McKinsey & Company

Perspectives on advanced air mobility

Navigating the emerging passenger urban and regional air-mobility industry

Summer 2022

Perspectives on advanced air mobility is written by experts and practitioners in McKinsey's Global Aerospace & Defense Practice along with other McKinsey colleagues.

Cover image:
© LuFeeTheBear/Getty Images

Editorial Board:
Robin Riedel, Ilan Rozenkopf

External Relations, Global Advanced Industries Practice:
Taylor Burns

Editor: Eileen Hannigan

Practice Contacts:
Linda Dommes, Nadine Grießmann

Art Direction and Design:
Leff Communications

Contents

Introduction

Although “flying taxis” are not yet part of our daily lives, the technology is advancing, regulators are developing certification pathways, and the public is intrigued. Airlines, airports, and aerospace companies are incorporating new types of passenger transport into their plans. Meanwhile, automotive OEMs and others in the broader mobility ecosystem are carefully following developments related to electric vertical takeoff and landing (eVTOL) aircraft, knowing that they could provide a new sustainable option for passenger transport at the urban and regional level.

Investors sense the momentum behind passenger advanced air mobility and are directing more funding to the sector—$4.8 billion in 2021 and $1.2 billion in the first months of 2022 alone. In our lifetimes, we will likely see this new form of air transport emerge. Many companies hope to receive regulatory certification for their eVTOLs by the middle of the decade. A future trip from San Francisco to Lake Tahoe could take under an hour by eVTOL, compared with almost four hours by car. Going from Zurich to St. Moritz would take about 30 minutes by air, compared with two-and-a-half hours by car.

This issue of *Perspectives on advanced air mobility* consolidates some of our most interesting research from the past few years, focusing on the core challenges and opportunities in this emerging industry. While many hurdles remain for passenger advanced air mobility, entrepreneurs, incumbents, and other industry stakeholders are prepared to tackle them. Supplementing our research, this compendium also includes interviews with leaders of three companies specializing in air-mobility concepts: Joby, Lilium, and Volocopter. These frontline accounts will provide an insider perspective on the industry.

We hope that these articles will provide insightful views on advanced air mobility, including the opportunities and challenges ahead. Questions and comments, especially those that encourage dialogue, are welcome.

Robin Riedel
Partner and global co-leader of McKinsey’s Disruptive Aerospace sector
San Francisco

Ilan Rozenkopf
Partner and global co-leader of McKinsey’s Disruptive Aerospace sector
Paris

Taxiing for takeoff: The flying cab in your future

How big is the potential market for personal air mobility, and what will it take to develop it successfully?

by Robin Riedel and Shivika Sahdev

Originally published January 8, 2019

Could your next commute involve a “flying taxi”? Even today, in major cities such as Hong Kong and New York, a fortunate few escape the gridlock and congestion on the ground altogether by taking helicopters to and from work. Each day in São Paulo, for example, hundreds of people trade a four-hour commute on the ground for a ten-minute helicopter ride costing anywhere from $500 to $1,500. While expensive for everyday commuters, the dream of rising above the ever-increasing road-traffic congestion, coupled with the promise of new technological advances, explains why the idea has recently gained significant momentum. In fact, the media buzz surrounding the topic has grown more than tenfold in the past 18 months, as measured by mentions of personal air mobility and similar terms.

What if the cost of flying over congested traffic were to fall to $150 or less? The flying taxi of the future—enabled by vertical takeoff and landing (VTOL), electric propulsion, and advanced flight control capabilities—could achieve these lower prices. This flying taxi will be energy efficient, quiet, nonpolluting, and eventually pilotless. Investments in technologies such as batteries, autonomous systems, and vehicle platforms have already exceeded an estimated $1 billion in less than three years. New players are entering the arena, challenging more established companies and potentially disrupting the aerospace and automotive status quo.

Big or really big market?

The concept of flying “cars” has captured the imaginations of people in already-involved industries, like aerospace, and others, such as automotive OEMs, start-up players, and venture capitalists. However, uncertainties remain as to how large (and profitable) the market will ultimately become, and—even more important—what business models will make the markets work and where value pools will be. At a minimum, it seems reasonable that niche markets will spring up around the world, driven by local champions using mostly existing infrastructure and current regulatory frameworks, targeting passengers who value their time but cannot quite afford a full helicopter charter. In some cities, entrepreneurs are already experimenting with “app based” helicopter business models that make urban flying more accessible. Even if nothing else changes, existing technology, as a lower-cost alternative to traditional rotorcraft, will make those business models even more viable.

Exhibit 1 provides a conservative estimate of the “base case” flying taxi market, revealing a pathway to an operator market of approximately $1.5 billion by 2040.[1] In this scenario, personal air mobility remains a luxury option and does not achieve scale. Vehicles remain expensive (somewhere between $750,000 and $1.5 million each), with an operating cost that improves somewhat versus today’s helicopters (about $3 per seat-mile compared with roughly $4 to $6 per seat-mile for traditional helicopters), and operators use mostly existing infrastructure. That said, a consumer price point per mile of anywhere near direct operating cost will still require significant business-model innovation. Even the smallest helicopter today commands more like $30 to $50 per passenger-mile in the charter market to offset the costs of empty legs, less than full occupancy on many flights, and overhead, as well as to ensure the operator has some profit.

But assuming a price point similar to black-car pricing, the market could support approximately 1,000 vehicles per year. That’s big, but not really big. Yet there is precedent in the disruptive mobility space of starting at the high end and moving down to the mass market over time. Electric vehicles and GPS navigation come to mind in this respect. There is no question that the potential market of people who want to move through cities more quickly is next to unlimited. The real question is, what will it take to unlock that potential?

