

In collaboration with the Ministry
of Civil Aviation of India



Skyways to the Future: Operational Concepts for Advanced Air Mobility in India

INSIGHT REPORT
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Foreword



Vumlunmang Vualnam
Secretary, Ministry of Civil
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The advent of air travel has revolutionized transport, mobilizing millions globally. Today, as technology advances, aviation remains a crucial driver of economic and social connectivity. As the third-largest domestic aerial market globally, India stands at the threshold of a new revolution. With schemes and frameworks aimed at extending aviation to the last mile, advanced air mobility (AAM) presents a unique opportunity to address challenges due to urban sprawl as India experiences rapid economic progress. Furthermore, regional mobility will enhance access to jobs and finance, ensuring no one is left behind in the broader transport network. The value chain of AAM offers India the chance to take a leading position in manufacturing, operations, supply chains and training expertise. Given India's culturally diverse geography, the seamless integration of AAM into the Indian market will help develop a model for aspiring nations.

This concept of operations (CONOPS) report is a key milestone in our journey towards realizing the full potential of AAM in India. It represents the culmination of extensive multistakeholder dialogue among industry leaders, government, regulators and experts from various domains that have set the stage for AAM. To harness this sector's opportunities, we have built a strong community of purpose to address key elements from an end-user perspective.

Since our inaugural session at the Paris Air Show in 2023,¹ attended by key decision-makers from India and around the world, we have worked

diligently to realize our vision. Further, India's safety regulator, the Directorate General of Civil Aviation (DGCA), has issued comprehensive advisory circulars on commissioning vertiports and ensuring AAM aircraft's airworthiness. In September 2024, India participated in the International Civil Aviation Organization's (ICAO) Advanced Air Mobility Symposium in Montreal, where an India-led initiative was showcased.² The broader objective of the symposium was to raise awareness about the extensive benefits of AAM. Our goal is to curate and develop a safe, sustainable, inclusive and economically viable AAM ecosystem while improving quality of life for all citizens. The CONOPS presented in this report serves as a foundational guide for achieving this vision, providing clear guidance on airspace management, regulatory frameworks, operational standards and community engagement.

This report also marks the beginning of a sunrise industry. As we move forward, continuous innovation, collaboration and adaptability will ensure the successful rollout of AAM in India. We are committed to working closely with all stakeholders to realize the vision of making AAM accessible, inclusive, safe and impactful.

We are immensely proud of the work that has gone into this effort and believe that it will serve as a foundation for the future of advanced and short-haul air mobility for all (ASHA). Together, we will shape the future of aerial mobility for generations to come.

Foreword



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India exemplifies the power of multilateralism in transforming lives and uplifting over a billion people. With its rich cultural diversity and rapidly growing economy, India has made remarkable strides in recent years. As it passed the G20 leadership baton to Brazil, the G20 New Delhi Leaders' Declaration highlighted how a dynamic and resurgent India is committed to bridging the gender divide through increased female enrolment in STEM (science, technology, engineering and mathematics) fields, accelerating low-emission technologies, and ensuring that the cities of tomorrow are both resilient and sustainable.

India's aviation sector stands as a testament to the country's forward-thinking leadership and commitment to inclusive growth. The Regional Connectivity Scheme, Ude Desh Ka Aam Nagrik (UDAN), has democratized air travel, making it affordable, safe and accessible to millions. Advanced air mobility (AAM) is the next chapter in this story, introducing new aerial vehicles and technologies that will expand last-mile connectivity across India. This visionary approach positions AAM as a pioneer for the future of air mobility, bringing swift, efficient transport to the broader population.

This report embodies the spirit of multilateralism and inclusivity, demonstrating how a collaborative, multistakeholder approach can create a roadmap for a dynamic, emerging sector. Developed in collaboration with the leadership of India's Ministry of Civil Aviation and the Directorate General of Civil Aviation (DGCA), it maps out the essential elements of an AAM ecosystem. Notably, this document's list of authors includes four accomplished women leaders, each an expert in her field, reflecting a commitment to diversity and gender inclusion.

As Prime Minister Narendra Modi emphasized at the Asia Pacific Ministerial Conference on Civil Aviation, held in partnership with the International Civil Aviation Organization, air taxis are soon to become a reality in India. This report serves as a foundational guide to the architecture of a comprehensive AAM ecosystem, bridging policy, technology and practice.

Moving forward, it is crucial to transform this academic foundation into tangible, on-ground action through coordinated pilot programmes. This document offers a detailed framework for India's journey in AAM, which is set to redefine urban and regional transport and inspire a new era of sustainable mobility.

Executive summary

This report serves as a primer for India's AAM sector, touching upon crucial ecosystem elements to unlock the sector's potential.

Advanced and short-haul air mobility for all (ASHA) is set to transform urban and regional transport. Currently, India ranks third globally in domestic passenger traffic. This concept of operations (CONOPS) report outlines key elements of the advanced air mobility (AAM) ecosystem critical to the sector's success in India. The report aims to inform local decision-makers who may lack subject matter expertise and familiarity with aviation terminology. It serves as a blueprint for the phased adoption and integration of AAM across the country, targeting critical areas such as airspace management, infrastructure development, regulatory frameworks and community engagement.

The report focuses on the economic impact that should be considered when planning and designing these vehicles for various use cases. AAM provides innovative solutions to alleviate urban congestion, improve access to remote regions and identify new economic opportunities. Through AAM, India can witness a new economic opportunity by relieving urban transport distress and access to markets for regional India. This will improve access to jobs, healthcare and economic clusters and contribute to India's broader development goals.

The report outlines India's AAM roadmap, focusing on the need for integrated vertiport networks, a robust regulatory ecosystem and advanced technologies to ensure safe, sustainable and

scalable air mobility solutions. Key strategic actions include:

- Establishing urban and rural vertiports, with a priority on safety, accessibility and transport needs
- Integrating AAM into India's multimodal transport system, ensuring seamless interaction with existing infrastructure like airports and helipads, as well as with road and rail infrastructure
- Addressing key challenges such as noise mitigation, energy demands and community acceptance
- Developing a replicable framework that supports India's formally issued vertiport requirements³ ensuring public safety while supporting the growth of this emerging sector

Ultimately, AAM is not just a transport solution but a powerful tool for social inclusion and economic growth. As India accelerates towards becoming a global leader in AAM, this CONOPS report provides the roadmap to ensure its safe, inclusive and equitable adoption.

To validate this report, it is imperative that a sandbox exercise follows to validate the concepts presented here.

Introduction

The modernization of India's multimodal transport system will be driven by advanced air mobility.

India's top 10 cities must have a well-established network of vertiports that are well-integrated with airports and helipads and the broader road network. There should be a replicable model where dedicated maintenance, repair and overhaul facilities are in proximity to vertiports. Advanced air mobility (AAM) aircraft must be cost-efficient in comparison to radio and app-based premium cab services. AAM can contribute to decongesting arterial roads in India's cities, especially around buildings, clusters and fulfilment centres for logistics. Locations such as mall roofs, terraces and hospitals are especially suitable for integrated vertiports, and India needs a supportive advanced regulatory framework that supports AAM.

This concept of operations (CONOPS) report outlines the potential for AAM to revolutionize India's transport landscape. It explores the technology, infrastructure needs, economic considerations and social implications of integrating AAM into the national mobility ecosystem. The primary objective is to provide a comprehensive framework for a phased implementation strategy, ensuring safe, efficient and inclusive AAM adoption across India. The CONOPS also attempts to equalize access to this technology by ensuring that rural populations also stand to benefit from implementation.

Overview of AAM

The word "aircraft" is typically associated with high-speed aeroplanes that transport people and cargo across cities and continents via airports. In simple terms, it is a machine that can derive support in the atmosphere through reactions in

the air other than those on the Earth's surface.⁴ Configurations include:

- **Aeroplanes (fixed-wing):** Typical planes, such as commercial jets, seen in the sky every day. They have wings that don't move (fixed) and fly forward to create lift.
- **Helicopters (rotary-wing):** Aircraft with spinning blades (rotors) on top. The rotating blades lift the helicopter straight up, allowing it to hover, take off and land vertically.
- **Multirotors:** Drones with multiple spinning rotors (usually four or more). The rotors lift the drone into the air, allowing it to hover and move in any direction.
- **Airships/hot air balloons (lighter-than-air aircraft):** Airships and hot air balloons float because they are filled with lighter-than-air gases like helium. Airships can be steered, while hot air balloons drift with the wind.

As technology advances, however, the world is witnessing new forms of aerial vehicles that can access hard-to-reach areas – that traditional aeroplanes cannot – more sustainably. These vehicles range from small drones delivering sensors or medical supplies to remote areas to future air taxis designed to carry passengers for the last mile. Electric vertical take-off and landing (eVTOL) and short take-off and landing (STOL) aircraft are fixed-wing aircraft that can take off and land on runways much shorter than those needed by conventional aircraft. They offer on-demand passenger and cargo transport within urban and regional areas. Through such vehicles, AAM holds the potential to decongest roads, improve accessibility and create new economic opportunities.

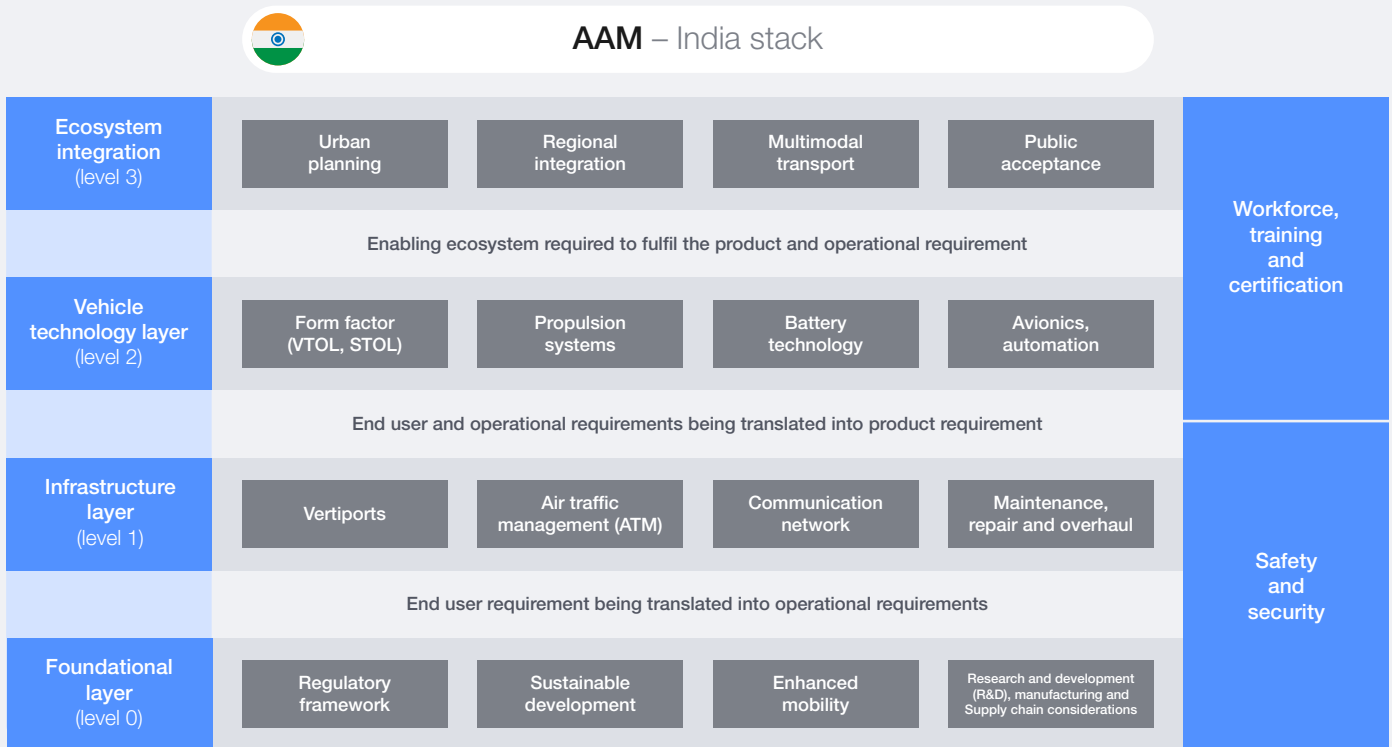


India is at the threshold of a transformative shift in mobility, and AAM represents a pivotal step toward unlocking the potential of our skies. With the development of this concept of operations, we are laying the foundation for a future where air transport is not just faster and more efficient, but also accessible, sustainable and inclusive for all Indians. This collaboration with the World Economic Forum underscores our commitment to embracing innovation while ensuring safe and secure integration into our national airspace.

The Hon. Kinjarapu Ram Mohan Naidu, Minister of Civil Aviation, Ministry of Civil Aviation of India



FIGURE 1 | The India AAM stack



Source: World Economic Forum; Deloitte.

Definitions and principles

AAM encompasses a diverse range of technologies, including eVTOL aircraft, electric drones and other urban air mobility (UAM) vehicles. The core components of AAM include:

- **Electric propulsion:** Reducing noise and emissions compared to traditional aviation
- **Vertical take-off and landing (VTOL) and STOL:** Enabling operations from dedicated infrastructure (vertiports) or modified infrastructure
- **Piloted, remotely piloted, autonomous or semi-autonomous operations:** Increasing efficiency and safety in the future
- **On-demand services:** Offering a flexible and personalized transport option

Additionally, AAM significantly intersects with the United Nations Sustainable Development Goals (UN SDGs), given its coverage across sectors – urban planning, agriculture, supply chain and logistics, emergency services, public health and safety. The SDGs cover various social, economic and environmental global challenges to achieve an equitable future. More recently, the Asia and

Pacific Ministerial Declaration on Civil Aviation (Delhi) highlighted the importance of “identifying opportunities for innovation and the adoption and integration of new technologies, such as AAM, to keep pace with global advancement in information technology and artificial intelligence”.⁵

AAM: What’s in it for India?

