and storage of medical waste.
    - Drive new demand for space to create new Air Medevac transport bases.
    - Consider new regulatory frameworks for electrified medical flights.
    - Improve access to emergency medical care for rural residents in proximity to major cities.

Stakeholders who seek to implement UAM face substantial challenges across various technological, policy, and public-facing domains. However, the potential impacts on airport planning and operation may also bring substantial potential opportunities for invested stakeholders.

In the area of financing UAM infrastructure at airports, existing federal sources of funding such as the Airport Improvement Plan (AIP) and Voluntary Airport Low Emissions (VALE) programs may provide some opportunities for both UAM and airport stakeholders to bring UAM services to their communities. Federal regulators have signaled willingness to consider UAM projects eligible for grants and reimbursements for development and may serve as an effective springboard for broader airport improvement projects that can enhance capacity, environmental sustainability, efficiency, and service.

In addition, both Air Metro and Air Cargo create potential business development opportunities for both airport and local community businesses through possible promotional partnerships. The fact that both UAM use cases are customer-facing may provide other local businesses with customer access that they do not currently have. Further, municipal and state planners and business development councils may benefit from partnerships with UAM development coalitions to create cost-sharing arrangements or other mechanisms that bring UAM services to their communities.

Lastly, local healthcare providers and regional or reliever airports may find advantages in partnerships with Air Medevac providers seeking to establish bases. This could improve healthcare outcomes for local communities and expand emergency care.

UAM Impacts on Airports

Over the next 15 years, the International Air Transport Association forecasts a steady growth of 2.5 percent in the legacy U.S. air passenger market, in the face of a worldwide growth rate of 3.7 percent over the same period (International Air Transport Association, 2019a). And though the 2019 Air Cargo market is experiencing a slight downturn owing to ongoing international trade tensions, experts anticipate a near doubling of the industry over the next few decades. The International Air Transport Association reports negative worldwide air freight market growth across 2019 (International Air Transport Association, 2019b), though Boeing projects long-term growth between 2017 and 2037 (Boeing, 2017). The inclusion of UAM in U.S. transportation systems may compound this expected growth and impact national airports in various ways.

Use Case: Air Metro

Passenger, Cargo, and Aircraft Activity It is anticipated that Air Metro traffic may drive significant increases in passenger activity over the next few decades, particularly at more mature stages. Such activity is likely to impact airports' passenger-facing facilities and their operation across several fronts, including:

- Expanding airport transit systems and allotting space for UAM facilities
- Increasing utility and resource consumption
- Increasing revenue from food, beverage, and retail sales

In the near term, it is expected that Air Metro will arrive in select U.S. cities with routes to and from major hub airports (e.g., Dallas Fort Worth or Los Angeles International Airports). Such hubs currently have the capacity to absorb some amount of new passenger activity and may lease space to UAM facility developers and operators. However, movement of passengers throughout the airport may be impacted by skyport design and placement decisions. For example, if skyports are constructed on top of parking facilities, UAM passengers may simply move to and from the airport terminal building like all other passengers. In contrast, if skyports are constructed elsewhere on the airport grounds (e.g., on or near rental hangars), airports may need to extend passenger transport systems, such as Automated People Mover (APM) systems, which may be used to connect UAM skyports and airport terminals.

At more mature stages of UAM development, high UAM passenger volumes in many major U.S. cities may drive large amounts of traffic to and from major airports. In such a scenario, it is likely that significant airport real estate may need to be allocated for UAM skyports and larger "skyhubs." More specifically, high passenger volumes may result both from the airport as the passenger origin/destination and from major UAM hubs serving as a connection point for popular routes. In addition to spatial considerations, such increases may drive higher utilization of facility utilities (e.g., water, electricity), as well as retail and concession consumption.

Operations and Maintenance As UAM passenger transport will function in unique ways compared with legacy aviation, such as using large-capacity charging equipment and a rapid operating cadence, creating specific concerns for maintenance operations at U.S. airports, including:

- Potential changes to the preventative maintenance scheduling for landing pads
- Procedural differences in the inspection and care of high-voltage charging systems

Early-stage UAM operations will likely require some changes to sections of airport agreements with the FAA that involve operations and maintenance of facilities, particularly as they relate to pad maintenance. There is some uncertainty regarding the degree to which eVTOL (or hybrid variants) will cause more wear on landing pads than traditional rotorcraft, and additional study will be prudent. Nonetheless, airport maintenance staff will need to be mindful of necessary changes to preventative and remedial maintenance procedures.

As UAM operations scale and adoption grows, airports could see substantial increases in traffic to skyports located at or near airports. Many UAM stakeholders foresee increased volume of operations than is typical with legacy rotorcraft. Under this scenario, preventative maintenance schedules will likely need to be modified, along with the airport's FAA operating agreement on maintenance and operation. In addition, the operating and maintenance needs of the electrical charging infrastructure required for UAM may differ substantially from that of existing electrical systems.

Safety and Security Implementation of UAM passenger transport will create new safety and security issues for airport operators. The FAA has cited professional aviation organizations in briefings describing the importance of safety and security in a holistic understanding of UAM development. The FAA is particularly interested in safe integration of technologies such as UAS into the national airspace (Federal Aviation Administration, 2019a). These issues are likely to cause significant impacts for airport stakeholders, including:

- Safety risks associated with integrating new forms of flight into legacy aviation airspace
- New cybersecurity threats arising from increasing integration of computers with flight systems
- Safety and security risks prompted by increasing levels of autonomy

Regardless of the degree of short-term adoption of UAM Air Metro service, passenger-carrying commercial eVTOLs will likely require attention for critical safety and security issues. First, eVTOLs, though similar in operation to rotorcraft, may require different considerations for safe routing around airports owing to differences in performance (e.g., maximum flight time, operating speeds, pilot control, etc.). Second, unlike legacy aircraft, computer-controlled systems will likely be native components of the overall system, creating the potential for both safety and security risks from misuse, accident, or deliberate attack. Though preventing or mitigating these risks largely falls to the vehicle and UAM ecosystem designers, airport operators must be aware of functional implications for the safety of airport personnel and customers in the event of accidents.

In the longer term, many anticipate a future of UAM in which increasing levels of autonomy are introduced to both UAM vehicles and traffic management systems. Caution on the part of regulators to permit autonomy at any level of aviation is well-founded; modern autonomous systems—anchored in exotic machine learning and artificial intelligence platforms—are not well understood and may create significant uncertainty for operators in their proximity. Journalists at the MIT Technology Review point out that most machine learning (and AI, more generally) algorithms operate in a "black box" whose inner workings often produce results unintuitive to humans (Knight, 2017). Airport-based traffic controllers, ground support staff, and flight crews may be impacted by potentially unpredictable autonomous systems behavior.

Infrastructure Facilities to support UAM passenger operations will be similar in many ways to those required for small, regional air carriers. A potential area of difference may be how airside, curbside, and landside facilities are arranged in relation to one another. Some vertiport concepts are modeled on traditional airports, while others demonstrate a high degree of integration of passenger arrival, boarding, and departure areas. The concepts chosen will have to balance regulatory considerations, feasibility, and functionality and will likely impact airports in several ways, such as:

- Spatial considerations, allotment, and planning for vertiports
- New forms of charging systems and associated changes to airport electrical grids
- Increased demands on airport infrastructure used to support planning and logistics

Even in the early years of UAM integration, airport operators should anticipate significant changes in the infrastructure needed to support operations. First, UAM vertiports—in whatever form they eventually take—will impact the allotment of space at U.S. airports. Depending on the scale of operations, UAM service providers may require facilities ranging in size from that of current heliports to larger, multi-pad areas with dedicated passenger terminals (see Figure 5). In addition, these facilities will likely require new forms of charging systems that directly affect airport electrical infrastructure.

Longer term, stakeholders may see these challenges grow in scope. Expansion of UAM to a significant number of airports may create financial challenges for airport development and maintenance. Further, UAM infrastructure operators may begin to compete with legacy airport users for federal support funding, including grants and disbursements. Indirectly, growth in UAM operations may also create hurdles for airport infrastructure used to support logistics, planning, and operations.

Cost component	Comments	Skystop	Skyport	Skyhub
Pad material costs, $	▪ Constructed of reinforced concrete [1] ▪ **Skystop:** 1-pad, FATO area[2] 4500 sq-ft, total area 20,000 sq-ft ▪ **Skyport:** 2-pad, 7-10 parking spots, FATO area[2] 4500 sq-ft, total area 165,000 sq-ft ▪ **Skyhub:** 1 to 2-pad, 20 parking spots, FATO area[2] 4500 sq-ft, total area 380,000 sq-ft	$66,000	$500,000	$1.25M
Time for pad construction, Manhours	▪ .055 manhours per sq-ft ▪ Anchored in surveys of helipad development projects with published timelines	1,100	9,075	20,900
Flight deck labor cost, $	▪ Labor rate of $20 per manhour ▪ **Skystop:** Crew of 10 working 8-hour days, completion time ~14 days ▪ **Skyport:** Crew of 15 working 8-hour days completion time ~2.5 months ▪ **Skyhub:** Crew of 25 working 8-hour days, completion time ~3.5 months	$22,000	$182,000	$500,000
Charging station cost, $	▪ Mean cost of an analogous electric vehicle charging station (equipment and install) $52,000 ▪ **Skystop:** Single charging station, as a backup for emergency or atypical events ▪ **Skyport:** 8 charging stations assumed ▪ **Skyhub:** 20 Charging statins assumed	$52,000	$416,000	$1M
Terminal cost, $	▪ Average rate of $197 / sq-ft4 ▪ **Skystop:** Likely not to exceed 3000 sq-ft[3] ▪ **Skyport:** Assumes 35,000 sq-ft terminal ▪ **Skystop:** Assumes 80,000 sq-ft terminal	$591,000	$6.9M	$15.8M
Site and operational capex, $	▪ Land procurement and preparation (survey, grading, soil treatment) ▪ Safety and security (barricades, lighting, cameras, *etc.*) ▪ Regulatory compliance assurance and inspection	$500,000	$4.1M	$9.5M
Total cost, $/location	▪ **Skystop:** costs may range from $1 – 2.5M ▪ **Skyport:** Miscellaneous costs may lead to cost variance of $2 - $5M ▪ **Skyhub:** Miscellaneous costs may lead to cost variance from $5 – 10M	**$1.2M**	**$12.1M**	**$28.1M**

1 Reinforced concrete priced at $3.30 per sq. ft. (ConcreteNetwork.com)
2 FATO area (1.5 x rotor diameter)^2 uses assumed 'rotor diameter' of 45 ft.
3 Terminal space has been scaled based on occupancy and capacity assumptions
4 Facility development cost reflects average rate for total construction cost, including labor

SOURCES: Federal Aviation Administration, Heliport advisory circular; Compass International, Airport costs; and US DOE electric vehicle equipment cost

Figure 5. Assessment of unit-development costs for types of UAM infrastructure.

As pictured above, costs for single-pad skyports, which provide network density for UAM operations, are expected to reach $1.2 million. Skyhubs, which are envisioned as the airport-centric node of a city's UAM passenger network, may cost as much as ~$30 million. In the middle, Skyports may cost ~$12 million and will be used to add density and improve throughput at major sites (e.g., convention centers) in urban areas.

Stakeholders Few stand to be impacted by the adoption of UAM Air Metro as significantly as airport stakeholders, perhaps excepting UAM passengers. The livelihoods of airport stakeholders depend on the efficient and cooperative operation of airport systems. As a result, this diverse set of stakeholders should be mindful of potential impacts of UAM passenger operations, including:

- Likely impacts on TNCs from competition between UAM and ground-based ridesharing services
- Increased competition for airport services and real estate from the addition of UAM operations
- Changes to daily life for airport communities arising from noise and new mobility
- Necessary input from governmental organizations on UAM rollout requirements

At early stages, integration of Air Metro at airports is likely to drive significant changes for transportation stakeholders—most notably TNCs, who may be competing with UAM for passenger trips to and from airports. However, these impacts may change if TNCs are able to integrate their ground-based ridesharing with UAM, as Uber intends to do (Haines, 2019). Airport businesses may also be impacted by the construction or renting of space for UAM bases, driving increased demand for airport space. In any case, planning for early UAM operations will require input from many local and federal governmental organizations on vehicle certification, airspace management, and local transportation network panning.

At more mature UAM stages, significant increases in adoption—possibly driven by reduced unit pricing or expanded availability—may be sufficient to increase air travel access and convenience. In such a scenario, airport stakeholders like airlines stand to benefit from increased passenger demand, which may drive additional business for service providers like operators of garages, hotels, and MRO providers. UAM may also drive changes for airport communities, whom the FAA have identified as being important to proper airport planning. FAA Advisory Circular 150-5050 outlines best practices for incorporating community feedback into airport planning on issues such as noise, local business development, and airport access (Federal Aviation Administration, 2016). Such changes, such as increased mobility, may be positive, while others, such as increases in ambient noise, may create challenges.

Community Airport communities may face significant noise and environmental impacts as Air Metro grows in utilization and brings service to many U.S. airports. As groups like Airbus's Altiscope have pointed out, perception of UAM noise will be one factor determining its level of acceptability to the public. In fact, according to research by Altiscope, noise associated with electric propulsion was considered more annoying than equivalent noise levels for automobile traffic (Altiscope, 2018). Similarly, environmental impact is one of the most often touted reasons to support UAM transportation. For both, airport communities may expect significant changes from Air Metro, chief among them being:

- Likely increases in ambient urban noise and a rise in overall daily noise disturbances.
- Potential reductions in engine exhaust accompanied by externalized increases in electrical power production.
- Increased use of batteries, potentially increasing environmental contamination.

In the early years of UAM Air Metro, airport communities may be impacted by some degree of noise from UAM vehicles. However, it is presently unclear how that noise profile will differ from conventional rotorcraft. What seems more apparent is that low-level rotorcraft are likely to increase levels of ambient urban noise. In addition, the limited adoption of UAM vehicles at early stages may reduce local air pollution (e.g., smog) through conversion of some number of ground-based trips to UAM trips.

At more advanced stages, airports will likely see increasing utilization of UAM vehicles. As noted above, UAM passenger trips may displace a substantial number of ground-based vehicle trips, which predominantly use fossil fuels, and may thereby contribute to substantial decreases in air pollution and contaminants. However, increasing utilization of electric aircraft may create new challenges for efforts to minimize ground-based contamination. Specifically, lithium-ion batteries utilize fluids that may contaminate groundwater and soil when spilled, which could pose a larger risk in more mature operations.

Use Case: Air Cargo

Of all UAM use cases, the drone delivery model for Air Cargo appears most likely to see significant adoption in the short term. Last-mile drone delivery organizations like Google's Wing have already begun commercial deliveries, and Amazon's Prime Air service is anticipated to begin operation any day. Amazon announced in June 2019plans to begin operations "within a few months" (Bartley and Ridzuan-Allen, 2019). Forecasters such as Morgan Stanley project strong adoption of this delivery model in both urban and rural areas due to rapid delivery speeds and automation efficiency.

Passenger, Cargo, and Aircraft Activity With the first drone delivery operations beginning in late 2019, many major corporate stakeholders aim to begin widescale commercial operations in a number of retail delivery spaces. Google Wing, partnered with FedEx and Walgreens, completed the first commercial drone delivery in the United States in October 2019 (Elias, 2019). In both the near and long term, these operations are likely to impact activity around airports in several important ways:

- Increasing the traffic of aircraft in controlled airspace surrounding airports.
- Prompting growth in air freight shipping operations based in major airports.

In the short term, drone delivery companies may wish to operate at or near airports. As the Radio Technical Commission for Aeronautics points out, more than half of Americans live within Mode C veil airspace, or heavily controlled airspace within ~35 miles of an airport, a number that is anticipated to grow in coming years (RTCA, Inc., 2017). As these populations represent a majority of the addressable drone delivery market, many operators may see logistical benefits from operating within this airspace, even if the drone base is not part of the airport itself. This presents potential logistical challenges for traffic management of manned aircraft in the area that many are currently working to address.

In the longer term, it is anticipated that higher levels of autonomy may enable operators to pursue more complex operations. This will likely further increase aircraft activity in the airspace near airports and may require more advanced forms of UAS Traffic Management (UTM). Such systems may include additional ground-based infrastructure or human oversight. Further, if the popularity of drone-based delivery grows in the ways expected, it will likely prompt upstream increases in legacy air freight shipping of commercial and retail products.

Operations and Maintenance While drones used for cargo delivery are unlikely to overtly impact airport maintenance practices (e.g., runway wear and tear), increasing use of sUAS to deliver packages may produce substantial direct and indirect challenges from their introduction to maturity, such as the following:

- Drive increases in consumer purchases and air freight cargo, leading to greater maintenance demands on facilities.
- Create new demands on electrical grid infrastructure, both in overall draw and in instantaneous usage.

In the short term, cargo delivery via drone may have several indirect impacts on airport maintenance operations. In particular, airports may have to contend with increased maintenance requirements for freight storage, sorting, and logistics systems located onsite. This may arise from increased consumer demand for retail delivery driving growth in legacy air freight markets. Maintenance impacts may include increased wear on transport and sorting systems for air freight, as well as greater utilization of processing facilities.

