# Embracing *Advanced Air Mobility*

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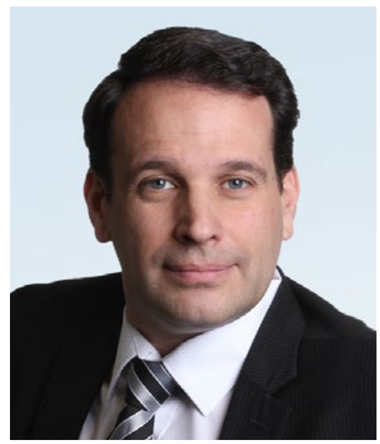
# Moving Forward, Full Throttle, Wheels Up



Successful airports of the future will be agile airports. A range of factors—from the global pandemic to rapid technological advancements—requires airports to adapt and respond effectively. Another key factor is climate change, which is driving the need to implement net-zero practices for all elements of airports, from terminals and landside vehicles to aircraft and ground support equipment. Airports are under pressure, not only to develop infrastructure that supports projected travel demand but also to reduce carbon footprints.

Utilization of fossil-free energy sources—electric and hydrogen technologies and sustainable aviation fuel—is essential to connect more communities and advance equitable solutions while supporting sustainable growth. The challenge is to move forward as these clean technologies mature, enabling the development of new transportation services such as advanced air mobility.

We are pleased to offer WSP aviation insights on how to turn envisioned higher-level futures into 21st-century realities.

Here's to an exciting future for aviation.

Eric Peissel
Global Director, Transport & Infrastructure

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# Agility Underpins Future-Proof Airports

## Providing spaces and services to support future travel demand and changing passenger preferences

October 13, 2021

**Tim Morrison**

Aviation Director
**United Kingdom**

Airports are at a crossroads, challenged to make decisions that will shape a strong future in the aftermath of the COVID-19 pandemic. Moving forward from a severely disrupted airport ecosystem requires a new way of thinking that incorporates agility at the core of all efforts.

What does agility involve? How can agility prepare airports for rebounds in air travel and effective response to heightened passenger expectations? In the following Q&A, Tim Morrison, Aviation Director, WSP in the UK, discusses how this capability can facilitate sustained positive change and support performance for years to come.

## What is agility in the context of an airport, and why is it essential?

**Tim Morrison:** Agility is the power to adapt and adjust in a timely way; it is also the ability to anticipate and be responsive to customer needs. Agility requires an airport planning strategy that builds in flexibility.

An agile airport combines several key actions: embracing digitalization to improve operations and continuously advance the passenger experience; adapting to different economic models; and deploying Modern Methods of Construction [MMC] during redevelopment—all within an overarching decarbonization wrapper.

To be fully agile towards achieving optimal continuous service, each of these facets must reach their full potential. Taking a Future Ready[1] perspective will enable the best possible impact. Future Ready considers key trends—related to society, climate, resources, and technology—when making decisions to support today's and tomorrow's needs.

Airports are dynamic ecosystems, able to respond to change while also being catalysts for change. This dynamism has already been demonstrated in various ways, such as their finance structure, be it public or private or a combination of them; the application of technology enabling seamless home-airport-destination travel experiences as well as contactless security and CT [computerized tomography] scanning; and the generation of opportunities to advance the airport experience rather than encouraging passengers to rush through, to and from the gate. Airports have long embraced DfMA [Design for Manufacture and Assembly]; this MMC philosophy is the best way to expand and redevelop airports whilst maintaining operations. Utilizing pre-assembled modules—a kit of parts—is key. Looking into the future, facilities should embrace re-using a given kit of parts over and over again in different configurations to suit varying spatial requirements. This re-use practice, a natural extension of the MMC approach, enables projects to drive down the use of raw materials and reinforces the circular economy mindset too.

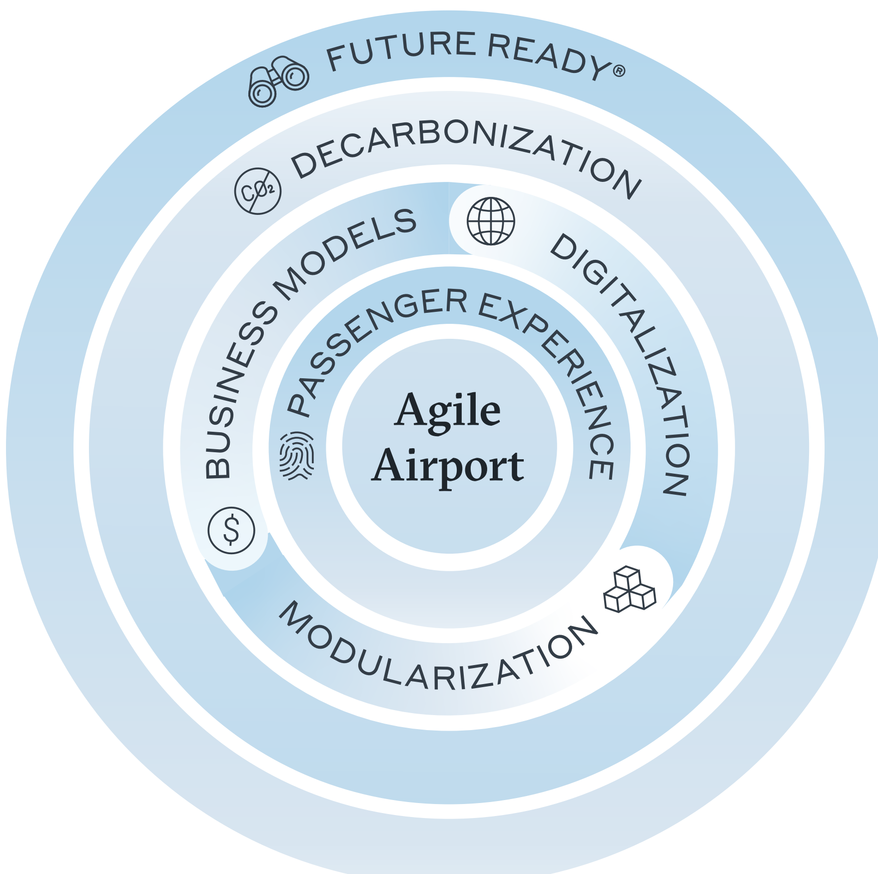


Figure 1 – Key aspects to develop agile airport ecosystems

1 Future Ready is WSP's global innovation program. Future Ready® is a registered trademark of WSP Global Inc. in Canada and New Zealand. WSP Future Ready (logo)® is a registered trademark of WSP Global Inc. in Europe, Australia and in the United Kingdom.

