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Advanced Air Mobility: Shaping the Future of Aviation

WHITE PAPER

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Images: Getty Images

Contents

Foreword

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We stand at the beginning of a transformative era in aviation, driven by new possibilities brought by groundbreaking technologies and a critical need for sustainability. To support this transformation, the World Economic Forum has launched the AVIATE: Advanced Air Mobility initiative. Central to AVIATE is a commitment to the safe, sustainable and equitable integration of advanced air mobility and autonomous aviation technologies into the global airspace. It focuses on the nascent sub-sector of advanced air mobility (AAM), given that this will be the first one to adopt the new technological advancements in the sky, from automation to electric propulsion systems, and from advanced materials to next-gen communication systems.

The reasons to help enable the nascent sector of AAM are manifold. First, the societal relevance of AAM in a wide variety of sectors: from the delivery of logistics to difficult-to-reach locations, to speedy response in healthcare emergencies, from the fight against wildfires to precision agriculture. Second, the safety benefits: air travel is already the safest mode of transport, yet 80%[1] of the existing aviation accidents are caused by human error. Autonomous technologies can help address this, as well as addressing the increasing shortage of pilots in more and more geographies. And third, the economic implications of AAM: the potential value of AAM will be highly significant by 2030, involving an entire value chain and resulting in the creation of numerous new jobs.

This white paper marks the end of the first phase of the AVIATE: Advanced Air Mobility initiative. It outlines the main use cases of AAM and the key enablers needed to make them a reality. It also outlines different stages in the road towards more automation in aviation operations, given that increased levels of automation will be key in the roadmap for financially viable AAM operations. The paper also emphasizes the infrastructure needed to introduce AAM, which is often overlooked in favour of discussions around aircraft certification.

Finally, this paper identifies and elaborates on some use cases of AAM, from passenger transport to cargo delivery and medical services, underscoring how these applications could transform the approach to mobility and logistics. The insights presented are the product of extensive discussions with the AVIATE: Advanced Air Mobility community.

Throughout its various phases, AVIATE's mission is to assist the private and public sectors in understanding the complexities of these technological advancements, to identify best practices that maximize their benefits and minimize unintended risks, and to facilitate the deployment of these technologies globally through the World Economic Forum's network of independent Centres for the Fourth Industrial Revolution.

To date, the initiative has engaged more than 30 entities in the broader aviation ecosystem, a strong multistakeholder community including constituents from the public sector, private sector, civil society and research institutions. This collaborative effort will keep evolving in subsequent phases, propelled by the collective aim of achieving a more sustainable and innovative aviation sector. Together, we can redefine the boundaries of what is achievable in the skies and beyond.

Executive summary

Advanced air mobility (AAM) is spearheading innovative new technology in the aviation industry. Despite a strong history of automation, the sector is yet to create a clear taxonomy towards full autonomy, which is necessary for all stakeholders to agree on the required standards and regulations. This white paper supports a spectrum of human in-, on- and over-the-loop, with increasing levels of remote control and numbers of vehicles handled even as direct human intervention and responsibility for all operations decreases.

Application opportunities for AAM are manifold across passenger and non-passenger (goods and services) transport clusters. Use cases thereby stretch across various geographic expansions, from urban to regional. Behind respective operationalization, two driving stakeholder groups can be differentiated: private (pure commercial focus) and public-private (societal focus with commercial viability as the baseline).

To initially adopt and later scale these opportunities, three categories of enablers are vital: social acceptance, operational feasibility and financial viability. The degree of importance of each category of enablers depends on the use case. For the development of passenger-related use cases, social acceptance is most crucial. Non-passenger applications will thrive through financial viability best achieved by increased levels of automation.

AAM adoption is expected to benefit various industries (e.g. healthcare: high speed, better coverage and accessibility); different geographies (e.g. remote areas: better accessibility and lower risk in dangerous surroundings); and people (e.g. (sub)urban transit: faster, increased convenience and more pedestrian space). Some use cases are already being piloted in confined regulatory sandboxes designed to test and derive best practices for the mid-term.

Nevertheless, the ecosystem is not yet ready for large-scale adoption. More cohesive regulations need to be put in place to certify vehicles and autonomous operations. Digital infrastructure needs to be developed to orchestrate seamless airspace operations, while wider physical infrastructure build-up is required to integrate AAM into the existing transport infrastructure.

Looking ahead, AAM will democratize and enable higher degrees of automation for commercial aviation. Yet, many obstacles are yet to be overcome on the road to wider adoption and autonomy. The industry will benefit from implementation roadmaps that accelerate the roll-out of AAM, enabling a more prosperous future for the sector and for society as a whole.