Unlocking a $500 billion-plus market

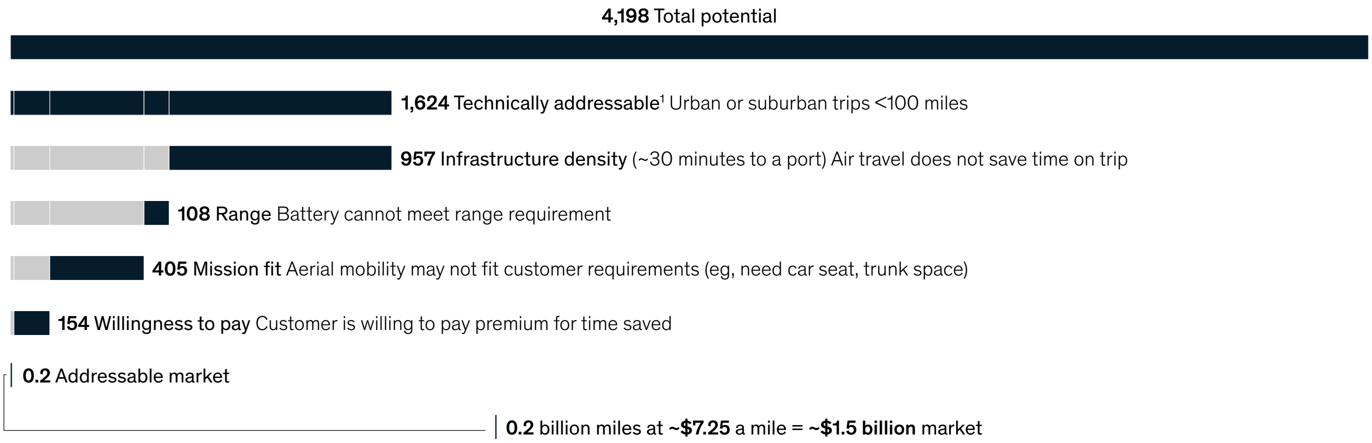
Counter to the base-case estimate above, imagine an ecosystem of players including OEMs, suppliers, maintenance and charging companies, infrastructure players, investors, regulators, and policy makers

[1] All values are in 2018 real dollars.

Exhibit 1

The ‘flying taxi’ operator market could reach approximately $1.5 billion by 2040.

Base case for personal air-vehicle market, billions of miles



[1]Excludes current air travel or rural-to-rural travel.

coming together and overcoming key challenges related to technology, regulation, cost, and customer acceptance to achieve higher adoption rates. In this scenario, the worldwide market could grow to $500 billion to $600 billion annually.

To grow the flying taxi market to this size will require radical changes, such as automotive-scale manufacturing, pilotless flying, a total rethink of air traffic control, cost-effective physical and charging infrastructure, and high vehicle-utilization levels. A rationale exists for achieving this scale, but it will require several enablers to become reality, which is no simple task and could take a long time.

Fully electric propulsion and the importance of energy density. Much of the focus for batteries has been on cost per energy storage (for example, dollar per kilowatt-hour). But for aviation, which fights a constant battle against gravity, the metric of energy density (watt-hour per kilogram) is even more essential. The industry must achieve the battery performance required to sustain electric vertical takeoff and landing (eVTOL). To enable this, battery density must nearly double from today’s approximately 200 watt-hours per kilogram, and these batteries must achieve aviation-grade safety standards. This is critical to reduce the noise and cost of operating these vehicles.

Regulatory support. Regulators must certify the new batteries, electric motors, distributed propulsion systems, features of autonomous flight, and vehicles integrating these components, as well as approve the operation of eVTOL aircraft at low altitudes and above people in cities. This must be done in a manner that addresses noise and safety issues in a manner acceptable to all. Without this, vehicles will not be able to access routes where most people travel.

Air traffic control system. Regulators, traffic control agencies, software players, and others must create, test, and implement the technology platform for unmanned traffic management (UTM). The traffic volumes expected in this market will far exceed any low-altitude flight in a city today. To manage this much higher flight volume safely and efficiently at low altitudes, the industry needs an entirely new system that does not depend on individuals and is interoperable with existing air traffic control systems.

Fully autonomous, pilotless flight. Technology and regulation must allow full autonomy for flying taxis. This will require technology platforms that are interoperable (that is, that work across multiple vehicles), can effectively communicate with the UTM system across cities, and are able to meet the necessary safety standards required for regulatory approval. Full autonomy is critical to achieve the scale needed to address pilot shortages and ensure all available seats can be leveraged for revenue generation.

Vertiports and physical infrastructure. Infrastructure players, investors, and others must come together to create the physical and charging infrastructure required for flying taxis to efficiently land, take off, charge, and receive maintenance. Delivering expected time savings for passengers will require ubiquitous vertiport locations, and achieving enough scale will require huge increases in vertiport density over time. It is likely that first movers will have an advantage by securing the most attractive sites along high-traffic routes.

Customer acceptance. Eventually, the scale of the market will hinge on customer acceptance. Customers must become comfortable climbing into the equivalent of a flying sport-utility vehicle without a pilot, which could take time across all demographics and trip types. The customer journey will need to be a pleasant one, with an interior that is quiet, at a comfortable temperature, and designed to allow passengers to use time productively if they so choose.

The fundamental result—90 percent lower operating cost. Overall, for large-scale customer adoption and the mass market, trip costs must ultimately compete with ground travel. That means the cost of a trip must decline by more than 90 percent compared with the estimated $4 to $6 in direct operating cost per seat-mile that helicopter travel costs today (Exhibit 2). Once the industry attains the above enablers, it can achieve the lower costs that can allow mass adoption.