## The impact of COVID-19 continues to test response and recovery capabilities across sectors and societies. How can airports leverage this experience as they move forward?

**Tim Morrison:** The last year has clearly demonstrated the importance of being agile or nimble, words not typically associated with airport infrastructure.

This agility is a function of mindset and behaviour and of the physical infrastructure. Experience over the past year has promoted a rethink regarding our surroundings and how to carry out business in an environment that will require business and industry to rapidly respond to more unexpected events; future occurrences will likely necessitate expediting or modifying plans to accommodate new needs.

Certainly, 2020 presented new considerations, such as how to integrate testing centres, quarantine hotels, alternative queuing; and how to use robots to maintain hygiene standards safeguarding staff and the public; it has also underlined the need for airports around the world to operate as highly diverse businesses in order to cope with the drop-off of traditional aeronautical revenues. Alternative non-aeronautical revenue opportunities include conference facilities, hotels, public arenas, sports facilities, pick-up points for internet retailers, leisure facilities, food and beverage destinations, quick-change stands or pop ups, and even pet kennels.

The agile mindset will help airports to embrace diversification of the traditional airport landscape. Contemporary airport designs have been exploring potential uses of airport spaces within and around these sizable built assets to make airports a destination and help them integrate further into their adjacent communities. This process started some years before the pandemic and will likely accelerate now—the pandemic has highlighted the vulnerability of non-aeronautical revenue generation, which has typically been associated with the flying passenger.

## You mentioned that agility is not typically associated with airport infrastructure. Can you explore agility in relation to new assets and existing assets?

**Tim Morrison:** Airports represent a massive investment in fixed assets. These assets—terminals, runways, taxiways, carparks, rail stations, offices—are all built with a purpose and a lifespan. To be competitive, airports will increasingly need to repurpose these assets—to reinvent the uses of the assets and/or ensure they can expand or contract over time to support travel demand[2] and changing passenger preferences. The art of agility is to ensure the output solution to the original brief is not so rigid that the use is singular and therefore prevents any other use in the future, thus requiring a demolition to start again. This adaptability does not need to be accompanied by an increase in capital costs. In fact, the valuation of the built assets when they have this inherent adaptability will be greater as they will not have the traditional shelf life.

This 'loose fit' response to the brief does require a way of thinking that supports flexibility from the planning stage of infrastructure projects through the lifecycle of the asset. Using a digital toolkit, we are now more than ever able to create scenarios for well-considered decision-making. Indeed, the 'what if permutations are aplenty. The application of the digital tools by innovative thinkers also allows assessment of the asset's investment value in terms of the embodied carbon, not just the operational carbon. This whole-life carbon approach to development analysis will come to the fore as aviation endeavours to meet its 'license to grow' challenge. Whole-life carbon assessment is the rapidly emerging environmental measure associated with the built environment. This approach broadens consideration of carbon emissions, moving away from the focus on operational carbon in decision-making to tackle embodied carbon. Unlike operational carbon, which can be improved during the lifetime of a building, embodied carbon is all the emissions associated with the materials used—arising from extraction, manufacturing, transportation, installation, maintenance, and disposal.

The whole-life carbon analytical approach to the use of existing assets based on criteria such as embodied carbon will be driven by use of alternative materials in designs and digital tools that support such innovative applications.

2 "The Impact of COVID-19 on the airport business and the path to recovery," Advisory Bulletins, Airports Council International (ACI), March 25, 2021.

## What lasting positive change can an agile mindset bring to the severely disrupted airport ecosystem?

**Tim Morrison:** While the pandemic experience has been harrowing, it has also presented opportunity to explore how to take stock and ensure we build back in ways that allow us to integrate fast-moving initiatives, especially those related to creating greener flight. This imperative requires collaborative efforts to accelerate the use of sustainable aviation fuel (SAF) and embark on paths to embrace hydrogen infrastructure and electrification of built assets, specifically ground support equipment and aircraft and; there is also a need to determine how to incorporate AAM [advanced air mobility] into the airport matrix. Each of these functions requires foresight, a will to embrace change and an appreciation of the transition periods. None of these will be overnight interventions; they will develop and co-exist for many years alongside existing infrastructure.

These green initiatives are key to meeting sustainability objectives and supporting the 2050 net-zero goal. There is a nice circularity here when considering these future aviation fuels and the local community; airports could also become the local hydrogen vehicle refuelling station and electric vehicle recharging facility, offering business diversification and a service to the local community.

As travel rebounds at different paces around the world, successful airports will be agile airports—those with adaptable physical infrastructure that enables effective response to changing circumstances resulting from a range of factors, be they economic or political events, a seismic mood change in retail, climatic disruptions, a national or international security incident, or a global pandemic.

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# Getting Ready for Advanced Air Mobility

## Essential steps for integrating aerial innovation into communities—to connect more places, advance equitable transportation solutions, and achieve timely delivery of vital services

A new era of transportation is dawning as advanced air mobility (AAM) becomes part of mobility ecosystems. AAM represents the next generation of aircraft innovation, bringing mobility options to communities for passenger, air cargo, and emergency services. AAM is part of the approaching Fourth Industrial Revolution characterized by the unprecedented speed and scope of technological advancement, integration of technologies, and the transformative impact these developments bring across industries and societies.