Looking further ahead, a more mature Air Cargo market may drive the same set of indirect impacts discussed above while also directly impacting airport maintenance through onsite drone delivery operations. Drone delivery that operate directly from airports may create new challenges for airport operations and maintenance from airport-based facilities that place new demands on airport electrical grid systems.

Safety and Security The FAA's implementation of the Low Altitude Authorization and Notification Capability (LAANC) system has provided air traffic professionals with better control and awareness of drones operating at or near airport airspace. LAANC allows drone operators to receive airspace flight authorizations in real time while providing data about their flights to other airspace users (Federal Aviation Administration, 2019b). Although this capability will help airport personnel to improve operational awareness of drone operations in their space, Air Cargo traffic may create new challenges for safety and security, such as:

- Safe routing of drones and other aircraft through airport airspace.
- Security threats from malicious drones or accidents from improperly controlled drones.
- Risks to people on the ground from large fleets of more autonomous drones.

In the short term, increasing drone traffic around airports is likely to create challenges for safe airspace management. As Air Cargo operators begin to operate fleets of drones, it is likely to create logistical challenges for route planning of other aircraft in the area. In addition, groups like the Transportation Security Administration (TSA) have identified drones as a technology whose increasing usage is likely to pose potential incursion threats to U.S. airports. Lawmakers and policymakers are currently divided on appropriate response to drone incursions at U.S. airports (Sands, 2019). As Air Cargo traffic increases, airport operators may need to address procedures for how to handle such incursions.

As Air Cargo reaches more mature states, these challenges are likely to grow. More sophisticated drones, management systems, and risk management procedures can likely lessen some safety and security impacts, but experts anticipate emerging problems. For example, large drone fleets may burden dedicated aviation communication channels, which could create issues for safe management of other aircraft. In addition, greater autonomy used in sUAS traffic management could potentially create issues for safe operation of vehicles, people, and other property at the airport.

Infrastructure According to the Airports Council, over $128 billion in infrastructure spending will be required by 2023 in order to meet anticipated growth in air passengers and cargo. In fact, 56 percent of new infrastructure spending is expected to be necessary to repair, upgrade, or expand existing terminals (Airports Council International, 2018). Critically, this spending only accounts for legacy forms of aviation. UAM use cases like Air Cargo will likely require significant additional funding and considerations to be fully realized, including:

- New demands for space and airport facilities.
- Increased burdens on airport infrastructure to maintain acceptable transfer times and departure schedules.

At early stages, Air Cargo operations may require airport planners to examine freight movement around the airport, as operations create new demands for retail goods. If it is economical, Air Cargo operators may house drone fleets at the airports themselves, creating new demand for airport space, facilities, and utilities. As the majority of cargo deliveries will be small packages weighing under 5 pounds and throughput will likely be high volume, these facilities may differ in size from many current-generation, large-freight storage facilities.

At later stages, more mature Air Cargo operations could create substantial increases in air traffic around the airport. This may create challenges for airport infrastructure devoted to airspace management, routing, and logistics that will need to be addressed, including new facilities for human airspace management or ground-based equipment such as radar, radio antennae, and other detection/communications equipment. Necessary additions in the latter category will depend in part on the certifiability and feasibility of communications, navigation, and surveillance systems for sophisticated drone fleets.

Stakeholders Air Cargo operations present an opportunity to transform local economies through rapid parcel delivery at potentially cheaper unit costs, particularly in rural areas. The Wall Street Journal notes that the cost-effectiveness of drone delivery depends on the efficiency of routes compared to ground-based transport, which is easier to solve along sparsely populated urban delivery routes (Winkenbach, 2019). This opportunity invites particular impacts—some beneficial and others challenging—for many classes of airport stakeholders, who operate at a critical nexus of transportation infrastructure. Such impacts may include:

- Regulatory challenges associated with operating drone fleets within controlled airport airspace and greater autonomy of operation.
- Community challenges associated with added noise from the new delivery service.

Upon introduction, the scale of Air Cargo operations is unlikely to create significant impacts on airport space or infrastructure at most airports. However, a significant increase in the amount of drone traffic through the veil of airport airspace will likely create new challenges for regulators and airport traffic management stakeholders. Additionally, drone delivery operations based at airports may create demand for a new form of MRO services to maintain large drone fleets.

At greater stages of maturity, drone fleet operators are likely to benefit from increasing automation of drones themselves, as well as their networking and control infrastructure. This high degree of automation will create challenges for regulators, who have often struggled with risk-appropriate oversight of autonomous systems in aviation. Oliver Wyman, reporting for Forbes, attributes current reluctance to approve autonomous Beyond Visual Line of Site drone operations in uncertainty around the performance characteristics of current-generation drones (Wyman, 2018). Further, as operations grow, retail-delivery drones may become ubiquitous in local airspace. As a consequence, local communities may have to deal with noise-related challenges even as the delivery services create new conveniences.

Community At present, virtually all consumer last-mile delivery is performed using ground-based vehicle fleets (e.g., USPS, FedEx). A robust Air Cargo industry would displace some degree of those deliveries using lightweight, autonomous, electrified drones and may impact communities in terms of changes in ambient noise and environmental effects. Specifically, airport planners should be mindful of impacts such as:

- Increased noise above standard levels for communities in the Air Cargo service area.
- Likely decreases in carbon dioxide emissions from decreasing reliance on ground-based transport.

As UAM Air Cargo deliveries begin entering service, communities may begin to see relatively quick adoption, compared with other UAM use cases. Particularly in more rural areas, where ground-based transport is less economical than in urban areas, drone delivery may begin to displace a substantial number of ground-based trips. Growth in aerial drone traffic may substantially impact community noise profiles, as sUAS are loud enough to be heard over ambient traffic noise, particularly in urban settings.

At more advanced stages, airport communities may begin to see a high degree of drone delivery traffic, creating additional ambient noise challenges that may need to be addressed through scheduling, zoning, or noise-dampening technologies. In terms of environmental impacts, drone traffic displacing ground-based travel will likely reduce emissions of gases like carbon dioxide, though most package delivery is done with natural-gas-burning vehicles, which produce fewer emissions than gasoline-powered vehicles. However, this will also be accompanied by increasing use of electrical power, which has variable environmental impact depending on how power is generated. Communities will need to balance costs associated with different forms of power generation with feasibility and environmental concerns.

Use Case: Air Medevac

One of the major drivers of medical flight costs, according to the Association of Air Medical Services, is the variable cost of helicopter fuel. According to the Association of Air Medical Services, high operational costs are being passed on to patients due to lagging insurance coverage (Association of Air Medical Services, 2017). Further, demand for air ambulance services is growing, in part spurred by rural hospital closures and improved treatments for strokes and cardiac events. Other factors include changes to federal medical programs that incentivized proliferation of air medical services (Tozzi, 2018). UAM passenger-carrying vehicles represent a possible solution to these problems and may impact the operational activities of U.S. airports as a result.

Passenger, Cargo, and Aircraft Activity Growth in air ambulance traffic broadly is likely to impact airport activity through increased air traffic around urban airspace. Although UAM vehicles could effectively improve air medical transport, this technology is likely to increase air traffic significantly—traffic that is generally given priority routing. As a consequence, airport operators must be prepared to contend with impacts such as:

- Potential issues regarding scheduling aircraft around emergency medical UAM flights.
- Facilities planning to accommodate increasing utilization by Air Medevac operators.

At early stages, adoption of UAM vehicles for medical flights is likely to be more gradual than other use cases. As a result, airport operators may expect few major shifts in aircraft activity around airports. What medical flights using electric VTOL aircraft do occur will function similarly to current rotor air ambulance missions, which are given priority flight clearance by the FAA over all traffic save aircraft in distress. The FAA grants priority clearance to flight plans filed using the call sign "MEDEVAC" (Federal Aviation Administration, 2015a). This can have secondary impacts on arrival/departure scheduling at airports of all sizes that must be addressed.

Current trends in survivability for heart attacks and strokes are expected to continue but depend on rapid treatment. In many cases, particularly for rural patients or those not near major hospitals, air transport is the only realistic way to overcome time constraints. According to the Wall Street Journal, half of major heart-attack victims in the United States lack timely access to the most highly recommended treatment options (Winslow, 2007). Assuming that UAM vehicles are well-suited for medical missions, adoption in the longer term is likely to grow in major metropolitan areas. As a result, airport operators and those involved in air traffic control may have to contend with an increasing number of medical flights, which will require more bases equipped to handle Air Medevac flights (i.e., charge, maintain, and prepare for missions), which could impact planning of airport facilities and spaces.

Operations and Maintenance As with the Air Metro use case, it is probable that Air Medevac will require airport maintenance staff to re-evaluate procedures for inspecting and maintaining landing areas and taxiways for aircraft. However, given the differences in anticipated market sizes between Air Metro and Air Medevac, the overall degree of impact for airports may be less for the latter use case. Regardless, airport operators can benefit from addressing various impacts, such as:

- Changes in the rate of degradation of landing pads and taxiways.
- High power draw for charging systems impacting electrical infrastructure.

For early Air Medevac use cases, airport maintenance operators should be mindful to observe how UAM vehicles impact landing pad and taxiway wear. It is currently unclear to what degree eVTOL aircraft will affect landing structures compared with legacy rotorcraft. In addition, charging infrastructure for electric aircraft will likely require high-voltage equipment to support rapid and high-capacity charging of vehicles. These systems may be more susceptible to various types of damage from excess heat or high currents.

At full maturity, such forms of wear and tear may require revising of schedules for preventative maintenance and inspection. These schedules are generally used both for the benefit of the airport and to demonstrate compliance of the airport with the FAA. Wide adoption of UAM vehicles for medical air transport could require substantial changes to these procedures and their associated compliance requirements.

Safety and Security The nature of air ambulance flights involves a certain degree of risk; flights are on demand, are often rapid response, and may require minute-by-minute adjustments to flight clearances, routing, and takeoff. Failing to prepare for these operational realities can create delays that risk harm to patients and cause problems for the airports from which the ambulances operate. Airport stakeholders would benefit from consideration of impacts, including:

- Increased power demand and the presence of high-voltage power supply systems.
- Proper storage/handling of medical waste and how it is carried by eVTOL vehicles.

As early Air Medevac operations begin in select cities, airport planners may need to address planning challenges related to operating bases for medical transport eVTOL. In particular, electric aircraft create new power consumption demand challenges for airport infrastructure. These challenges include the magnitude of power usage spikes, as well as the likely increase of overall power consumed. High-voltage power systems may create potential occupational health and safety issues for ground crews and airport maintenance staff.

As operations scale up and reach more mature stages, the number of air ambulance operating bases is likely to grow. This will likely mean increasing use of airport space for such bases and a commensurate rise in eVTOL traffic and transportation of medical supplies and equipment. Such systems may require airport operators and stakeholders to revise procedures for the safe storage and handling of medical waste. Further, the safety of patients transported using UAM vehicles remains relatively uncertain compared to legacy aircraft. Airport operators may benefit from preparing ways to manage risks to patients and medical flight crews.

Infrastructure Air Medevac service has the potential to radically improve urban medical response. Combined with new medical procedures that increase the survivability of severe traumas, it is reasonable to anticipate strong demand for such a service. However, such services will likely entail some challenges for airport infrastructure planning and operation, including:

- Airport facility and spacing allotment to create new Air Medevac bases.
- Growth in the supporting infrastructure required to properly manage airport traffic.

Near-term Air Medevac infrastructure needs will likely be limited, requiring space comparable to current air ambulance (rotorcraft) facilities. However, a key difference is that Air Medevac will require expansion of electrical grid infrastructure to support high-voltage charging. One way this can impact infrastructure needs is the increased risk of electrical fires from battery failures. The FAA has highlighted “thermal runaways” as one of the primary risks associated with lithium-ion battery technologies in Advisory Circular 20-184 (Federal Aviation Administration, 2015b). Facilities to house Air Medevac operations will need to account for these risks in the design and implementation of appropriate fire suppression systems.

At more mature stages, it is anticipated that the U.S. air ambulance market as a whole is expected to expand significantly, which may drive increased utilization of electrified UAM vehicles. Airport operators may expect growth in the number of Air Medevac bases at airports of varying sizes, which will create new demands on infrastructure such as facilities, pad space, electrical grid, and route planning. Given how medical flights are prioritized over other traffic (save distressed aircraft), increases in the number of medical flights by UAM vehicles may alter scheduling and on-time metrics.

Stakeholders Airport stakeholders may see substantial near and long-term impacts from successful adoption of UAM-based air ambulance service. In particular, a diverse set of airport stakeholders will be impacted by Air Medevac operations based in airports, as well as operations in protected airspace. To accommodate this new service, airport planners and stakeholders must be prepared to contend with a variety of direct and indirect impacts, including:

- Improved access to emergency medical treatment for communities near local airports.
- New medical flight management challenges for national aviation regulators and local lawmakers.
- Increased demand for space and resources at airports among airport businesses and operators.

In the early years of Air Medevac, the stakeholders most directly impacted are likely to be community members in proximity to the base of operations. These stakeholders are likely to benefit from rapid, maneuverable aircraft able to deliver lifesaving medical treatment. Furthermore, given the relative infrequency of medical flights, average ambient noise levels are unlikely to increase significantly. However, regulators may need to reconsider oversight guidelines for emergency flights using electric propulsion, as they may impact requirements for range, speed, and payload. In addition, local regulators may need to determine how best to incorporate emergency transport via eVTOL into existing air medical services.

In advance of the mature stage, airport planners—and those affected by their decisions, such as on-premise tenants and business stakeholders—will likely have to incorporate an increasing number of bases for Air Medevac (and air ambulances more broadly) at area airports. Such facilities will require space and new infrastructure for charging and will likely increase demand for limited airport space.

Community Near-term growth in U.S. air medical transport is likely to be driven by decreasing rural access to medical care and improved treatment options. Consequently, airport communities may be impacted by noise and environmental factors related to UAM Air Medevac, including:

- Changing ambient noise profiles from UAM vehicles that are likely to be exempted from standard noise ordinances aimed at passenger transport.
- Emerging environmental concerns from new medical flight base construction and vehicle emissions.

Early in the adoption of UAM Air Medevac, airport communities may see some number of medical flights using rotorcraft replaced by UAM aircraft. Currently, there is no clear consensus on the differences in ambient noise created between legacy rotorcraft and distributed electric propulsion vehicles like those being developed for UAM. In any case, medical flights may necessitate special consideration for noise, as they will likely not be subject to flight restrictions that are otherwise used to reduced community noise and disturbances.

At more mature stages of Air Medevac, airport stakeholders and their communities may anticipate significant growth in the construction of support bases. Increasing construction of this type may necessitate increased consideration of environmental impact and land use. In addition, replacing traditional rotorcraft medical flights, which use conventional aviation fuels, with electrified UAM aircraft may result in significant decreases in carbon emissions and associated environmental contamination and air pollution.

UAM Opportunities for Airports

With or without UAM, the U.S. airport industry and its stakeholders are likely to see significant changes in coming decades. Airport planners should be prepared to address emerging trends such as:

- Growth in air passenger travel and freight shipping.
- Efforts to modernize U.S. airspace management through programs such as the FAA's Next Generation Air Transport (NextGen) program. The NextGen program is due to be fully integrated by 2025 and includes new technologies and procedures designed to better integrate and standardize information sharing, communications, and navigations (Federal Aviation Administration, 2019c).
- Increasing access to large amounts of consumer data

Use Case: Air Metro

Financing As with any potentially disruptive technology, Air Metro will likely require significant investments to bring operations to U.S. cities. In particular, infrastructure requirements present potential financing challenges for service providers. However, existing programs offer potential avenues to mitigate financial risk across stakeholders and create opportunities for UAM service, including:

- Infrastructure planning support from the FAA's AIP. Through AIP funding, reliever airports can expect 90 to 95 percent cost coverage for projects such as runway, taxiway, and apron construction or facility rehabilitation, lighting, signage, drainage, and land acquisition (Federal Aviation Administration, 2017a).
- "Clean" technology projects funding from the VALE program. Eligible airport development projects designed to achieve environmental emissions targets have received an average of $2.8 million per grant since 2005 (Federal Aviation Administration, 2019d).

UAM infrastructure that is collocated with airports that are eligible for AIP funding may itself be eligible for developmental project grants through that same program. This creates significant opportunities for both airport planners and UAM stakeholders aiming to locate Air Metro facilities at medium-sized primary hub airports or smaller reliever airports. However, to be considered for this funding, an airport must be part of the National Plan of Integrated Airport Systems (NPIAS). If participating, airports can apply for grants used to expand airport capacity, improve noise abatement, or other capital improvement projects.