Looking across the set of enablers, it is clear that no single player can deliver all of them alone. Instead, a broad ecosystem of stakeholders must come together to make them happen.

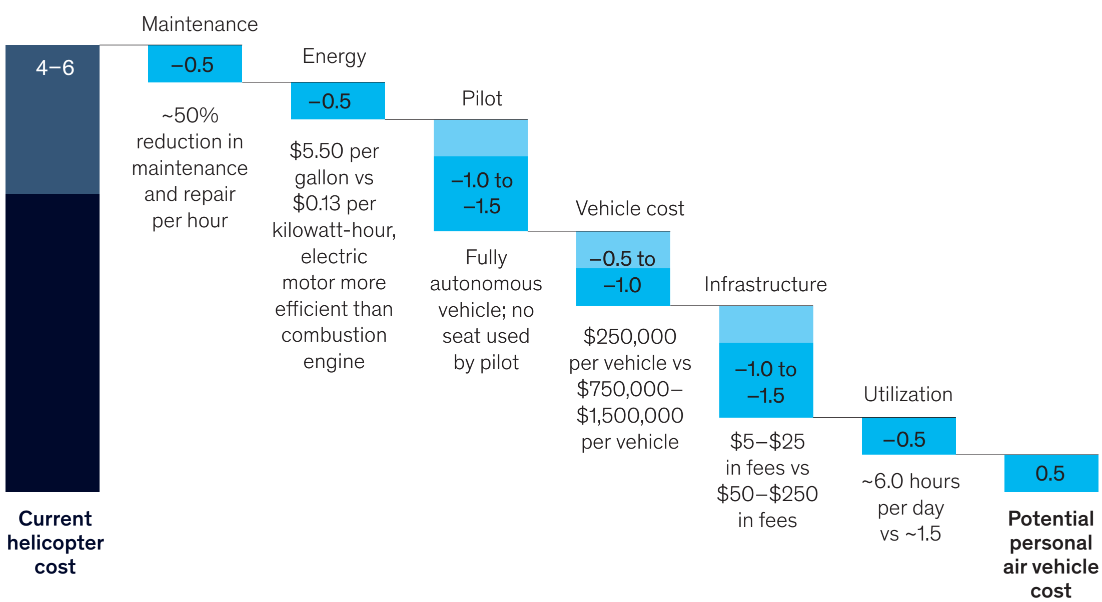
Not all enablers are equal

The impact of each of the above enablers is difficult to untangle because they are highly interrelated,

Exhibit 2

Operating costs could evolve for personal air vehicles.

Potential evolution for personal air vehicle, operating cost per seat-mile, $



Note: An updated version of this exhibit from a later article appears on page 32.

and progress in one area will likely affect work in another. While market enablers must happen to achieve scale, they will not each have an equal impact. Much effort now focuses on the technology and regulation, but infrastructure density will likely play the biggest role in driving scale once the technology is ready and regulatory reform passes.

Here is why: the closer passengers are to a vertiport, the greater their potential time savings and the more an air-taxi trip makes sense (Exhibit 3). Take a 40-mile commute into a city center from an airport, for example. Driving in traffic takes about 90 minutes; using a flying taxi from a vertiport that is 15 minutes away would take less time but would still be about an hour. If the vertiport were two to five minutes away, that could cut the trip down to 30 minutes. The distance to the vertiport dramatically affects the time saved and determines whether the trip is worthwhile from a commuter's point of view.

To illustrate the importance of infrastructure density as a market enabler, consider its impact on market size relative to trip price. Our models suggest that reducing trip price by a factor of ten would likely increase the market size fivefold. However, reducing the average distance to the nearest vertiport from about 30 minutes to about three would expand the market 25 times.

Simply put, the more infrastructure there is, the more trips it "makes sense" for a passenger to fly. Consequently, lacking enough infrastructure, only a handful of trips exist where it would make sense to fly. In this situation, reducing costs would make only a few more of those trips feasible.

Finding the industry's profit centers

At any market size, the personal-air-mobility market will generate new sources of value. Nonetheless, finding the most profitable ones will be a challenge. Initially, when personal air mobility is a niche market, the vehicle itself will serve as a critical control point because of its expense and likely price premium. At this stage, sales will probably number a few hundred units per year. The vehicle will also serve as a lynchpin for downstream services—particularly maintenance and repair.

The at-scale market implies a different world—one in which at least 25,000 vehicles sell per year in the United States alone at prices below $250,000 each. This price point will emerge as the industry achieves manufacturing scale and the vehicle platform commoditizes. In this scenario, downstream services like UTM and infrastructure are much more likely to be larger, with higher-margin profit pools. This is because these services will feature higher complexity and end up having higher barriers to entry once a player builds a viable solution.

The clear imperative for early-market players involves finding a value proposition that extends beyond the vehicle and that adapts over time. While the aircraft may be a control point in the initial market, it is unlikely to remain the most attractive play if the market reaches scale and the vehicle becomes commoditized.

Helping the personal-air-mobility market take off

Getting the flying taxi industry off the ground will require a team effort. Potential industry stakeholders include regulators, start-ups, traditional airplane and automobile manufacturers, cloud-based technology players, electric-vehicle (EV) charging networks, private-equity companies, venture capitalists, financing entities, commercial-real-estate developers, civil architecture firms, and insurance companies, to name only a few. Given this eclectic group of players, different stakeholders will require tailored investment strategies to support the market and to allow for businesses to position themselves to profit from the disruption.

All players need to invest in understanding the potential structure of the ecosystem: Will it be a platform model with a consumer-facing app at the center and commodity capacity such as vehicles and vertiports plugging into it? Will it be a few large players that will own the ecosystem end to end, factory to app? Will it be much more like today's aerospace and automotive industries, with OEMs and operators each playing their role? Beyond this core strategic question of the structure of the ecosystem—and what actions will shape the industry to the preferred model—stakeholders need to take specific actions to set themselves up for success in the market.