During the first two industrial revolutions, new technologies—steam and electric power, respectively—transformed the means and capacity of production. Today's Fourth Industrial Revolution builds on the digital revolution that began in the 1950s and is distinguished by a fusion of technological advances that is blurring the lines between the physical, digital, and biological aspects of life.[1] To be prepared and foster a community voice for effective implementation, governments (all levels)—both urban and rural—should start planning for AAM as part of broader metropolitan and regional mobility plans.

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1 Klaus Schwab, "The Fourth Industrial Revolution: what it means, how to respond," World Economic Forum, January 14, 2016

## The Evolution of Flight

| | 1900-1939 | 1940-1979 | 1980-1999 | 2000-2020 | 2021-2040 |
|---|---|---|---|---|---|
| | **WWI, Aviation Pioneers** | **WWII, the Space Race, Commercial Aviation** | **Digital Age** | **Increasing Air Traffic** | **The Changing Mobility Landscape: the Next Generation of Aircraft Innovation** |
| *Aviation Trends and Innovation* | Advances in engine technology and aerodynamics make powered flight possible for the first time.<br>**1903**-the Wright brothers: first recorded powered, sustained and controlled flight in a heavier-than-air flying machine<br>**1927**-Lindbergh: first solo non-stop trans-Atlantic flight<br>**1939**- the first jet-propelled aircraft | Wide-scale development and production of the jet engine<br>Rapid military technological advancements | Advancements in avionics, aircraft design, and manufacturing techniques<br>Deregulation of airlines, among other factors, leads to unstable financial environment<br>Community pressure limits the utilization of small airports and heliports | Continuous and exponential growth* in commercial aviation, both cargo and passenger<br>Introduction of new large aircraft into terminal planning<br>Proliferation of drones as they transition from military to commercial applications, aided by advancements in battery technology and in composite materials | The International Civil Aviation Organization (ICAO) works alongside national aviation regulators to continue to harmonize and expand systems across the globe through initiatives like "No Country Left Behind"<br>People spend more time at airports, creating a new need to focus on amenities and non-aviation services<br>Introduction of new types of aircraft, including electric, hydrogen based, and hybrid<br>Advanced air mobility and new forms of low-altitude aviation that can offer low-emission, low-noise alternatives |
| *Outcomes* | Development of the airshow or passenger trip as a novelty | The rapid growth of commercial aviation<br>Space Race–Development and proliferation of aerospace and aviation technology | Rapid increase in utilization of aviation services for cargo and freight<br>Increased access to/democratization of air travel | Airport development leads to self-contained cities (aerotropolis)<br>Emphasis on safety and airspace deconfliction, resulting from geopolitical events (9/11) and introduction of new low-altitude aircraft, e.g. drones | New Mobility trends impact revenue at airports, especially relating to parking and amenities that affect the passenger experience<br>Simultaneous advancements (AVs, EVs) in the mobility system create opportunity to leverage electrification. |

* The global COVID-19 pandemic has caused economic issues across many industries, with aviation being at the forefront. Global recovery to 2019 levels is projected to take several years, into 2023 for markets with significant domestic air travel, especially leisure travel, and 2024 for markets that have significant international traffic.
Source: "The Impact of COVID-19 on the airport business and the path to recovery," Advisory Bulletins, Airports Council International (ACI), March 25, 2021.

AAM has the potential to connect more communities and bring industry to diverse places through fast and sustainable mobility by air; it can also bring new possibilities for e-commerce, parcel delivery, and essential emergency services. Yet, if integration is not adequately planned within communities, AAM implementation could face local backlash and give rise to issues as seen with on-demand electric scooters. Globally, many cities were not prepared for the influx of shared micromobility operations, thereby missing opportunities to take a broader view of mobility and provide supportive infrastructure and productive partnerships for positive long-term development. This lack of preparedness also meant that many local authorities were unable to cope with the sheer volume of e-bikes and e-scooters congesting sidewalks and roadsides.

Coordinated planning—encompassing mass transit authorities and transport providers across modes, including rail and road—will help bring the best mix of options to people and facilitate the integration of AAM services into local combined offers through mobility-as-a-service (MaaS).

It will be important for local stakeholders—such as community members, business owners, city and aeronautical planners, and surface and air transportation officials, whether urban, suburban or rural—to be involved as transportation options evolve; users of the systems must be engaged to assist in shaping transportation landscapes.

## Overview

AAM will bring additional mobility options to communities for emergency, passenger, and air cargo services. Air travel is already a primary transport mode yet lacks low-cost operations within a city and for local regional service. AAM holds promise to close these gaps thanks to progress in propulsion systems, automation, and digitalization. AAM includes operations from new electric and hybrid-electric aircraft that can take off and land vertically (VTOL) and new generational hybrid aircraft that can perform short takeoffs and landings (STOL) (Figure 1). The larger aircraft carrying passengers will initially be piloted, with plans for fully autonomous flight to come in the more-distant future.


Figure 1 - electric and hybrid aircraft – from VTOL to STOL: Mission requirements drive aircraft performance.

The aim of urban air mobility (UAM), a subset of AAM, is to provide a wide range of services—intracity and intercity—including on-demand air taxis, air shuttles, cargo air vehicles, and medical emergency services.[2] UAM allows travel across cities with ease from vertiport to vertiport, assisting where it may be difficult to build additional infrastructure for roads or rail lines. Regional air mobility (RAM), another subset, includes operations from urban, suburban and rural communities, bringing aerial services to new areas often excluded from commercial aviation. Many of the local airports that are forgotten or underused, can serve as a strategic center for RAM operations. These airports can provide convenient options for commerce and critical supplies using the infrastructure already in place.[3]

AAM can be simplified further into three categories of application (Figure 2) and includes operations from uncrewed aircraft systems[4] (UAS), often referred to as drones, for cargo delivery or emergency services.