1 Advanced air mobility: The disruptive force transforming aviation

Advanced air mobility paves the way for disruptive innovation in the aviation sector.

Innovations such as artificial intelligence, cloud computing, 5G (fifth generation telecommunications), smart infrastructure, electric motors and sensor technologies are rapidly disrupting various industries and sectors of the global economy. Aviation is no different. Despite it being a highly regulated industry, a new industry branch is embedding numerous innovations in the air: advanced air mobility.

Advanced air mobility (AAM) is a broad concept, a playground for innovation that addresses varied topics such as levels of automation, electric aircraft, novel materials and AI route optimization. According to the US Federal Aviation Administration (FAA), advanced air mobility is "an umbrella term for aircraft that are likely highly automated and electric".[2] This industry branch is still in the research and development (R&D) stage, which allows for strong innovation in the coming years. At the same time, AAM is far enough ahead to consider it a reality and able to already make an impact in the short term.

The future of AAM is electric and is leveraging increased levels of automation. The electric engines of these aircraft support the sector's path to reach net-zero by 2050[3] despite the rapid increase in air travel demand (an estimated 40% increase in the number of flights compared to 2019).[4] Electric engines are also quieter than traditional propulsion engines, contributing to noise reduction.

Autonomous capabilities enabling unmanned or remotely supervised operations can help the aviation sector in several ways. They can help address the current shortage of pilots driven by the post-COVID rebound in travel, which is expected to accentuate in the near future (Airbus and Boeing estimate between 585,000[5] and 649,000[6] new pilots will be needed by 2040). Autonomy will also make the business models related to AAM operations more robust. The caveat is: the autonomy timeline is still uncertain. Currently, tasks in conventional aircraft are automated to a high degree, but several additional steps are needed to make these uncrewed operations a reality. Box 1 presents a multidimensional framework for autonomy in aviation.

In order to enable these unmanned or remotely supervised operations, regulation and public acceptance will need to keep pace with the rapid technological developments. All stakeholders must appreciate the positive societal impact that AAM can have in a wide variety of sectors and geographies. This impact can be leveraged with different stages of automated operations on board.

This white paper focuses first on the wide range of AAM use cases. It then highlights key factors to enable further developments and deployments, and areas where the public and private sectors need to work together. Finally, it zooms into three important, early-adopter sectors that are expected to propel the sector further.

BOX 1 | Defining autonomy capabilities in aviation

Automation in self-contained, functional areas (e.g. the autopilot, as a combination of steering and navigation) has been considered an industry standard in aviation for years. However, it will still take time until the industry achieves high levels of automation. A clear taxonomy can help – in the automotive sector, there is a well-established taxonomy on the levels of driving automation, but an automation taxonomy is yet to be agreed upon by the aviation ecosystem.

Figure 1 presents an automation taxonomy for aviation. It is a simplified framework on the distribution of key responsibilities and actions between the human and the aircraft. This taxonomy identifies three key stages: human-in-the-loop, human-on-the-loop and human-over-the-loop. While the human-in-the-loop still owns and performs tasks itself (e.g. controlling and communicating), the human-on-the-loop may operate multiple aircraft remotely from the ground. Towards full automation, the human eventually moves over-the-loop during the operations, with humans only setting the goal of the mission and supervising fleets in multi-vehicle operations.

The actions among the key functions of aviation have been clustered into three main categories: aviate, navigate and communicate. Each of these main categories will, for the different automation degrees, have sub-systems that will be manual, automatic, automated or autonomous. This can vary depending on the phase of the flight (e.g. take-off vs. cruising) and the potential hazards (e.g. weather conditions, traffic and technical failure). The first automation functionalities have a safety-enhancing goal and evolve into more efficiency-improving goals once their safety is guaranteed – as technical capabilities and public acceptance increase further.

The role and location of the pilot changes with increasing automation. For example, in a remotely supervised or autonomous aircraft, the pilot may be located outside of the aircraft. This will have an impact on public perception. However, an aircraft with the two highest degrees of automation should never require the pilot (be there a pilot onboard or not) to take control of an autonomous aircraft to avert an incident – though they may choose to do so voluntarily.