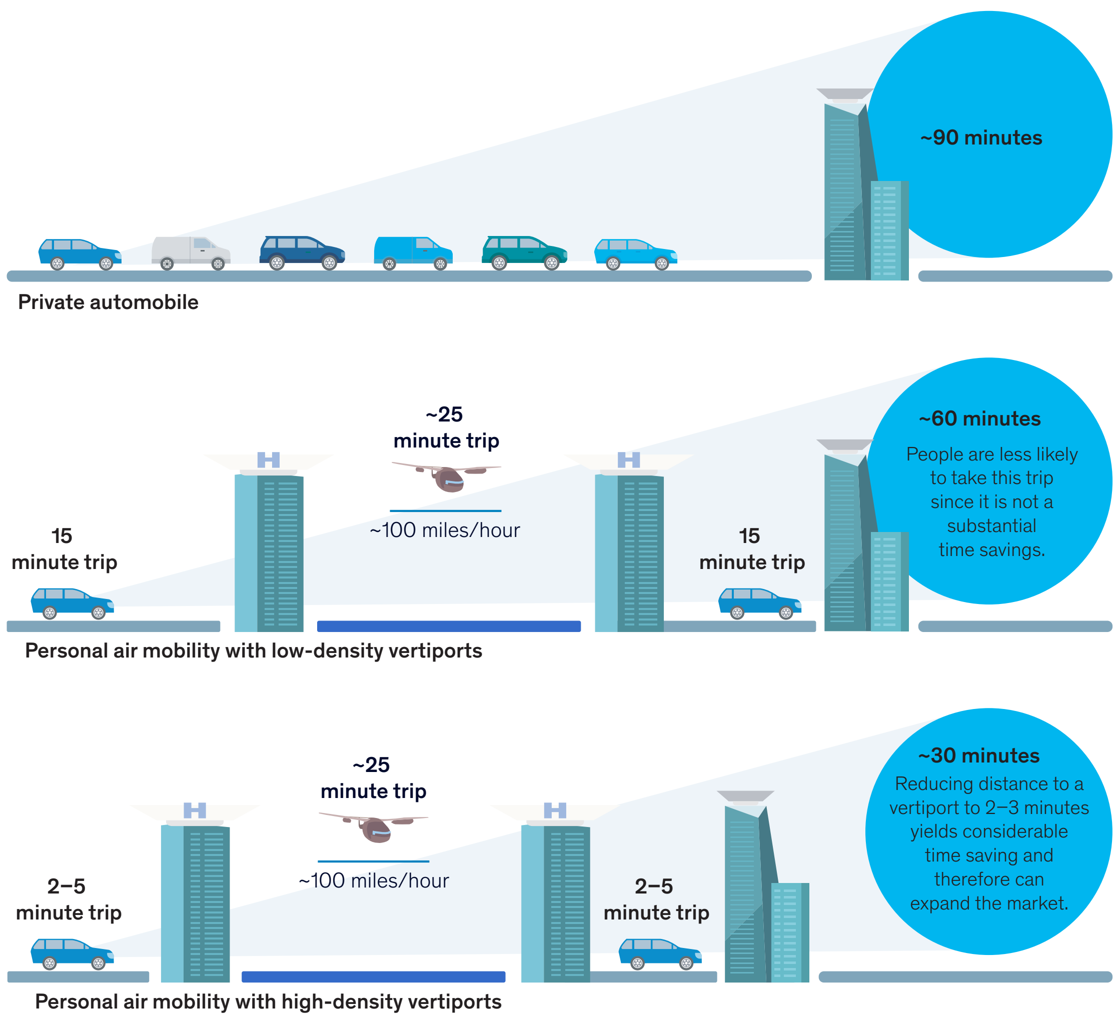
Regulators. Regulators might consider focusing on five primary actions. First, develop new aircraft certification standards; second, take steps to enable the integration of the new UTM system with traditional air traffic control networks; third, enable test-flight programs; fourth, create standards and certification for autonomous flight; and, finally, provide incentives and subsidies for personal air mobility, such as current EV support.

Aerospace and automotive incumbents. Given their technical expertise and industry experience, traditional aerospace incumbents have a head start in developing vehicle platforms, the clout to help establish standards and aircraft-certification specifics, and the ability to run safe-vehicle pilot programs. They also have the advanced R&D capabilities required for autonomous-flight systems and UTM. Automotive OEMs specialize in high-volume manufacturing of highly technical products—a must if large-scale fleets of flying taxis hope to get off the ground.

Exhibit 3

Infrastructure density will play a big role in the uptake of personal air vehicles.

Trip time to cover around 40 miles, by method of transit, minutes per trip



Software and technology players. The software and cloud infrastructure required to accelerate this disruption goes beyond the scope of traditional avionics and will attract new companies to the personal-air-mobility ecosystem. Likewise, a robust UTM system will require onboard software (detect and avoid), mapping and route-optimization tools, and external inputs such as real-time weather reports.

Physical infrastructure companies. Who will build and pay for the vertiports and charging infrastructure to bring the market to scale? One clue comes from current on-road mobility tie-ups among ride-sharing companies, commercial-real-estate developers, and charging networks for EVs. The collaborators must create high-throughput vertiports in dense urban environments, designing their networks and pricing access to pay off capital investments. These investments could range anywhere from $2 million for a small single-spot vertiport on an existing building to $200 million (or more) for a megahub with ten to 20 spots, retail, and other services built from the ground up.