One of the principal advantages of UAM passenger service is the potential offset of some amount of polluting emissions from displaced ground-passenger miles. Programs like the FAA's VALE offer one avenue to incentivize airport operators and developers to pursue development projects that help states achieve cleaner air targets. One of the largest categories of funded grants is for gate electrification projects. Airport and UAM stakeholders may benefit from planning UAM facilities to meet the requirements of such grants, potentially offsetting 75 to 90 percent of the construction costs. Further, VALE explicitly encourages projects that utilize alternative fuel vehicles and may be used to reimburse incremental costs associated with their charging infrastructure. VALE defines alternative fuel vehicles to include both all-electric and hybrid-electric vehicles (Federal Aviation Administration, 2017b).

Business Development Opportunities Advances in consumer data analytics and changes to the way air carriers are owned and financed are likely to coincide with new modes of regional travel like Air Metro to give passengers more transportation options. Across the airport value chain, these shifts may lead to new opportunities for airport stakeholders, including:

- Establishing cooperative development agreements between UAM stakeholders and airport/real estate operators.
- Creating new business opportunities for MRO and airport services providers.
- Enhancing land use master planning and support local businesses.

Passengers who use Air Metro may negatively affect garage operator parking revenue or may be willing to travel farther from the airport for hotel accommodations. Such stakeholders may opt to engage with UAM developers to instead frame cooperative development agreements, sharing costs associated with construction of mixed-use infrastructure to diminish negative impacts to return on investment. Similarly, construction of new UAM infrastructure, including skystops and hubs at airports, may create an opportunity to work with municipal governments. Public-private partnerships like the LaGuardia Airport expansion provide a possible model of this partnership in an airport context. Led by Skanska and other partners, the $4 billion public-private partnership will modernize and expand LaGuardia Airport's B terminal to facilitate increased passenger capacity and airport access (LaGuardia Gateway Partners, 2016).

Other stakeholders, such as MRO providers and airport service providers, may see a strong benefit from UAM passenger operations based at airports. MRO providers, for instance, may be able to work with UAM fleet operators to contract out servicing of eVTOL vehicles. Taking advantage of this opportunity may require some investment in specialized training of personnel to service UAM aircraft. UAM adoption may also provide an opportunity to re-negotiate airport contracts with providers of janitorial, retail, and concession services to control rising costs of service, even as higher passenger throughput fuels revenue growth.

In addition, passenger UAM service may create opportunities to improve local communities. First, UAM stakeholders can work with local and federal government agencies to properly zone land use around UAM infrastructure. Land use master planning can benefit from consideration of UAM by properly zoning land for commercial use to mitigate residents' exposure to noise. Efforts started in the 1970s to curb the effects of aviation-related noise have led to a more than tenfold decline in the number of Americans "exposed to significant aviation noise" (Federal Aviation Administration, 2018). Second, UAM fleet operators may need to support local businesses through increased urban foot traffic anchored in improved mobility. It may then benefit urban businesses and UAM stakeholders to identify revenue-sharing agreements, such as using UAM trips to guide passengers to local businesses through ads or exclusive offers.

Use Case: Air Cargo

Financing Drone-based Air Cargo operations are likely to require fewer improvements to airport operations than other UAM use cases collocated with airports. However, AIP funding may serve as a source for funds to aid in accommodating mature-scale drone operations at airports and may be used in the following ways:

- Improve signage and lighting used to manage drone operations at the airport.
- Install or improve various noise abatement systems and modernize airport noise mitigation procedures.

Unlike Air Metro or Air Medevac, Air Cargo creates relatively little demand on existing airside structures. Pavement surfaces for aircraft are unaffected, existing traffic management systems are unlikely to be utilized, and ground crews will likely have little role in drone operations. However, new considerations for Air Cargo operations will likely result in updates to signage and lighting used to help guide all operations throughout the airport. Airport planners can work with UAM stakeholders to seek AIP funds to update these systems.

In addition, Air Cargo stakeholders and airport planners may opt to plan for noise abatement from the outset. Large drone fleets coming to and from the airport constantly throughout the day are likely to create significant additional ambient noise. Systems and procedures to help mitigate this noise and create minimal disturbance to local communities can take advantage of AIP funding specifically for this purpose.

Business Development Opportunities The Air Cargo delivery scenario is an appealing potential business case for both retail consumers and large-scale delivery companies. For the former, the speed and convenience may entice customers to pay markups in the range of $1 to $5 per delivery. Amazon Prime Air is targeting an approximate $1 per delivery fee (Smith, 2015). For package delivery companies, drone delivery creates an opportunity to minimize inefficiencies in traditional ground-delivery routes. For airports and their stakeholders, there are additional business opportunities, particularly at mature stages, including:

- Identifying new aeronautical revenue sources in fees for drone deliveries from airports
- Establishing facility/space rental agreements for Air Cargo operators
- Fostering relationships with local businesses to expand their customer reach

The weight of individual drone deliveries is likely to be fairly low; many project approximately 5 pounds (e.g., Amazon expects its drones to deliver 5 lb payloads up to 15 miles away in 30 minutes or less [Vincent & Gartenberg, 2019]). However, Air Cargo operations will likely seek to make up for low aggregate freight tonnage with volume. Therefore, airports may seek to identify a fee structure for deliveries from airport-based operators that create a significant source of aeronautical revenue. Additionally, to aid in cost management, airport master planners and facilities operators could potentially benefit from work with Air Cargo fleet operators to determine appropriate rental agreements for airport space.

Air Cargo also creates significant opportunities for local business development and growth, particularly as operations mature. In the short term, most anticipate that Air Cargo deliveries will largely focus on internet-ordered retail spending. However, at more mature stages, Air Cargo may enable local businesses to reach more customers in their immediate communities through added services and convenience. Local businesses leaders and development councils may seek to work with Air Cargo operators to promote their products and get them to new customers. Ventures most likely to benefit from such agreements include local restaurants and small-scale consumer goods manufacturers.

Use Case: Air Medevac

Financing Improving access to emergency medical care can be critical to more rural communities and might thereby serve significant public interests. General aviation airport planners, as well as municipal policymakers, may be able to improve healthcare access in their communities by working with Air Medevac stakeholders to finance the construction of dedicated bases, taking advantage of federal grant funding in the process, principally through:

- AIP grants for general aviation airports, paired with modest local matching funds.

Today, many air ambulance operations are based out of general aviation airports that do not offer regular commercial service. Though such airports generally receive fewer AIP funds than other airports in the NPIAS, capital improvement projects related to medical flight operations are considered eligible. As a result, planners of such airports, along with UAM Air Medevac stakeholders, may elect to form development partnerships to seek funding for Medevac bases. These grants can be used to cover some or all of the costs of new pads, signage, and improvements to overall aircraft operations. One way to increase the likelihood of achieving such grants is to work with municipal lawmakers to obtain matching funds, possibly funded through debt financing. The Congressional Research Service has stated that one of the priorities of AIP grants should be to improve small state and community airports (Congressional Research Service, 2019).

Business Development Opportunities Increasing sophistication of emergency healthcare paired with shrinking access to local hospitals in the United States creates an environment conducive to growth in the air ambulance market. In particular, Air Medevac represents a potentially viable way into this growing industry as electricity costs for UAM vehicles create likely operational savings over variable legacy fuel costs. Airport operators and stakeholders can take advantage of the growth in this industry in several ways:

- Establishing relationships with smaller or less-trafficked airports (e.g., reliever or regional airports) to establish Air Medevac bases.
- Forming risk-sharing partnerships with local governments to develop infrastructure.

Unlike UAM passenger businesses, individual Air Medevac operations do not require large fleet sizes housed at each base. In fact, according to the Atlas and Database of Air Medical Services, the average U.S. rotorcraft air ambulance base only operates one to two helicopters. Alaska leads the United States with an average 3.3 helicopters per air ambulance base, with D.C. in second place, with two (Association of Air Medical Services, 2019). As a result, a significant business development opportunity for the Air Medevac industry will likely be for smaller, regional airports to strike deals with UAM-inspired air ambulance operations for use of facilities and pad space.

Alternatively, new construction of infrastructure to support Air Medevac operations may benefit from risk-sharing agreements with municipal leaders and public partners. As Air Medevac offers a potentially valuable public utility by providing enhanced access to emergency medical care for citizens, there may be a strong incentive to foster relationships such as PPPs with local governments to attract these operations to underserved areas. In addition, as with Air Metro services, MRO providers may see some benefit in working with operators to identify risk-appropriate arrangements to service eVTOL fleets.

CHAPTER 6: PLANNING STRATEGIES ON INTEGRATING UAM INTO AIRPORTS

☛ *In this chapter, AAM will be used in its original context for clarity regarding planning due to Urban Air Mobility (UAM) Advanced Air Mobility (AAM) and Regional Air Mobility (RAM) having unique planning considerations.*

Introduction

AAM encompasses various aerial vehicles and use cases that might justify different planning approaches in order to take into consideration their specific facility requirements. AAM includes UAM and regional air mobility (RAM).

UAM provides on-demand, intra-urban connections with VTOL aircraft. Their operations feature characteristics of both air taxis and ground TNCs. The feasibility of UAM has already been demonstrated in few large metropolitan areas. For instance, São Paulo, Brazil, accommodates over 400,000 conventional helicopter operations (pre-COVID-19 levels). UAM might be implemented at many more large cities over the coming decades using electric VTOLs, which are significantly quieter, greener, and potentially cheaper to operate than conventional VTOLs (helicopters). While UAM will use urban helistops and helipads (sometimes referred to as vertistops and vertipads), airports might consider developing a heliport (or vertiport) to diversify their accessibility and prove faster connection to their catchment areas. These heliports might be located outside of the main aircraft operating area, such as the former heliport of Los Angeles International Airport on the rooftop of parking garage P-4, in order to satisfy the specific needs of this traffic (e.g., security).

Some inter-urban connections might use constrained facilities with runways shorter than 5,000 feet. (1,500 meters) that cannot be expanded because of encroachment or other physical limitations. On-demand and scheduled flights would be performed by short takeoff and landing (STOL)-capable aircraft. Most of these aircraft should have slightly higher capacity and range than VTOLs. Existing STOL aircraft include the DeHavilland Canada DHC-8 and Pilatus PC-6. Similar to UAM, STOL AAM would be provided by more socially acceptable electric or hybrid-electric aircraft. Billy Bishop Toronto City Airport in Canada and London City Airport in the United Kingdom are perhaps the busiest urban STOL ports in the world.

RAM will connect communities with conventional takeoff and landing aircraft. The RAM fleet will feature commuter (2 to 20 passengers) and later regional (20 to 100 passengers) electric and hybrid-electric aircraft. On-demand and scheduled flights should be offered from smaller airports to other community airports or larger aviation facilities. The current operations of air carriers such as Cape Air in the northeast region of the United States and Harbour Air in the Puget Sound (Seattle-Vancouver) area have RAM features. Cape Air operates from both small facilities (e.g., Nantucket Memorial Airport) and large hub airports (e.g., Boston Logan International Airport and St. Louis Lambert International Airport).

Stand-Alone UAM and STOL Facilities

The FAA has indicated that an advisory circular specific to vertiport design is being considered. In the meantime, stand-alone vertiports for UAM should be planned according to the overall approach described in FAA Advisory Circular 150/5070-6B – Airport Master Plans, as well as the general requirements AC 150/5390-2C – Heliport Design. However, neither advisory circular accounts for UAM, and their contents do not always apply to vertiports or require developing a specific study to adapt these standards to atypical vehicles. For instance, conservatively assuming that eVTOLs have the same performance as conventional helicopters, AC 150/5390-2C standards still apply to helicopters with one main rotor axis only, while most eVTOLs have several main rotors and non-typical configurations.

STOLports are defined by the International Civil Aviation Organization as "unique airports designed to serve airplanes that have exceptional short-field performance capabilities." Guidance on STOLport planning is available in ICAO Doc 9150 “Stolport Manual.” STOLport planning and design in the United States shall follow the standards and recommendations applicable advisory circulars, and in particular FAA AC 150/5300-13A – Airport Design and AC 150/5070-6B – Airport Master Plans.

At airports where separate heliport/vertiport or STOLport facilities are provided, the airspace/airside interactions between these “stand-alone” AAM facilities and the rest of the airfield facilities should be carefully considered. This includes, but is not limited to, runway-to-runway or final approach and takeoff area (FATO) separation distances, air traffic control considerations, aircraft rescue and firefighting, TSA requirements, accessibility to people with reduced mobility, etc.

Integration of Advanced Air Mobility into Airport Master Planning

Long-term airport development and planning is governed by individual airport master plans. Master plans are intended to develop airports safely and efficiently by looking toward the future to dictate development and planning needs. The master planning process establishes capital development initiatives for an airport and a long-term plan for increment and flexible development. Master plan studies include environmental considerations, facility requirements, ALPs, facility implementation plans, and financial feasibility analysis, among other components.

FAA AC 150/5070-6B – Airport Master Plans provides guidance to prepare a master plan. According to the advisory circular, the master plan provides the framework needed to guide future airport development that will cost-effectively satisfy aviation demand, while considering potential environmental and socioeconomic impacts. The master plan is a comprehensive study of the airport that describes short-, medium-, and long-term plans for airport development.

With the emergence of AAM, master plans will need to consider the new airside and airspace users:

1. **Pre-planning:** During the pre-planning process, the planning needs shall be identified based on future potential shortcomings. These could be triggered by a capacity reached, introduction of new aircraft types, or the emergence of a critical environmental problem. Airport stakeholders can also identify future needs and communicate these to the airport leadership. Typically, airlines can announce their intensions to open new routes with a new aircraft type. At this stage, it should be determined what type of study will be needed—a full airport master plan or a simple technical report.
    - AAM: The pre-planning process will not be fundamentally impacted by AAM and should consider the introduction of new aircraft types, which could trigger the need for a specific planning study. If applicable, the scope of work should state that AAM should be considered throughout the master planning process.
2. **Public Involvement:** A public involvement program should be created in the earliest stage of master plan development. Such programs are intended to share information about the planning study and to provide collaboration among the airport sponsor, users and tenants, resource agencies, elected and appointed public officials, residents, travelers, and the general public. It is

important the public before any major decisions are made to both consider their comments and educate them about the future potential airport development.

- AAM: RAM at existing airports should not significantly impact the existing practices for public involvement, thanks to its potential benefits to the airport environment and reductions in noise exposure. However, the conversion of smaller facilities to commercial STOLports or the introduction of new UAM routes will require specific public involvement programs.

3. **Existing Conditions:** Master plans require an inventory of existing conditions for both physical attributes and operational and performance characteristics of the airport and related facilities and infrastructure. They include the airside, passenger terminal, and landside facilities. The regional setting of an airport and the surrounding land use patterns should be examined, and an environmental overview performed.
    - AAM: The inventory of existing conditions includes documenting the utility infrastructure. It also includes the identification of commercial service and general aviation facilities and planned improvements, which may include existing plans for electricity and hydrogen storage and distribution facilities, if applicable.
4. **Aviation Forecast:** Aviation activity forecasting completed during the master planning process informs future facility requirements, as well as the timeline for airport development and improvements. An appropriate forecast methodology must be selected according to the level of effort required by the master plan. This step is crucial in master plan development, and the forecast must be submitted to the FAA for review and approval before being used as a basis for the facility requirements.
    - AAM: Aircraft fleet-mix projections are a component of the master planning process that will also need to consider AAM in the future. Identifying the share of AAM among future aircraft operations will help in planning for their accommodation. Like the different aircraft categories, the different categories of AAM should be identified and forecast individually. However, AAM operating on a dedicated infrastructure should be carefully distinguished, which will trigger the need for specific facility requirements. Gate utilization and turnaround times should also be considered as some AAM, especially RAM aircraft, could operate on existing terminal facilities. The forecast should also address future changes in service patterns resulting from the introduction of AAM that could impact the aviation activity should be addressed.

    Note: The FAA does not provide a specific AAM forecast to be included in the Terminal Area Forecast. However, guidance will be provided in the deliverables of ACRP project 03-51 "Electric Aircraft on the Horizon – An Airport Planning Perspective." Moreover, early national trends on AAM may appear in the FAA Aerospace Forecasts. Forecasts on UAS operations are already available.
5. **Facility Requirements:** After the approval of aviation forecasts, the next step is to determine the adequacy of the existing airport facilities to accommodate future demand, and whether any additional facilities will be required. These requirements are driven by the circumstances of each airport, including capacity shortfalls, enhanced security requirements mandated by the TSA, new or updated design standards, the airport sponsor's and the stakeholders' strategic vision for the airport, and outdated facilities.
    - AAM: AAM triggers four specific facility requirements:

i. A potential terminal building dedicated for AAM passenger operations

ii. Charging infrastructure to supply electric or hydrogen power to AAM through electric chargers and hydrogen refueling

iii. Airport electricity infrastructure to support and enable the charging infrastructure

iv. Hydrogen infrastructure for supplying gaseous hydrogen to AAM with fuel cells

The airport sponsor should discuss their specific situation with the relevant stakeholders to determine their needs for charging infrastructure and hydrogen infrastructure.