FIGURE 1 | **Automation taxonomy for aviation**

Increasing automation →

	Human-in-the-loop		Human-on-the-loop		Human-over-the-loop
Types of automation	Manual	Low automation	Partial automation	High automation	Autonomy
Human involvement	Human operates aircraft		Human instructs aircraft	Human supervises aircraft	Human supervises aircraft or fleet
Workload capacity	One aircraft only			One or a few aircraft	Many aircraft
Pilot/supervisor tasks and responsibilities: Aviate	Controls all functions	Controls all functions Some functions can be automated (e.g. speed, altitude)	Main functions are automated Human control can be assumed over most functions	All functions are automated Functions can be instructed, if needed	
Pilot/supervisor tasks and responsibilities: Navigate	Controls flight plan	Manages flight plan Gets support from automated navigation	Automated system follows assigned flight plan with adjustments based on ATC or some hazards Pilot/supervisor can override decisions	Automated system follows assigned flight plan with adjustments based on ATC or all hazards Pilot/supervisor can override decisions	System determines flight plan based on assigned mission with adaptation based on real-time information Pilot/supervisor can override decisions
Pilot/supervisor tasks and responsibilities: Communicate	Communicates directly with ATC* and others	Communicates directly with ATC and others Some functions are automated (e.g. situational updates)	Some clearances and requests from ATC are automated Pilot/supervisor maintains verbal communication	Clearances and requests from ATC are mainly automated Pilot/supervisor maintains verbal communication	System determines flight plan based on assigned mission with adaptation based on real-time information Pilot/supervisor can override decisions
Illustrative examples**	Basic general aviation aircraft First generation commercial aircraft	Consumer drones Commercial jetliners	Modern commercial jetliners First generation eVTOLs*** BVLOS**** commercial drones	Remotely-supervised air taxis Remotely-supervised drones	Autonomous air taxi fleets Autonomous delivery drone fleets

Note: *ATC: Air traffic control; **These examples aim to simplify understanding by illustrating with familiar aircraft types. The type of automation will depend on the embedded systems; ***eVTOL: Electric vertical take-off and landing vehicle; ****BVLOS: Beyond visual line of sight

Source: World Economic Forum

Figure 1 can be used as a taxonomy to provide a widely accepted language on the roles and responsibilities of humans and aircraft. It is important to note that different research bodies from academia and industry are currently working on detailed taxonomies. The taxonomy above aims to be comprehensive for broader stakeholders. Converging on a joint understanding of autonomy will be a key cornerstone for international, unanimous regulation, and its execution across various jurisdictions.

2 The diverse AAM landscape

The speed of AAM adoption across its different use cases will vary based on their social acceptance, operational feasibility and financial viability.

Establishing common ground when discussing AAM is key not only for the industry, but also for governments to regulate the ecosystem and for the public to understand the societal impact. The following section provides a structured overview of the various, key AAM use cases and their enabling factors.

2.1 Systematizing AAM use cases

Different lenses can be applied when clustering AAM use cases. Figure 2 clusters use cases according to three key categories: the nature of what is transported (people, goods or other uses), the key stakeholder type driving the implementation (private or public-private), and the geography where the operations take place (urban, suburban rural or regional).

The first category of use cases, organized by the nature of what is transported, comprises three main clusters: passenger transport, cargo transport and other services (the final category providing a service rather than transporting people or goods from point a to point b). For the development of passenger-related use cases, social acceptance will be key. As a result, it is expected that increased levels of automation will only be achieved well after 2030. Automation is expected to be taken up more rapidly for the other two categories, which will also rely on autonomous capabilities to be economically attractive.

These three clusters can be further split according to the interest groups that are key to driving the use-cases' commercialization into private-driven and public-private driven. Private-driven use cases will require a robust business model with strict emphasis on cost efficiency and operational effectiveness to achieve financial viability, so that they can outperform alternative modes when measured through unit economics. Public-private driven use cases will rely on government funding for their financial viability. This public funding would be backed by the strong societal impact that the use case can unlock (e.g. ambulance services).

Last, use cases are mapped according to their geographical scope. As seen in Figure 2, a single use case can have value in various geographical contexts. For example, point-to-point shuttles can operate in an urban environment for transporting passengers from train stations to sports events, as well as in regional settings to enhance connectivity between remote communities and nearby urban centres. Depending on the geographic scope, however, some operational considerations differ, and the associated levels of risk can vary (e.g. the difference between performing operations in remote areas with low population density vs. areas that are densely populated – the latter being riskier due to the larger impact in case of an accident).