How quickly personal air mobility emerges and how large the market ultimately becomes remain uncertain. We nonetheless believe the promise of flying taxis is real. Fulfilling its market destiny will require sustained funding and support across a wide group of stakeholders. Industry players thus need to focus on coming together to realize the enablers mentioned above. And beyond innovative technologies and brick-and-mortar investments, this idea will require collaboration across many industries—that are not used to working together—to create an ecosystem capable of launching a successful flying taxi industry that the everyday commuter is comfortable making a part of their mobility ecosystem.

Robin Riedel is a partner in McKinsey's San Francisco office, and **Shivika Sahdev** is an associate partner in the New York office.

The authors wish to thank Evan Anderson, Alex Dichter, Tore Johnston, Dickon Pinner, and Jannis Töpfer for their contributions to this article.

Customers taking to the air

Up in the air: How do consumers view advanced air mobility?

Our new global survey shows that consumers are ready to take advantage of advanced air mobility, but concerns remain.

by Benedikt Kloss and Robin Riedel

Originally published June 1, 2021

Will it fly? Companies and investors in the fledgling advanced air mobility (AAM) industry are betting billions that the answer is yes. AAM features a new set of mobility use cases that include people and cargo transport—think flying taxis, cargo drones, and the like—and funding has accelerated in recent months. The uptick has been so rapid, in fact, that total disclosed investments exceeded $8 billion at the end of March 2021. People transport has seen the most recent investor interest, drawing more than 80 percent of total funding, but cargo-delivery drones might soon see an upsurge.

While investors and other industry stakeholders are excited about AAM's potential, the consumer view is less clear. Will people happily board flying taxis and accept drone deliveries, or do some reservations remain? To gain a fuller understanding of the issues at play, as well as potential demand, McKinsey surveyed approximately 4,800 consumers in Brazil, China, Germany, India, Poland, and the United States in March 2021. The research involved use cases for both people moving and cargo transport. Our goal was to investigate consumers' future willingness to adopt and pay for AAM services, as well as their preferences and concerns.

Asking people about a product or service that does not yet exist—including passenger AAM vehicles—is always challenging. After all, a consumer's stated preference and actual behavior can differ, especially when the scenario involves a theoretical offering that is not yet on the market. That said, our survey does provide some important insights about potential use cases and the AAM market that industry stakeholders may find helpful as they plan their future strategies.

Consumer insights on flying taxis

We looked at six people-moving use cases involving widely different activities:

- commuting to and from work
- errands
- business travel
- short-distance leisure travel, such as trips to the cinema
- long-distance leisure travel, such as visits to family members in other cities
- trips to and from the airport as part of a longer journey

These potential use cases would involve AAM vehicles, such as electrical vertical takeoff and landing aircraft, electric conventional takeoff and landing aircraft, and electric short takeoff and landing aircraft, which fly at lower altitudes within urban, suburban, and regional areas. The AAM vehicles would be operated by pilots in the medium term, with semiautonomous or autonomous vehicles becoming available over the longer term.

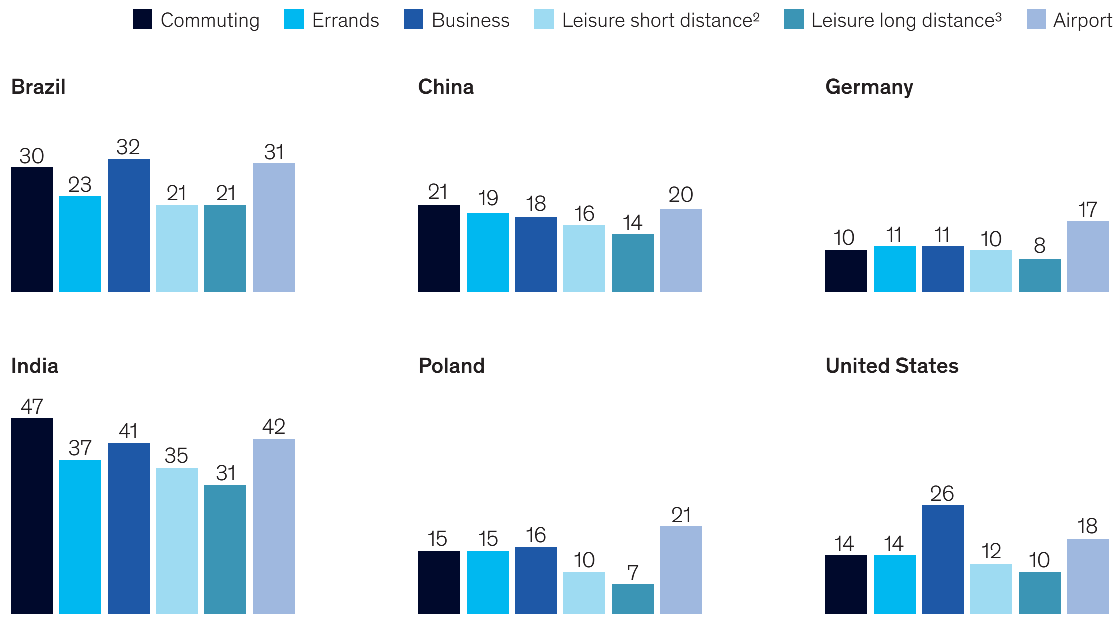
Willingness to adopt passenger AAM and preferred use cases vary by country

Interest in using passenger AAM was highest in India and Brazil. From 31 to 47 percent of Indian respondents said they would definitely consider using an AAM vehicle in the future, depending on use case, as did 21 to 32 percent of Brazilian consumers (Exhibit 1). German respondents expressed the lowest interest level for most use cases, with the percent of respondents stating that they would use an AAM vehicle ranging from a low of 8 percent for long-distance leisure travel to a high of 17 percent for airport trips.