6. **Alternatives Development and Assessment:** Based on the facility's requirements, an alternative development process is to identify alternative ways to address previously identified facility requirements; to evaluate the alternatives, individually and collectively; to gain a thorough understanding of the strengths, weaknesses, and other implications of each; and finally select a recommended alternative.
    - AAM: During this stage, the airport sponsor and planners would benefit from exploring preferred terminal buildings dedicated for AAM sites, charging locations, and tie-in options, and identifying any other necessary electrical system upgrades. The evaluation of each alternative must include specific criteria regarding AAM, such as the location site of the terminal building, the impacts of the location of the charging infrastructure, the environmental impacts of these chargers, and the financial feasibility.
7. **Airport Layout Plans:** The drawing sets of the airport layout plans (ALPs) must include a cover sheet, the ALP depicting existing and future airport facilities, a data sheet, a facilities layout plan, a terminal area plan, an airport airspace drawing, a drawing of the inner portion of the approach surface for each runway, an on-airport land use drawing, an off-airport land use drawing, an airport property map, a runway departure surface drawing for each runway, a utility drawing, and airport access plans. ALPs are also subject to approval by the FAA in order to receive federal funding.
    - AAM: The AAM infrastructure (terminal building, airside electricity power supply infrastructure, electric chargers, alternative charging means, hydrogen infrastructure) may be depicted in the ALP drawing set.
8. **Facilities Implementation Plan:** This plan is the framework for how to implement the findings and recommendations of the planning effort. Plans differ depending on the complexity of a project and vary from one airport to another. Local conditions will significantly influence the schedule, the costs, and any special regulations.
    - AAM: The implementation of the AAM infrastructure should be considered. Electricity and utility connection providers should be involved in this plan if an upgrade of the power supply infrastructure and the connection to the grid is required. Such an approach needs to consider the future of the overall electricity demand of the airport, as well as plans for decentralized power generation, including micro-grid.
9. **Financial Feasibility Analysis:** During this analysis, the airport sponsor must demonstrate their capability to fund the projects in the master plan and present the capital improvement program.
    - AAM: AAM infrastructure should be treated like any other project and should present the different sources of funding for which AAM facilities are eligible.

Integration of Advanced Air Mobility into Statewide Aviation System Planning

State aviation system planning is a strategic process to assess all the public-use airports in a given state, determine their and their users' current and future needs, the relationship between the airports, and their ability to meet forecast demands. These plans are also used to evaluate funding priorities and policy, or regulatory changes needed to ensure the system's safety and capacity. They often consider the economic impacts and benefits of aviation to a state's economy, how broader industry trends are in turn affecting aviation, and future developments. The planning horizon varies but often includes both short- and long-term analyses, similar to those of the airport master plan.

The statewide aviation plan is the equivalent of an airport master plan at the state level. It encompasses all the airports within the state. It is a technical report that provides information and analysis regarding the system of airports and whose main goal is to provide an efficient airport system that integrates with and participate in the economic development in the state.

The following section describes the potential impacts of AAM for each element of a typical statewide aviation plan.

1. **Aviation System Goals and Objectives:** During this first step, the state's vision of its aviation system must be defined and translated into goals and objectives to achieve that vision. These provide markers for tracking progress toward that vision. A specific committee should be appointed whose purpose is to supervise and define the direction of the system plan. This committee should include members with responsibilities and knowledge directly related to the airport and aviation.
    - AAM: The definition of goals and objectives will not be fundamentally impacted by AAM. However, these vehicles should be considered in the scope of the plan. The state can also select to evaluate the specific needs of the different AAMs and potential funding to make its state aviation system accessible to AAM.
2. **Existing Conditions:** Similar to a master plan, a statewide aviation plan requires an inventory of existing conditions for both physical attributes and operational and performance characteristics of the airport system and related facilities and infrastructure. The air navigation and airspace should also be included.
    - AAM: The inventory of existing conditions may document the current accessibility of the state aviation system to AAM with a mapping of the existing aircraft and AAM charging infrastructure and hydrogen-fueling services.
3. **Aviation Forecasts:** The trends and forecasts of aviation activity within the state must be analyzed and will be used as a basis for the capacity and need analysis.
    - AAM: Aircraft fleet-mix projections need to consider AAM. Identifying the share of AAM among future aircraft operations will help with planning for the development and funding of AAM services and support facilities. Like the different aircraft categories, the different categories of AAM should be identified and forecast individually. However, AAM operating on a dedicated infrastructure should be carefully distinguished from other aircraft operations, which could trigger the need of specific facility requirements. Gate utilization and turnaround times should also be considered as some AAM, especially RAM, could operate on existing terminal facilities. Additionally, future changes in service patterns resulting from the introduction of AAM that could impact the aviation activity should be considered.

4. **Capacity/Needs Analysis**: Based on the aviation forecasts, the capacity of the existing infrastructure must be assessed to evaluate the ability of the regional airport system to accommodate the future demand. Following this evaluation, it must be determined whether the current infrastructure is sufficient for the future aviation demand, and whether any additional facilities are required.
    - AAM: It is important that the stakeholders of AAM operations are gathered at this stage in order to understand the needs of the community, as well as the ambitions of the economic community and of the state regarding AAM. Statewide coordination can be achieved through a specific working group setup to discuss and determine the needs of the aviation community. The energy industry and state regulators (e.g., state department of energy or energy commission) may also be involved in this process.
5. **Alternatives Development:** During this phase, following the capacity/needs analysis, the different alternative actions to meet the goals and objectives of the state vision are developed. Subsequent analysis can be performed to evaluate each airport and the relevant project to meet the established targets.
    - AAM: AAM must be considered in the capacity/needs analysis, and special provisions regarding the availability of AAM infrastructure, such as terminal buildings and charging solutions, should be developed. AAM manufacturing, maintenance, associated employment opportunities, and utilities providers should be involved in the development of alternatives.
6. **Recommendations:** The last phase is to recommend the different actions, alternative strategies, airport metrics, and evaluation of system needs through the development of policy recommendations.
    - AAM: Policy perspectives regarding the integration of AAM at the state level should be developed in this section. They can include considerations regarding strategies to incentivize AAM, potential state funding or support to increase accessibility to the state aviation system, evaluation of the impacts of AAM on fuel revenue, and evaluation of different scenarios to compensate this loss.

CHAPTER 7: AIRPORT ASSESSMENT TOOLKIT

The toolkit provides assessment tools to assist airports in understanding their readiness and provide example action items to move forward with UAM integration. This chapter provides guidance on the toolkit as it stands now, with an understanding that the final deliverable will be an interactive toolkit. The iterative toolkit is developed in Excel for panel review prior to programming. The assessment tools are separated into the following categories of airports to help assess the differing needs of each type of airport.

- Hub
- Reliever/General Aviation Urban
- General Aviation – Suburban
- General Aviation – Rural

Assessment Process

The first step for airports is to assess where they are currently and where they want to go regarding future UAM operations and what initiatives are viable for the particular airport. Table 11 illustrates questions that airports should ask to better position themselves for taking advantage of UAM initiatives as an initial step in the assessment process.

Table 11. Self-assessment checklist - Questions airports should ask themselves to better position themselves for taking advantage of UAM initiatives.

- ✓ Do you understand general opportunities available at the airport both from a current perspective and in terms of changes on the horizon for the electrification of aviation and UAM initiatives?
- ✓ Are there demand and demographics to support UAM initiatives at the airport?
- ✓ Have you implemented any processes to attract business opportunities? (e.g., collection of resources and strengths, beautification of the airport, UAM accessibility, favorable lease agreements, and collaborations with Economic Development Teams).
- ✓ Have you accessed the current power load and potential of growth for the airport?
- ✓ Are you generally in touch with where the airport stands in its current practices compared with its peers, compared with state-of-the-art and leading-edge practices, and compared with those airports that are just beginning to find their way into practice?
- ✓ Have you evaluated current leases and updated plans for collaboration with new tenants at the airport?
- ✓ Have you coordinated with city and Department of Transportation planners, state aeronautics, metropolitan transportation organizations, transit agencies, and other stakeholders to identify common goals for AAM, multimodal integration, or smart city initiatives?
- ✓ Do you have processes in place for successful community engagement?
- ✓ Have you coordinated with OEMs and service providers to help understand opportunities and specific needs to incorporate before planning for UAM initiatives?

After initial considerations are analyzed, critical success factors (CSFs) should be identified to further assess and raise awareness of an airport's readiness. Table 12 introduces 10 CSFs deemed essential to fostering emerging practices generally within the airport and to advancing specific strategies. These CSFs are designed to help airports cultivate and evaluate their capabilities to advance innovative practices and identify the actions required to assess and ultimately implement those that prove worthy of agency practice.

Table 12. Critical success factors.

Critical Success Factors	Explanation
Awareness of UAM initiatives	Being in tune with state-of-the-art, emerging, and innovative practice trends, and where the airport falls in relation to these
Readiness for UAM	Awareness of the airport's readiness for emerging UAM initiatives
Infrastructure for UAM	Infrastructure assessment to understand the airport's strengths, weaknesses, opportunities, and threats
Planning Considerations	Awareness of what should be considered when planning for integration of UAM use cases at airports
Awareness with Performance and Application	Awareness of how well the airport is performing compared to others, how good the airports performance tracking is, and how the airport uses this performance awareness in evaluating outcomes and setting targets
UAM Supportive Systems, Programs, and Budgets for UAM	Systems, programs, and budgets in place that facilitate consideration of innovations
Friendly Culture and Organization Toward UAM initiatives	Commitment to continuous improvement, receptivity to change, willingness to invest in beneficial practices, ability to assess risks vs. rewards, willingness to take prudent risks, tolerance for setbacks, ability to learn and adjust from experience
Supportive Staff for Emerging and Innovative UAM Practices	Possession of the right staff in knowledge, skills, experience, and buy-in of UAM initiatives
Legal, Regulatory, and Policy Issue Management	Being adept at dealing with legal, regulatory, and policy challenges
External Collaboration	Communication and collaboration with key public and private sector interests and influences within and outside the airport community

Using a Capability Maturity Framework (Mallela, et al. 2020) the CRF can be assessed across three levels to assist airports in determining the extent they are positioned to evaluate and potentially adopt AAM initiatives at their facility. Table 13 illustrates an excerpt from one of 10 CSFs applied in the UAM Airport Assessment Tool.

Table 13. Excerpt of critical success factors from UAM Airport Assessment Tool.

Critical Success Factor	Component	Level 1	Level 2	Level 3
1. Awareness of UAM	Context Awareness: *FAA & NASA AAM Initiatives; OEM and Service Provider partnerships; Electrification of Aviation Initiatives;*	Largely unaware, or very limited awareness and interest	Some awareness and moderate interest in following the fundamental and applied research and development	High level of awareness and a keen interest in closely following fundamental and applied research and development in this area

Critical Success Factor	Component	Level 1	Level 2	Level 3
	Alternative aviation approaches being developed and tested			
	Specific Awareness: *Air Passenger Mobility (e.g., Air Metro, Air Taxi), Air Cargo, Emergency/Non-Emergency Services (e.g., Air Medevac, Medical Provider, Public Safety)*	Largely unaware of UAM and how it could impact the airport.	Have some awareness of UAM and experience among early adopters	Have been closely tracking UAM initiatives and experiences in the testing and trials among early adopters

The assessment is a straightforward process of systematically evaluating the airport's capabilities in relation to each CSF.

These factors are numbered in a recommended order but can be assessed in any order that suits the user. The user considers the criteria under each of the matrix's three levels and selects the level that most closely describes their level of readiness. The value of the level (1, 2, or 3) is not the focus of the assessment as much as gaining an understanding of agency capability and potential gaps in capability relative to the CSF criteria. For example, a user may consider all three criteria for a particular CSF and decide that some aspects of Level 1 and some aspects of Level 2 apply simultaneously and choose to characterize the airport's capability as somewhere between levels.

The airport's ability to advance operations toward UAM initiatives are categorized into three levels:

- Level 1 – The airport is in a relatively weak position to advance the UAM practice, with significant gaps in capability.
- Level 2 – The airport is in a potentially tenable position to advance the practice and address some gaps in capability that could pose risks to a successful implementation.
- Level 3 – The airport is well-positioned to advance toward UAM initiatives.

The Go/No-Go Decision

The Capability Maturity Framework (CMF) assessment of capability, in combination with the Required Action Framework (RAF) (see Table 14) action steps, should provide the information needed for the airport's decision-makers to make a "go/no-go" decision on whether to advance initiatives to the testing and evaluation stage. It also provides an ability to move forward quickly following a "go" decision.

From the two-step process (assessing capability using the CMF) and determining required action steps using the RAF, a go/no-go recommendation for advancing a specific practice implies several possible actions:

1. "No-go": Decide not to advance UAM initiatives now because of:

a. Insufficient interest

b. Insufficient capability

c. Insufficient resources

d. Inability to overcome barriers

e. Inability to mitigate risks to an acceptable level

f. Some or all of the above

Include a discussion of the consequences and ramifications of not advancing toward UAM integration.

2. “Not-now”: Continue to monitor progress with the practice development and application elsewhere, as well as all of the above factors that led to a “not-now” decision at this time, and revisit the decision when circumstances warrant. Include a discussion of the consequences and ramifications of not advancing the practice at this time, and an indication of when revisiting the practice would be prudent.
3. “Slow-go”: Decide to advance the practice but for some combination of reasons, do so at an “evolutionary” pace by naturally incorporating UAM initiatives into the airport’s practices as it becomes relatively mainstreamed. Include a discussion of the consequences and ramifications of a “slow-go” decision.
4. “Go-now”: Decide to expeditiously advance the emerging practice into the airport’s UAM initiatives, including an expedited testing and evaluation phase, potentially in collaboration with others interested in advancing it within the airport sector.

The final go/no-go decision may rest with multiple decision-makers; therefore, the CMF and the RAF should contain sufficient information to support the recommendation and be packaged and summarized according to the preferences of those making the decision.

Table 14 provides an example set of recommended, generalized actions for one of 10 CRFs of UAM to help an airport identify and develop the actions necessary to populate an RAF. These actions follow the organization of the CMF, with a few sets of actions suggested for each CSF component.

Table 14. RAF suggested actions.

Critical Success Factor	Component	Potential Target (Level 3)	Suggested Actions
1. Awareness of UAM	Context Awareness: *FAA & NASA UAM Initiatives; OEM and Service Provider partnerships; Electrification of Aviation Initiatives; Alternative aviation approaches being developed and tested*	High level of awareness and a keen interest in closely following fundamental and applied research and development in this area	***Develop, maintain, and leverage awareness of the context of UAM initiatives.*** Track state of practice via electronic and print media, conference attendance, committee participation, and peer dialogue. Develop and maintain an approach to assessing the applicability of the practice to existing airport practices, its current performance and efficacy, and efforts to improve upon them.

Critical Success Factor	Component	Potential Target (Level 3)	Suggested Actions
	Specific Awareness of UAM: *Air Passenger Mobility (e.g., Air Metro, Air Taxi), Air Cargo; Emergency/Non-Emergency Services (e.g., Air Medevac, Medical Provider, Public Safety); What it is; What it does; Where it should work well; Where it might not apply; Level of effort and resources required (staffing, expertise, facilities, equipment, time and budget) equipment, time and budget)*	Have been closely tracking UAM initiatives and experiences in the testing and trials among early adopters	***Develop and sustain a technical understanding of the importance of the UAM practice.*** Stay abreast of the practice's application for each use case and determine which would be most relevant to the airport and community. Compile information on which applications may be easy wins and what partnerships may work well, as appropriate. Include the following considerations: where it should work well, where it might not apply, and the level of effort and resources required (staffing, expertise, facilities, equipment, time, and budget).

Decision Tree

The decision tree is another assessment tool that can help airport owners, operators, and planners understand various courses of action and specific critical items stemming from the uncertain factors associated with the integration of UAM at airports. Figure 6 and Figure 7 Illustrate a few examples of decision trees available in the toolkit.

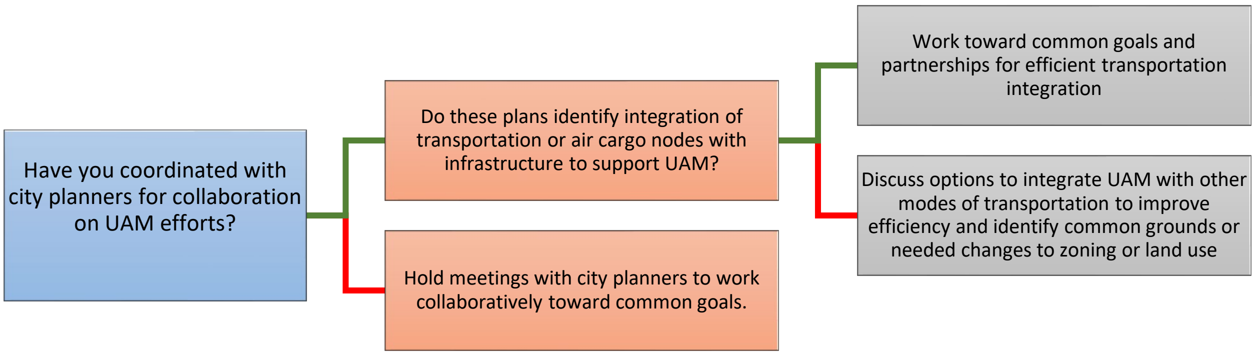


Figure 6. Decision tree example.