In many ways, transport systems are the veins of the Indian economy. India’s transport system is central to India’s economy. As India’s metropolitan cities stand at the forefront of the nation’s economic growth, its citizens’ transport and mobility needs must be met effectively and efficiently. Cities with a higher travel demand indicate an upward trend in economic activity. Furthermore, several major cities are now subject to traffic congestion during rush hour. The late arrival of a commuter to their workplace is not only a loss for the commuter but also a productivity loss for the organization. In 2023, a survey in Bengaluru, India, revealed that 57% of private vehicle owners and 55% of public transport users regularly arrived late to the office. The study also estimated that approximately 700,000 productive hours were lost due to lateness in 2018, leading to a financial cost of INR 11.7 billion (Indian rupees).⁶ Additionally, AAM can increase accessibility in rural and hard-to-reach areas. The role of advanced and short-haul air mobility for all (ASHA) stands to expand significantly in these contexts.

TABLE 1 | **Potential benefits of AAM for India**

Time efficiency and speed	AAM offers faster point-to-point travel, avoiding ground-level congestion and taking more direct routes, significantly reducing travel times.
Traffic alleviation	AAM can help reduce congestion on roads and highways by moving people and goods through the air, easing ground-level traffic.
Environmental sustainability	Electric AAM vehicles produce fewer emissions, contributing to reduced air pollution and greenhouse gas emissions. This aligns with sustainability goals.
Flexible and adaptable transport	AAM is versatile and can be adapted for various purposes, including passenger transport, cargo delivery and emergency services.
Enhanced safety standards	AAM vehicles often feature advanced safety systems, redundancy and autonomous capabilities, reducing the risk of accidents.
Urban planning optimization	AAM can influence urban planning by reducing the need for extensive ground-level infrastructure, allowing cities to optimize land use.
Economic growth and job creation	The AAM industry can create new jobs and stimulate economic growth through vehicle manufacturing, infrastructure development and related services.
Noise reduction	AAM vehicles are designed to be quieter, reducing noise pollution, in turn encouraging community acceptance in urban and suburban areas.
Connectivity in remote areas	AAM can improve connectivity to remote and underserved regions, providing a lifeline for communities that were previously isolated.
Disaster response and humanitarian aid	AAM can facilitate rapid disaster response by delivering medical supplies, humanitarian aid, and conducting search and rescue operations.
Technological innovation	The development of AAM technologies drives innovation in electric propulsion, autonomous systems, ATM and more.
Customized and personalized transport	AAM offers tailored transport options, providing personalized services to passengers and cargo owners.
Integration with existing transport modes	AAM can seamlessly integrate with existing transport modes, providing multi-modal options for travelers and shippers.
Global connectivity	AAM has the potential to connect cities and regions globally, reducing travel times and creating global economic ties.
Infrastructure cost savings	AAM reduces the need for costly ground-level infrastructure expansion, saving on infrastructure investments while improving transport options.
Regional connectivity	AAM has the potential to significantly enhance regional connectivity, making it easier for people and goods to move between various regions. This increased connectivity can have a range of economic, social and logistical benefits.

“ AAM aircraft can use existing infrastructure, such as the rooftops of malls, buildings, hospitals and existing helipads, instead of dedicated helipads.

In India, state- and city-level logistics plans should factor AAM into the multimodal transport system. A strong infrastructure strategy accounts for the use and repurposing of existing infrastructure, while planning the development of new vertiports will support the advancement of the AAM agenda.

Lessons from the helicopter market

In the financial year (FY) 2022-23, the total number of helicopter hours in India was about 58,000, compared to 2.7 million in the US.⁷ This indicates an open avenue for AAM to expand and operate to address key infrastructure, regulations, economic viability and supply chain bottlenecks.

Why is the AAM market expected to succeed when the helicopter market in India has not met its anticipated usage levels since its introduction? Several factors contribute to the imminent expansion of AAM:

- **Costs:** With fewer points of failure, AAM aircraft can incur significantly lower operational costs than helicopters. In particular, eVTOLs may be more energy-efficient, relatively quieter and require less maintenance than helicopters. Electric propulsion systems also introduce a sustainability element to the sector.
- **Infrastructure:** Unlike helicopters, land acquisition may not be a significant challenge for AAM. These aircraft can use existing infrastructure, such as the rooftops of malls, buildings, hospitals and existing helipads, instead of dedicated helipads.
- **Regulatory:** Regulations supporting AAM are evolving in a well-informed and evidence-based manner. The sector is highly technical, involving airspace management and overall aircraft operations. Therefore, regulatory inputs will also come from software experts in the industry. Helicopters, on the other hand, faced substantial regulatory hurdles.

- **Demand:** India's requirements align closely with AAM's capabilities. For example, primary healthcare accessibility, urban decongestion, and efficient transport of people and high-value cargo are critical needs. AAM solutions, such as air taxis for urban areas, air ambulances for medical transport and connections to rural regions, address these requirements effectively.

The city of São Paulo represents a compelling example for comparison. Brazil has a helicopter fleet of over 2,000, with São Paulo alone accounting for 411 aircraft and 260 helipads out of the country's total of 427. A helicopter lands in São Paulo every 45 seconds, indicating the potential of UAM. São Paulo is a decisive case of how a financial hub, rapidly urbanizing and home to 12 million people, uses magnified airspace for urban mobility. With greater adoption, the city has seen a democratization of this mode of transport akin to radio and web-based services around the world. A typical take-off/landing fee stands at \$40.⁸

Despite its vastness, India has a fleet of 300 helicopters, with 250 registered and operational civil helicopters and over 1,000 helipads. Even during the COVID-19 pandemic, when medical evacuations were at an all-time high, the helicopter sector did not see much upturn. On the other hand, the pandemic caused a significant rise in drone-based medical deliveries across India post-2020.⁹ The decline in helicopter adoption was due to several factors, including financial viability, integration with air traffic control (ATC), understanding helicopter flight rules beyond visual flight rules (VFR), challenges with last-mile connectivity and infrastructure, and the need for dynamic pricing models.

Electric aircraft, eVTOLs and STOLs are well-suited and present an excellent case for India to mainstream the technology. Despite the odds and market factors against helicopters, the response to the Ude Desh ka Aam Naagrik (UDAN) scheme proposed by the Government of India has been overwhelming. The concept of AAM in the transport sector bridges the economic gaps in large cities. It overcomes many negative factors such as infrastructure, emissions, maintenance costs, potential to automate and ease of use.

FIGURE 2 | Elements of the AAM ecosystem in India



1

Designing the vertiport environment

Safety, access and necessity are key factors in selecting vertiport locations to address India's diverse needs.



“ To build public trust, vertiports must be in areas that are safe for take-off and landing activity.

The vertiport environment

Vertiports are the key physical infrastructure required for AAM. They enable taking off, landing, charging and a good flow of passengers and goods within the terminal and beyond (multimodality options with the broader transport system). The vertiport environment involves several key factors, including space availability, meeting safe landing requirements, setting up charging infrastructure and ensuring a smooth passenger experience.

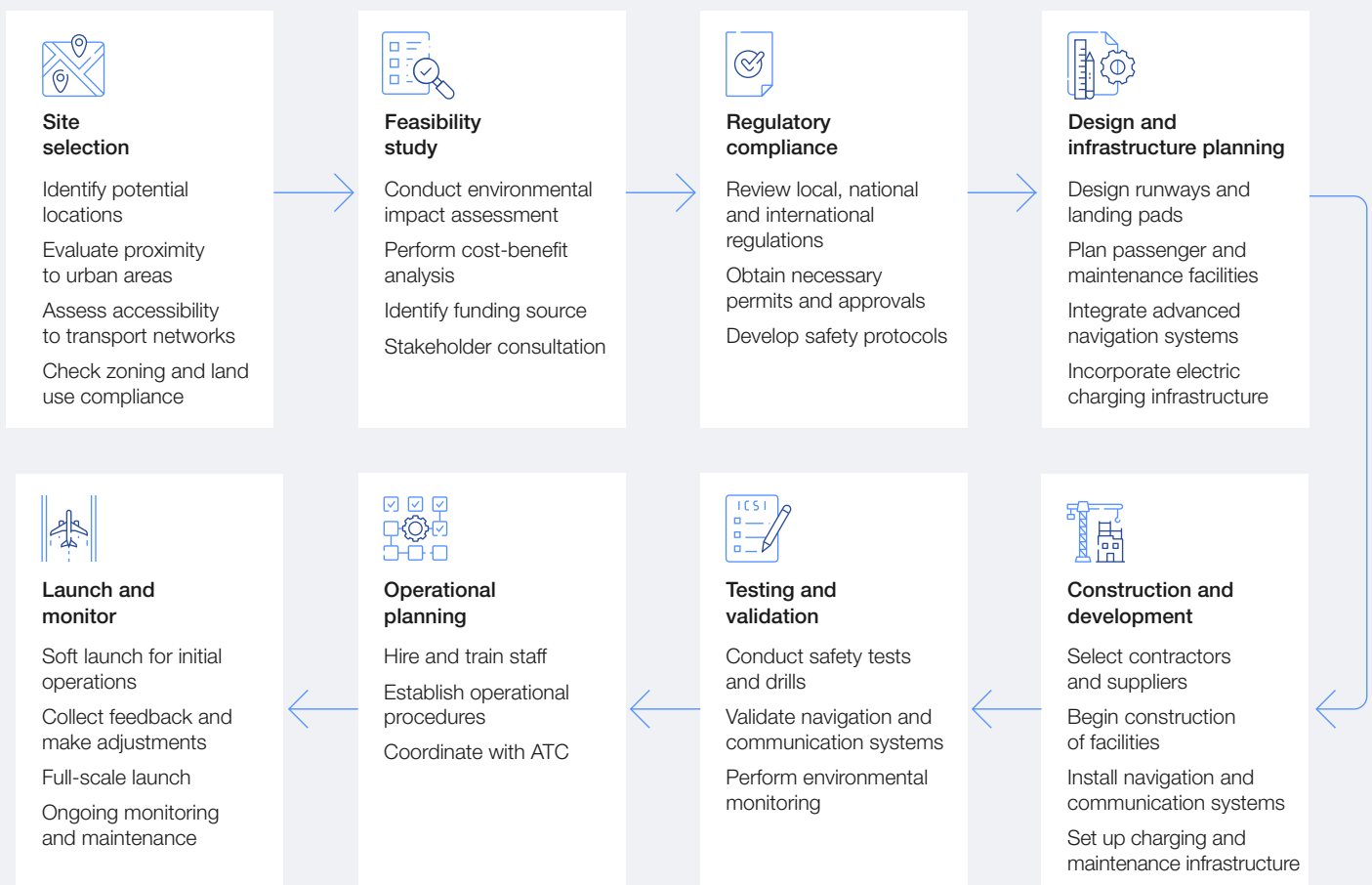
Figure 3 provides a flowchart with the key decision steps for setting up a vertiport. While multiple aspects are at play, determining the vertiport location has three overarching objectives: ensuring safety, contributing to access and equity, and addressing a transport need.

- **Safety:** Against the backdrop of India’s rapidly expanding urban landscape and complex geopolitical environment, safety and security must be non-negotiable in the development and deployment of AAM aircraft. To build public trust, vertiports must be in areas that are safe for take-off and landing activity. Vertiports must also be designed to fit harmoniously within neighbourhoods, ensuring minimal noise pollution. This can be achieved through risk mitigation strategies, conducting thorough

safety assessments and audits, and making well-informed decisions about the vertiport’s location. Proximity to emergency response services and hospitals is also key to ensuring that timely action can be taken in the event of any untoward incident.

- **Access and equity:** The potential of AAM as an opportunity to be a mass-market transport in India is immense, given the size and density of India’s population. For the country to reap the overall benefits of the technology, the system must be designed to make the sector accessible to more than just those with higher disposable incomes and a greater willingness to pay for the service. Rural and underserved areas must directly connect to urban clusters in tiers 1, 2 and 3 cities. This requires a deeper integration of AAM into intermodal transport, serving as connectors to and from major hubs like train stations and bus stops.
- **Necessity:** Positioning a vertiport must be a strategic decision. It must cover the outcomes that the specific area is looking to achieve. These could include decongestion of an urban corridor, connecting an underserved area to an economic cluster or delivering medical supplies and high-value cargo to a remote area. Economic viability can be ensured if these decisions are made based on demand.

FIGURE 3 Decision criteria for setting up a vertiport



“Vertiports in rural India should be able to handle diverse operations, ranging from heavy-lift cargo delivery to passenger transport.”

Scorecard for decision-making on vertiports in India

Taking a structured and quantitative approach is important while planning to set up a vertiport in India. India's Aerodrome Advisory Circular sets the necessary preconditions to set up a vertiport while providing guidelines for designing, operating and authorizing.¹⁰ As India is characterized by highly complex transport patterns, high population density in urban areas, vast rural areas and established transport infrastructure, a scorecard may help determine key candidate cities or towns in urban and rural India.

Priorities for urban India

Safety is crucial in areas that have a high population density. Vertiports must be located in areas that allow aircraft to easily navigate high-rise buildings and designated landing funnels around airports. This positioning greatly impacts public safety, ensuring that no uninvolved parties are affected by AAM operations.

Locations prone to congestion, such as business districts and intermodal hubs like intercity stations, could be prioritized for vertiport placement, aligning with demand. However, noise mitigation must be seriously considered in areas near residential locations.

Space utilization is paramount in an urban setting. Vertiport planning with local decision-makers and municipalities must incorporate this to ensure swift passenger turnover.

Priorities for rural India

In rural India, areas requiring essential transport access should be prioritized. For example, it is important to link remote areas to urban centres in nearby towns, use air ambulances to connect community health centres to district hospitals and create corridors to transport agricultural goods from farms to markets.