Exhibit 1

Willingness to adopt advanced air mobility (AAM) services varies, with no use case clearly outpacing the others.

Adoption, by use case, % of respondents saying they would definitely switch to an AAM vehicle[1]



[1]Respondents were asked to "imagine that instead of using your current transport mode you outlined, you could opt to get around in the small aircraft described earlier"; n = 4,600, with 400–500 per country.
[2]Within city.
[3]Longer distance to outside of city.
Source: McKinsey Advanced Air Mobility Consumer Survey, March 2021

So far, no clear winning use case for people moving has emerged; in each country, most use cases attracted somewhat similar levels of interest. Still, there are indications of potential winners in each country. For instance, compared with respondents in other countries, US consumers had much higher interest in business travel. When we did a qualitative analysis of the survey comments, we discovered that a major reason for this sentiment was the perceived higher convenience of AAM vehicles. German consumers were much more likely to express willingness to adopt AAM services for airport trips than other use cases, and Polish consumers were less interested in adopting these services for short-distance leisure trips, selecting this use case one-third to half as often as the others.

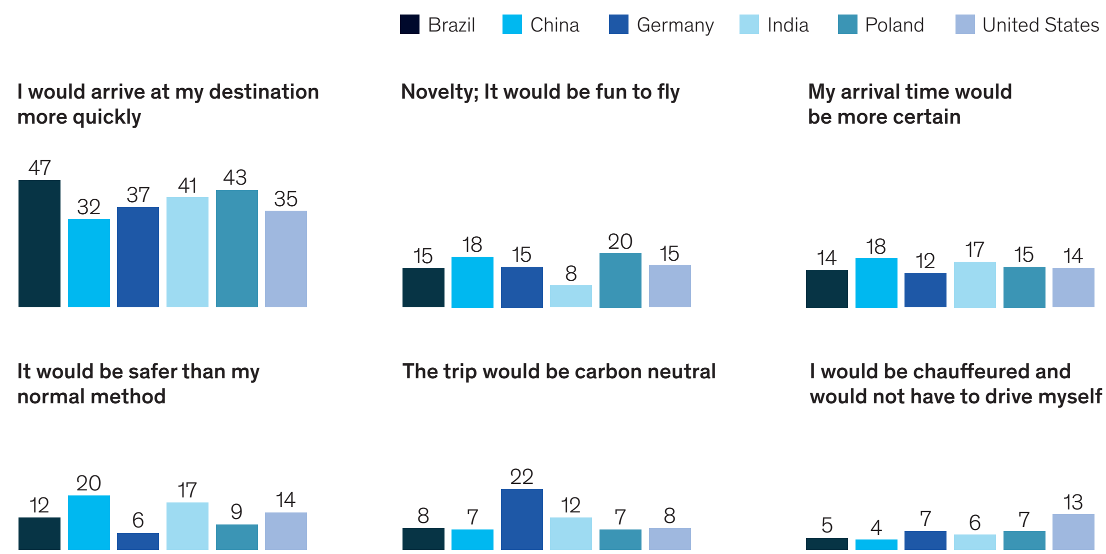
Consumers had different motivations for considering manned services

When respondents were asked about their main reasons for considering manned AAM services, the largest share—more than 30 percent in each country—expressed a desire for shorter travel times (Exhibit 2). This preference was particularly evident in countries that rank high for congestion levels and time lost in traffic. For instance, 47 percent of Brazilian respondents and 41 percent of Indian respondents wanted shorter travel times. Unsurprisingly, four Indian cities were among the world's ten most congested in 2019, prior to the pandemic, and two of the 20 most congested cities were in Brazil.[1] Across countries, the desire to have a more certain arrival time was also frequently cited as a reason to use an AAM vehicle.

Exhibit 2

Across countries, reduced travel time was most often cited as the main reason to consider an AAM vehicle.

Main reason for considering an AAM vehicle, % of respondents, by country[1]



[1]Respondents were asked, "In order of highest to lowest importance, what are the top 3 reasons you would be willing to switch?"; n = 4,600, with 600–1,000 per country.
Source: McKinsey Advanced Air Mobility Consumer Survey, March 2021

[1] TomTom Traffic Index, April 2021.

India and Brazil show the most willingness to pay for future flying-taxi offerings

Some regional differences were observed in willingness to pay. Thirty-six percent of Indian consumers said they would definitely pay five times the price of their current transport mode to hop on an AAM vehicle for a trip to or from an airport, as did 30 percent of Brazilian respondents—the highest rates reported in our survey (Exhibit 3). These findings are likely related to the lower price levels for other mobility options in these countries, as well as the higher congestion rates and time lost to traffic. In the other countries, less than 20 percent of respondents were willing to pay the same premium for airport trips in an AAM vehicle.

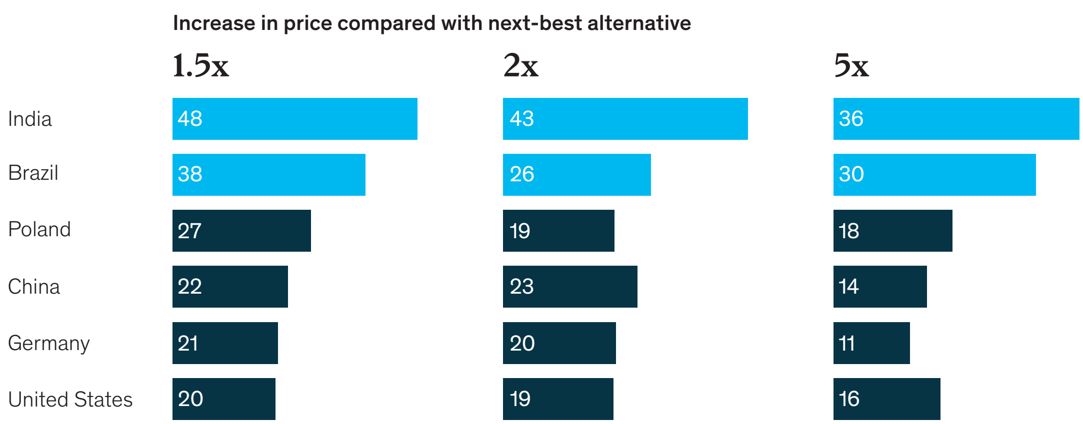
Germany ranked lowest in willingness to pay, which might seem counterintuitive, since it has one of the highest disposable-income levels. When we analyzed the qualitative data and survey comments, however, we found that Germany's excellent existing transportation infrastructure reduced the advantages of using an AAM vehicle for airport trips.