FIGURE 2 | **Advanced air mobility use case overview**

<table>
<tr><th>Main cluster</th><th>Sub-cluster</th><th colspan="4">Geographical areas</th></tr>
<tr><th></th><th></th><th>Urban</th><th>Suburban</th><th>Rural</th><th>Regional</th></tr>
<tr><td rowspan="5">Passenger transport</td><td rowspan="4">Private-driven</td><td colspan="4">Point-to-point shuttles and lines</td></tr>
<tr><td colspan="3">Taxi service</td><td></td></tr>
<tr><td colspan="3">Scenic flights</td><td></td></tr>
<tr><td></td><td colspan="2">Individually owned eVTOL*</td><td></td></tr>
<tr><td>Public-private driven</td><td colspan="2">Ambulatory services (including staff deployment)</td><td></td><td></td></tr>
<tr><td rowspan="5">Cargo transport</td><td rowspan="3">Private-driven</td><td colspan="2">Food and grocery delivery</td><td colspan="2">Heavy air cargo</td></tr>
<tr><td colspan="3">Last-mile parcel delivery</td><td></td></tr>
<tr><td colspan="3">Internal logistics</td><td></td></tr>
<tr><td rowspan="2">Public-private driven</td><td colspan="2">Disaster response (e.g. fire fighting)</td><td></td><td></td></tr>
<tr><td colspan="3">Medical goods</td><td></td></tr>
<tr><td rowspan="7">Other services</td><td rowspan="4">Private-driven</td><td colspan="3">Inspection and maintenance</td><td></td></tr>
<tr><td colspan="3">Leisure and entertainment</td><td></td></tr>
<tr><td>Advertisement</td><td></td><td></td><td></td></tr>
<tr><td></td><td colspan="2">Agriculture</td><td></td></tr>
<tr><td rowspan="3">Public-private driven</td><td colspan="2">Surveillance</td><td></td><td></td></tr>
<tr><td></td><td colspan="2">Environment monitoring</td><td></td></tr>
<tr><td></td><td colspan="2">Emergencies and disaster prevention</td><td></td></tr>
</table>

Note: *Electric vertical take-off and landing vehicle

Source: World Economic Forum

At the moment, dominant aircraft designs for respective use case clusters have not yet been established and are therefore purposely excluded from this white paper. Aircraft design will have a decisive impact on adoption as it will directly influence the three key enabler categories: social acceptance, operational feasibility and financial viability. The next chapter addresses these key enablers for faster and wider adoption of the various kinds of AAM.

2.2 Key enabling factors

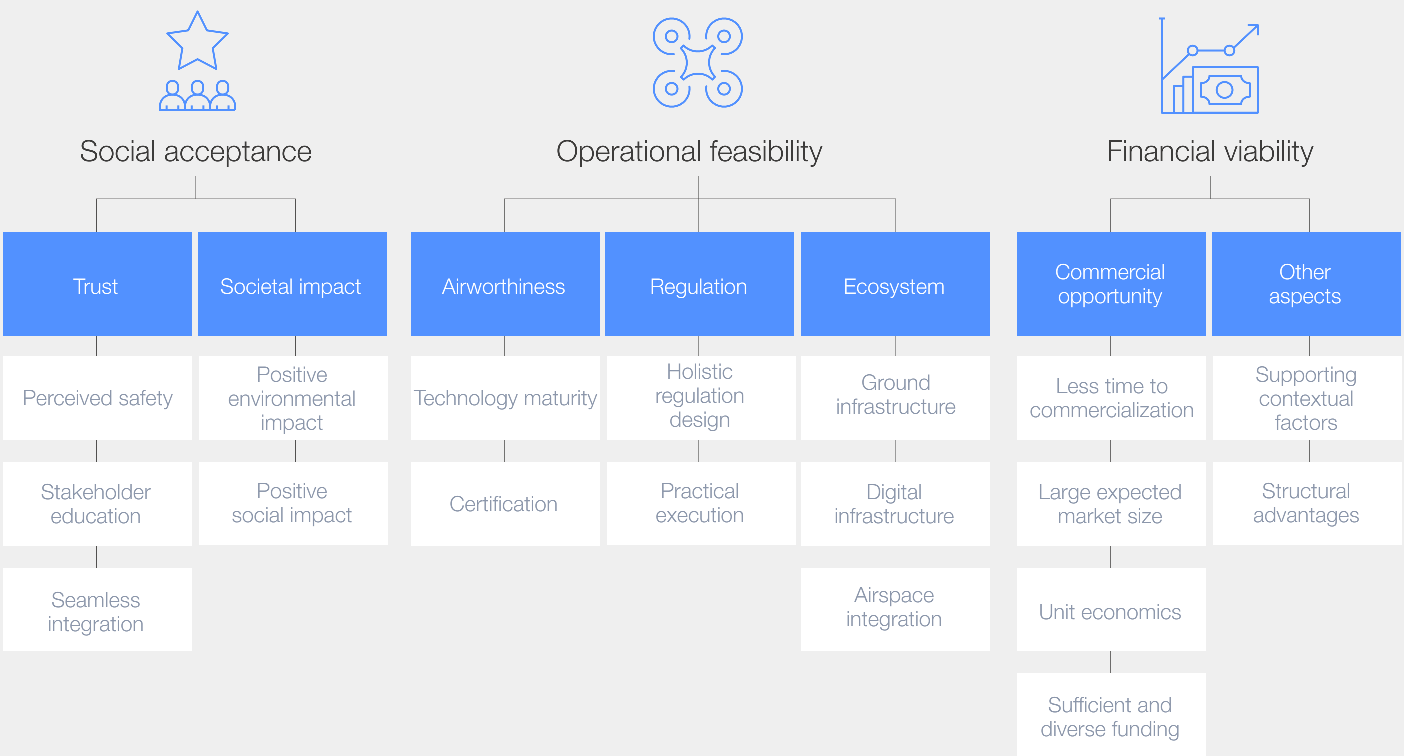
Successful, widespread implementation of AAM use cases over the coming years will be driven by three categories of enablers: social acceptance, operational feasibility and financial viability. Figure 3 outlines the key components of these enabler categories. It simplifies the relationships between enabling factors and, due to clarity reasons, does not illustrate the interdependences among the different components. For example, clear understanding of the positive social and environmental impact of AAM technologies will ensure that both funding and the necessary regulation – for both the AAM aircraft and the surrounding infrastructure – are put in place.