**Passenger Air Mobility**

Passenger air mobility can be carried out through UAM and RAM to transport people across cities and regions where current commercial aviation is often cost-prohibitive and not competitive with other modes of transportation. For congested cities and rural commutes, passenger air mobility would utilize the skies with a more rapid transportation option, offering a safe lower-cost alternative by using low-noise electric propulsion solutions. Various operators around the world have signed orders with OEMs for over 6,000 advanced passenger aircraft.[5]

**Air Cargo**

Air cargo connects people with food, goods and medicine. Operations enabled by AAM could include parcels delivered by small UAS to secure lockers or individual residences, and food or other goods such as medication dropped in front of people's doors. Instead of a multiday timeline for delivery, orders could be delivered in 30 minutes or less and at one tenth the cost of road travel.[6] Also, local air freight transported between smaller airports and toward larger cargo hubs could be transported by advanced battery-electric or hydrogen-electric aircraft. Today, they are carried by small turboprop or piston-engine aircraft (also known as "feeders").

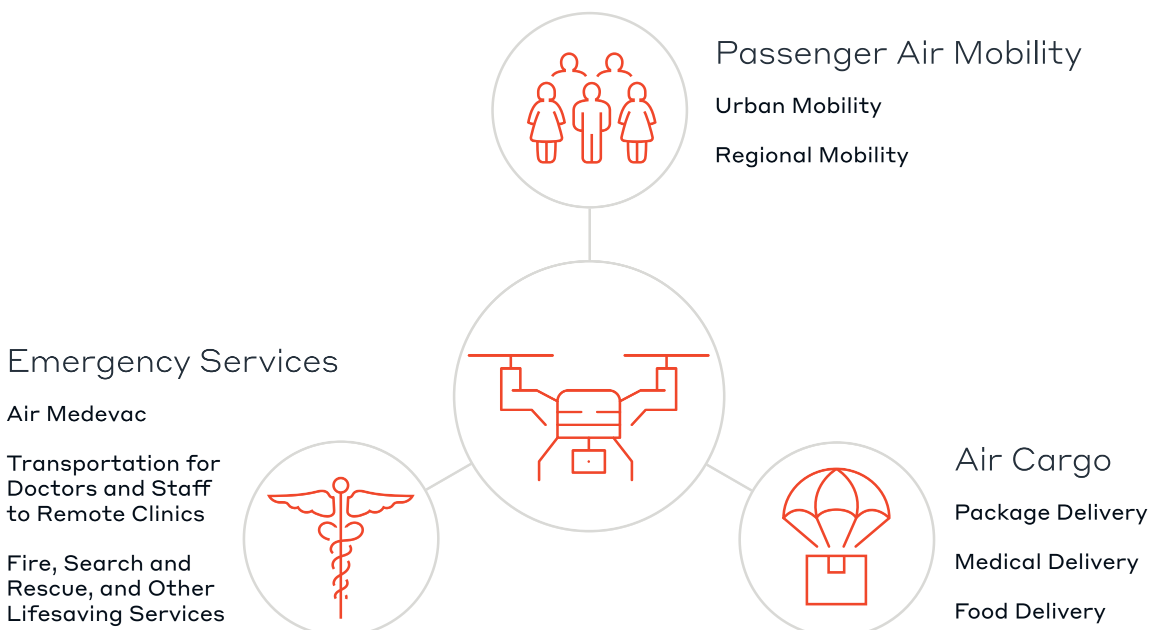


Figure 2 - AAM applications

2 Urban Air Mobility and Advanced Air Mobility, Federal Aviation Administration (FAA).
3 Regional Air Mobility, NASA.
4 Uncrewed aerial systems include unmanned aerial systems (without humans on board) and automated or remotely piloted passenger aircraft.
5 Based on publicly disclosed agreements as of April 2022, including both firm and non-firm orders.
6 John Koetsier, "Drone Delivery Is Live Today, And It's 90% Cheaper Than Car-Based Services," Forbes, August 18, 2021.

Operations for air cargo are already occurring, and passenger air mobility OEMs are aiming to start operations in 2024. For instance, U.S.-based UPS Flight Forward has ordered 150 eVTOL Beta Technologies Alia.[7]

#### Emergency Services

AAM vehicles can be used for emergency services. Electric VTOLs could replace conventional helicopters for most emergency medical service missions. For this market segment, over 1,000 orders for aerial vehicles have been placed worldwide.[8] Also, UAS can provide aerial support where helicopters cannot go and where conventional vehicles are not performant due to congestion on the ground. This includes air medevac to transport critical patients or transfer medical staff to clinics in remote locations and using UAS to deliver lifesaving devices or assist with search and rescue or public safety.

#### Other Applications

AAM technologies and vehicles can also be used for aerial work (e.g., surveys, heavy load lifting), law enforcement (e.g., air patrol, reconnaissance), and military operations (e.g., tactical projection).

## Benefits

In addition to bringing convenient, rapid intercity and intracity travel, AAM is forecasted to deliver a variety of other positive impacts.

#### Lower Commerce Costs

E-commerce has increased following the worldwide COVID-19 pandemic. As lockdowns were implemented, the need for goods still existed, and many turned to e-commerce to assist. With more people turning to e-commerce, AAM air cargo may be a way to further support an expanding e-commerce market. Multiple trials and commercial operations are taking place in many regions globally using UAS to deliver goods. With remote working increasing, people expect goods to be delivered, to more efficiently manage their time. E-commerce also decreases costs for vendors, reducing the need for expensive storefronts; e-commerce businesses could also benefit from lower delivery costs from UAS package delivery.

#### Connect Communities, Provide Accessible Transportation, and Support Decarbonization

In terms of everyday lives, AAM will bring more efficient travel, cutting journey time down to minutes from hours. AAM can connect more communities, extending air travel to areas currently not served or underserved by aviation.