While some areas of rural India are sparsely populated, vertiport positioning must be determined based on the terrain, ease of accessibility and travel expense through traditional means of transport. Vertiports in rural India should be able to handle diverse operations, ranging from heavy-lift cargo delivery to passenger transport.

Rural areas may benefit from additional regulatory support in developing a skilled workforce, infrastructure and efficient operations. These economies can be revitalized as they gain access to broader markets, creating more job opportunities. Additionally, tourism can be boosted through AAM connectivity.

FIGURE 4 Ensuring that all Indian vertiports are sustainable



Scorecard for vertiports

In alignment with the previously mentioned priorities, the following scorecard may be considered a guide while planning a vertiport.

TABLE 2

Vertiport feasibility scorecard using key criteria for urban and rural areas

Criteria	Description	Weight (urban)	Weight (rural)	Score (1-5)	Weighted score (urban)	Weighted score (rural)
1. Location necessity	Assess the need for new vertiports in the area	0.15	0.20			
	Consider traffic congestion and demand for intra-city/intercity travel in urban areas; connectivity in rural areas	0.15	0.20			
2. Safety considerations	Evaluate the safety of the proposed vertiport location	0.20	0.15			
	Assess factors like airspace management, proximity to emergency services and public safety risks	0.20	0.15			
3. Environmental and social impact	Consider potential noise pollution, public acceptance and environmental impact	0.15	0.10			
4. Urban planning integration	Assess the integration of the vertiport with existing urban planning and infrastructure	0.10	0.05			
5. Population density	Evaluate the population density and its potential to drive demand for AAM services	0.10	0.15			
6. Travel patterns	Analyse existing travel patterns and the potential for AAM to enhance connectivity and reduce travel time	0.10	0.15			
7. Existing transport infrastructure	Assess the ability of current transport infrastructure to support AAM integration	0.10	0.10			
8. Economic potential	Evaluate potential economic benefits, including job creation, tourism and business opportunities	0.10	0.15			
9. Topology and design feasibility	Assess the suitability of the area's topology for vertiport construction, considering design options like rooftops or ground-based facilities	0.05	0.05			
10. Interoperability	Ensure the vertiport can accommodate various AAM vehicles, promoting standardized infrastructure	0.05	0.05			
11. Readiness index	Assess the location's readiness for AAM integration based on land availability, regulatory frameworks, public acceptance, connectivity and workforce availability	0.10	0.10			
a) Land availability	Availability of suitable land for vertiport construction	0.10	0.10			
b) Regulatory frameworks	Presence of regulations supporting AAM operations	0.10	0.10			
c) Public acceptance	Public acceptance based on surveys and community engagement	0.10	0.10			
d) Connectivity	Connectivity to existing transport networks	0.10	0.10			
e) Skilled workforce	Availability of a skilled workforce for vertiport operations	0.10	0.10			

How to use the scorecard

1. **Assign scores:** For each criterion, rate the proposed vertiport location on a scale of one to five.
2. **Calculate weighted scores:** Multiply the score by the corresponding weight for urban or rural settings.
3. **Sum weighted scores:** Add the weighted scores across all criteria to get a total score for both urban and rural contexts.
4. **Comparison:** Use the total weighted score to compare different locations, prioritizing those with the highest scores for vertiport development.

BOX 1 4-V vertiport topology: four topological configurations

Depending on volume needs, a 4-V (verge, vantage, vista and vertex) configuration system should be considered for vertiport topologies. These configurations are designed to accommodate different capacity requirements, available space, maintenance levels and operational needs. They are adaptable and can be expanded based on local decision criteria, ensuring flexibility in urban and rural settings.

Verge

The verge configuration is suited for small-scale operations and is ideal for urban or regional nodes with space constraints. It can be used for rooftop vertiports or emergency landing sites. Verge configurations can also support drone operations for medical or emergency supply deliveries. This setup is optimal for tertiary nodes in an aerial or multimodal transport network.



Application: Urban or regional locations, emergency services, small-scale operations



Function: STOL and VTOL operations with basic passenger amenities and limited maintenance

Vantage

The vantage configuration is designed for medium-scale operations, offering enhanced facilities and the ability to handle more flights per hour. It is well-suited for regional hubs, particularly at transport interchanges such as bus or railway stations, where multimodal transfers are common. Vantage configurations provide expanded maintenance and passenger amenities, making them ideal for heavier cargo and medical transport.



Application: Regional nodes, multimodal transport hubs



Function: Supports higher flight frequency and offers expanded fuelling, maintenance and passenger services

Vista

The vista configuration is the largest and most capable, designed for high-volume, large-scale commercial operations. It is ideal for integration with airports or as standalone hubs on major transit routes. Vista vertiports can accommodate a high number of flights per hour and offer advanced amenities, making them suited for air taxi services, heavy cargo transport and large-scale commercial operations. These hubs also allow for extensive aircraft servicing and maintenance.



Application: Airport hubs, busy urban or regional corridors



Function: Capable of handling high-volume traffic with advanced passenger and aircraft maintenance services

Vertex

Further, a minimalist configuration may be considered for locations where electrification is not feasible or required. It is primarily suited for low-demand areas, emergency landings or temporary operations. This can serve as a basic landing and take-off site, offering minimal infrastructure and services, making it ideal for remote or rural locations where power and facilities are limited.



Application: Remote or rural areas, emergency landing sites, temporary setups



Function: Supports basic VTOL operations without the need for charging or electrical infrastructure – suitable for drones, non-electric aircraft or emergency use cases, with minimal passenger and maintenance services.

2 Developing an integrated airspace

Integrating AAM through the use of dynamic corridors can facilitate seamless coexistence with traditional aircraft and airspace operations.



Understanding the low-level airspace economy

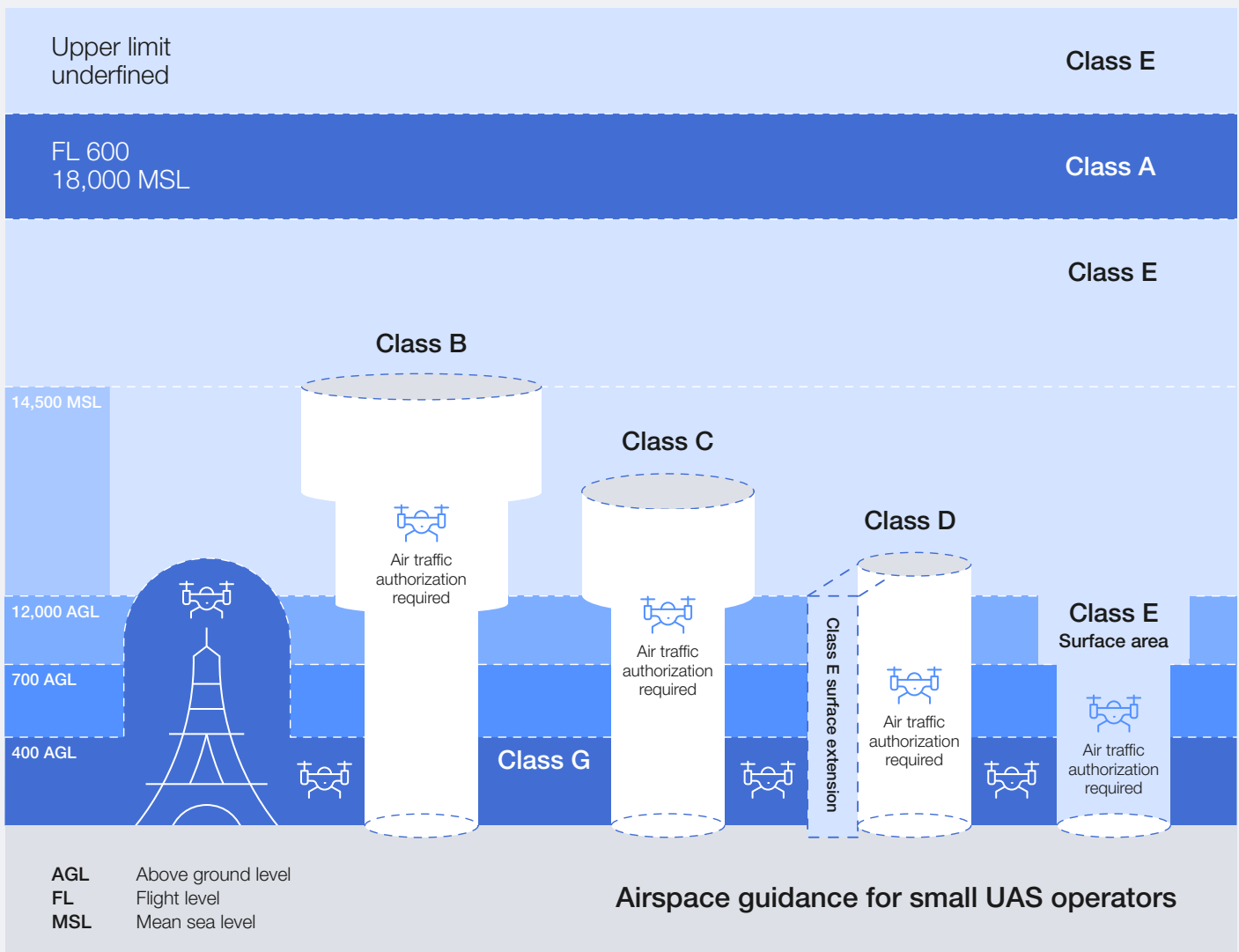
Low-level airspace refers to the part of the sky closer to the ground, typically where helicopters and drones operate. It is carefully managed to ensure safe sharing between various types of aircraft.

UAM and the use of drones in low-level airspace enable a whole new class of operations and have the potential to power a new economy of low-level airspace. The rapid progress in this technology will enable a new class of vehicles and operations in low-level airspace, contributing to the productivity and efficiency of economic activity within cities and regions. The low-level airspace economy has the potential to transform life in both communities and cities, with its operational possibilities offering exciting opportunities for growth and innovation.

Starting with the use of small drones, UAM will then be integrated into low-level airspace. The airspace will accommodate new vehicles and operations in a step-by-step fashion in parallel with the acceleration of technological capability.

While crewed aviation flights currently outnumber small drone flights, uncrewed operations in low-level airspace will eventually dwarf crewed operations at any level of airspace. While the timing of this shift is hard to predict, it represents a fundamental change in how low-level airspace is managed and used. In this sense, this airspace is undergoing a profound transformation. Effective management of this modernization will enable the integration of these new operations to economically benefit communities. Therefore, efficient airspace design and management should be crucial pillars in supporting safe, reliable and efficient UAM operations in India's cities.

FIGURE 5 Federal Aviation Administration's airspace guidance for unmanned aircraft system (UAS) operators



Source: Federal Aviation Administration. (2018). *Airspace Guidance for Small UAS Operators*.

“ Not only does the organization of airspace need to be more dynamic, but changes based on demand, density and other factors will now need to be factored in.

Airspace design and modernization

A new framework for airspace design and management must be developed to accommodate the dynamic nature of new operations and vehicles. It is envisaged that UAM will not require a new class of airspace, but operations will happen in existing airspace classes.

These changes in airspace represent a marked departure from traditional airspace management operations and the crewed aviation ecosystem. Not only does the organization of airspace need to be more dynamic, but changes based on demand, density and other factors will now need to be factored in.¹¹ In traditional aviation, the airspace system is designed by a competent authority and managed by air navigation service providers near airports for crewed operations. In the context of UAM, the airspace (e.g. class G) may be managed by private entities, e.g. providers of service to UAM. The ATC is made aware of the operations if there is a safety and/or operational risk with crewed aviation (e.g. movement from class G to class B). To ensure cooperative traffic management, situational awareness of operations in different classes of airspace should be digitally transferred and made available to ATC and private entities managing UAM airspace. This will help to avoid possible disruptions in this new world of aviation.

This new paradigm in airspace management means that new systems, processes and tools must be developed to enable operations in urban environments. Some initial work on standards and CONOPS from other countries – e.g. the Federal

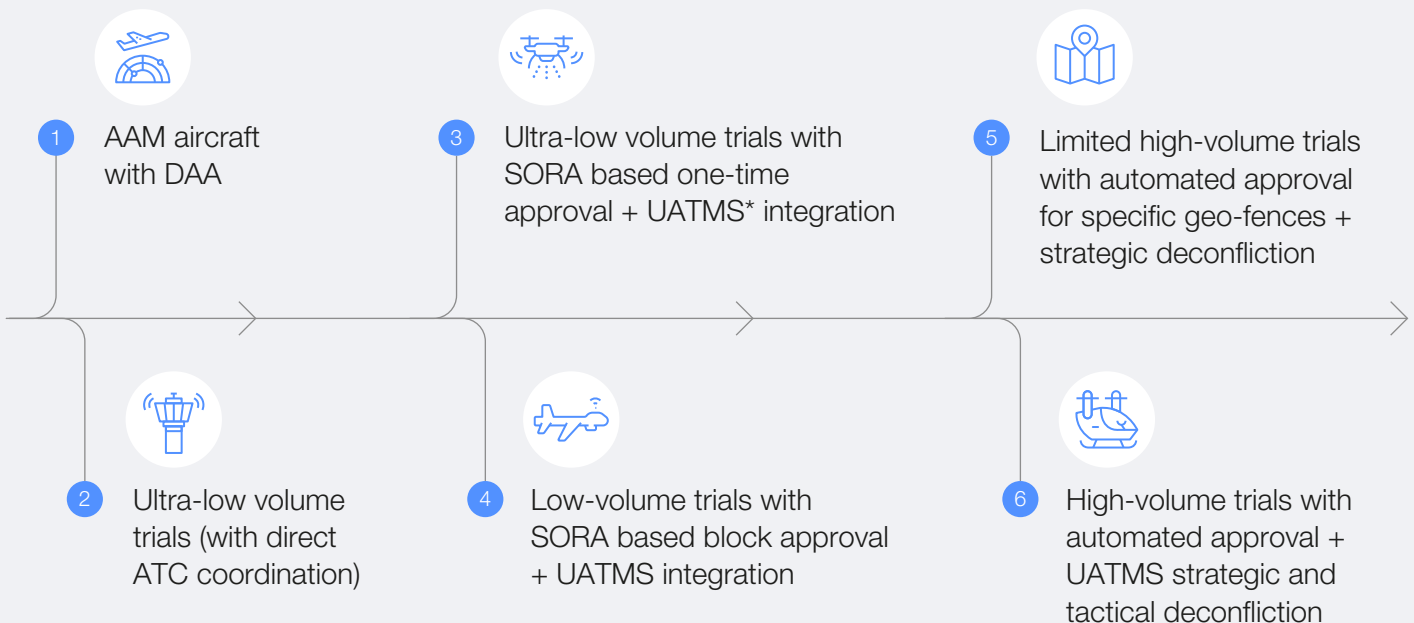
Aviation Administration (FAA) in the US¹² – envision the role of public or private entities to support the traffic management services within UAM environments. This significantly differs from the current airspace management model, which places ATC in the centre. The new CONOPS encourages industry and public sector entities to actively participate in flight safety and decision-making for air traffic management (ATM).