Our survey suggests that consumers are willing to pay a premium for AAM service even for traveling very short distances.

Exhibit 3

Indian and Brazilian consumers showed the highest willingness to pay more for an airport trip via AAM vehicle compared to their current transport mode.

% of respondents willing to pay more for an airport trip via AAM, by price difference[1]



[1]Respondents were asked to "imagine that instead of the current transport mode you used for your last airport trip, you could opt to get around in the small aircraft described earlier. How much more would you be willing to pay?" They were asked this question with 3 different price points; n = 2,800 in total for airport use case, with 400–500 per country.
Source: McKinsey Advanced Air Mobility Consumer Survey, March 2021

Today's limousine and ride-hailing users might be first adopters

Almost 35 percent of today's ride-hailing users for airport trips said they would definitely switch to an AAM vehicle, as did 32 percent of limousine users. These groups may be among the first adopters of AAM for two reasons: ride-hailing users are already accustomed to new shared-mobility options, and limousines are relatively expensive, making the higher price of an AAM vehicle less of a jump. Among taxi users, 29 percent said they would switch to an AAM vehicle, as would 27 percent of those who use car rentals. The cost of these services is comparable to those of limousines and ride hailing, so the price increase is again less of a factor. Those who used private cars or public transit for their trips were least likely to say they would switch (23 percent for each category). A possible explanation for public-transit users' lower likelihood of switching is that this group may be the most price-sensitive.

The main consumer concerns about passenger AAM relate to safety and price

Across countries, more than 60 percent of respondents said safety was their top concern about AAM vehicles, making it the most important issue by far. Many people appeared particularly concerned about autonomous flight—a development expected down the road. Our qualitative analysis of survey comments showed that some consumers have concerns about flying in piloted small aircraft today, making their hesitancy about autonomous flight unsurprising. Others indicated that autonomous travel should first demonstrate proof of concept on the ground.

About 10 to 20 percent of respondents across countries reported concerns about ticket prices. While this put pricing in second place as a concern, the numbers are relatively low. These findings are in line with the fact that many respondents expressed willingness to pay a higher rate for AAM services.

Demographic trends provide hints about demand

Our survey showed that the number of people who were willing to use an AAM vehicle for an airport trip decreased with age. In a similar trend, the number of people saying they would definitely consider a switch to an AAM vehicle increased with household size. For instance, only 8 percent of respondents in single-member households would consider a shift, compared with 22 percent of those in households with more than four people. This suggests that the most likely AAM adopter is between the ages of 18 and 29 and lives in a large household. Gender did not appear to have a significant impact on preferences.

Multiseater AAM vehicles might be adopted and in demand

Consumers might be willing to share trips with other riders on AAM vehicles. Although we conducted our survey during the COVID-19 pandemic, less than 5 percent of respondents across countries viewed trip sharing with strangers as the main reason not to consider future AAM services. While this may sound counterintuitive, it reflects findings from a recent McKinsey survey in which consumers said they planned to return to their precrisis mobility levels and behaviors when the pandemic ends. Therefore, providers may find opportunities to deploy shared multiseater AAM vehicles in the future. The fact that people in larger households are more willing to consider AAM vehicles may contribute to a future need for vehicles with higher passenger capacity.

Consumer insights on cargo-drone delivery

We have divided the main use cases, such as inner-city and last-mile deliveries, into clusters, based on domain—public services, B2B, or B2C—and level of operational risk (Exhibit 4).