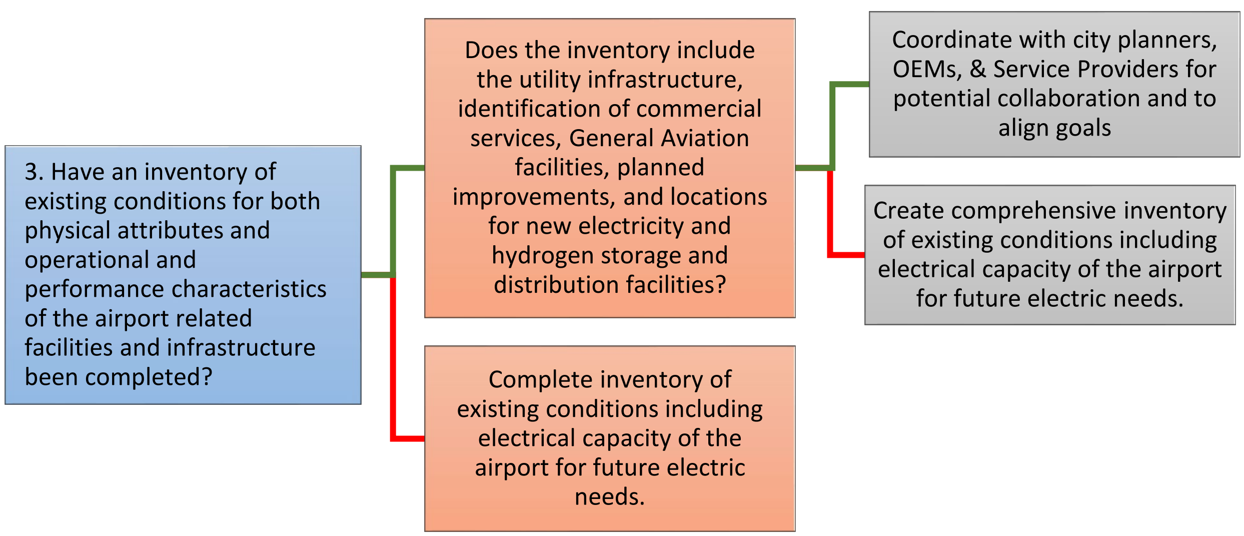


Figure 7. Master planning – decision tree.

CHAPTER 8: STAKEHOLDER ENGAGEMENT ON RESEARCH TASKS

In addition to an extensive review of literature, the WSP team conducted initial interviews to validate the findings of the literature and fill gaps in the research. Interviews were conducted with TNCs, city planners, OEMS, airport operators, and FAA personnel, and information gathered from the technical working group (TWG), and a questionnaire distributed to stakeholders. The next steps will include further dissemination of the questionnaire to provide further feedback in addition to additional interviews and TWG meetings. These steps will provide additional insight and practical guidance to achieve the goals for this project. The team has followed the stakeholder engagement plan, questionnaire, interview subjects, and structure of the TWG as described in this chapter.

Stakeholder Engagement Plan

Table 15 outlines proposed methods of outreach and involvement of various stakeholders throughout the planning process. A more in-depth description of the methods follows.

Table 15. Stakeholder engagement.

Method of Engagement	Stakeholders	Insight on UAM Challenges	Timeline
(1) Questionnaire	Airport Manager OEMs State Division of Aeronautics Directors Key UAM Experts	General UAM Questions Airport-Specific UAM topics OEM specific UAM topics (See proposed questions)	The survey was disseminated, and additional outreach and dissemination are provided through the TWG and WSP outreach.
(2) Personal Interviews	Survey participants Additional UAM experts as needed	Technical advice Follow-up to survey responses	As needed
(3) Technical Working Group	List of current TWG members listed below	Airport-centric challenges and goals for UAM OEM challenges for UAM Group collaboration on UAM topics Review of project items	Two virtual workshop meetings in April June workshop (virtual) July workshop (virtual) August workshop (virtual)

Questionnaire

The team distributed a survey of questions to stakeholders to gather responses about challenges and insight about UAMs from an airport, OEM, and regulatory perspective. The survey allows for a better understanding of key issues from multiple viewpoints. The team reviewed the questionnaire's answers to identify potential interview candidates, listed at the end of this section. The survey questions were updated as per the interview panel's feedback.

The list of questions has multiple categories to gather issues from different perspectives. The categories include general questions that may apply to all involved; questions relevant to hub, reliever, and general aviation airports; and UAM OEMs.

General Questions:

1. What are the short-term and long-term impacts and opportunities that Urban Air Mobility (UAM) provides for the airport industry?
2. How will UAM affect the following airport types differently? (Part 139, NPIAS GA, Non-NPIAS GA)?
3. Where would UAM operations be the most efficient?
    - ☐ Part 139 Hub Airports
    - ☐ Part 139 Non-Hub
    - ☐ General Aviation NPIAS Airports
    - ☐ General Aviation Non-NPIAS
    - ☐ New Infrastructure
    - ☐ City UAM Landing Sites (e.g., private vertiports, existing helipads, etc.)
    - ☐ Other (Please specify)
4. What kind of UAM operations are best suited at hub airports?
    - ☐ Airport to CBD
    - ☐ Airport to Airport
    - ☐ Airport to new areas (e.g., vertiports, new construction.)
    - ☐ Other (Please specify)
5. Where would UAM operations be best suited for optimal passenger transfer at airports?
    - ☐ Commercial Part 121 Terminals
    - ☐ General Aviation/Part 135 FBO Facilities
    - ☐ Other (Please specify)
6. What ways could UAM improve passengers' end-to-end experience over traditional transportation?
7. How will congestion management for aircraft landside and passenger processing be addressed for UAM?
8. Will security for UAM be handled through the TSA, as commercial operations are conducted, or through FBOs like in Part 135 operations?
9. What changes are needed in the technology infrastructure to support UAM? (e.g., mapping the airport to terminals, sufficient bandwidth of Wi-Fi, new check-in procedures, etc.,)
10. What additional ground support equipment may be needed to support UAM at an airport?
11. How important it is for UAM aircraft to be capable of flying existing SIDS & STARS?

12. Could the Small Aircraft Transportation System (SATS) initiative help UAM?
13. Could UAM reduce congestion and delays in the air transportation system or create more?
14. What other weather forecasting and radar equipment at airports/vertiports required for safe operations?
15. What would be the minimum infrastructure requirements for supporting UAM operations at different stages of maturity?
16. What changes, if any, are needed to foster community acceptance of UAM at airports?
17. What planning considerations are needed for airports to prepare for the range of identified impacts and opportunities for the following subjects:
    - ☐ Passenger, cargo, and aircraft activity;
    - ☐ Operations and maintenance;
    - ☐ Short-term and long-term airside, terminal, and landside facility requirements;
    - ☐ Financing, including revenue generation;
    - ☐ Safety and security;
    - ☐ Community (e.g., noise, environmental, and compatible land use);
    - ☐ Stakeholders (e.g., tenants and business partners); and
    - ☐ Opportunities for business development.
18. What steps are needed to integrate into the existing airport environment?
19. Are lease agreements structured to allowing UAM to come to the airport?
20. What changes to lease agreements are needed to facilitate UAM at airports?
21. Would UAM be a value add or value detractor to airports?

Hub/Reliever Airport-Specific Questions

1. Do you have any plans to incorporate Urban Air Mobility (UAM) or Advanced Air Mobility (AAM) into your airport?
    - ☐ If yes, at what stage are you currently in?
        - Initial Planning
        - Plan Creation
        - Implementation
        - Other (Please specify)
    - ☐ If, no, what are the reasons for not planning for AAM
        - Funding limitations
        - Time constraints
        - Infrastructure constraints
        - Waiting for changes to regulatory environment

- Other (Please specify)

2. Have you incorporated AAM or UAM into your Master Plan?
   - ☐ Yes
   - ☐ No
3. What source of funding will be the primary source needed for infrastructure changes for UAM needs?
   - ☐ FAA
   - ☐ State
   - ☐ Local
   - ☐ Airport financed
   - ☐ Private Investors
   - ☐ Other (Please specify)
4. What role do you see your airport performing for Advanced Air Mobility? (Select all that apply.)
   - ☐ Passenger Hub
   - ☐ Package Delivery Hub
   - ☐ Medical Package Delivery Hub
   - ☐ Medical Passenger Hub
   - ☐ Other (Please specify)
5. With current operation and congestion loads, do you have the capacity to accommodate UAM operations?
   - ☐ Yes
   - ☐ No
6. What is the primary risk associated with implementation of UAM at the airport?
   - ☐ Aircraft incursions
   - ☐ Safety of passengers
   - ☐ Electrical demand
   - ☐ Funding limitations
   - ☐ Noise abatement
   - ☐ Other (Please specify)
7. What items are most important to ensure OEMs vehicle technology considers airport infrastructure needs? (select all that apply)
   - ☐ Software integration
   - ☐ Airport Planning Coordination
   - ☐ Protocol Coordination

- ☐ Other (Please specify)

8. What impacts from shorter distance trips and increased arrivals/departures do you envision UAM having on airport operations?
   - ☐ Increasing delays
   - ☐ Decreasing delays
   - ☐ Providing additional revenue streams
   - ☐ Decreasing revenue streams
   - ☐ Other (Please specify)
9. Where would UAM operations be best suited for optimal passenger transfer?
   - ☐ Commercial Part 121 Terminals
   - ☐ General Aviation/Part 135 FBO Facilities
   - ☐ Other (Please specify)
10. What mode of transportation will you use to mobilize UAM passengers to/from landing sites?
    - ☐ Existing infrastructure (e.g. airport terminal/gate system)
    - ☐ Separate UAM terminal/gate system
    - ☐ Airport shuttle
    - ☐ Curbside
    - ☐ Other (Please specify)
11. Do you have any plans to build infrastructure to support the electrification of aviation?
    - ☐ Yes
    - ☐ No
12. Do you have infrastructure to support UAM package delivery?
    - ☐ Yes
    - ☐ No
13. How will you facilitate UAM landing sites?
    - ☐ Use existing helipads
    - ☐ Create new landing areas
    - ☐ Have not planned for any UAM landing sites
14. Do you have space allocated for UAM landing sites?
    - ☐ Yes
    - ☐ No
15. Do you have plans to build any landing sites for UAM?
    - ☐ Yes

☐ No

16. Do you have any land-use policies that would be favorable for UAM and other complementary businesses to create a diverse revenue stream?

    ☐ Yes

    ☐ No

17. What changes to land-use policy would foster businesses growth at the airport for UAM operations?
18. What trade-offs and impacts may exist to the airport master plans at various stages of integration for UAM vehicles, considering an airport and its communities' unique attributes?
19. What regulations (federal, state, or local) will need to be implemented or modified to enable Advanced Air Mobility (UAM) at your airport?
20. What impact on airport economics, both revenue and costs, as a result of forecasted UAM activity levels do you anticipate?
21. What impacts do you anticipate from new business development opportunities generated from UAM (e.g., retail tenants, accessibility from downtown establishments, and new charges for Transportation Network Companies?
22. How could your unique characteristics and local socioeconomic conditions advance UAM?
23. How will shorter distance trips and increased frequency of arrivals/departures impact your current operations?
24. What impacts do you envision for airport safety and handling procedures, and security protocols to handle new types of payloads (e.g., bloodwork, lab tests, medical supplies) or higher volumes of passengers?
25. Do you have any other items not addressed in this survey that you would like to include?

General Aviation Airport-Specific Questions

1. Do you have any plans to incorporate Urban Air Mobility (UAM) or Advanced Air Mobility (UAM) into your airport?

   ☐ If yes, at what stage are you currently in?

   - Initial Planning
   - Plan Creation
   - Implementation
   - Other (Please specify)

   ☐ If, no, what are the reasons for not planning for UAM

   - Funding limitations
   - Time constraints
   - Infrastructure constraints
   - Waiting for changes to regulatory environment

- Other (Please specify)

2. Have you incorporated AAM or UAM into your Master Plan?
   - ☐ Yes
   - ☐ No
3. What source of funding will be the primary source needed for infrastructure changes for UAM needs?
   - ☐ FAA
   - ☐ State
   - ☐ Local
   - ☐ Airport financed
   - ☐ Private Investors
   - ☐ Other (Please specify)
4. What role do you see your airport performing for Advanced Air Mobility? (Select all that apply.)
   - ☐ Passenger
   - ☐ Package Delivery
   - ☐ Medical Package Delivery
   - ☐ Air Ambulance
   - ☐ Other (Please specify)
5. What is the primary risk associated with implementation of UAM at the airport?
   - ☐ Aircraft incursions
   - ☐ Safety of passengers
   - ☐ Electrical demand
   - ☐ Funding limitations
   - ☐ Noise abatement
   - ☐ Other (Please specify)
6. What items are most important to ensure OEMs vehicle technology considers airport infrastructure needs? (select all that apply)
   - ☐ Software integration
   - ☐ Airport Planning Coordination
   - ☐ Protocol Coordination
   - ☐ Other (Please specify)
7. What mode of transportation will you use to mobilize UAM passengers to/from landing sites?
   - ☐ Separate UAM terminal/gate system
   - ☐ Walking

- ☐ Shuttle
- ☐ Other (Please specify)

8. Do you have any plans to build infrastructure to support the electrification of aviation?
   - ☐ Yes
   - ☐ No
9. Does the airport have the electrical capacity to support charging of electric UAM vehicles that will range from 7-35 kW?
   - ☐ Yes
   - ☐ No
10. Do you have infrastructure to support UAM package delivery?
    - ☐ Yes
    - ☐ No
11. How will you facilitate UAM landing sites?
    - ☐ Use existing helipads
    - ☐ Create new landing areas
    - ☐ Have not planned for any UAM landing sites
12. Do you have space allocated for UAM landing sites?
    - ☐ Yes
    - ☐ No
13. Do you have plans to build any landing sites for UAM?
    - ☐ Yes
    - ☐ No
14. Do you have any land-use policies that would be favorable for UAM and other complementary businesses to create a diverse revenue stream?
    - ☐ Yes
    - ☐ No
15. Do you currently have a ground transport system partner that could help provide transportation options to/from the airport?
    - ☐ Yes
    - ☐ No
16. Where would UAM operations be best suited for optimal passenger transfer?
    - ☐ Commercial Part 121 Terminals
    - ☐ General Aviation/Part 135 FBO Facilities
    - ☐ Other (Please specify)

17. What changes to land-use policy would foster businesses growth at the airport for UAM operations?
18. What trade-offs and impacts may exist to the airport master plans at various stages of integration for UAM vehicles, considering an airport and its communities' unique attributes?
19. What regulations (federal, state, or local) will need to be implemented or modified to enable UAM at your airport?
20. What impact on airport economics, both revenue and costs, as a result of forecasted UAM activity levels do you anticipate?
21. What impacts do you anticipate from new business development opportunities generated from UAM (e.g., retail tenants, accessibility from downtown establishments, and new charges for Transportation Network Companies?
22. How could your unique characteristics and local socioeconomic conditions advance UAM?
23. How will shorter distance trips and increased frequency of arrivals/departures impact your current operations?
24. What impacts do you envision for airport safety and handling procedures, and security protocols to handle new types of payloads (e.g., bloodwork, lab tests, medical supplies) or higher volumes of passengers?
25. What is needed for UAM service providers to integrate into existing airport operations?
26. Do you have any other items not addressed in this survey that you would like to include?

OEM and Service Provider Specific Questions:

1. How many operations do you envision having in the near term and long term?
2. What are the main cities where you are anticipating first to start operations?
3. Do you have any current working relationships or partnerships with the cities or airports?
    - ☐ Yes
    - ☐ No
    - ☐ Working on building relationships
4. What items are most important to ensure airports can integrate with OEMs vehicle technology and infrastructure needs? (check all that apply)
    - ☐ Software integration
    - ☐ Airport Planning Coordination
    - ☐ Protocol Coordination
    - ☐ Other (Please Specify)
5. What items specifically are a deciding factor when deciding which cities to focus on for your operations?
6. What Standard Departure and Arrival Procedures from an airport would be complimentary to your operations?

7. What costs are expected to be shared and passed onto the airports or cities?
8. What changes are needed to expedite UAM?
9. What other needs do you have that need addressed from an airport perspective?
10. What maintenance capabilities and facilities will be needed to accommodate your aircraft at airports?
11. What additional airport infrastructure will be needed to support your aircraft?
12. What regulations are enabling or hindering your progress?
    - ☐ Federal
    - ☐ State
    - ☐ Local
    - ☐ All of the above
    - ☐ Other (Please specify)

Interviews

Personal interviews have been conducted and will continue as needed throughout the research process to add clarification and gather further insight from the survey responses and to seek technical advice on complex topics. The interviews will be conducted on an as-needed basis.