This new management system is envisioned to be mainly digital and increasingly automated. This is partly due to the nature of the low-altitude economy – it is simply not possible for trained ATC to manage the volume of flights projected. Since various UAM operations and small drones share the airspace, a network of providers is anticipated. This network will allow the exchange of flight information and other data, giving operators a real-time view of airspace to ensure proper separation and maintain safety. The role of ATC and ATC systems will change. The eventual goal of the modernization programme is airspace integration so that all types of operations are enabled.

Roll-out

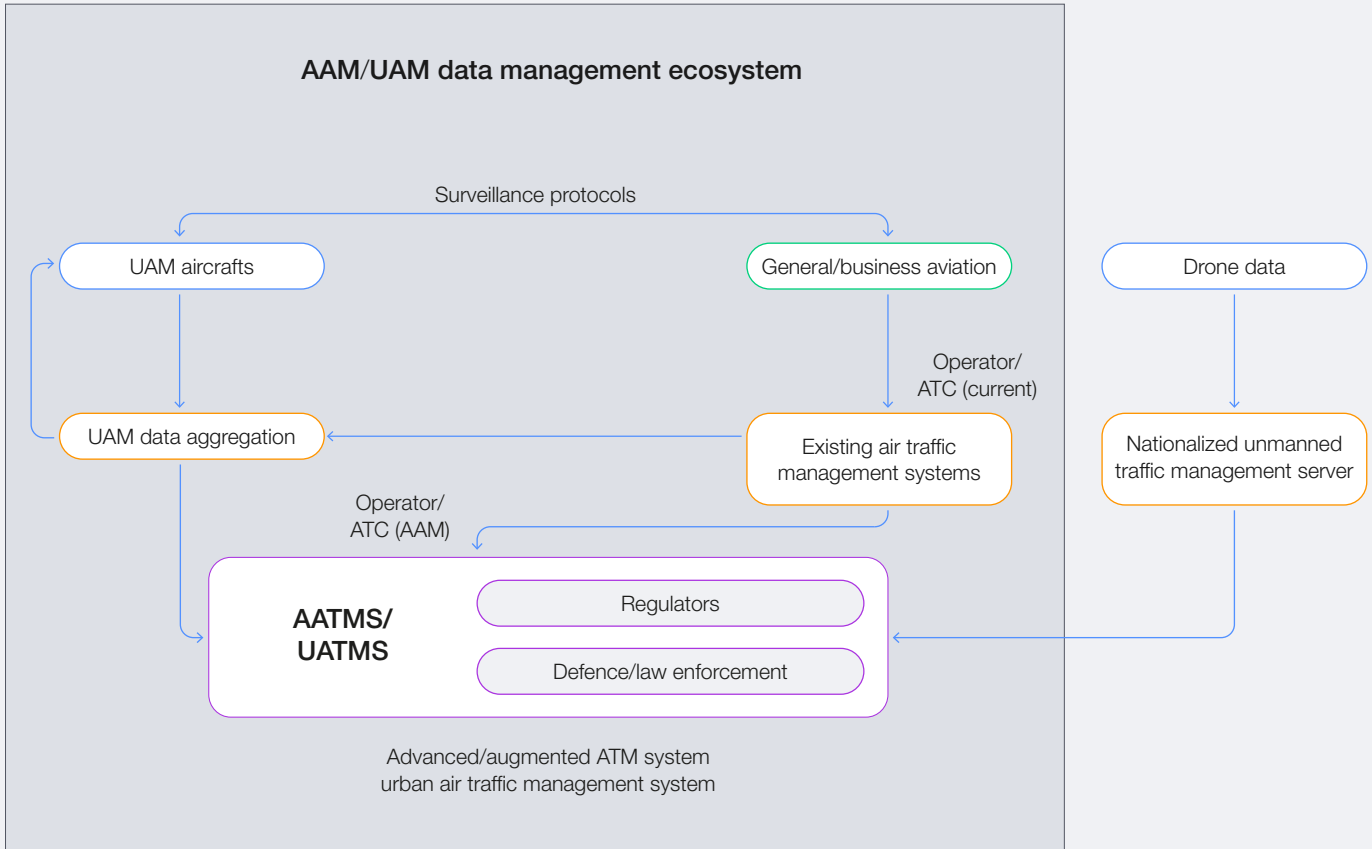
A phased roll-out plan with increasing levels of autonomy will enable a smooth transition from current helicopter operations to a highly networked, dense AAM with high levels of automation to cater to such high volumes. Aircraft should have detect-and-avoid (DAA) or sense-and-avoid (SAA) capabilities that will help the pilot assess traffic.

FIGURE 6 High-level rollout flow



*Unified ATM systems

FIGURE 7 | Data ecosystem for integrated AAM/UAM with existing ATMs for seamless airspace management



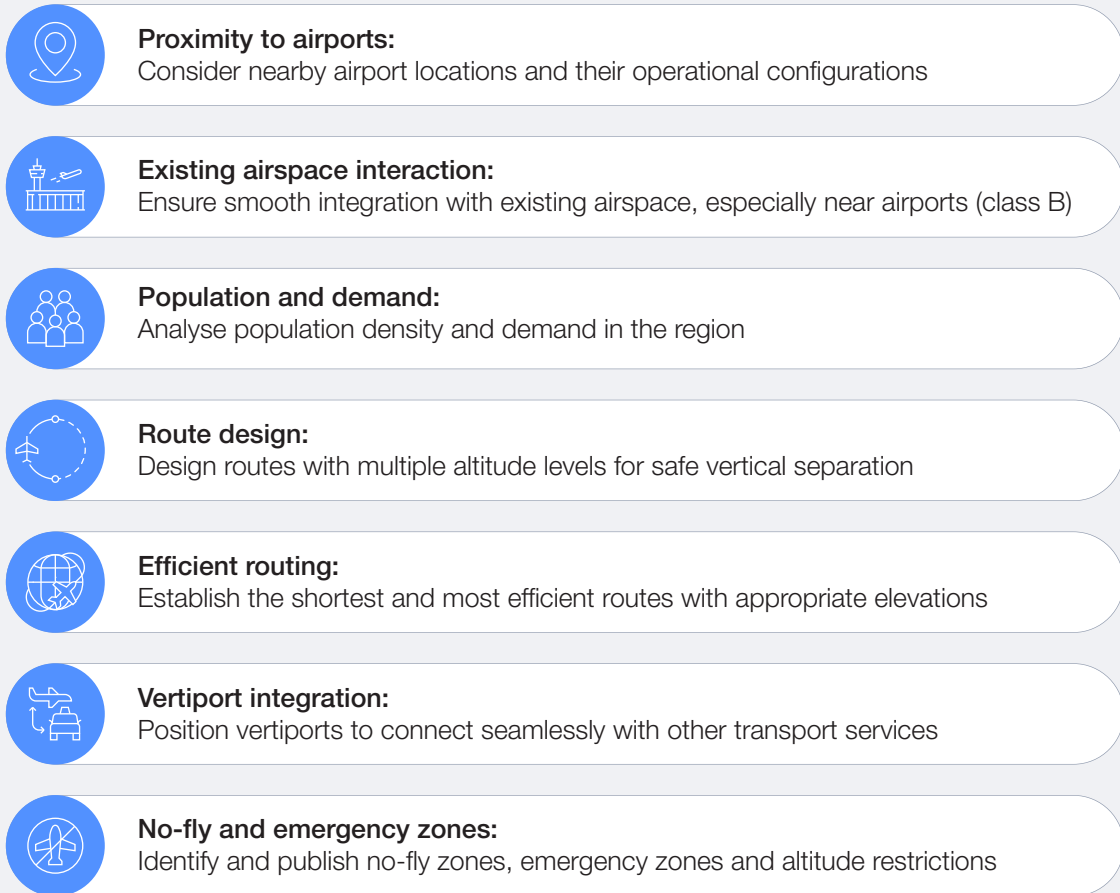
Source: The ePlane Company.

Airspace allocation for AAM in India

AAM will operate in the existing airspace classes, meaning it must coexist with traditional aviation without compromising safety. To ensure smooth integration, some key principles need to be considered. For incumbent air traffic to remain unaffected by AAM, existing frameworks and protocols, such as instrument flight rules (IFR) and VFR, which govern existing air traffic, must be adhered to. Furthermore, AAM systems must establish a pathway to autonomy to avoid overburdening ATCs. However, this will require a phased approach. To achieve this, automated flight management and collision avoidance systems must be at the forefront of AAM. Airspaces in India

are diverse, with unique characteristics based on ownership, geopolitics and terrain. Flexibility is, therefore, key from an AAM standpoint. Operational procedures for AAM should ensure adaptability in different scenarios, be it high air traffic density, varied weather conditions or other aspects. Apart from humanitarian and healthcare operations, airspace access must be equitable. A digital public infrastructure (DPI) framework ensures that all operators can access the most efficient airspace corridors and routes according to the nature and requirements of the operation. A sandbox test focused exclusively on AAM traffic can help develop a pilot project that ensures AAM operations do not conflict with traditional aircraft. This approach can inform the creation of guidelines to prevent air traffic issues and support safe integration into existing airspace.

FIGURE 8 | Factors for identifying UAM corridors: management



Important considerations for airspace management

VFR and IFR

VFR and IFR are two sets of regulations governing how aircraft are operated. VFR allows pilots to fly using visual cues from the ground and sky, requiring clear weather conditions and visibility. It is commonly used for short flights when the weather is clear to ensure the safety of operations.

On the other hand, IFR is used when visual references are inadequate for safe flying, such as in poor weather or at night. Under IFR, pilots rely on instruments to navigate and communicate with ATC to obtain guidance on the safety of flight paths and expected obstacles, following specific procedures to ensure safety in low-visibility conditions.

With AAM and this new aviation paradigm, new flight rules may be developed in different jurisdictions, and the Indian ecosystem must pay attention to these, especially in cases with a high level of autonomy.

VFR corridors

A VFR corridor is a designated airspace area where pilots flying under VFR can pass through controlled areas without needing ATC clearance. These corridors allow smaller planes to fly at lower altitudes without interfering with commercial jets. Pilots in VFR corridors must rely on their own navigation and visual observation to avoid obstacles and other aircraft in order to pass through controlled airspace safely.

These corridors are general flight paths across the different classes of airspace without a specifically defined course. They are commonly used to plan flights that enter, exit and pass through complex airspace to avoid class B airspace.

Dynamically delegated corridors

Dynamically delegated corridors (DDCs) are airspace routes that are temporarily created or adjusted in real-time to accommodate specific traffic flows, usually in response to changing air traffic demands or environmental conditions. These corridors are similar to VFR corridors but are

“ A tactical and strategic deconfliction service is essential since AAM is expected to expand air mobility into a vast, interconnected, dynamic system.

dynamically changed over short intervals based on weather, UAM density, air traffic, etc. The flexibility of DDCs helps improve efficiency and adaptability in modern ATM. Rules and procedures are also defined for coordinating traffic flows within these corridors. Authorization may be required to fly within these corridors, and the integration of unmanned aircraft system (UAS) traffic management is crucial to manage and synchronize uncrewed and crewed aircraft movements effectively.

1 Performance related operations

- Technology will be a major enabler in handling and managing traffic and providing scene awareness in a dense traffic and congested operating environment. UAM operators with the most advanced technologies will be able to fly the most efficient routes in certain situations. These routes depend on technologies like precise navigation, DAA systems, noise reduction and vehicle-to-vehicle communication.
- Some DDCs may only be open to aircraft equipped with a specified level of navigation precision, providing more direct routing options to these aircraft.
- Some DDCs are designed to accept aircraft that can provide precise arrival times. This accommodates a high volume of flights through these designated corridors, significantly enhancing operational efficiency.

2 Digital flight rules

- To accommodate safer protocols in digital flights, a different set of weather minimums for certified equipment would be required than current definitions of visual meteorological conditions used by pilots.
- VFR corridors enable VFR traffic to fly within controlled airspace (typically classes B, C and D) without requiring communications with ATC, thus providing partial autonomy during flight.
- Automation capabilities and communication and navigation systems will be crucial in successfully implementing piloted, remotely piloted and autonomous flights for AAM.

- The air traffic controller treats DDCs just as it treats VFR corridors. The air traffic controller does not provide traffic or separation service within these corridors.
- An automated traffic management service, which can be used for coordination, may also define DDCs within the boundaries of class E airspace.