AAM can also enable transportation to serve more people by offering an accessible option for people with limited mobility.

Transportation to family and friends who may have been out of reach from neighboring areas could become viable with this new transportation option. AAM can set in motion new economic relationships through these new physical connections. Likewise, AAM can assist in bringing additional services to remotely situated Indigenous communities to help empower growth and resilience.[9]

The power of AAM has already been demonstrated in the medical field—with drones delivering vaccines and other medical supplies to communities in need during the COVID-19 pandemic. AAM offers greater potential to deliver organs in transplant scenarios and successfully carry out rescue missions in remote places. In addition to transporting medical doctors and their staff to remote locations and facilitating the establishment of more clinic locations, AAM could deliver needed medicines after a virtual doctor visit. AAM has the potential to improve access to healthcare for regions known as “medical deserts,” populations currently without adequate care.

With climate-change impacts increasing, AAM aircraft will help fuel the shift to zero-emission technologies—using electric and hydrogen technologies to reduce greenhouse gases—while providing needed services. However, it is not enough to fly zero-emission aircraft—as part of a holistic approach to decarbonization, flight operators will need to procure low-carbon energy and fuel or produce such energy and fuel locally with low-carbon technologies.

7 “UPS Flight Forward adds innovative new aircraft, enhancing capabilities and network sustainability,” UPS, April 7, 2021.
8 Based on publicly disclosed agreements as of April 2022, including both firm and non-firm orders.
9 *Economic Impacts of Advanced Air Mobility*, Canadian Advanced Air Mobility Consortium, November 13, 2020.

From a sustainable transportation planning standpoint, having provisions flown directly to people's homes via electric small UAS could reduce the number of delivery trips to brick-and-mortar stores; this shift would support sustainable transport while bringing further efficiency to the supply chain.

### Revive Rural Areas and Small Airports

AAM can help revive rural communities and airports. For example, in the United States, while the interstate has brought many benefits since its development in the 1950s, it has caused economic hardship for rural communities that depended on the traffic that flowed through their communities. Before the interstate system, people driving through on local highways were the lifeblood of these communities. Once the interstate came and the routes no longer brought people into communities, the rural towns slowly dwindled economically.

Many rural communities in the United States have suffered from a lack of career opportunities, resulting in generations moving away and never returning. Fading small towns have created a dilemma for those who want to live in these areas where their families have resided for generations; meanwhile, other small towns are reviving with an influx of newcomers seeking a different way of life, an improvement on the high cost of living and long commutes within dense metropolitan areas.[10] In both cases, regional air mobility could create or improve connectivity relative to rural communities with affordable, high-speed, intra- and inter-regional mobility.

At the same time, suburban areas are growing in size, and some rural areas around big cities are subject to urbanization—they are taking on urban characteristics. To avoid causing congestion issues in the sky, AAM should be integrated with other transportation options, to play a part in multimodal systems. As part of an overall solution, AAM can augment transport where other modes are not sufficient, enabling people to utilize the best option to meet their transportation needs.

### Open Up New Opportunities

Rural communities have the potential to become destinations for AAM aircraft, not only to bring local populations to their destinations, but also open new opportunities for local businesses, delivering tourism to lesser-served areas or offering local products to new customers. This is particularly true in regions of the world where the ground transportation infrastructure is either not available, underdeveloped or unsafe.

Revitalizing rural airports that are less utilized can enable them to become a meeting place, a center of activity for the community as well as a transportation hub to connect people to other cities and with other transport modes; these airports could then bring needed jobs to rural communities to improve economies. In light of the global shift to fossil-free fuels, the airports could function as infrastructure assets for electrification, serving as recharging and refueling "stations" for the community, increasing both airport and community power resilience.

Furthermore, the scaling of operations will support renewable materials and composites for AAM aircraft and bring opportunities for new careers to support operations.

Overall, a new generation of aerial vehicles can improve the quality of life for many individuals in line with United Nations Sustainability Development Goals (SDGs), such as fighting climate change, creating resilient and inclusive infrastructure, creating good-paying jobs, and developing sustainable cities and communities.

10 The Future of Airports: A Vision of 2040 and 2070, Topic No. 1: The World in 2040 and 2070, ENAC Alumni, April 2020.

## How to Prepare for AAM

There are a number of considerations for the airport sector and for local planning authorities to consider as they seek to include AAM in their plans:

**Community Engagement**

For AAM to be successful, community engagement should be at the forefront of implementation. It will be necessary to engage all local populations and help the public understand what AAM is and what it is not. A good place to start would be messages that discuss AAM representing the next generation of aviation innovation that can help bring equitable solutions through cargo deliveries and emergency services to those in need.

Original equipment manufacturers are promising lower costs for electric aircraft relative to the conventional comparable alternative. However, the question for communities will be how far this price reduction can go and whether or not AAM passenger air mobility will ultimately be a game changer for the wide travelling public or a high-speed but expensive mobility option that middle-class households may use occasionally. The uncertainty around the cost for users and the process to lower this cost over time should be communicated clearly to the public. Also, the development of AAM should neither hinder public transit services nor divert funding from affordable ground mobility, including the vicinity of larger aviation facilities.[11]

Also, it is essential to ensure one community is not inconvenienced by noise,[12] visual pollution, or limited access to AAM while another community fully benefits from the technology. It is essential to learn from past approaches in transportation planning and development and focus on the unique interests of local communities, as well as place diversity and equity at the core of public policies in planning. Engaging with the public to help shape decisions regarding new technologies is in the community's best interest and helps drive innovative solutions appropriate for each community.

Integrating AAM into local transportation planning conversations can facilitate this process. It will also ensure that the emergence of such mobility is not detrimental to other services, especially public transportation, and that these efforts advance mobility for all.