The research team identified the following potential interview candidates:

- Aaron Organ – Utah Valley University Researching UAM Community Integration
- Adam Goldstein – Archer Aircraft (Partnering with United)
- Adam Cohen – Senior Research Manager University of California Berkley
- Air Medical operating to Zurich (Need Contact)
- Amber Wilson – Manager of Aviation Technology at Virginia Department of Aviation
- Basil Yap – North Carolina Department of Transportation (NCDOT) Beyond Program Manager
- Bill Wyatt – Salt Lake City International Airport Manager
- Bob Brock – Kansas Director of Aviation
- Bobby Walston – NCDOT Director of Aeronautics
- Brian Corbett – Ross Aviation (Partnered with Blade UAM Inc for eVTOL Vertiports and Fixed-Base Operator or FBO services)
- Brett Adcock and Adam Goldstein – Archer Aircraft partnering with United Airlines
- Bryant Garrett – Ogden-Hinckley Airport Manager
- Chris Howe – Lead Operating Officer Canadian Advanced Air Mobility Consortium
- Carolina Department of Transportation (DOT) Division of Aviation
- Choctaw Nation of Oklahoma Division of Strategic Development

- Cal Coopmans Utah State University – IPP Reno
- Chip Gentry – Memphis-Shelby County Airport Manager (IPP/Beyond Program)
- Christina Nutting – Airport Planning Specialist, FAA
- Clint Harper – Aeronautics Economic and Business Development Manager, Utah DOT
- Dag Falk-Pedersen of Avinor (Norway Airport Operator)
- Danielle McLean – CEO Happy Takeoff
- Darshan Divakaran – AFWERX
- David Oord – Head of Regulatory Affairs Americas Lilium
- David Ulane – Director Colorado Division of Aeronautics
- Fred Judson – Ohio UAS Program Manager
- Gabriela Juarez, City Planner, Dept. of City Planning Greater Los Angeles
- Jared Esselman – Director Utah Division of Aeronautics
- Jim Halley, Director of Airport Planning & Programming, TxDOT
- Jim Herrera – FAA AAM/UAM Program Manager
- Joerg Mueller – Head of Urban Air Mobility at Airbus
- Kelly Campbell – AAAE Chair – Director of Aviation at Lubbock Preston Smith International Airport
- Kent Duffy, FAA National Resource Expert for Airport/Airspace Capacity, FAA
- Luis Merderos – Advanced Air Mobility Risk Manager at National Aeronautics and Space Administration (NASA)
- Marion Blakey – Former FAA Administrator
- Mark Moore – Whisper Aero
- Mary Beth – California Director of Aeronautics
- Mary Stringer - Manager for Automated Flight and Contingency Management in Advanced Air Mobility at NASA
- Melissa Tomkiel – President and General Council BLADE UAM Inc. (Vertiport Chicago Powered by Blade)
- Meredith Bell – Vice President, Communications and Marketing at Lilium
- Michael Marcolini – President, Marcolini Consulting LLC
- Michelle Frazier – Tennessee Director of Aeronautics
- Mike Pape – Idaho Director of Aeronautics
- Mikkel Fenneberg – Support and Research for Falck (UAV Medical Operations)
- Myron Scott Wright – President UPS Flight Forward

- Nancy Gao Ehang – UAM/UAS Operation Manager, EHang Holdings
- North Dakota IPP/Beyond Test Site
- Paul Stanley – Autonomous Systems Safety Engineer, The Boeing Company
- Parimal Kopardekar (PK) – Director of NASA Aeronautics Research Institute
- Peter Bell – Founder at Urban Air Mobility Coalition for Affordable Housing
- Robert C. Huck, PhD – Director of Advanced Technology Initiatives, Chocotaw Nation of Oklahoma
- Robert Jackson – Planning and Environmental Program Mgr., North
- Ross Aviation – FBO planning for eVTOL Vertiports
- Ryan Marlow – Alaska UAS Program Manager
- Ryan Naru – Government Affairs Analyst, Joby Aviation
- Sebastian Thrun – CEO KittyHawk
- Susan Shea – Illinois DOT Director of Aeronautics
- Tarek Tavshouri – California UAS Program Manager
- Thomas "Max" Platts – Washington State Department of Transportation (WSDOT)
- Troy LaRue – Alaska Aviation Operations Manager
- Yolanka Wulff – Executive Director at CAMI

Technical Working Group

A TWG was created and includes the following representatives:

Technical Working Group Members

- Adam Cohen – Senior Research Manager, UC Berkley
- Adrienne Lindgren – State and Local Partnership Lead
- Amber Wilson, PhD., IACE, ASC – Manager of Aviation Technology, Virginia Department of Aviation
- Ann Richart, AAE – Aeronautics Director, Nebraska Department of Transportation
- Benjamin Elkins – UAS Coordinator, Idaho Division of Aeronautics
- Brendan Reed – Director of Airport Planning & Environmental Affairs, San Diego International Airport
- Clint Harper, C.M. – Urban Air Mobility Fellow, Urban Movement Labs
- Danielle McLean – CEO, Happy Takeoff
- Darshan Divakaran – President, AIRAVAT
- Fred Judson – Director, Ohio UAS Center

- Gabriela Juarez – City Planner, Department of City Planning Greater Los Angeles
- James L. Grimsley – Executive Director of Advanced Technology Initiatives, Choctaw Nation of Oklahoma – Division of Strategic Development
- Jared Esselman C.M. – Director of Aeronautics, State of Utah
- Jeffrey Belt, Ph.D. – Technical Lead: Battery Development, Characterization, and Performance Evaluation, EP Systems
- James Herrera – Urban Air Mobility/Advanced Air Mobility Program Manager, FAA
- Justin Guan, AICP – Community Planner, FAA
- Katie Gilmore – UAS Program Manager, MnDOT Aeronautics
- Keri Lyons – Technical Advisor, FAA Office of Airports
- Lori Lee – Aviation Planner, California Department of Transportation (Caltrans) Division of Aviation
- Thomas S. “Max” Platts – Aviation Planner, WSDOT
- Michael Armstrong – CTO, EP Systems
- Michael Marcolini – President, Marcolini Consulting LLC
- Nikki Navio, AICP – Transportation Planner, Wasatch Front Regional Council
- Paul Stanley – Autonomous Systems Safety Engineer, The Boeing Company
- Richard Sewell – Aviation Planner, Alaska Statewide Aviation
- Ryan Marlow – UAS Program Coordinator, Alaska Statewide Aviation
- Ryan Naru – Government Affairs Analyst, Joby Aviation
- J. Scott Drennan – CEO, Drennan Innovation
- Steven Melander – Test Pilot, Sunrise Engineering
- Tarek Tabshouri – Chief, Office of Technical Services and Programs, Caltrans Division of Aeronautics
- Yolanka Wulff – Executive Director, CAMI

Goals for the workshops:

- Bring together the stakeholders of UAM at airports.
- Share information on the challenges of integrating UAM at airports.
- Provide a forum for airports and OEMs to discuss needs and challenges.
- Discuss findings and interim guidance for ACRP 03-50.
- Ensure the deliverables address the needs of the industry.

The TWG will meet throughout the project to discuss findings and gain additional insight for the project. The schedule for workshops will be:

- Two workshops in April
- June workshop
- July workshop
- August workshop

The meetings will provide an opportunity for workgroup members to give input on what is most useful and help with gap analysis and implementation of the plan. The workgroup may choose to invite experts to present on relevant topics.

The agenda for the meetings will include the following topics:

April Workshop

- Introduction to ACRP 03-50A Project
- Airport classes and requirements for UAM integration
- Required changes to support new infrastructure needs
- UAM funding considerations
- Leasing agreements
- Airport UAM infrastructure requirements for vehicles and passengers
- Maintenance requirements at airports
- Needs of the airport/OEM industry

June Workshop

- Toolkit and Interim Report review
- Recent updates and insight on current UAM initiatives

July Workshop

- Business case framework for UAM integration
- Impact areas
- Planning considerations

August Workshop

- Guidebook, interactive toolkit, technical memo review

CHAPTER 9: GUIDEBOOK OUTLINE

The guidebook will provide airport operators with a robust and practical understanding of the airport UAM market, a detailed evaluation of the impacts and opportunities for airports and airport stakeholders, and a step-by-step guide on how to use the interactive toolkit through an individual airport's planning process for UAM operations.

As UAM operations at airports are in their nascency, this guidebook aims to clearly define the major technological and regulatory uncertainties that are still to be defined. The WSP team will recommend methods for ongoing engagement between airports and OEMs/suppliers.

The guidebook will be broken down into eight primary sections, as illustrated in Figure 8:

Figure 8. Guidebook Outline

Market Assessment

The guidebook opens with an executive summary of the UAM market as it pertains to airports. This section provides airports with a detailed set of perspectives on the underlying drivers and market forces that underpin passenger, cargo, and medical use cases for airport-based UAM operations. The WSP team's assessment provides downside, baseline, and upside scenarios for user adoption to help airports understand the full array of potential activity levels airports may need to address.

Major topics include:

- Executive summary of overall UAM market
- Definition of UAM for 03-50 and primary airport-related use cases
- "State-of-the-Art" overview of the UAM market to date for each use case, including a review of major OEMs and suppliers, classes of vehicle designs, and technologies in development

- Definition of major variables that underpin quantification of market activity (e.g., volume of passengers)
- Assessment of major variables impacting the development and adoption of the UAM market, including underlying drivers and trends for anticipated changes
- Baseline, downside, and upside scenario analysis of likely activity volume, sequencing and timing, and potential business models for each UAM use case affecting airports

Business Case and Implications for Airports

This chapter of the guidebook discusses business cases, implications, and guidance for integration of UAM at airports, which includes:

- Multimodal integration considerations regarding the means to efficiently integrate UAM with other multimodal transportation options
- Considerations on airport infrastructure, funding, and partnerships
- Guidance on stakeholder engagement, including key messages

Use Cases and Applications for Urban Air Mobility

This chapter discusses the motivation and primary use cases for UAM: Passenger, Air Metro, and Air Cargo. The chapter includes applications and UAM aircraft operations for each use case to illustrate the current state of the industry worldwide.

Impact and Opportunity Evaluation

After a thorough market assessment of UAM for airport planners, the guidebook will closely examine the impact—and potential opportunities—UAM may have for airports from a planning and investment perspective. This guidebook chapter offers insight across the major variables affecting airports, including, at minimum:

- Impact on airport passenger volume from potentially higher levels of UAM-driven passenger, cargo, and medical activity. Volume is a cascading factor, as significant swings in volume will drive the intensity of impact on nearly all other variables, particularly infrastructure, financing, stakeholders, and community considerations.
- Impact on airport operating procedure and required maintenance capabilities to service and deploy a variety of UAM vehicles in multiple mission profiles. This study will explicitly address the impact of sequentially more AVs, which could add a layer of complexity to airport operations and maintenance.
- Impact on airport safety and handling procedures, and security protocols to handle new types of payloads (e.g., sensitive medical material such as biological samples) or higher volumes of passengers. This section will include cybersecurity impact to the operation of AVs.
- Impact on airport community, particularly relating to noise considerations from new flight-tracks or new vehicles, as well as environmental impact on water, wetlands, zoning, air quality, and potential impact on historical or cultural artifacts.

- Impact on airport infrastructure (curbside, terminal, and landside) across a variety of constraints (e.g., funding constraints, turnaround time, or transfer time constraints).
- Impact on airport technology, not only on Air Traffic Control software and protocols, but also on broader partnership impacts and opportunities, including how airport planners can engage OEMs to ensure that vehicle technology considers airport infrastructure needs.
- Impact on airport economics, both revenue and costs, as a result of forecast UAM activity levels to and from airports, a range of mission profiles, and a range of trends in technology and regulation. This chapter will also include discussion of the interconnected dynamics between airport economics and external transportation parties (particularly TNCs).
- Impact on airport customer experience due to sequential deployment ("phasing") of various UAM solutions, including layout concerns, access issues on curbside, transfer delays in terminal, or airside delays from airspace conflict.
- Implications for new business development opportunities for airports, including retail tenants, downtown establishments that become accessible to airports due to UAM solutions, and new charges for TNCs.

Planning Strategies

This chapter will provide guidance on planning strategies for UAM, including:

- Stand-alone UAM and STOL facilities
- Integration of AAM into airport master planning
- Integration of AAM into statewide aviation system planning

Airport Interactive Toolkit

This chapter will include instructions and background information on the interactive toolkit that was developed by the WSP team during Task 3. The interactive toolkit will supplement the report to provide practical tools for airports to assess their readiness and key considerations for UAM integration.

The interactive toolkit includes:

- Brief Instructions for toolkit (detailed instructions are located in the Interim Report in Chapter 7)
- Self-Assessment Checklist
- Airport-Centric Assessment Tools, including CMF and RAF worksheets to assess a go/no-go decision for:
    - Hub
    - Reliever/General Aviation for Urban
    - General Aviation for Suburban
    - General Aviation for Rural Airport
- Decision trees created for the following areas:
    - Master Planning

- Hub
- Reliever/General Aviation Urban
- General Aviation Suburban
- General Aviation Rural

Glossary

The guidebook will also contain a final glossary of all key terms used throughout the deliverables.

Bibliography

The guidebook will contain a final bibliography.

Implementation of Research Findings and Products Memo (Technical Memorandum)

The guidebook will be complemented by a memo providing guidance on how to most effectively implement the findings and products delivered from the research. The memo will also include key discussions that are not addressed in the guidebook but are essential considerations for the next steps in research and implementation. The memo will be tailored to the specific needs and based on the guidance of the project panel, but will at a minimum include:

- Recommendations on how to best translate the research findings/products into practice
- Identification of possible institutions that might take leadership in applying the research findings/products
- Discussion of issues affecting the potential implementation of the findings/products and possible actions to address these issues
- Methods of identifying and measuring the impacts associated with the implementation of the findings/products
- Identification of future areas of research
- Identification of roles and responsibilities of different stakeholders for the integration of UAM aircraft
- Discussion of barriers and challenges associated with potential UAM use cases and applications

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ANNOTATED BIBLIOGRAPHY

REVIEW OF LITERATURE

To ensure appropriate reflection of the state-of-the-practice as well as emerging practice as a part of the market assessment study, the research team reviewed an extensive collection of UAM literature. The team gathered and distilled both generalist UAM papers and airport-specific documents to inform the research. The types of documents reviewed included:

- Industry white papers and technical reports.
- Reports published by research institutions, foundations, and other non-profit organizations.
- Airport initiatives for future mobility and sustainability.
- Municipal strategic documents and outreach to industry.
- Major press releases and newspaper articles from industry players.
- Federal, state, and local legislation for land use, general aviation, and the environment.
- Standards development organization meeting minutes.
- Construction practices and guidelines for airports.
- Applicable judicial cases.
- Expert interviews with industry and airport influencers (prior to survey).

As noted, the team did not limit the literature review to the traditional sources of published, peer-reviewed articles in trade journals—a staple of applied research work for ACRP—but reached a broader set of publications. Stakeholders in this space, and especially those from the technology sector and airlines, do not typically publish papers in traditional peer-reviewed journals.

ANNOTATED BIBLIOGRAPHY

Source #	*Citation*
[1]	WSP Research Team **Airspace Design Research** • Based on interviews with UAS, UAM, and UAM Traffic Management (TM) experts and stakeholders. • Discussion of eVTOL (and sUAS) airspace management proposals by early industry leaders and regulators, including: o Major stakeholders. o Current system Concept of Operations (ConOps). o Proposed improvements. o Examines the major technical, regulatory, and practical obstacles facing implementation of eVTOL systems. o Identifies current status and gaps in existing and proposed UAM airspace design challenges, research, and approaches. **Aviation Procedures** • Characterizes the hurdles in developing eVTOL flight procedures and current efforts to do so by governmental organizations, OEMs, and UAM system operators. • Reviews existing proposals for general versus specific vehicle flight instructions. • Outlines the likely near- and long-term requirements of aviation procedures for eVTOL vehicles in urban environments. • Articulates procedures for all phases of flight. • Identifies the need for tailored emergency protocols. • Based on discussions with in-house Ascension senior advisors and industry experts. **Machine to Machine (M2M) Communication** • Communications technology, security, availability, and infrastructure, including industry-adjacent standards, current systems, and elements of platforms. • Highlights gaps between existing aviation communications technology and that required for M2M communication in UAM eVTOL. • Based on discussions with in-house Ascension senior advisors and industry experts. **UAM Navigation** • Outlines the largely untested and unregulated plans for eVTOL navigation systems in urban environments. • Compares planned eVTOL navigation systems (GPS/INS) with proposed alternative/redundant technologies.