Trust is the first cornerstone of social acceptance, with perceived safety and privacy playing crucial roles. Education and proof of existing capabilities will significantly contribute to this understanding. Beyond establishing trust, achieving social acceptance will be facilitated by a tangible public benefit. This includes deploying AAM instead of more polluting alternatives, and deploying AAM to address current societal challenges, such as improving healthcare or enhancing the inclusivity of remote communities. In order to facilitate adoption, the integration must be seamless for users, providing an intuitive experience that is well-connected with existing systems.

Operational feasibility is also critical for the implementation of AAM. The technology is maturing sufficiently to soon enable safe, reliable and recurrent operations, and many operators anticipate scaling operations before the decade's end. Regulations must evolve to keep pace to enable fast and reliable certification of new systems and to enable the standardization of the ecosystem. To this end, infrastructure will be key – see Box 2 that zooms in on infrastructure needs.

Finally, financial viability is essential as it not only sustains operations but also attracts the necessary funds for the substantial initial capital expenditures. Not only must the sector demonstrate that the economic model is viable and more effective than existing alternatives, it must also prove that there is sufficient market depth and that the timeline towards commercialization will not be too long. Funding should ideally come from both public and private sectors, as both societal and economic benefits are expected from this technology. This multistakeholder approach is crucial for the long-term success and integration of these technologies into mainstream society.

FIGURE 3 **Key enablers for advanced air mobility adoption**



Source: World Economic Forum

When referring back to the main use-case clusters of Figure 2, the key enablers that unlock passenger transport are different from those that unlock cargo transport and other services. Hence, a split between passenger- and non-passenger use cases seems pertinent when highlighting the enablers of the different use cases.

The community has identified the following top enablers for passenger use cases:

– Perceived safety and security. Ensuring high levels of safety and increased cybersecurity precautions will enhance public confidence in new AAM systems. Perceived safety will be as relevant as actual safety, highlighting the importance of public acceptance and the need to consider design and user experience implications in AAM development.

– Ground infrastructure. Time savings will be a key value offered for passengers in AAM operations. Ground infrastructure should ensure seamless integration of AAM into the wider transport network as well as incorporate time-saving technologies such as biometrics and automated baggage handling systems. Ground infrastructure will be a key component in the customer experience, and, as a result, in AAM success for passenger use cases.

– Airspace integration alongside digital infrastructure. Both are crucial for scaling operations and for ensuring safety in busy environments such as cities, which are among the first locations where passenger AAM use cases are expected to take off. Operating over busy cities will require multiple obstacle clearances and the handing of restricted areas and microclimates. Regulators and public authorities will need to advance the work on developing new processes and systems (e.g. unmanned traffic management) to enable autonomous operations over the medium to long term.

The top enablers identified for non-passenger use cases are:

– Unit economics. Wider AAM adoption is enabled through expected efficiency gains over alternative modes. Superior unit economics will however only be achieved if scaling is possible.

– Airspace integration and digital infrastructure. Like for passenger use cases, this aspect remains a key enabler. Unlike for passenger use cases, this driver is important due to the high volume of operations that is expected for non-passenger use cases. High-volume operations will increase complexity for verbal communication, requiring new processes that are most likely to be automated. Otherwise, long-term sector development will be hindered.

– Positive environmental impact. This impact will result from lower CO_2 emissions compared to existing alternatives as well as less noise pollution, especially compared to helicopters. Both these benefits can facilitate public acceptance and provide environmental gains, in line with the evolution of international regulations and the environmental, social and governance (ESG) policies of companies.