3 Support services

- Information regarding traffic location, DDC status, meteorological information, obstruction locations, traffic coordination and landing site information will need to be provided and fed into the onboard systems.
- The services provided will be similar to and possibly share elements with the unmanned traffic management (UTM) system.
- A tactical and strategic deconfliction service is essential since AAM is expected to expand air mobility into a vast, interconnected, dynamic system. Strategic deconfliction refers to the planning phase, where potential conflicts between aircraft are avoided before flights even begin. This is achieved by assigning specific flight paths, altitudes and timing well in advance, often during the flight planning stage. The goal is to ensure that the overall airspace use is optimized and that aircraft will not come into conflict as they follow their routes. This proactive approach aims to minimize risks and avoid congestion over a longer period.
- Tactical deconfliction occurs in real time during flight operations. It requires air traffic controllers and pilots to make on-the-spot decisions to avoid immediate conflicts, such as when two aircraft come too close to one another. Controllers may give instructions on changing altitude, speed or direction to resolve these situations as they arise. Tactical deconfliction is a reactive process used when unforeseen events or changes in traffic require immediate intervention to maintain safe separation between aircraft.

The transition to digital aviation presents an opportunity to reimagine the safety and risk framework in aviation operations. India's aviation system is fundamentally built for the safety and security of passengers and others sharing the airspace. As airspace gets busier, digitalization and automation play a very important part in operations' management, oversight and information-sharing mechanisms. Many suggest that digitalization is necessary for managing air traffic, as human controllers may struggle to keep up with the increasing information and workload. The airspace management system must be able to coordinate both the highly automated vehicles and crewed flight operations within it. Digital aviation, therefore, will facilitate the integration of crewed aviation with uncrewed aviation.

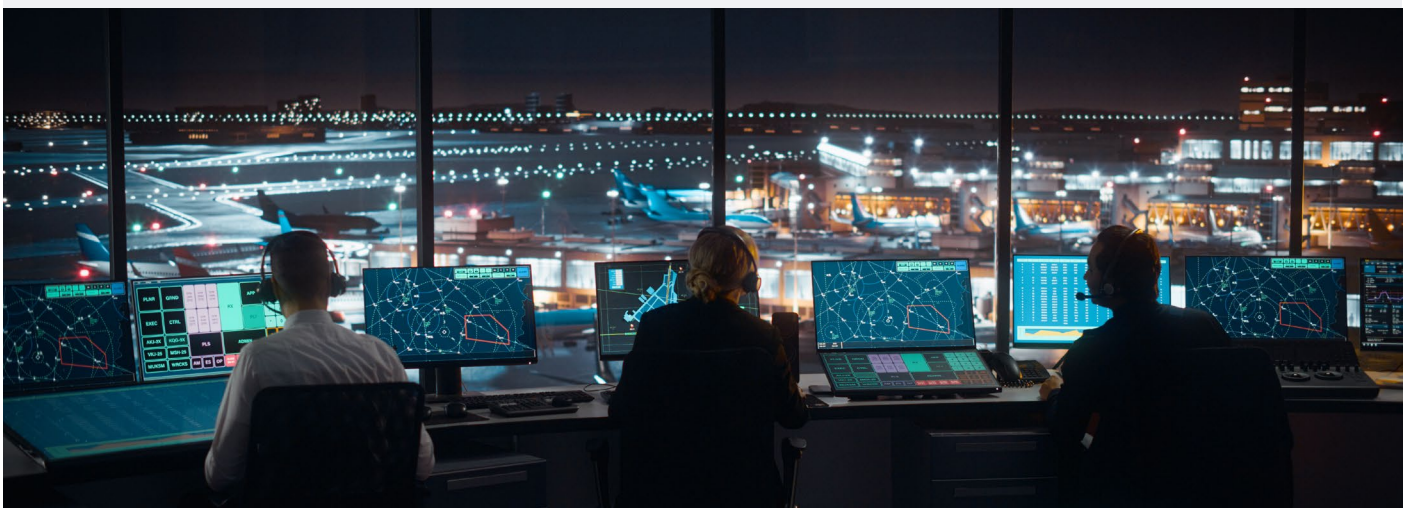
In this context, some parts of the traffic management system can be built as DPI to reap the benefits of incorporating these technologies into airspace management without compromising safety. These public infrastructure elements of airspace management are vital in monitoring and verifying traffic management systems. This is especially true in repetitive, routine transactions where private monetization is not desirable or does not make sense. Airspace management operations will always be in the public interest to some extent. DPI is normally built from open source software, and communities in the open source network (e.g. [OpenUTM](#) and [XTMAlliance](#)) have built open, standards-compatible traffic management systems. These can be used in India to build the public interest component of airspace services. Using verified open tools and technology will help cut costs, increase redundancy and boost reliability in the UAM and lower-airspace context.

Building DPI for UAM is especially crucial because it has been observed that traffic management services are important enablers of safety and trust in flight operations. To fulfil the promise of UAM, the airspace must be open and democratized to ensure maximum participation, access and equity without compromising safety. In the low-airspace economy, many operations involving small drones will pose lower risks and operate under different business models to crewed aviation. In this mixed operational environment, airspace safety must be maintained almost as a public utility that private parties share. Building upon existing open source tools safely with verification mechanisms in India will ensure that the infrastructure serves all participants in the airspace.

- The benefits of using and deploying open, verified and standards-compliant systems are numerous for airspace: They provide data sovereignty and customization options that can be tailored to the Indian context.
- They come with a community that can be harnessed and a flexible support and licensing model that can be customized for India.
- They enable other government or private participants to join the airspace and participate in a standards-compliant fashion.
- In the long term, they provide maximum flexibility and security in the context of the national airspace, which represents critical national infrastructure.

In the context of AAM, it is important to acknowledge a few crucial areas to ensure the effective and correct implementation of DPI:

- Domain expertise: Implementing open-source-based public infrastructure requires extensive knowledge of both aviation and software systems, including AAM/UTM concepts, standards and regulations.
- Technical complexity: Integration with existing aviation infrastructure can be challenging, involving potential compatibility issues and the need for seamless data flow between different ecosystem components.
- Expert support: Deployment, configuration and ongoing maintenance often necessitate specialized assistance, especially for organizations with limited IT capabilities.
- Resource demands: Customizing or developing additional modules requires careful planning, budgeting for skilled developers and allocating time for testing and integration.
- Continuous adaptation: The rapidly evolving nature of AAM and related technologies demands ongoing learning, system updates and alignment with the latest standards and best practices.



3 Evaluating economic considerations

AAM provides the advantage of lower operational costs as fossil fuel rates continue to rise.

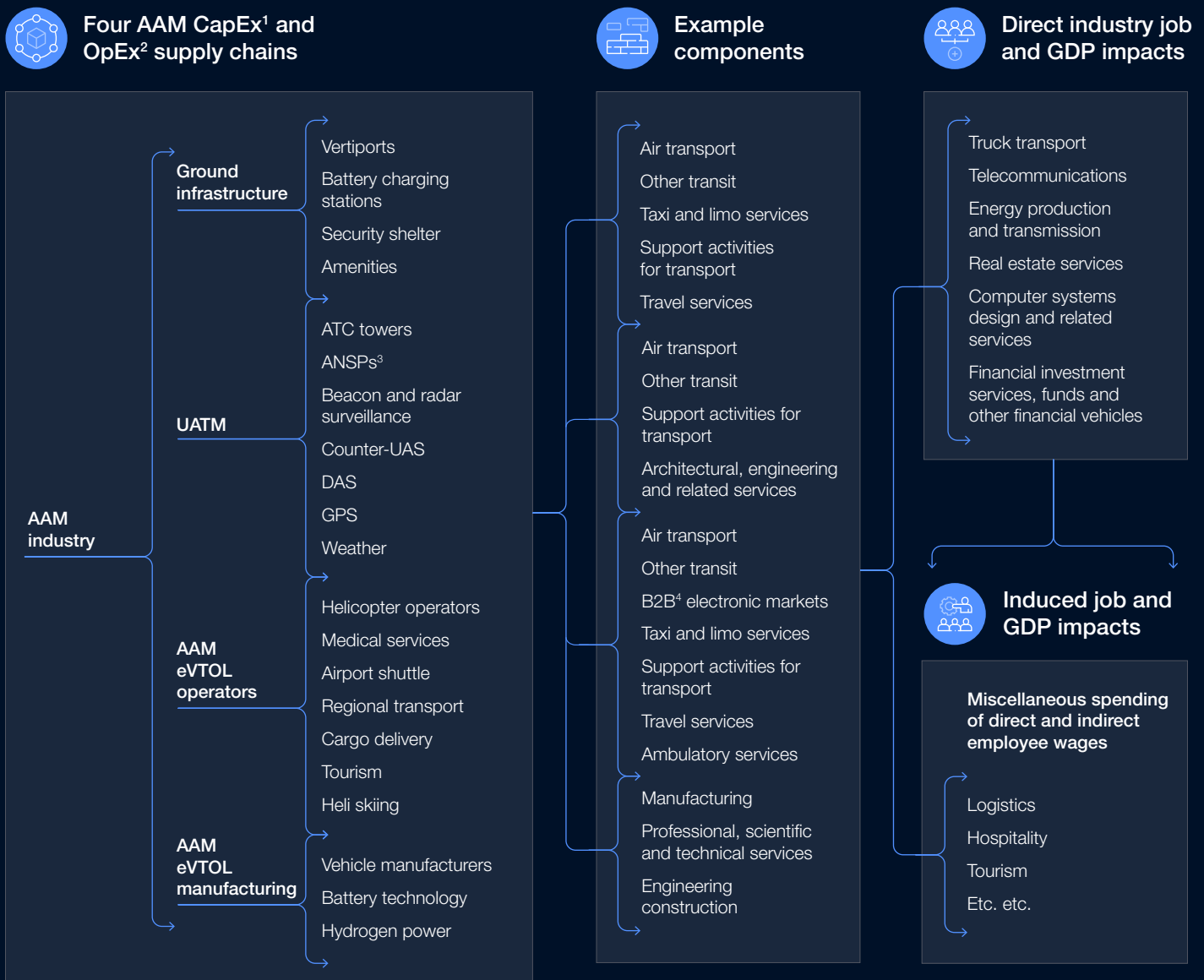


In 2022, the global market size of AAM was estimated to be \$8.93 billion. It was expected to reach \$45.12 billion by 2030 at a compound annual growth rate of 22.45%.¹³ India is making rapid strides in its goal to streamline and future-proof its transport sector. The next generation of transport in India is poised to become increasingly safe, secure, efficient and potentially autonomous. In ground mobility, India's purchasing trends around advanced driver-assistance systems (ADAS), which include partial vehicle automation, demonstrate a growing interest in advanced vehicle technologies. The India ADAS market is experiencing robust growth and is projected to reach \$7.99 billion by FY 2031 from \$1.52 billion in FY 2023.¹⁴

India is seen as a key market with the potential to shape the future of global transport and infrastructure. In the AAM sector, given the population, geography and challenges in surface transport and aspirations, India is best placed to create an ecosystem that is supportive of and adaptive to diverse geopolitical environments. Taking lessons from conventional aviation in India, it is pertinent to establish and develop the **entire value chain** (including production, operations, support and services) to reap optimum benefits from this new ecosystem.

The sector will gain much-needed momentum with incentive schemes focused on design, performance and employment, positioning India as a key player in AAM. Figure 9 highlights the potential areas of job creation and gross domestic product (GDP) growth:

FIGURE 9 Potential areas of job creation and GDP growth by AAM industry



Notes: 1. Capital expenditure; 2. Operating expenditure; 3. Air navigation service providers; 4. Business-to-business.

Source: Canadian Advanced Air Mobility Consortium (CAAM). (2020). *Economic Impacts of Advanced Air Mobility*. https://www.pnwr.org/uploads/2/3/2/9/23295822/economic_impact_assessment_-_caam_-_v1.0.pdf.

Components of the total cost of operations for AAM

The cost of operating AAM in India will be impacted by:

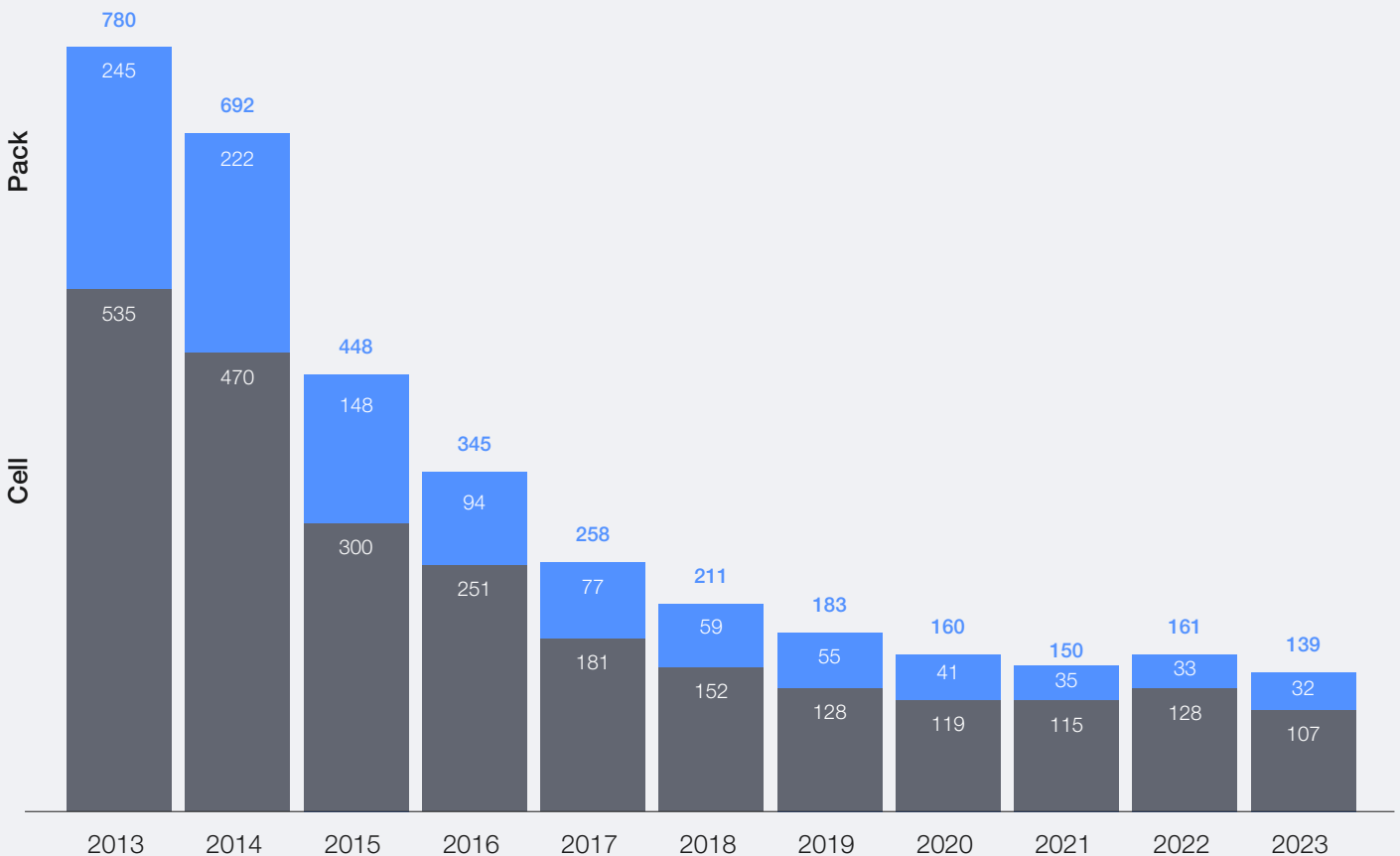
- Upfront capital cost of setting up the vertiports, accompanying infrastructures and the product cost itself
- Costs of operating the vertiports, maintenance, repair and overhauls
- Utilities and labour costs (e.g. fleet operators, pilots, etc.)