**Bridge Silos – organizational and regulatory**

It will be essential for aviation and surface transportation organizations that have traditionally worked separately to bridge silos and work together—to plan for AAM. There will be many associated challenges, such as regulations, policies, planning, and even terminology. With variations across sectors and industries, a holistic perspective of cross-sector challenges is necessary for AAM integration. AAM expands the mobility context and should inform future collaborative discussions about transport on local and regional levels.

Regulations are still adapting to incorporate this nascent industry. Airports have significant opportunities as AAM emerges—to consult, with supporting guidance and tools,[13] air carriers and other flight operators as well as fixed-base operators. Multiple emerging technologies—including electrification of aviation, connected and automated vehicles (CAVs), and shared mobility—will influence AAM planning efforts toward delivering equitable and sustainable solutions. Understanding how to apply these technologies in a broader transport context will be essential for AAM implementation to have the best community impact.

11 Gaël Le Bris, "Way of the Future: Airports at the Horizon of 2040 and 2070," TR News No. 331, January-February 2021, the National Academies of Sciences, Engineering, and Medicine.

12 Erich Thalheimer, "Community acceptance of drone noise: The drone of drones" INTER-NOISE and NOISE-CON Congress and Conference Proceedings, InterNoise21, Washington, D.C., USA, pages 1-965, pp. 913-924(12).

13 WSP is currently developing ACRP 03-50: An Airport Centric Study of the Urban Air Mobility Market for the U.S. Transportation Research Board (TRB). The study examines a wide range of issues associated with the rapidly advancing landscape of AAM, including insights on the current state of the UAM market, while supplying practical guidance for planning for UAM under an uncertain regulatory and technological environment.

### Incorporate AAM Into Wider Plans – toward a low-carbon future

Efforts to reduce dependency on carbon fuels are underway across sectors. Still, many considerations are required to prepare for a shift to more sustainable solutions (e.g., electric or hydrogen alternatives). When transitioning from fossil fuels, a thorough knowledge of emerging technologies that support transport solutions and the complexities of current and future capacity needs will be necessary. Understanding current infrastructure capacity and the potential for innovative technologies to generate power will be critical. Airports will need to identify other sources of revenue as aviation fuel revenue declines with increases in electricity and hydrogen utilization. New sources of revenue could include user fees for operations, such as electrical charging fees, or revenue generated from new tenants that support AAM.

Globally, CAVs and AAM involve many of the same needs in relation to charging; co-locating charging infrastructure may be necessary if drastic infrastructure changes are needed to support both technologies. As efforts increase to reduce carbon impact, funding and grants are increasingly available, (e.g., in relation to the Infrastructure Jobs and Investment Act in the United States). Understanding funding options for private, public or public-private partnerships will be essential to drive efforts forward.

### Prioritize Investments – within the new landscape of e-aircraft, particularly eVTOL applications

AAM is expected to provide benefits but may initially be cost-prohibitive for end-users of passenger air mobility and emergency services. However, as operations scale, these costs are forecasted to be competitive with other mobility solutions. For rural communities, a central charging hub that has the capacity to support AAM vehicles and other electric vehicle needs could be cost-efficient and supportive of a range of vendor services (e.g., food and recreational) when infrastructure upgrades are necessary to facilitate the high electrical demand of charging. As communities and airports plan to support AAM, it will be necessary to complete an infrastructure study to have a picture of the current infrastructure and its strengths and weaknesses, determine steps to increase capability and determine where AAM will best fit into their unique environment for highest efficiency. In the United States, such a study is underway by WSP for the Utah State Division of Aeronautics and is expected to be completed by the end of 2022.[14] In general, it will be critical to understand the potential demand for services, give thought to the possibilities AAM may bring, and determine whether AAM is feasible at the current time.

As the world turns toward renewable energy, research and guidance reports are evolving such as the recently released Airport Cooperative Research Program (ACRP) Research Report 236 on electric aircraft and hydrogen technologies.[15] This report, with an associated toolkit, offers an introduction to the emerging electric aircraft industry, gives estimates of potential market growth, and helps airports estimate the potential impacts of electric aircraft on their facilities and prepare to accommodate them. The report was developed for US Transportation Research Board but can be applied globally. Additionally, the Washington State Department of Transportation Electric Aircraft Study[16] provides insight that can be complementary to multiple efforts toward electrification at airports around the world.

It will be essential to understand the appropriate locations for vertiports and their impacts. Some considerations are noise profiles for the area, zoning, land use, obstacles in the air or on the ground, power infrastructure, and a support network for multimodal transportation options[17] (e.g., shared mobility services, rail, and bus). If on a parking garage, the vertiport will need structural assessment, fire code, power, and means to support additional traffic for operations. Another consideration is optimal geographical placement for first mile/last mile transportation needs.

14 WSP is currently conducting a study for the Utah State Division of Aeronautics to identify assets and needs for the full implementation of advanced air mobility. The study evaluates the state as a whole, identifying areas for first adoption, then opportunities for expansion for an innovative, collaborative multimodal transportation system that is integrated for improved access to goods and services without adding pavement and lane miles.

15 WSP developed ACRP Research Report 236: Preparing Your Airport for Electric Aircraft and Hydrogen Technologies for the U.S. Transportation Research Board (TRB). Along with the research report, an assessment tool is available, to estimate the long-term electricity demand of the entire airport ecosystem considering the "electrification of everything"—from the curbside to the runway.

16 WSP prepared the Washington State Electric Aircraft Feasibility Study for the Washington State Department of Transportation Aviation Division of Aviation. The study provides a roadmap for policy makers, airports, industry, and the general public to facilitate the growth of the electric aircraft industry.

17 WSP has delivered ACRP 03-50: An Airport Centric Study of the Urban Air Mobility Market to the U.S. Transportation Research Board (TRB). The study examines a wide range of issues associated with the rapidly advancing landscape of AAM including insights on the current state of the UAM market, while supplying practical guidance for planning for UAM and multimodal integration. The research report is expected to be released in summer 2022.