Source #	Citation
	• Highlights the unique intersection of customer demand, regulatory uncertainty, and industry reluctance that presents barriers to operationalizing UAM navigation. • Based on discussions with in-house Ascension senior advisors and industry experts. **UAM Airspace Surveillance** • Examines the readiness and maturity of existing systems to address required surveillance needs. • Highlights the difference between cooperative and non-cooperative surveillance. • Identifies privacy concerns that non-cooperative surveillance systems raise among the public in urban environments. • Based on discussions with in-house Ascension senior advisors and industry experts. **Detect and Avoid** • Assesses existing technologies utilized by sUAS and eVTOL developers to enable active detection and avoidance of mobile and stationary flight hazards. • Categorizes major elements into key subsystems, highlighting maturity of development along the value chain. • Weights the relative strengths and weakness of various subsystem approaches. • Based on discussions with in-house Ascension senior advisors and industry experts. **Automated Mission Management** • Evaluates the capabilities of existing automated mission management (AMM) systems and technologies and assesses them against theoretical requirements of mature UAM vehicles and operations. • Articulates major approaches to automated mission management. • Highlights developmental challenges to commercializing AMM for eVTOL applications. • Based on discussions with in-house Ascension senior advisors and industry experts. **Vehicle Health Management** • Identifies potential requirements for future UAM Vehicle Health Management (VHM) systems for UAM. • Discusses the capability and suitability of current VHM systems in use on conventional aircraft and rotorcraft. • Based on discussions with in-house Ascension senior advisors and industry experts. **UAM Port and Pad Design** • Defines UAM infrastructure classes (e.g., port vs. pad). • Review range of UAS-specific port and pad designs for suitability.

Source #	Citation
	• Based on in-house Ascension senior advisors and industry expert interviews. **Cybersecurity** • Explores the current state of cybersecurity standards and policies for aviation. • In addition, it examines potential future cybersecurity requirements for manned and unmanned UAM vehicles and operations. • Based on in-house Ascension senior advisors and industry expert interviews. **TNC-Multimodal Integration** • Defines multimodal options for integration and connection to airports. • Planning for infrastructure to support multimodal options. • Based on in-house WSP senior advisors and industry expert interviews. **Airport Planning for UAM** • Discusses integration of UAM into airport master planning. • Discusses integration of UAM into statewide aviation system planning. • Based on in-house WSP senior advisors and industry expert interviews. **Community Outreach and Engagement** • Defines engagement and outreach opportunities for operators to engage with the public and stakeholders. • Discusses key messages for outreach and engagement. • Based on in-house WSP senior advisors and industry expert interviews.
[2]	K. Balakrishnan, J. Polastre, J. Mooberry, R. Golding, and P. Sachs, "Blueprint for the Sky: The Roadmap for the Safe Integration of Autonomous Aircraft." Airbus LLC, Sunnyvale, CA, 06-Sep-2018. https://storage.googleapis.com/blueprint/Airbus_UTM_Blueprint.pdf • Outlines the regulatory and technological vision of a multipurpose airspace for conventional aircraft, unmanned aerial systems, and eVTOL aircraft. • Focuses on three use cases: Remote inspection and monitoring, automated package transport, and localized passenger transport. • Envisions a federated airspace management framework of a "coordinated network of services" (e.g., UAM TM service supplier). • Suggests implementation details to NASA's UTM and Europe's SESAR frameworks.
[3]	"Boeing and SparkCognition to Launch Joint Venture SkyGrid," Boeing Mediaroom. Boeing, 20-Nov-2018. https://boeing.mediaroom.com/2018-11-20-Boeing-and-SparkCognition-to-Launch-Joint-Venture-SkyGrid • Announces the launch of SkyGrid—a joint venture between Boeing and SparkCognition • One of several such emerging software platforms, albeit one of the few by a major, multinational aerospace company, aimed at ensuring the safe, secure integration of autonomous cargo and passenger air vehicles in the global airspace.

Source #	*Citation*
	• Uses blockchain technology, artificial intelligence-enabled dynamic traffic routing, data analytics, and cybersecurity features. • Aimed at a broad range of missions and services using UAS, including package delivery, industrial inspections, and emergency assistance.
[4]	P. Butterworth-Hayes, "Urban Air Mobility Takes Off in 64 Towns and Cities Worldwide," Unmanned Airspace, 10-Dec-2018. https://www.unmannedairspace.info/urban-air-mobility/urban-air-mobility-takes-off-63-towns-cities-worldwide/ • Catalogs 64 towns that have begun operational or research-oriented UAM projects. • Itemizes city/town UAM operations by country and explains the extent of activities taking place.
[5]	"CAAS, EASA, and Airbus Collaborate to Advance Safety of Unmanned Aircraft Systems in Urban Environments," European Union Aviation Safety Agency (EASA). 13-Jul-2018. https://www.easa.europa.eu/newsroom-and-events/press-releases/caas-easa-and-airbus-collaborate-advance-safety-unmanned-aircraft • Announces joint venture between Civil Aviation Authority of Singapore (CAAS), the European Aviation Safety Agency (EASA), and Airbus to establish safety-focused UAM procedures and standards in urban environments. • Focus is on establishing seamless multimodal transportation networks in smart cities. Use cases focused on addressing the sustainability and efficiency of parcel delivery businesses in large urban environments like Singapore.
[6]	J. Holden and N. Goel, "Fast-Forwarding to a Future of On-Demand Urban Air Transportation." Uber Elevate, San Francisco, CA, 27-Oct-2016. • Treatment of barriers to operationalizing on-demand, end-to-end, "Air-Taxi" eVTOL concept. • Proposes a plan for operationalizing eVTOL in the near-future by utilizing existing National Airspace System (NAS).
[7]	"Flight Path for the Future of Mobility." Boeing NeXt, St. Louis, MO, 26-Nov-2018. http://www.boeing.com/NeXt/common/docs/Boeing_Future_of_Mobility_White Paper.pdf • Notes that the forecast for the UAM market will be worth tens of billions of dollars across the value chain. Also notes that there are over 100 vehicles in various stages of development globally. • Identifies that in addition to OEMs, passenger operations, UAS traffic management, operations and maintenance, infrastructure, insurance, and financing are a part of the UAM value chain. • Outlines the challenges that may be faced in developing an integrated airspace system compatible with UAM. • States the need to work closely with regulators to develop the appropriate standards to enable safe, large-scale UAM operations.

Source #	*Citation*
	• Outlines 10 potential "keys" to unlocking UAM, several of which are of interest to the aviation industry. *Note: In September 2020, Boeing stopped its NeXT initiative due to COVID-19 impacts on business but indicated that its efforts will continue elsewhere within the business.*
[8]	D. Geister and B. Korn, "Concept for Urban Airspace Integration DLR U-Space Blueprint." Institute of Flight Guidance, DLR Group, Washington D.C., Dec-2017. https://www.dlr.de/fl/Portaldata/14/Resources/dokumente/veroeffentlichungen/Concept_for_Urban_Airspace_Integration.pdf • Proposes a blueprint for UAM TM in very low level and remaining airspace. • *Specifically addresses the utility of this model in Europe's developing "U-Space" framework.* • Examines proposed model's technical, regulatory, and safety aspects.
[9]	International Civil Aviation Organization (ICAO), "Remotely Piloted Aircraft System (RPAS) Concept of Operations (ConOps) for International IFR Operations." ICAO, Montreal, Canada, 23-Oct-2017. https://www.icao.int/safety/ua/documents/rpas conops.pdf • ICAO aims to provide a general ConOps for remotely piloted aircraft for use by United Nations member nations. • Focuses on high-level rules that can be used to guide development of more specific regulatory guidelines. • Provides nations with information to guide standards and practices.
[10]	"Revising the Airspace Model for the Safe Integration of Small Unmanned Aircraft Systems." Amazon.com Inc., Seattle, WA, Jul-2015. https://utm.arc.nasa.gov/docs/Amazon_Revising the Airspace Model for the Safe Integration of sUAS[6].pdf • *Excludes eVTOL, focuses on sUAS.* • Proposes a dedicated civil airspace model for sUAS, separate from conventional aircraft. • Outlines the preconditions and stakeholders necessary to develop.
[11]	P. Sachs, "TR-006: Applying Visual Separation Principles to UAV Flocking." Altiscope, Airbus LLC, Sunnyvale, CA, 20-Jul-2018. https://storage.googleapis.com/blueprint/TR-006_Applying_Visual_Separation_Principles_to_UAV_Flocking.pdf • Proposes a technical model for adapting visual flight separation principles (general aviation) to "flocks" of UAVs to highlight potential means of mitigating safety risks posed by dense UAV traffic.

Source #	*Citation*
[12]	P. Sachs, “TR-008: A Quantitative Framework for UAV Risk Assessment: Version 1.0.” Altiscope, Airbus LLC, Sunnyvale, CA, 13-Sep-2018. https://storage.googleapis.com/blueprint/TR-008_Open_Risk_Framework_v1.0.pdf • Explores Altiscope’s approach to developing a risk model and what the results may look like. • Identifies several high-level challenges, and approaches to resolving them.
[13]	P. Sachs, C. Dienes, E. Dienes, and M. Egorov, “TR-009: Effectiveness of Preflight Deconfliction in High-Density UAS Operations.” Altiscope, Airbus LLC, Sunnyvale, CA, 03-Oct-2018. https://storage.googleapis.com/blueprint/TR-009_Preflight_Deconfliction.pdf • Outlines a study that evaluated the effectiveness of preflight deconfliction practices in high-density UAS operations through use of Altiscope’s UTM/UAM TM prototype and airspace simulator.
[14]	O. Schneider, “METROPOLIS Concept Design Report.” Delft University of Technology, Delft, Netherlands, Oct-2014. https://homepage.tudelft.nl/7p97s/Metropolis/downloads/Metropolis_D2-2_Concept_Design_Report_v10.pdf • Simulates four airspace models based on likely UAM use cases. • Outlines how four aerial vehicles may navigate traffic, avoid collisions, and address anomalies (inclement weather, new terrain). • Paris selected as representative geography for four potential ConOps.
[15]	“TR-001: Understanding UAV Mission Risk.” Altiscope, Airbus LLC, Sunnyvale, CA, 28-Jan-2018. https://storage.googleapis.com/blueprint/TR-001_Understanding_UAV_Mission_Risk.pdf • Explores Altiscope’s approach to developing a risk model and what the results may look like. • Identifies several high-level challenges, and approaches to resolving them.
[16]	“TR-002: Metrics for Near-Miss Events: Understanding Airprox, NMAC and ‘Inadequate Separation’.” Altiscope, Airbus LLC, Sunnyvale, CA, 22-Jan-2018. https://storage.googleapis.com/blueprint/TR-002_Metrics_for_Near-Miss_Events.pdf • Explores and compares three terms and classification standards for evaluating and classifying near-miss events in aviation.
[17]	“TR-003: Using Fault Trees to Compute UAV Mission Risk.” Altiscope, Airbus LLC, Sunnyvale, CA, 12-Feb-2018. https://storage.googleapis.com/blueprint/TR-003_Using_Fault_Trees_to_Compute_UAV_Mission_Risk.pdf • Outlines the steps and analysis performed by Altiscope when evaluating UAV mission risk utilized fault tree frameworks.
[18]	“TR-004: Metrics to Characterize Dense Airspace Traffic.” Altiscope, Airbus LLC, Sunnyvale, CA, 07-Jun-2018. https://storage.googleapis.com/blueprint/TR-004_Metrics_to_characterize_dense_airspace_traffic.pdf • Proposes and outlines two metrics for characterizing the density of airspace traffic in urban areas.

Source #	*Citation*
[19]	D. P. Thipphavong, R. D. Apaza, B. E. Barmore, V. Battiste, B. K. Burian, Q. V. Dao, M. S. Feary, S. Go, K. H. Goodrich, J. R. Homola, H. R. Idris, P. H. Kopardekar, J. B. Lachter, N. A. Neogi, H. K. Ng, R. M. Oseguera-Lohr, M. D. Patterson, and S. A. Verma, Urban Air Mobility Airspace Integration Concepts and Considerations. Atlanta, GA: AIAA, 2018. https://utm.arc.nasa.gov/docs/2018-UTM-ConOps-v1.0.pdf • Characterizes the use cases and considerations involved in realizing UAM operations in the U.S., beginning with helicopter flights in Los Angeles and New York from 1940 onwards to modern concepts of autonomous air-taxi services. • Describes NASA's ongoing research for integrating anticipated UAM operations into the current NAS and details the current state of UAM realization in several key areas, including: Vehicle design, airspace design, and hazard and risk management. • Establishes a scope for the role that NASA intends to take in contributing to UAM integration as a public service. • Declares an intent to work with relevant stakeholders to establish ConOPs for various aspects of UAM operations.
[20]	Federal Aviation Administration (FAA), Unmanned Aircraft Systems (UAS) Traffic Management (UTM) Concept of Operations, 1.0 ed. Washington D.C.: Office of NextGen, 2018. https://utm.arc.nasa.gov/docs/2018-UTM-ConOps-v1.0.pdf • Presents a concept of operations for UTM (servicing sUAS) over the next three to five years. • ConOps currently explores sub-400-foot altitudes and unrestricted class G airspace. • Creates a framework that can be expanded to additional domains: moving across airspaces and flying in dense traffic.
[21]	J. Bachman, "Autonomous Flights Are One Step Closer to Reality," https://www.bloomberg.com/news/articles/2018-10-10/will-you-fly-when-your-pilot-is-a-robot • Explores the current state of autonomous technologies in commercial cargo aviation.
[22]	"Boeing Autonomous Passenger Air Vehicle Completes First Flight," https://www.boeing.com/features/2019/01/pav-first-flight-01-19.page. 23-Jan-2019 • Announces completion of the first flight of the Passenger Air Vehicle prototype.
[23]	"CityAirbus eVTOL to be tested in Germany," www.wingsmagazine.com, 20-Mar-2019. [Online]. Available: https://www.wingsmagazine.com/cityairbus-evtol-16169/ • Airbus unveils a demonstration model of the CityAirbus aircraft and plans for testing near Ingolstadt.

Source #	*Citation*
[24]	"Heavy lifter: Boeing reveals new design concept of Cargo Air Vehicle," https://www.boeing.com/features/2018/07/cav-concept-07-17.page. 16-Jul-2018 • Announces the unveiling of a new design concept for the Boeing HorizonX Cargo Air Vehicle.
[25]	O. Johnson, "CityAirbus set for first flight in March," Vertical Magazine, 20-Feb-2019. [Online]. Available: https://www.verticalmag.com/news/cityairbus-set-for-first-flight-in-march/ • Announces Airbus Helicopters' intention to complete first flight of CityAirbus in March 2019.
[26]	Z. Lovering, "Flight Test Update: 50 Flights," Vahana.aero, 22-Feb-2019. [Online]. Available: https://vahana.aero/flight-test-update-50-flights-53af963e1750 • Announces a milestone of 50 test flights for the full-scale Vahana aircraft.
[27]	P. Crist and T. Voege, "Safer Roads with Automated Vehicles?" International Transport Form, Corporate Partnership Board, 2018. https://www.itf-oecd.org/sites/default/files/docs/safer-roads-automated-vehicles.pdf • Examines how increasing automation of cars and trucks could affect road safety. • Outlines which security vulnerabilities will need to be addressed for ground-based automation. The vulnerabilities in air will likely be different and more complex in some ways. • Identified lessons learned from automation of vehicles to determine any similarities for aerial vehicles.
[28]	J. Ramsey, "Audi demonstrates Pop.Up.Next air taxi at Amsterdam Drone Week," Autoblog, 28-Nov-2018. [Online]. Available: https://www.autoblog.com/2018/11/28/audi-demonstrates-pop-up-next-air-taxi/ • Airbus, with partner Audi, demonstrated a working ¼ scale prototype of the P0p.Up.Next flying taxi at the LA Auto Show in 2018.
[29]	M. S. Reveley, J. L. Briggs, J. K. Evans, S. M. Jones, T. Kurtoglu, K. M. Leone, C. E. Sandifer, and M. A. Thomas, "Commercial Aircraft Integrated Vehicle Health Management Study." NASA, Feb-2010. https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20100011007.pdf • Conducted research to develop validated tools and technologies for automated detection, diagnosis, and prognosis to mitigate adverse events during flight. • Study reviewed statistical data and literature to establish requirements for future of work in VHM-related hardware and software.
[30]	D. Werner, M. Guterres, and J. Gundlach, "Job Number 1: Detect and Avoid," https://aviation.aiaa.org/detect-and-avoid/, AIAA, 01-May-2017 • Discusses the importance of and challenges associated with developing Detect and Avoid technologies for small and large UAS.