The capital costs associated with establishing AAM as a transport model in India will be significantly influenced by real estate and construction expenses, which will vary depending on the chosen city and prevailing market rates. However, substantial uncertainty remains regarding the components of product costs, necessitating a more thorough investigation.

AAM product costs will be heavily impacted by research and development (R&D) efforts, particularly in designing components that must meet stringent safety regulations while maintaining lighter and more compact structures. This will likely extend design cycles, require more expensive materials and demand stricter testing protocols. Additionally, manufacturing will necessitate specialized infrastructure, and end-of-line testing will require advanced systems to ensure safety compliance. These factors will drive up the overall product cost, underscoring the need for further in-depth analysis. Furthermore, approximately 40% of the total product cost will be attributed to the battery and its components. The product cost will also be influenced by battery lifespan and replacement cycles, with potential for repurposing batteries for other applications through recycling after their AAM life cycle ends. While battery prices are declining, the laws and costs surrounding lithium battery recycling in India are still under evaluation.

FIGURE 10 Volume-weighted average lithium-ion battery pack and cell price split, 2013-2023

Real 2023\$/kWh¹



Note: 1. Cost (in dollars) per kilowatt-hour adjusted for inflation to 2023 values.

Source: BloombergNEF. (2023). *Lithium-Ion Battery Pack Prices Hit Record Low of \$139/kWh*. <https://about.bnef.com/blog/lithium-ion-battery-pack-prices-hit-record-low-of-139-kwh/>.

“ Using second-life batteries for non-aviation applications will reduce hazardous waste, conserve resources and reduce energy storage costs.

Rising utilities costs, labour costs and other operational expenses, including the network consumption cost, will influence operational costs associated with AAM operation in India. Compared to other modes of transport, AAM provides the advantage of lower operational costs, as the fossil fuel rates will continue to rise. The labour costs, however, will add to the operational costs compared to the conventional mode of transport in India. The current shortage of commercial pilots, combined with high demand, is expected to drive salaries even higher. Currently, the average year-over-year increase in salaries of commercial pilots is around 8%, while the median salary ranges between \$12,000-28,000 (INR 1-2.4 million) annually in India.

Technical ramifications: Dealing with diverse market segments will impact the nature of service and **form factor**, among other things. Urban corridors may need agile, smaller and swifter fleets, while regional fleets may require robust vehicles capable of handling longer commutes and heavier loads. This fleet diversification will require investment in research, manufacturing and operational infrastructure.

- **Energy and charging infrastructure:** Urban eVTOL services will demand high-speed charging facilities to support frequent flights. These hubs should be located near business districts or other key urban areas. It may be important to consider a “bus-stop” approach, where all vertiports or pads do not necessarily have to be electrified. For regional AAM flights, longer-range and lower-frequency flights might demand different battery solutions, such as larger capacity but slower charging systems. Additionally, alternative energy sources (e.g. solar power) could be necessary to support eVTOL operations in areas lacking grid infrastructure.
- **Operational costs:** Operating in urban and rural areas will lead to variant cost structures. Urban areas with higher demand can better support premium pricing and dynamic models, but regional corridors will initially require subsidies to offset operational costs. These subsidies will ensure that rural services are economically viable while maintaining affordable consumer prices.
- **ATM and safety:** ATM systems in urban areas will be more sophisticated, given the presence of high-traffic airports, densely populated areas and helicopter and other aviation activity. Congestion and safety management will need higher levels of scrutiny and, therefore, staffing. Relational communication and navigation are crucial for regional transit, especially in areas with less-developed infrastructure than urban areas. These ATM systems will need to be interoperable and agile to suit the unique needs of each environment.

- **Maintenance and support networks:** Maintenance facilities and technical support will need to be built to ensure the reliability of AAM services. If these are strategically housed in regional hubs, operational costs for services, spare parts, repair technicians and backup power systems may be optimized.

According to aerospace analysts, the price per kilowatt-hour (kWh) for batteries is two to three times the current cost of automotive batteries.¹⁵

The higher quality of batteries used in aerospace allows these batteries to have a significant application in their second life across a variety of applications. Some are mentioned below:

Applications

1. Renewable energy systems
2. Energy storage for data centres and telecommunications towers
3. Electric vehicle (EV) charging infrastructure
4. Grid services (frequency regulation, peak shaving)
5. Backup power for critical infrastructure

Using second-life batteries for non-aviation applications will reduce hazardous waste, conserve resources and reduce energy storage costs.

These factors for product and infrastructure costs will determine the business case justification for the economic considerations for eVTOLs.

A report by the Institute for Social and Economic Change (ISEC) estimated that traffic congestion in Bangalore, India, caused around INR 11.7 billion in lost productivity in 2018, with approximately 700,000 hours wasted due to traffic jams.¹⁶

AAM is expected to reduce traffic congestion on Indian roads and provide significant benefits, such as saving lives through air ambulances. This makes a strong case for its use and highlights its potential return on investment (ROI) in contributing to the nation’s growth and GDP.

Pricing

As the sector takes shape, original equipment manufacturers (OEMs) and service providers are expected to begin developing pricing strategies to cater to their target markets. While doing so, it is important to keep in mind the buyer persona to cater to a pan-Indian audience. Early indications are that consumers may be willing to pay up to twice as much for a new mode of transport compared to what they currently spend on their existing

options. Currently, the commuter is willing to pay a significant premium for the time saved by air travel compared to traditional ground transport.

If potential eVTOL users are willing to pay INR 1,500 for a 20-kilometre trip and INR 2,000-3,000 for longer distances, such as 30-kilometre airport trips, other factors will influence the ideal pricing.

It is important to understand where the value of this technology lies both in urban and rural settings in India, as well as the different mechanisms that can be used to price AAM services.

- **Urban market willingness to pay:** Early adopters are perceived as significantly more willing to pay due to time savings, so a value-based pricing strategy may work for this segment. This tier includes personalized or VIP services, including private or semi-private flights with on-demand scheduling.
- **Regional market willingness to pay:** The purpose of introducing ASHA in regional India is to ensure that rural citizens have greater access to economic clusters, jobs and primary services such as healthcare. To ensure cost-consciousness, services can be subsidized through government schemes, such as the UDAN scheme, to incentivize fares and make them accessible to rural customers. This tier could focus on scheduled, shared air taxi services.
- **Dynamic pricing strategies:** Most suburbs in urban India have catchments that house mid-income groups who use public transport extensively. In urban areas, dynamic pricing models, similar to ride-hailing apps, could be applied with the additional location reference point. Peak times and popular routes could influence higher prices, while off-peak travel and less-frequented route prices could be lowered

to ensure wider coverage of citizens from all income groups.

- **Subscription (flexi-pass) models:** A membership model could be an effective pricing strategy for urban users, particularly those travelling to business districts or neighbourhoods. This could include subsidized rides for a fixed monthly or yearly fee, targeting regular users travelling daily.
- **Partnership with local authorities:** Pricing strategies can be built around partnerships with local governments and businesses in rural areas. For instance, reduced fares can be offered for essential services, such as medical transport and agricultural logistics. Bulk pricing for businesses that require mass cargo transit between rural and urban areas could also be considered.

Subsidized models through public schemes: The pricing strategy should include value gap funding to support rural connectivity, similar to the current UDAN scheme for air travel. This allows the service to penetrate deeper into rural areas, supplementing existing transport with reduced fares or government-subsidized services. These subsidies can encourage the adoption of ASHA vehicles while ensuring profitability for operators.

Government-backed initiatives (such as UDAN) that currently focus on affordable regional air travel could be expanded to support AAM deployment in regional India as well as suburban and arterial corridors in urban India. This would promote greater connectivity and stimulate economic activities, particularly in sectors like tourism and agriculture, where improved mobility can open new markets. In this context, AAM could serve as a catalyst for rural revitalization, bringing its benefits to underserved and geographically isolated regions.



4

Cultivating community acceptance and integration

To encourage acceptance of AAM integration, challenges related to noise, safety, accessibility and environmental impact must be addressed.



“ Infrastructure should be designed to streamline processes like check-in and check-out, ensuring that short flights have minimal wait times.

Community acceptance is critical for successfully implementing any new public service and is crucial for AAM implementation. Introducing new transport and connectivity solutions requires trust from both the service providers and the public, as well as active collaboration. Community buy-in also helps overcome the initial hurdles of technology adoption, and the feedback loop helps refine the service faster, thereby reducing the time to achieve ROI.

Community acceptance and integration of AAM will require addressing some key challenges:

- **Noise and environmental concerns:** Noise pollution is a major issue for communities near potential vertiport locations, especially with the high frequency of take-offs and landings. Noise can be minimized using **quieter propulsion technologies**, such as reducing rotor speeds and setting **noise emission limits** for AAM vehicles during the product certification phase. Additional measures might include curfews, upper limits on noise levels and surcharges for breaching permitted noise levels. Furthermore, establishing flight paths that avoid residential areas will help reduce the overall noise impact on communities, contributing to a more harmonious integration of AAM into urban environments.
- **Safety assurance:** A robust safety and regulatory framework is essential to building public trust. The Directorate General of Civil Aviation (DGCA) should lead comprehensive safety regulations with clear oversight and enforcement mechanisms. These regulations will ensure high safety standards and reduce the risk of incidents. Integrating advanced ATM systems for real-time monitoring is crucial to maintaining safe and seamless AAM operations.
- **Public awareness:** Effective public outreach is key to addressing concerns and building trust in AAM. Engaging **local ambassadors** can play

a pivotal role in promoting the benefits of AAM by connecting with communities and enabling early adopters to lead by example, helping to ease initial apprehensions. Involving AAM in **urban planning from the early stages** and including local communities in decision-making encourages collaboration and ensures access to AAM services across all socioeconomic groups. Additionally, incorporating **subsidy programmes** into fare structures can further promote inclusivity.

- **Equity considerations:** Bridging the digital divide is essential to ensure equitable access to AAM services, which may heavily rely on digital platforms. To achieve this, public access points for booking AAM services should be established, along with **user-friendly interfaces** with **multilingual support** to cater to diverse populations. Adoption can be encouraged through schemes similar to the UDAN initiative, with fare caps to make services affordable and accessible to all. Additionally, infrastructure should be designed to streamline processes like check-in and check-out, ensuring that **short flights, such as 15-minute journeys, have minimal wait times** and avoiding inefficient procedures like longer check-ins.
- **Accessibility in remote areas:** AAM has the potential to significantly enhance connectivity in remote regions where traditional transport infrastructure is limited. Ensuring **rural inclusivity** is crucial for broader acceptance, as it guarantees that all communities benefit from this technology, reducing initial apprehension and accelerating adoption. To achieve this, it is important to explore the **feasibility of developing vertiports** in strategic locations that connect remote areas, allowing AAM to bridge gaps in access to essential services like medical care. Integrating AAM into existing transport networks will also streamline long-distance travel between rural and urban areas.