BOX 2

The need for more advanced digital and physical infrastructure for AAM

Seamless AAM operations count on having the required digital and physical infrastructure in place. While industry discussions are often focused on aircraft certification, the surrounding ecosystem should not be overlooked. Digital infrastructure, which includes sophisticated communication systems, and physical infrastructure such as strategically located landing sites, are both critical. Currently, the physical and digital infrastructure is not adequate to meet the full operational demands of AAM. The key aspects to consider in creating the appropriate infrastructure are as follows.

The key physical infrastructure will be vertiports. Vertiports will have three key functions: landing and taking-off, charging, and connecting people and cargo to road, rail and/or sea transport infrastructure. The key stakeholders involved will be different. Hence, it is relevant to differentiate these functions:

– Landing and taking off: Landing site locations must be chosen with a focus on safety (e.g. considering location microweather and obstacle limitation surfaces) and be located to provide extensive coverage. Local planners and real estate developers will become important stakeholders since building and aviation standards will need to align to ensure successful vertiport developments. The local community is another important stakeholder that should be included at the start of the deployments since public acceptance will be a pre-requisite for successful implementation.

– Recharging or refuelling: Charging stations should ensure seamless operations, since AAM vehicles are mostly electric. Charging stations rely on grid connection, sufficient capacity and high charging quality – making energy players key stakeholders. Ideally, vertiports offer more than just electric charging points and are also equipped to accommodate alternative energy options such as hydrogen and biofuel, or battery swapping infrastructure. Thus, vertiports become energy hubs.

- Loading and unloading passengers or cargo: Urban terminals should ensure interconnectivity between different transportation modes to ease intramodality and enable synergies in the overall transport networks. Transport authorities thereby become key stakeholders to ensure that new AAM infrastructure is well integrated with existing transport infrastructure. This hub role will provide opportunities to revalue the surrounding real estate. These terminals will need to comply with (new) safety and security protocols, while offering a seamless, fast and enjoyable experience to passengers.

Vertiports, fulfilling the three previous functions, will not be the only ground infrastructure required for the successful rollout of AAM. To ensure safety, a good network of emergency sites will need to be in place. Other related AAM infrastructure will include vehicle manufacturing, training, as well as maintenance facilities.

The main purpose of digital infrastructure is to enable air traffic services. This will require appropriate communication systems, data management and cybersecurity. Public authorities will play an important role in ensuring their availability.

- Managing the airspace: Air traffic services and control are responsible for providing seamless airspace operations for all vehicles (even including medical services). While traditional Air Traffic Management (ATM) systems are designed for manned aircraft, the rise of unmanned aerial vehicles necessitates the development of specialized unmanned aircraft systems traffic management (UTM),[7] also called U-space[8] in Europe. These systems must integrate seamlessly with existing air traffic control frameworks and involve the harmonization and standardization of protocols across different regions, with new requirements for all airspace users, such as aircraft-to-anything systems (A2X). These specialized systems will improve overall airspace efficiency for both crewed and uncrewed aircraft operations and will lead to the emergence of Digital Flight Rules (DFR).

- Communicating: Communication systems must accommodate different levels of vehicle automation that need to communicate with one another. To ensure reliable and secure communication infrastructure, while adapting to contextual constraints, a variety of technologies will be implemented such as very high frequency (VHF) radio, satcom (satellite communication) and 5G.

- Processing data: Data management is a prerequisite for route planning, terrain mapping and collision avoidance. A vast amount of data from different sources and formats (for instance, radars, global positioning system (GPS) and weather monitoring systems) needs to be processed in real time, ensuring reliable and low-latency data management. Standards and protocols will enable the coexistence of different systems and ensure the ability to communicate between all types of devices (unmanned or piloted).

- Securing: Cybersecurity is essential to ensure the safety, reliability and integrity of AAM operations. As the aircraft rely heavily on digital communication, navigation systems and data exchange, they are vulnerable to cyberthreats such as hacking, data breaches and signal interference. Effective cybersecurity measures protect against unauthorized access and control, safeguard sensitive data, and prevent malicious attacks that could compromise the safety of the aircraft, passengers and the public.

New business and commercial models need to be implemented among stakeholders to ensure commercial viability of these infrastructure components. To enhance the effectiveness of multistakeholder collaborations, particularly in sectors where participants may not have a background in aviation standards, a comprehensive educational initiative is essential. This programme should aim to bring various stakeholders, including urban real estate developers, digital infrastructure providers and representatives from local governments and emergency services, up to speed on the relevant aviation regulations and standards. In this way, these diverse parties would engage more effectively in discussions and decision-making processes, ensuring that all viewpoints are considered and integrated into the development of common standards. This approach would enhance the overall quality and safety of the undertaken projects.