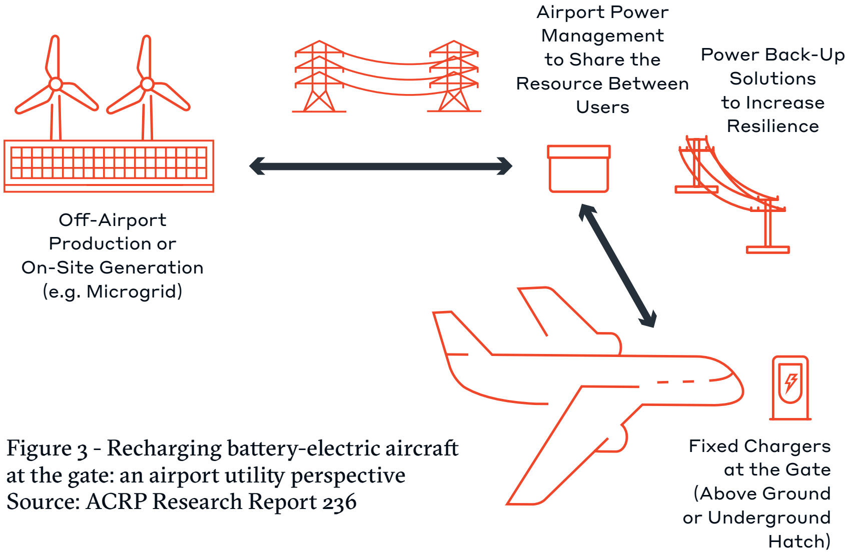


Figure 3 - Recharging battery-electric aircraft at the gate: an airport utility perspective
Source: ACRP Research Report 236

**Weather Considerations in Dense Urban Areas**

Understanding weather and air flow around high-rise buildings is imperative for VTOL safety in dense urban areas. Today, helicopter pilots rely primarily on visual information as well as their experience and knowledge of the local conditions when conducting operations in large cities under visual meteorological conditions. Individual skills and adequate procedures have been key to develop safe and efficient helicopter operations in cities such as São Paulo, in Brazil, which already has urban air mobility features with over 400,000 annual helicopter operations over the downtown area. As more aerial solutions emerge, there will be a need to expand services to all-weather operations, and it will be necessary to have improved weather monitoring and forecasting abilities to provide reliable information to pilots and uncrewed systems. Further research on micro-weather climates created from high-rise buildings and "urban canyons" will also be required to understand the impact on each vehicle class. The weight and aerodynamic characteristics of AAM aircraft will differ from other aircraft and may be affected uniquely by these dynamic environments. Planning for weather forecasting that supports the scaling of operations for AAM will be essential to help mitigate weather and wind-related events.

**Engage with all stakeholders – Innovation in AAM is moving rapidly**

These small, quieter aircraft will provide point-to-point, on-demand services that could be combined with ground mobility to form a door-to-door, smartphone-based Mobility as a Service (MaaS) offer. Including all stakeholders—the public, regulatory agencies (at all governmental levels), metropolitan planning organizations, and economic development agencies—will be critical to support seamless integration[18] of an efficient AAM system that meets the needs of every community.

*AAM is an emerging technology with potential social, economic and environmental benefits for communities around the world. Plans to implement AAM may differ regionally and among communities. All AAM plans will require extensive collaboration between multiple stakeholders across transportation modes to shape mobility landscapes that enable connected communities with equitable solutions. As AAM initiatives advance, it is essential to plan early, effectively engage community members, and determine where AAM can best benefit each community.*

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# Urban Air Mobility: A Wind Engineering Perspective

## Enabling urban air mobility to weather the storm

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Urban air mobility (UAM) is an emerging concept in air transportation featuring highly automated aircraft that are expected to include a mix of piloted, remotely piloted, and fully autonomous vehicles. The aim of UAM, a subset of advanced air mobility, is to provide a wide range of services—intracity and intercity—including on-demand air taxis, air shuttles, cargo air vehicles, and medical emergency services.

With an ever-growing urban population around the world, cities and megacities will inevitably look at UAM as an alternative transportation mode to help reduce pollution levels, improve connectivity, and reduce strain on existing transport networks.

In the context of UAM, electric-powered vertical take-off and landing aircraft, known as eVTOLs, provide perfect mobility solutions for densely built-up urban environments. Despite the significant technological advancements made in the Urban Air Mobility (UAM) industry in recent years, wind remains the most challenging natural physical phenomena confronting eVTOLs.

Weather events as well as their complex interaction with cities and megacities have the potential to influence many aspects of UAM, including safety, operations and passengers' comfort. Disruptions caused by strong winds, wind shear and turbulence can impact the operational down-time of eVTOLs, and the frequency of thunderstorm events could also dictate the financial viability of UAM operations in certain cities.

Generally, in urban environments, the building-induced hazards that arise from complex wind conditions near high-rise buildings will need to be taken into consideration during the planning stage of flightpaths and vertiport siting.

## Integral to Planning and Operations

### Modelling and Simulations

Within the modelling and simulation design space, advanced and extensive city-level as well as vertiport site-specific wind studies will be required—to quantify complex airflow patterns within the urban canopy, to assess the risk associated with atmospheric turbulence, and to assess the risk associated with proximity to high-rise buildings, particularly in relation to flight operations.

An initial assessment of city-level historical weather conditions—with a focus on the frequency of existing weather-related risks and their potential impact on operations and availability of service—will be crucial to support planning and inform investment decisions.