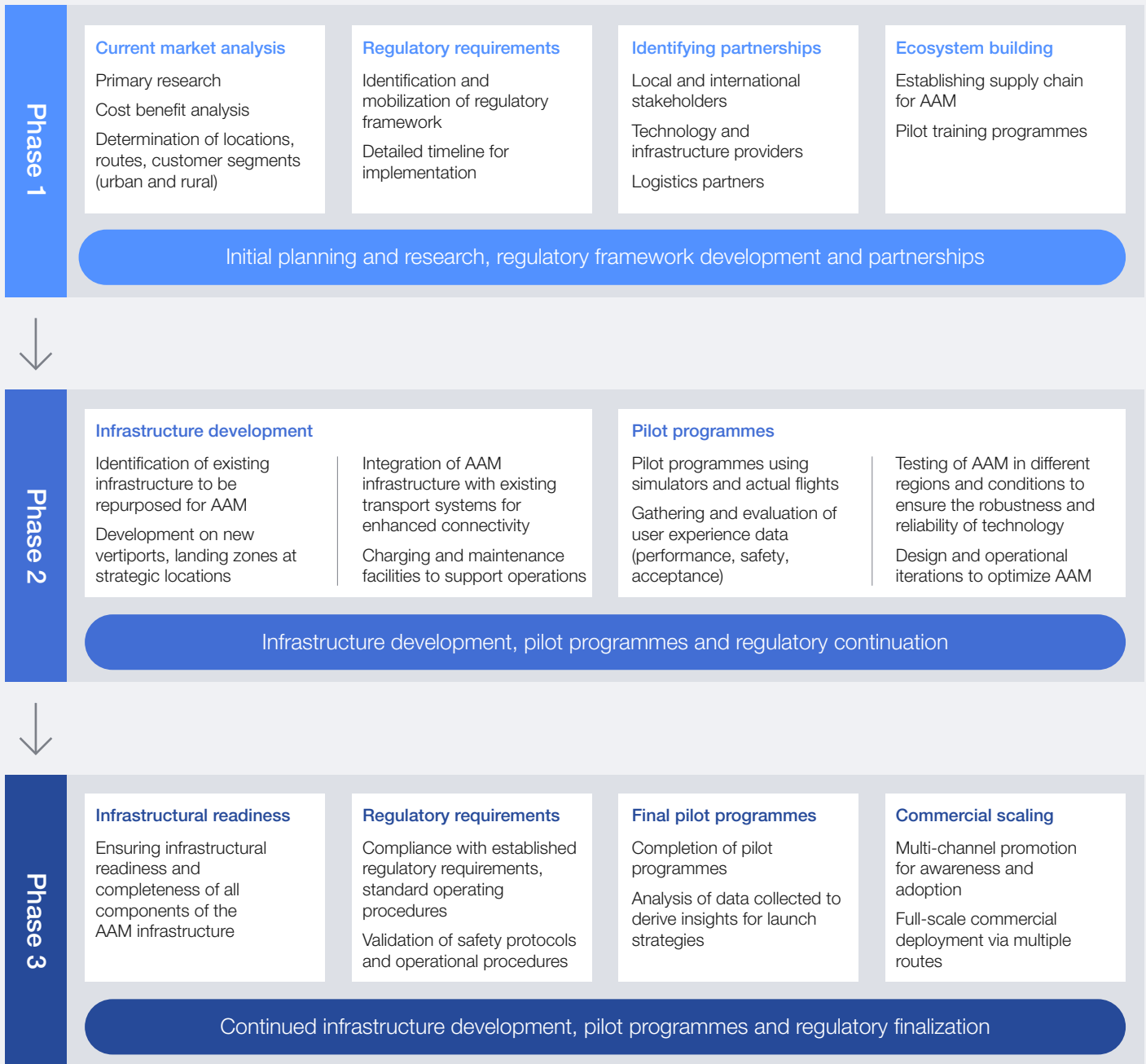
5 Implementing an AAM programme

A three-phased approach, emphasizing initial planning and devising regulatory frameworks, developing infrastructure and pilot programmes, and sandbox environments.



The following phases can guide local authorities (municipalities, collectorates) through the key steps of implementing an AAM programme:

FIGURE 11 Guided three-phased approach for implementing an AAM programme in a district



1. The three-phased approach to implementing an AAM programme ensures market analysis through primary research and cost-benefit analysis. It also determines programme locations and ecosystem building by identifying regulatory frameworks and partnerships.
2. The second phase involves developing infrastructure (repurposing old and developing new vertiports), with simulated and actual pilot programmes to test and iteratively improve the design and operations.
3. The third phase ensures the infrastructure is ready, considering and applying learnings from previous phases. The regulatory requirements are clearly defined and met to ensure compliance with safety protocols. Pilot programmes, data analysis and insights pave the way for a commercial launch with subsequent scaling over the next few years.

Key stakeholders for AAM implementation

Successful AAM integration requires collaboration between various stakeholders:

- Government agencies: DGCA, Ministry of Civil Aviation, urban development authorities
- State developmental authorities and planning agencies
- Municipalities and collectorates: responsible for local planning and infrastructure development
- AAM operators: airlines, drone service providers, vertiport operators
- Urban planning authorities: integrate AAM into urban planning initiatives

- Community groups: residents' associations and local non-governmental organizations
- Research institutions: provide expertise in technology, safety and economic analysis

Setting up a sandbox environment

Importance of a sandbox environment

A sandbox environment is crucial in developing, testing and implementing AAM in India. It provides a controlled setting where new technologies, operational procedures and regulatory frameworks can be explored without the risks associated with full-scale deployment. Sandboxes allow for the evaluation of UAM vehicles and infrastructure and integration with existing ATM and UTM systems.

TABLE 3 Potential benefits and lessons from a sandbox approach

Key benefits of a sandbox approach	Lessons from sandbox testing
<ul style="list-style-type: none"> – Risk mitigation: Allows for controlled testing of AAM systems, reducing the potential for operational and safety risks (ground and air) in a real-world environment – Validation of technology and procedures: Facilitates the validation of emerging technologies, communication protocols and safety procedures under realistic but safe conditions – Regulatory insights: Provides valuable feedback to regulatory bodies like the DGCA and the Airports Authority of India (AAI) on the operational and safety standards required for AAM – Stakeholder collaboration: Promotes coordinated efforts among government agencies, technology providers and industry stakeholders to address operational challenges and refine solutions – Community engagement and acceptance: Offers an opportunity to engage with the public and gather feedback, thus encouraging greater community acceptance of AAM initiatives 	<p>Testing within a sandbox environment could yield critical lessons that inform the broader implementation of AAM:</p> <ul style="list-style-type: none"> – Operational safety protocols: Develop and refine emergency procedures, such as sterile heights and safety lanes, based on real-world scenarios encountered during testing – Traffic management and airspace integration: Learn to seamlessly integrate UAM vehicles into existing ATC structures, including coordination with military and civil aviation authorities – Technology readiness levels: Evaluate the readiness of UAM and other CNS (communication, navigation and surveillance) systems, including low-altitude radars and sensors, under operational conditions – Performance metrics: Measure the capabilities and limitations of UAM platforms, informing decisions about operational corridors, airspeed, altitude restrictions and communication requirements



“ As operations increase, the pilot’s role will evolve from being on the aircraft to being remote, with command transitioning from onboard to remote operations.

A sandbox environment can be established to test AAM technologies and operational procedures in a controlled setting. This could involve:

- Using designated airspace for AAM pilot programmes
- Setting up a limited network of vertiports for initial operations
- Partnering with research institutions and AAM operators for testing and data collection
- Gathering evidence and making a commercial decision

Data collected during the sandbox phase will inform commercial decisions regarding AAM implementation. Key metrics to consider include:

- Public acceptance and user satisfaction
- Operational efficiency and safety record
- Economic viability and cost-recovery potential
- Training and skill development

AAM integration will require a skilled workforce for various roles, including:

- AAM vehicle pilots and air traffic controllers
- Vertiport operations
- Maintenance personnel
- Regulatory and safety specialists
- Urban planners specializing in AAM integration

Training and skill development

Training and skill development are crucial in ensuring that the ecosystem is ready for implementation of the AAM programme. The following steps highlight the basic enablers for a safe and seamless AAM implementation.

1 Multi-agency coordination

- Effective management of emergencies in AAM requires coordinated training programmes for aircrew, ground crew and emergency responders.
- Developing comprehensive, multi-agency training programmes that include technical training for operators and sensitization programmes for city and emergency response personnel is critical to improving multi-agency coordination, which is required for AAM to function seamlessly.

- Establishing training sessions for firefighting teams, emphasizing the use of appropriate equipment for specific scenarios, such as electrical fires, much like how the New York City Fire Department trains for high-rise building fires

2 Integrated response teams

- Rapid and effective emergency response requires well-coordinated teams and clear protocols.
- Creation of integrated response teams that include personnel from various agencies, equipped with standardized response protocols tailored to AAM emergencies.
- Example: In Singapore, integrated response teams composed of police, fire and medical personnel are trained to handle unmanned aerial vehicle (UAV) incidents, which can serve as a model for AAM.

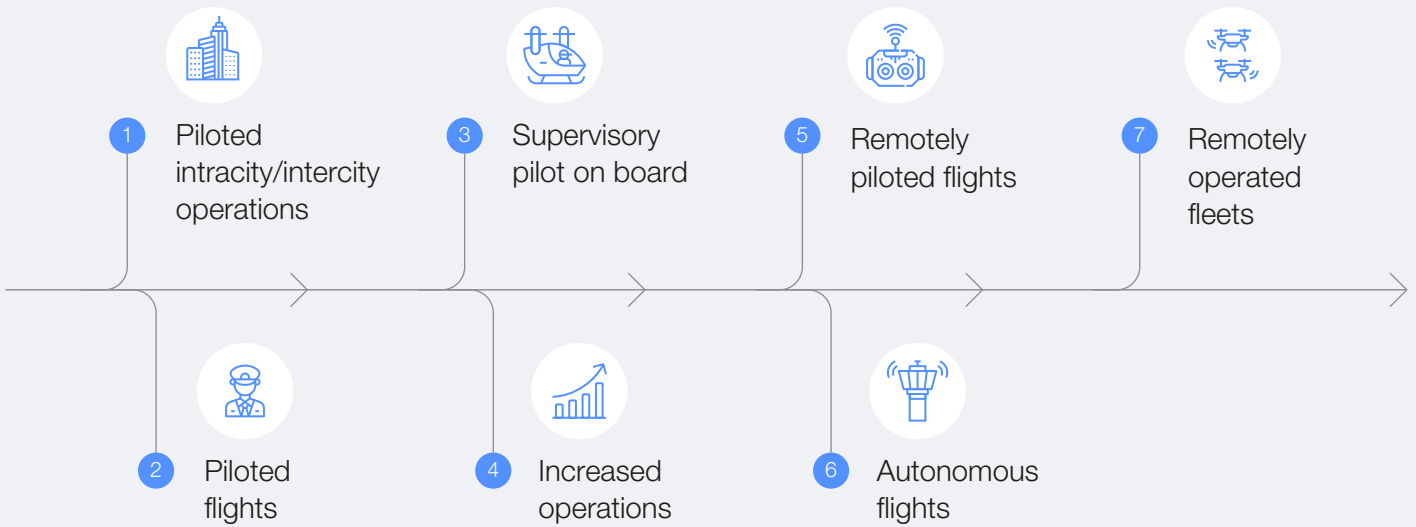
3 Emergency protocols

- Specific protocols should be developed for low- and ultra-low-level flight incidents.
- Establish and regularly update emergency protocols that address the unique challenges of AAM, including potential mid-air collisions and emergency landings.
- Example: The UK’s Civil Aviation Authority has developed UAV-specific emergency protocols that can be adapted to AAM operations.

The pathway to automation

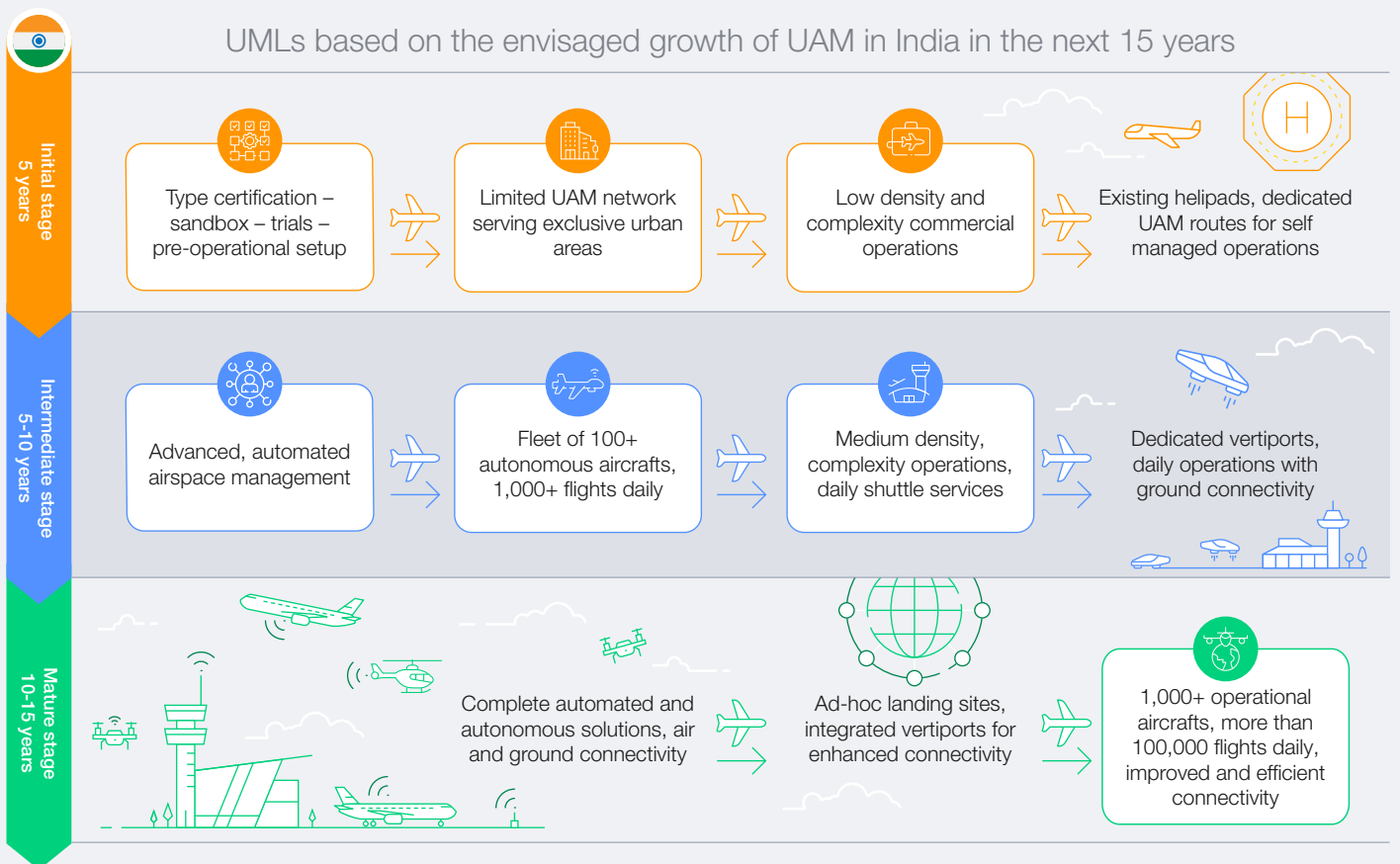
- All AAM equipment must be airworthy. Standardization ensures greater consumer confidence. India must undertake a comprehensive standardization process for all elements of the AAM ecosystem, starting with hardware. Developing a clear communication procedure in its certification process to align with European Union Aviation Safety Agency (EASA)/FAA standards will help optimize testing and reduce time to market.
- The growing number of flights in AAM systems is increasing their complexity and operational demands. As AAM systems evolve, this requires changes in airspace procedures, the development of new regulations and collaborative practices.
- As operations increase, the pilot’s role will evolve from being on the aircraft to being remote, with command transitioning from onboard to remote operations.
- The pilot’s role will also evolve as vehicles progress from lower to higher levels of automation, from human-in-the-loop (HITL) to human-on-the-loop (HOTL) to human-over-the-loop (HOVTL).