Source #	Citation
[31]	Office of Airport Safety & Standards - Airport Engineering Division, AC 150/5390-2C-Heliport Design. Washington, D.C.: FAA, 2012. https://www.faa.gov/airports/resources/advisory_circulars/index.cfm/go/document.current/documentNumber/150_5390-2 • Outlines general standards for the design and construction of heliports. • Defines unique standards for various heliport classes, including general aviation, transport, and hospital class. • Since heliports are considered an interim solution for eVTOL capable aircraft.
[32]	R. Alexander, "VTOL & Vertiports - A look at the Future." Uber, 14-Feb-2018. USHST Infrastructure Summit 2018 http://ushst.org.dnn4less.net/Portals/0/PDF/VTOLVertiports.pdf • Outlines the operational design principles and guiding criteria that drive Uber's vertiport design process. • Presents conceptual port layouts, along with future needs and recommendations.
[33]	M. Dwivedi, "A Multifaceted Approach to Autonomous Vehicle Cyber Security," RFID Journal, 11-Mar-2018. [Online]. Available: https://www.rfidjournal.com/articles/view?17023/2 • Outlines potential approaches developers of autonomous automobiles can take to protect their systems from cyber-attack.
[34]	A. Smith, "Airport security - an evolving challenge," International Airport Review, 08-Aug-2011. https://www.internationalairportreview.com/article/6045/airport-security-an-evolving-challenge/ • Examines the post-9/11 transformation of airport security systems with the integration of new procedures, technologies, and the challenges of the future.
[35]	M. Aaronson, M. Mester, G. Mallory, and S. Hattori, "The Aerospace Industry Isn't Ready for Flying Cars," BCG, 07-Jun-2018. https://www.bcg.com/en-us/publications/2018/aerospace-industry-is-not-ready-for-flying-cars.aspx • Outlines the key barriers aerospace companies face to capitalizing on the emerging UAM market. • Prescribes some steps that OEMs can take now that will enable them to develop a viable business model for UAM.
[36]	Airport and Airway Improvement Act of 1981. April 27, 1981. Ordered to be printed. 1981. https://www.congress.gov/bill/97th-congress/house-bill/2930 • Airport and Airway Development Act replaces the Airport and Airway Development Act of 1946 by providing additional federal assurances in promoting civil development of airports.
[37]	Airport Noise and Capacity Act of 1990. 1990. https://www.congress.gov/bill/101st-congress/senate-bill/3094/text • Airport Noise and Capacity Act of 1990 requires the establishment of a National Noise Policy in response to significant public noise complaints.

Source #	*Citation*
[38]	AC 150/5070-6B - Airport Master Plans. 2005. https://www.faa.gov/airports/resources/advisory_circulars/index.cfm/go/document.current/documentNumber/150_5070-6 • Provides guidance for the preparation of airport master plans that range in size and function from small general aviation to large commercial service facilities.
[39]	Airport Noise Compatibility Planning. 2018. https://www.faa.gov/airports/environmental/airport_noise/ • Federal Aviation Regulations Part 150 funds airport noise planning and projects, providing assistance to airport owners in identifying and implementing noise-reduction measures.
[40]	Aviation Safety and Noise Abatement Act of 1979. March 29 (legislative day, February 22), 1979. Ordered to be printed. 1979. https://www.congress.gov/bill/96th-congress/house-bill/3547 • Aviation Safety and Noise Abatement Act of 1979 provides FAA with key regulatory and assistance frameworks for noise compatibility.
[41]	Crown Consulting, Inc., McKinsey & Company, Ascension Global, and Georgia Tech Aerospace Systems Design Lab, *Urban Air Mobility (UAM) Market Study*. Washington D.C.: NASA ARMD, 2018. https://www.nasa.gov/sites/default/files/atoms/files/uam-market-study-executive-summary-pr.pdf **Market Assessment** • Econometric supply and demand model for three use cases (Last-Mile Delivery, Air Metro, and Air Taxi) against the top 15 largest U.S. metropolitan areas by 2030, covering ~121 million inhabitants. • Demand-side model provides growth in passenger volume, dollar revenue, and estimated profit. • Based on assumptions for target market spending on transportation and willingness to pay for key factors (e.g., speed, comfort). • Willingness to pay assumptions undergirded by surveying 2,500+ respondents and 200+ shipping coordinators. • Supply-side model creates a sensitivity curve of volume by cost points, based on: OEM cost structure (e.g., sensing, battery, manufacturing), infrastructure provisions (e.g., ATM, service centers, hubs), and fleet operator costs (e.g., certification, energy, insurance). • Weighs adoption against competing technologies that the market may choose instead (driverless cars, driverless ridesharing, robo-taxis, autonomous ground vehicle lockers). **Public Perceptions Survey** • Surveys 2,500+ consumers and 200+ shipping and logistics coordinators across five representative U.S. cities (NYC, Dallas, Washington D.C., San Francisco, and Detroit). • Evaluates public concerns in five categories: safety (trust of autonomous technology), privacy (camera equipment, sensing technology), jobs (concern

Source #	*Citation*
	over automating away work), environment (waste, wildlife impact, energy usage), noise, and visual disruption in residential neighborhoods.
[42]	Data relating to H.R. 3199 (Clean Water Act of 1977). 1977. https://www.congress.gov/bill/95th-congress/senate-bill/1952 • Section 401 articulates routine requirements for airport planners to demonstrate compliance with federal effluent limitations. • Section 404(b)(1) articulates alternative analysis compliance to minimize impact.
[43]	Emergency Planning and Community Right-To-Know Act (EPCRA). 1986. https://www.congress.gov/bill/99th-congress/house-bill/2560 • EPCRA outlines emergency planning and reporting requirements for listed hazardous chemicals, including threshold quantities for reporting at construction sites.
[44]	Endangered and Threatened Species Conservation Act (ESA) of 1973: report (to accompany H.R. 37). 1973. https://www.congress.gov/bill/93rd-congress/house-bill/37 • ESA 1973 contains specific statutes and implementing regulations that cover wildlife impact from airport construction: 16 United States Code (USC) Section 1531-1544, 16 USC Section 1536(a)(2), 16 USC Section 1536 (a)(3) and (4), 16 USC Section 1536(b), (c), (d), and 50 Code of Federal Regulations Part 402.
[45]	Booz | Allen | Hamilton, *Urban Air Mobility (UAM) Market Study*. Washington D.C.: NASA ARMD, 2018. https://www.nasa.gov/sites/default/files/atoms/files/bah_uam_executive_briefing_181005_tagged.pdf • Characterizes future UAM market viability for airport shuttle, on-demand air taxis, and air ambulance. • Uses 10 target urban areas to examine potential market size and barriers. • Identifies an array of legal/regulatory, certification, public perception, infrastructure, and weather constraints and offers strategies for continued collaboration across government and industry to address the challenges.
[46]	FAA Western-Pacific Region and S. May, "Los Angeles Helicopter Noise Initiative." 27-Feb-2014. https://www.scag.ca.gov/committees/CommitteeDocLibrary/atac022714_LAHelicopterNoise.pdf • Voluntary collaboration established in 2012 among helicopter operators, airports, and the community to work with FAA in developing agreements on routes, altitudes, best practices, outreach, and training.

Source #	*Citation*
[47]	"NYCEDC And Helicopter Tourism & Jobs Council Announce New Measures to Reduce Helicopter Noise and Impacts Across New York City," New York City Economic Development Corporation (NYCEDC), 01-Feb-2016. https://www.nycedc.com/press-release/nycedc-and-helicopter-tourism-jobs-council-announce-new-measures-reduce-helicopter • Joint agreement signed in 2016 between Helicopter Tourism and Jobs Council and NYCEDC to reduce helicopter noise.
[48]	"The Future of Vertical Mobility." Porsche Consulting Group, Atlanta, GA, 26-Mar-2018. https://fedotov.co/wp-content/uploads/2018/03/Future-of-Vertical-Mobility.pdf • Provides an analysis of the "vertical mobility" market from the present day to 2035 across three major use cases—industrial inspection, air taxi, and goods, in addition to other supporting services. Sizes the market to be approximately $75 billion by 2035. • Identifies that air taxi is only a complementary service and is dependent on other ground mobility services for end-to-end integration. Identifies transfer between other mobility modes as a constraint. • Introduces a common set of facts, metrics, and goals intended to assist the urban mobility "ecosystem" in making strategic decisions.
[49]	N. von Conta, "TR-007: Managing UAS Noise." Altiscope, Airbus LLC, Sunnyvale, CA, 10-Aug-2018. https://storage.googleapis.com/blueprint/TR-007_Managing_UAS_Noise_Footprint.pdf • Outlines sources of noise pollution likely to result from UAM and proposes means of mitigating that noise during standard operations. • Identifies existing research gaps regarding knowledge on sources of UAM noise, means of mitigating it, and the potential effects it may have in operations at scale.
[50]	P. Yedavalli and J. Mooberry, "An Assessment of Public Perception of Urban Air Mobility (UAM)." Airbus UTM, Sunnyvale, CA, 14-Feb-2019. https://drive.google.com/file/d/15YTiXudG_eb5IlkqqCMcE2SGvDBJA7_L/view • Outlines Airbus UTM's current assessment of public sentiment regarding the possibilities offered by UAM, contrasted with their concerns. • Offers insight into how public perception of UAM is presently situated among different demographics in different cities and countries around the world.
[51]	U.S. Environmental Protection Agency. (2019). *Green Vehicle Guide; Fast Facts on Transportation Greenhouse Gas Emissions*. 3–4. https://www.epa.gov/greenvehicles/fast-facts-transportation-greenhouse-gas-emissions • Provides facts and statistics on transportation greenhouse gas emissions for 2018.
[52]	Federal Aviation Administration (FAA). (2020). *Urban Air Mobility and Advanced Air Mobility*. United States Department of Transportation. https://www.faa.gov/uas/advanced_operations/urban_air_mobility/

Source #	*Citation*
	• Outlines FAA resources for UAM and AAM.
[53]	Manfred Hader and Stephan Baur. "The High-Flying Industry: Urban Air Mobility Takes Off." Roland Berger, November 10, 2020. https://www.rolandberger.com/en/Insights/Publications/The-high-flying-industry-Urban-Air-Mobility-takes-off.html • Market study on future urban air transport in the air taxi segment. • Estimates a $ 90 billion potential for the passenger drone market by 2050. • Discusses history and future of UAM. • Discusses how market participants can position themselves for the industry.
[54]	Philip Butterworth-Hayes. "Urban Air Mobility Takes off in 75 Towns and Cities around the World." Urban Air Mobility News (blog), March 7, 2019. https://www.urbanairmobilitynews.com/new-city-projects/urban-air-mobility-takes-off-in-75-towns-and-cities-around-the-world/ • Outlines multiple UAM operations in 75 towns and cities around the world.
[55]	Manfred Hader. "Urban Air Mobility: The Way to a Sustainable Intercity Air Transport." Roland Berger. Accessed March 13, 2021. https://www.rolandberger.com/en/Insights/Publications/Urban-Air-Mobility-The-way-to-a-sustainable-intercity-air-transport.html. • Interview with Dr. Jörg P. Müller, Head of Programs and Strategy at Urban Airbus Mobility, about Airbus's efforts in the UAM sector to offer a sustainable alternative to ground transportation. • Discusses major use cases for UAM. Some inner-city flights are identified as potentials, but the majority of the flights are forecast to be between cities and airports where interviewees see the highest potential in the mid-term. • Discusses major challenges for implementation of UAM—vertiports and integration with NAS are seen as major challenges in addition to electric conventional take-off and landing (eCTOL) technology issues.
[56]	A. Hawkins. (2020). *Flying taxi startup Lilium will build a hub for its electric aircraft in Florida - The Verge*. The Verge. https://www.theverge.com/2020/11/11/21558670/lilium-jet-flying-taxi-orlando-vertiport-hub-evtol • News article on Liliums plans for UAM in Florida. • Building vertiport in Aerotropolis in Lake Nova, Florida.
[57]	K. Hoff. (2019). Airplane Emissions. Center for Biological Diversity. https://www.biologicaldiversity.org/programs/climate_law_institute/transportation_and_global_warming/airplane_emissions/ • Provides statistics for emissions for airplane operations.
[58]	National Aeronautics and Space Administration (NASA). (2019, August 2). UAM Overview. NASA. http://www.nasa.gov/uam-overview • According to recent NASA-commissioned market studies, by 2030 as many as 500 million flights a year for package delivery services and 750 million

Source #	Citation
	flights a year for Air Metro services could make UAM a profitable, relevant enterprise.
[59]	Pannu, A. (2020). Is the Urban Transport Mix Ready for Air Mobility? Frost and Sullivan. https://ww2.frost.com/frost-perspectives/destination-versus-demand-is-the-urban-transport-mix-ready-for-air-mobility/ • Identifies 50-plus cities already testing and preparing for urban aero taxis flying in their skies. • Identifies top five cities for UAM.
[60]	R. Lineberger, A. Hussain, and D. Silver (2021). *Advanced air mobility | Deloitte Insights*. https://www2.deloitte.com/us/en/insights/industry/aerospace-defense/advanced-air-mobility.html • Outlines for implementation of AAM. • AAM represents an opportunity for the United States to be a global leader.
[61]	A. Lohn (2017). What's the Buzz? The City-Scale Impacts of Drone Delivery. In *What's the Buzz? The City-Scale Impacts of Drone Delivery*. https://doi.org/10.7249/rr1718 • Environments for strong cases for drone delivery. • Calculations for energy efficiency for UAS. • Drone centers needed for optimal operations. • Fleet and infrastructure considerations for sUAS package delivery.
[63]	K. O. Ploetner, C. Al Haddad, C. Antoniou, F. Frank, M. Fu, S. Kabel, C. Llorca, R. Moeckel, A. T. Moreno, A. Pukhova, R. Rothfeld, M. Shamiyeh, A. Straubinger, H. Wagner, and Q. Zhang (2020). Long-term application potential of urban air mobility complementing public transport: an upper Bavaria example. *CEAS Aeronautical Journal*, *11*(4), 991–1007. https://doi.org/10.1007/s13272-020-00468-5 • Models and methods to analyze and quantify the potential demand for UAM.
[64]	A. Reiche and R. Cohen (2018). *UC Berkeley Recent Work Title Urban Air Mobility Market Study Publication Date*. https://doi.org/10.7922/G2ZS2TRG • Market size and potential barriers to UAM. • Study provided for NASA. • Use case study for Air Shuttle, Air Taxi, and Air Ambulance.
[65]	D. Shicong (2020). *EHang Plans World's First Airport for AAVs in Chinese Beauty Spot*. YiCai Global. https://www.yicaiglobal.com/news/ehang-plans-world-first-airport-for-aavs-in-chinese-beauty-spot • Discusses intent to build the world's first airport terminal for AAV services in south China to hasten their use in aerial sightseeing. • Details cost and size of structure.

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[66]	P. Sisson (2020). *Expanding highways and building more roads actually makes traffic worse - Curbed*. Curbed. https://archive.curbed.com/2020/3/6/21166655/highway-traffic-congestion-induced-demand • Discusses impacts of building new roads and widening existing roadways. • Finds that widening roads does not prevent congestion.
[67]	United Nations. (2018). 68% of the world population projected to live in urban areas by 2050, says UN | UN DESA | United Nations Department of Economic and Social Affairs. In *United Nations News*. https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html • Statistics on world population. • Forecast for population centers to increase in urban areas.
[68]	N. Mallela, S. Sadasivam, R. Giordano, H. Kassoff, and S. Lockwood (2020). Strategic Issues Facing Transportation, Volume 7: Preservation, Maintenance, and Renewal of Highway Infrastructure. In *Strategic Issues Facing Transportation, Volume 7: Preservation, Maintenance, and Renewal of Highway Infrastructure*. Transportation Research Board. https://doi.org/10.17226/25757 • Describes the long-range strategic issues affecting the preservation, maintenance, and renewal of highway infrastructure. • Emerging PMR practice assessment, adoption, and action plan. • Detailed analysis models and assessment tools adapted for UAM toolkit.
[69]	Airport Categories – Airports. Federal Aviation Administration. https://www.faa.gov/airports/planning_capacity/categories/ • Defines airport categories by type of activities.
[70]	Allowable Population Density in Airport Safety Zones | Chapter 8 | Airport Land Use Plan | Long-Range Plans | Permit Sonoma | County of Sonoma. (n.d.). Retrieved May 4, 2021, from https://sonomacounty.ca.gov/PRMD/Long-Range-Plans/Comprehensive-Airport-Land-Use/Allowable-Population-Density-in-Airport-Safety-Zones/ • Discusses maximum population density for airport safety zones in Sonoma County California.
[71]	S. Lyon-Hill, M. Tiilashalski, K. Ellis, and E. Travis (2020). *Measuring the effects of Drone delivery in the United States*. https://vtechworks.lib.vt.edu/bitstream/handle/10919/100104/Effects of Drone Delivery US_September 2020.pdf?sequence=1&isAllowed=y • Detailed analysis of drone delivery in the United States. • Indicates drone deliveries can improve consumers' lives by expanding access to services, reducing unnecessary travel, and saving time. • Drone deliveries will be a disruptive technology for those who face mobility challenges.

Source #	*Citation*
[72]	EGIS Group. (2021). *Skycities. Skyways. Skytaxis. Dream Or Destiny?* https://www.egis-aviation.com/wp-content/uploads/2021/04/Egis-UAM-Skycities-skyways-skytaxis.pdf • Discusses AAM and UAM and key considerations on partnerships, integration, infrastructure, and challenges. • Provides UAM uses and attractiveness information and key items regarding revenue streams and business models. • Discusses barriers to Success for AAM and analyzes how UAM may function in new and old cities.