3 Sectors pioneering AAM

AAM impact is multifaceted, with its first use cases already benefitting different industries and geographies.

Based on the different enabler groups and their varying importance, some sectors are more likely to apply AAM for their operations at earlier stages. Already today we see different "sandbox" environments, in which use cases with different degrees of automation are being tested in a confined and regulated space, such as those around drone medical delivery in Africa[9] and digital agriculture in India.[10] However, so far minimal adoption in the wider day-to-day context has been achieved.

Ecosystem stakeholders identify healthcare, logistics for remote areas, and (sub)urban passenger transport as the leading AAM use cases, with benefits manifesting as societal value creation, enhanced operational feasibility or high financial viability.

These use cases also show how AAM can impact a wide range of industries and geographies. The following sections provide further insights and outline key pain points, benefits and needs for their deployment.

3.1 Healthcare

Healthcare-related use cases, such as transportation of patients, lab samples, organs or medical inventory, are expected to be commercialized first at a large scale. AAM offers cheaper, faster and better coverage of medical services, potentially enabling real-time medical supplies and inventory sharing between facilities. This can reduce the pressure on constrained healthcare capacity for emerging and developed economies. Therefore, these applications receive substantial public support due to their direct impact on healthcare accessibility and efficiency. At the same time, they make the sector more attractive for entrepreneurship as technology is demonstrably used "for good".

However, scalability, required to offset the high costs of vehicles, infrastructure, new processes and training of personnel, remains a significant challenge for related use cases, putting pressure on financial viability and posing funding challenges for providers. Nevertheless, social benefits can be identified in the short term while economic advantages will likely only materialize in the long term. For example, in case of patient transportation, the economic opportunity varies depending on whether the electrical vertical take-off and landing vehicle is dedicated to replacing helicopter operations or expanded to replace certain ground ambulance activities.

For every healthcare-related use case, AAM operations will have to be thoroughly integrated into existing medical processes and systems. This requires specific training for healthcare staff on the new technology to avoid operational disruptions. This will also involve specific regulations for the healthcare system, including the construction of aviation corridors and dedicated airspace integration for operators. Additionally, health insurance providers will need to adapt to evaluate coverage options for these new modes of transport.

Medical use cases are paving the way for most other AAM sectors benefitting from its positive societal impact. Emerging economies are likely to roll out these applications on a wider scale first (e.g. India)[11] as they have a higher proportion of underserved areas (with underdeveloped infrastructure and medical supply chains). Notwithstanding this, developed countries will also benefit, e.g. in cases of natural catastrophes.

3.2 Logistics for remote areas

For logistics, AAM presents transformative opportunities for both populated areas (e.g. last-mile deliveries) and remote areas (e.g. islands or offshore platforms). The latter initially offers better opportunities with lower risk (and is therefore the focus) as it allows for faster, more cost-effective and more environmentally friendly deliveries without any need for new infrastructure such as roads (hub-and-spoke-models are often implemented with flexible outlying points). This improves accessibility for remote communities, connecting them to other economies, which can lead to positive economic momentum. Affiliated missions also carry reduced risk; for instance, dangerous destinations do not need to be serviced by a person anymore, while remote areas generally do not require flying over densely populated areas.

However, regulators need to approve beyond-visual-line-of-sight (BVLOS) and simultaneous operations for multiple vehicles for this sector to be commercially viable in the long term. As cost savings through high-volume operations are unlikely, high levels of automation and multi-vehicle operations are essential prerequisites to achieve a sustainable business model. Until then, operations will be subsidized by local governments or other interest groups. In addition to advances in regulations, digital infrastructure should be developed on a global basis with common standards to enable tracking, mapping, and exchange of landing sites and flight paths – ideally in a uniform data structure. To leverage these data during operations, solid network connectivity (potentially satellite-based) in remote areas is a prerequisite.

Logistics for remote areas enables a more egalitarian society through better access to more goods "for everyone". These benefits do not only apply to emerging economies with limited road infrastructure. Developed economies can, among other benefits, improve the inclusion of people with reduced mobility, such as ageing populations, or decrease exposure for high-risk missions (e.g. offshore platform delivery). Due to the positive societal impact, there is very limited public opposition to remote logistics AAM use cases.