FIGURE 12 | AAM roadmap for evolution



To scale this over 15 years, NASA's UAM maturity levels (UMLs) framework¹⁷ could be adopted. The UMLs could then be modified based on the envisaged growth seen in India, with a greater focus on scaling operations and the ecosystem surrounding the aircraft.

FIGURE 13 | Envisaged UAM maturity levels for AAM



Source: Deloitte insights

Global examples

United States

In the US, more than 12 companies are actively engaged in developing AAM technology and manufacturing. FAA is currently drafting policies and certification guidelines for AAM to facilitate its safe and efficient integration into the national airspace. Commercialization of AAM in the US is expected to be achieved by the end of 2024.

Europe

Over 10 companies are involved in AAM technology and manufacturing, with the Netherlands emerging as the fastest-growing market in the region. The EASA is preparing to adopt final regulations for AAM operations. Similar to the US, Europe is also expected to see the commercialization of AAM by the end of 2024.

Japan

More than five companies are actively pursuing opportunities in the AAM sector. The country is working on a comprehensive roadmap for UAM adoption, which will finalize the operating environment and regulatory framework, aiming for

a commercial launch by 2025. Japan's roadmap for eVTOL incorporation outlines flight areas, operational methods and vertiport use, offering a template that could serve as a model for India's roadmap over the next 15 years.

South Korea

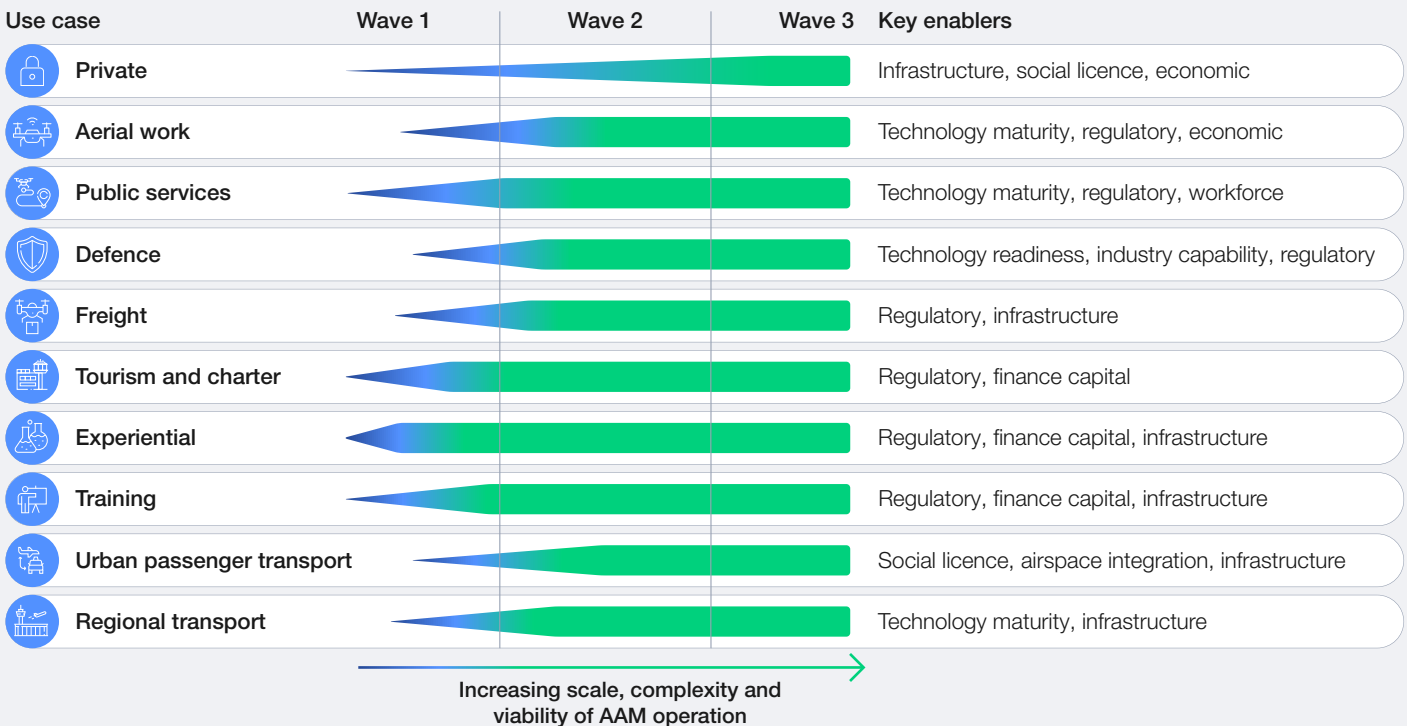
Earlier this year, South Korea commissioned an association for AAM, partnering with 67 organizations. The purpose is to deliver an entity that can develop universally acceptable standards for AAM vehicles. The entity aims to cross-pollinate key emerging areas such as AI, mobile communication and data with a focus on reliability and sustainability.¹⁸ Recently, the Incheon region issued a CONOPS for AAM.

Australia

In Australia, roadmaps have been developed for AAM based on concepts of use that are expected to work. These concepts of use are built on a framework consisting of a series of overlapping waves. Different regions and use cases will adopt these concepts at varying rates, influenced by key enablers outlined in Figure 14. Additionally, the progress of these waves depends on AAM demonstrations during major events, such as the Olympics.

FIGURE 14 Australia's AAM roadmap and the associated waves and enablers

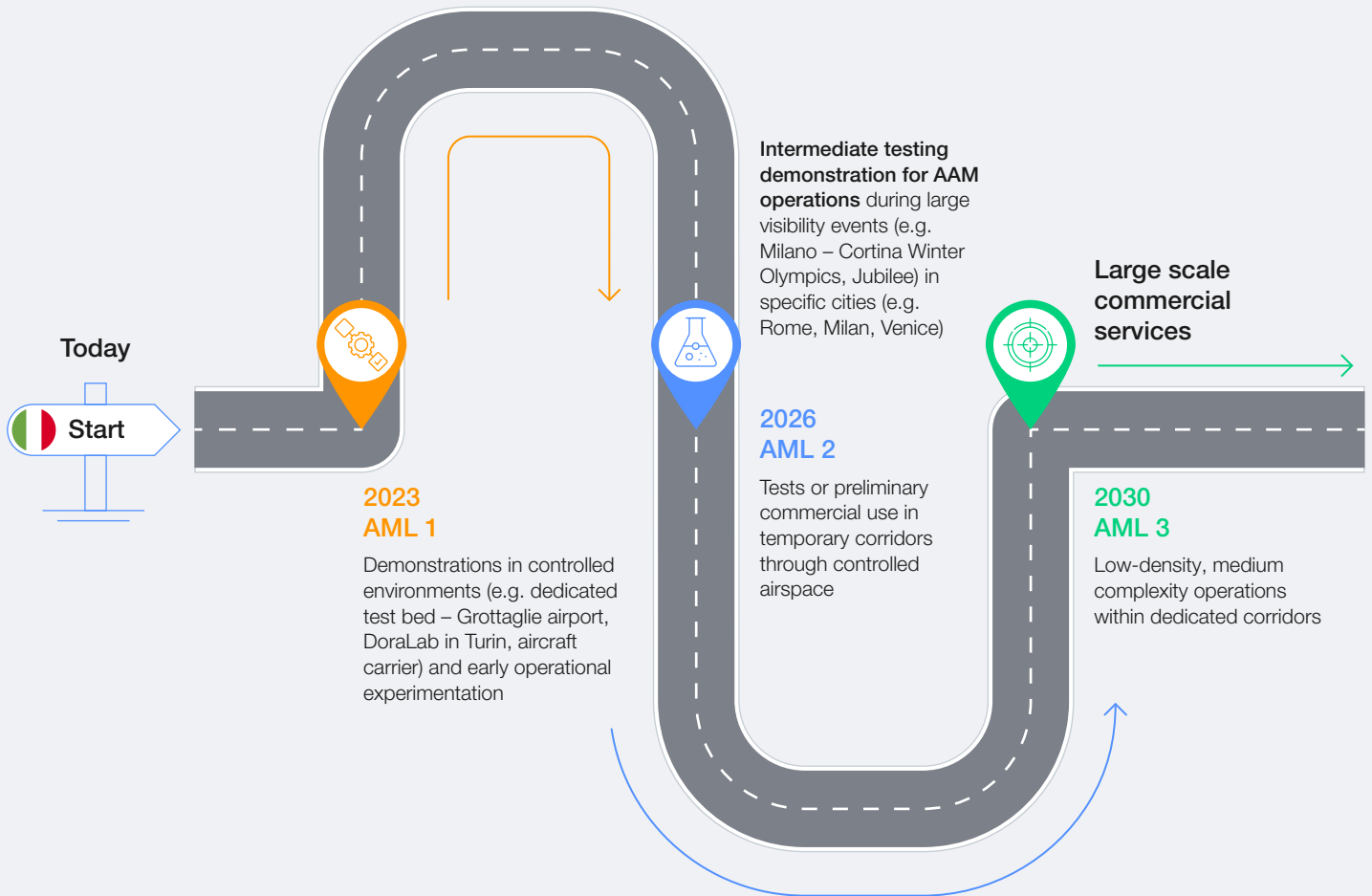
Likely entry into service



Source: Australian Association for Uncrewed Systems (AAUS). (2024). AAUS Release Vision Roadmap for AAM. <https://www.aaus.org.au/news-item/15577/aaus-release-vision-roadmap-for-aam>.

Italy's roadmap describes three AAM maturity levels (AMLs): AML 1 will see demonstrations in controlled environments, AML 2 will use controlled airspace for preliminary commercial use tests, and AML 3 (which Italy aims to reach by 2030) will see low-density, medium-complexity operations and large-scale commercial services in subsequent years.

FIGURE 15 Italy's AAM roadmap



Source: Italian Civil Aviation Authority (ENAC). (2021). *Roadmap AAM (2021-2030)*. https://www.enac.gov.it/sites/default/files/allegati/2021-Set/02_AAM%20Italian%20Ecosystem%20%E2%80%93%20Project%20overview%20and%20Roadmap_web.pdf.

Conclusion

The AAM ecosystem presents a wide range of transformative benefits for the future of transport, contributing to more efficient, sustainable and adaptable solutions. One of its most significant advantages is the potential for time efficiency and speed, offering faster point-to-point travel by avoiding ground-level congestion and taking direct routes. This can alleviate traffic on roads, improving the flow of goods and people while reducing strain on existing infrastructure.

AAM vehicles produce fewer emissions than traditional aircraft, reducing air pollution and greenhouse gas emissions. This supports global efforts to minimize the aviation sector's environmental impact, significantly contributing to carbon emissions. AAM can reduce emissions through electric propulsion systems and quieter vehicles, addressing concerns around noise pollution and enhancing community acceptance. Moreover, AAM offers flexibility and adaptability for passenger transport, cargo delivery and emergency services.

The versatility of AAM vehicles, combined with advanced safety systems and autonomous capabilities, enhances safety standards and reduces the risk of accidents. This flexibility extends to areas where the applications are most suited, such as disaster response, rapid delivery of medical supplies, air ambulances and humanitarian aid while supporting search and rescue operations. AAM will bolster India's existing disaster management resources, thereby providing relief to those in critical need.

AAM also reduces the need for extensive ground-level infrastructure. By optimizing land use, cities can develop more efficiently without the costs associated with expanding traditional transport infrastructure. Additionally, AAM improves connectivity in remote and underserved areas where surface infrastructure development is either

costly or impractical. This increased connectivity stimulates regional economic growth, social inclusion and logistical efficiency.

The AAM industry is also expected to stimulate economic growth and job creation through vehicle manufacturing, infrastructure development and new service creation. Technological advancements in electric propulsion, autonomous systems and ATM will drive innovation across related sectors.

AAM can integrate seamlessly with existing transport modes to provide multimodal options for passengers and cargo. It can reduce travel times between regions, cultivating stronger global economic ties. On a regional level, AAM can significantly enhance connectivity, offering economic, social and logistical benefits that contribute to broader development goals.

AAM can provide solutions to densely populated and rapidly urbanizing areas in India, such as Mumbai, Bengaluru, Kolkata and Delhi, where traffic congestion is causing severe economic losses. Bengaluru alone lost almost INR 200 billion in 2023 due to congestion, hampering productivity and worsening pollution. While traditional infrastructure development can only partially address these issues, AAM could capitalize on airspace for medium- and short-distance travel.

AAM holds the potential to revolutionize transport, providing a diverse range of benefits that extend beyond individual convenience, including environmental sustainability, economic development and societal well-being. It reimagines the movement of people and goods, offering solutions for urban congestion, regional connectivity and global transport efficiency. As countries like India face growing urbanization, AAM presents a viable, forward-thinking alternative for immediate and long-term needs.

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