### Predictive Design Tools

Design tools such as boundary layer wind tunnel testing and cloud-based computational fluid dynamics (CFD) simulations will need to be employed to quantify the complex city- and vertiport-specific three-dimensional turbulent flow features that are inherent in the urban canopy of modern cities and megacities and to ensure that building-induced hazards are taken into consideration. Wind tunnel testing will rely on the use of flow measurement techniques such as particle image velocimetry (PIV), whilst CFD simulations will rely on scale-resolving simulations (SRS) such as large eddy simulation (LES) or detached eddy simulations (DES). The results of these predictive tools will need to be frequently updated to take into account that cityscapes are not static entities.

Data collected experimentally (wind tunnel testing) and numerically (CFD simulations) could also be used to drive motion simulation testing to obtain pilots/passengers feedback, determine practical turbulence thresholds for safe and comfortable flight operations and deliver vertiport-specific training to pilots.

Figure 1 and Figure 2 show some of the visual outputs that can be obtained from detailed DES simulations.

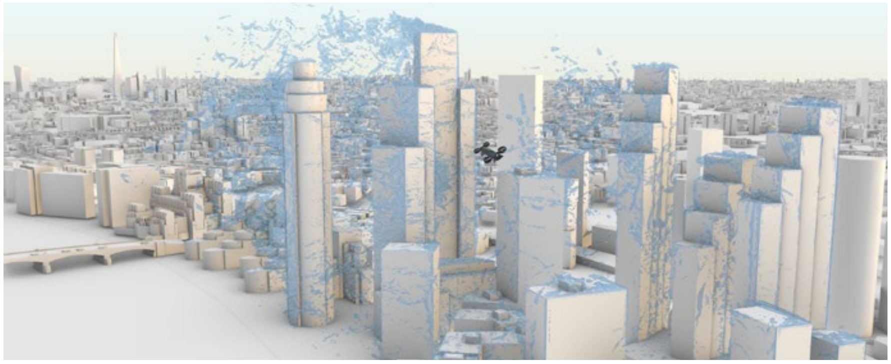

Figure 1 - a snapshot in time of a cloud-based DES where the turbulent wind formations generated by the buildings, part of the urban canopy, are clearly visible

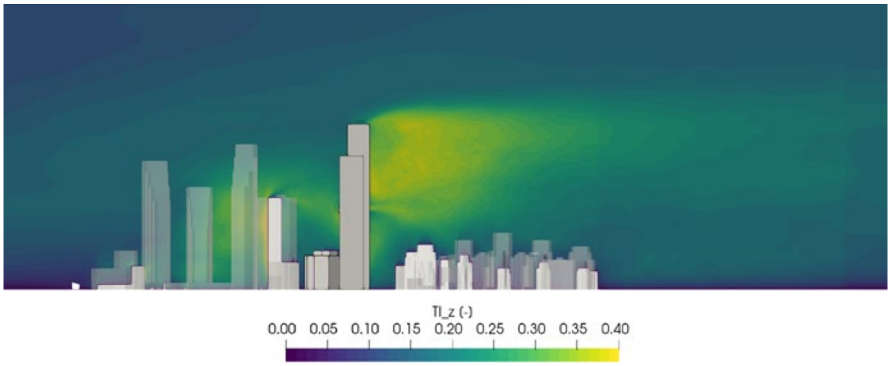


Figure 2 - standard deviation of the vertical airflow velocity across a complex three-dimensional wind field normalised by the corresponding average wind speed at a reference height of 10 metres

## Types of Wind Challenges

**Weather**

With cruise altitude expected to cap at approximately 5,000 feet, eVTOLs will largely be spending their life in the lowest portion of the troposphere—within the so-called 'atmospheric boundary layer'. Turbulence within this space is generated as the wind blows over the earth's surface as well as by thermal buoyancy.

When winds are strong, the turbulence that is generated by the terrain roughness (e.g., buildings, trees) prevails. In this scenario, winds near the ground will be far more turbulent than the ones at several feet above street level; and winds blowing over large cities will be far more turbulent than, for example, the ones coming off the ocean.

Despite being chaotic in nature, turbulence can be thought as the superposition of many whirls of air of varying sizes, often referred to as 'eddies'; an eVTOL, for example, will be particularly susceptible to eddies of a size that is either comparable or larger than the size of the aircraft itself. This means that the smaller the size of an aircraft, the more sensitive the aircraft will be to weather-related hazards as it will be susceptible to a much broader range of eddies.

The weather conditions within the airspace that will be occupied by eVTOLs will not only be influenced by the passage of low-pressure systems such as depressions or tropical cyclones, but also by far more dangerous and somewhat less well-understood thunderstorm-driven gust fronts.

**Urban Environment**

It is expected that eVTOLs will cruise within a certain UAM corridor at an altitude below the airway of conventional aircraft. These small aircraft will then be relying on a network of vertiports which will provide the necessary infrastructure for landing, recharging, and taking-off—a network that will need to be integrated within the urban canopy of existing and future cities and megacities.

When air flows over a city, there are several complex flow features that can produce rapid changes of speed and turbulence along certain flightpaths and result in a sudden drop in aerodynamic lift—these include wakes behind buildings, downdrafts, updrafts, funnelling between neighbouring buildings, shear layers close to the building corners, and horseshoe vortices.

Vertiports will need to be equipped with automated weather stations, LiDAR systems and wind profilers to provide automatic weather alerts and to inform vital no-go decisions. A network of meteo-drones will be needed to support weather-forecasting models. eVTOLs may also be equipped with sensors capable of measuring, whilst flying, the complex flow features that are typical of wind moving around buildings. These measurements will improve weather forecasting within urban environments, allowing the near-real-time performance predictions of the three-dimensional turbulent flow characteristics along the various flightpaths to be made available to all flying aircraft.

The size and light-weight nature of eVTOLs make them inherently more susceptible to gusty winds than conventional aircraft. Understanding and predicting how wind moves and swirls within an urban environment is therefore critical to ensure that wind-related risks will be minimised. Specialised wind engineering studies play a vital role in providing the technical expertise the global UAM industry requires to grow to its full potential.

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