3.3 (Sub)urban passenger transport

Rapid urbanization over the next decades (from the current average of 55%, to 68% by 2050)[12] puts increasing pressure on existing (sub)urban layouts. Experts suggest that AAM can help to counteract space constraints and traffic congestion (given the shortage of parking) while contributing to quieter and more pedestrian-friendly city environments. It further improves accessibility, travel flexibility and travel time, but only if integrated properly in existing modes of transport. It even increases range into more distant, suburban areas (e.g. as an alternative to extension of metro lines), enabling passengers to travel further in the same amount of time. However, it may spark induced demand – the phenomenon of people traveling longer distances and more often – potentially limiting the benefits of reduced congestion and a cleaner environment.

Currently, public acceptance is a key challenge. The expected high prices remind potential customers of helicopters ("a toy for the rich") rather than a mode of mass transport. This will not change in the short term, but society needs to be educated to counteract fears of noise pollution or a darkening sky impression from mass operations, which will not occur in the foreseeable future. The same holds true for privacy concerns related to mounted sensor technology passing over people's heads as not every vehicle uses cameras. Since most vehicles will initially be flying piloted, backlash stemming from autonomous operations is rather limited.

Furthermore, the existing electrical vertical take-off and landing aircraft (eVTOL, the preferred vehicle type of most operators) technology currently lacks standardized vehicle certification and a regulatory framework. This obstructs the integration of the wider ecosystem including the airspace itself. Landing site availabilities and regulator bandwidth are hurdles to overcome from an infrastructure angle. City planners need to smartly adapt existing infrastructure, especially in the urban context (e.g. creating landing sites at train stations), where building new infrastructure is often not possible due to space or permit restrictions. Moreover, building new infrastructure is very capital intensive with unpredictable returns at present, hindering public and private investment in vertiports.

From a commercial perspective, pilot-onboard operations will entail appreciable recruiting challenges, given both the training required and the implied salary cap to keep fares down, especially since manufacturing scalability for OEMs (original equipment manufacturers) remains a challenge at the initial stages. Moreover, high aircraft utilization is needed to break even, which necessitates quick turnaround times and a route network with established demand. The former requires quick-charging solutions with grid access that can cope during peak times, while the latter is more feasible initially on high-frequency "thick" routes such as airport transfer to city centres. Related physical security procedures are yet to be defined. The industry seems optimistic about the economic opportunity with a large potential market size, which could eventually lower service costs and thus pave the way towards democratized travel and further opportunities for regional passenger transport.

In summary, with an increasing number of urban "no drive" zones, in the initial stages, AAM for passengers can open the aerial dimension by servicing predetermined routes for more than just high-net-worth travellers. However, neither the public nor the ecosystem are yet ready to welcome this new mode of transport as an extension of current public transport. Over the next few years, industry consolidation could establish a dominant vehicle design and realize the required manufacturing economies of scale for long-term commercial success, going past the initially low travel volumes.

Conclusion

Advanced air mobility introduces a new era in aviation – yet has a long way to go for mass commercialization.

Advanced air mobility (AAM) is spearheading innovative developments in new technology in the aviation industry. Despite wide application opportunities across different sectors and first rollouts in confined sandboxes, widespread adoption is not yet on the horizon. Other than advancing technology, the industry will require a developed ecosystem and cohesive regulation – the latter covering both vehicle certification and AAM operations with increasing levels of automation.

New business models that share risk and ownership between private and public entities must be developed to unlock the sizeable investments needed in physical and digital infrastructure. Thus, each stakeholder must have access to a comprehensive understanding of AAM and clear visibility on the social, commercial and environmental opportunities.

Another prerequisite for faster rollout is public acceptance, which needs trust-building by emphasizing the societal benefits and limited adverse impacts of AAM. Education is key to inform the wider public about the strengths and limitations of AAM, and, with that, addressing some of the public concerns on safety (e.g. when it comes to autonomous aviation operations).

Given the multifaceted potential of AAM across sectors, stakeholders must work with different professionals on integrating AAM in their fields (e.g. from developing processes on how/when to send blood tests via drones, to developing building standards for vertiports in high-density built-up areas). New use cases will thereby be unlocked – from the provision of faster operations in the time-sensitive field of healthcare to enabling better access to supplies in remote locations.

Finally, AAM goes beyond unlocking new use cases for the aviation sector. AAM, and the high degree of automation it provides, serves as a front-runner in advancing automation for the entire aviation sector. This cutting-edge domain could represent the initial phase of a pivotal shift that can potentially redefine the aviation landscape in the coming years.

Going forward, the industry will benefit from implementation roadmaps designed to enable and accelerate the adoption of AAM. The AVIATE community will continue to foster global collaboration, by helping to shape key deliverables and by facilitating dialogues for the responsible integration of advanced air mobility and autonomous aviation technologies.

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