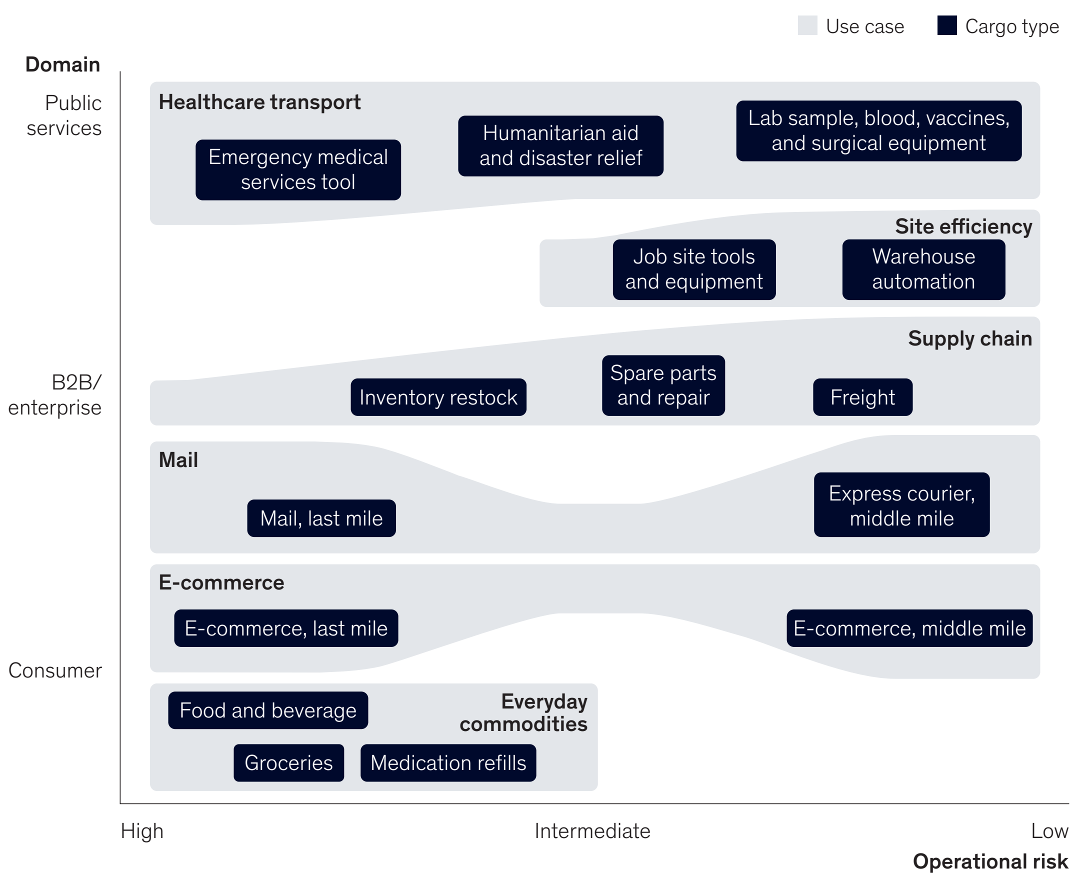
In our survey, we focused on consumer use cases for convenience products (such as groceries and prepared food), medication, small electronics (such as headphones and smartphones), clothes, and entertainment items (such as books and board games). Several insights emerged about cargo-drone delivery, including these:

— *Pricing is the main lever for winning market share.* Across most countries, our survey showed that cost would be the major consideration when respondents select a dedicated delivery mode. The share of respondents in most countries citing this as their top concern ranged from 39 to 59 percent (Exhibit 5). The only exception is China, where the largest share of respondents (43 percent) said their main consideration would be speed of delivery, compared with 26 percent selecting price. These findings suggest that for cargo drones to displace other delivery modes, they will need competitive pricing.

Exhibit 4

Use cases for cargo-drone deliveries are clustered based on domain and operational risk.

Non-exhaustive



Source: McKinsey analysis

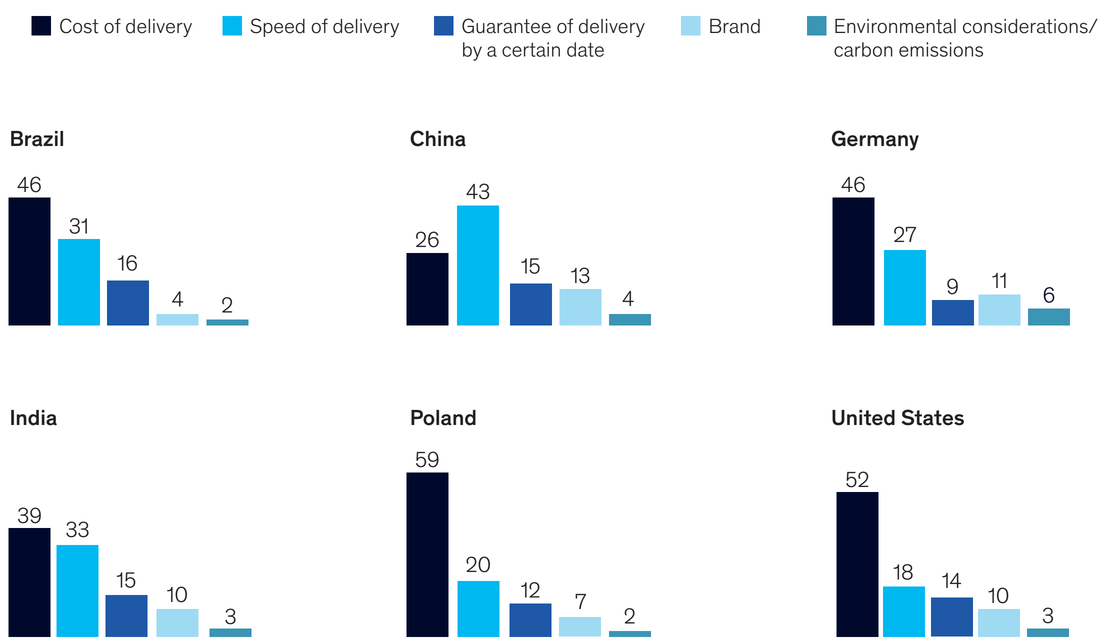
— *The cargo market is wide open for new entrants.* One indication of this market's potential comes from our survey findings that a delivery service's brand is a relatively unimportant consideration, ranking second to last across countries. In each country, less than 14 percent of respondents identified it as the main decision driver.

— *Stated interest in instant delivery varies widely across countries.* About 76 percent of Indian respondents said they would be willing to pay extra to have items delivered within one to two hours by cargo drone, as did 74 percent of Chinese respondents (Exhibit 6). German and US consumers were most reluctant to pay extra, with 17 percent in each country stating they were not interested in cargo drones for instant delivery. Our qualitative analysis of survey comments suggests that some respondents in these locations may value reliability more than speed.

Exhibit 5

In most countries, respondents were most likely to cite cost as the main basis for choosing a delivery mode; those in China prioritized speed of delivery.

Main reason to choose delivery mode, % of respondents[1]

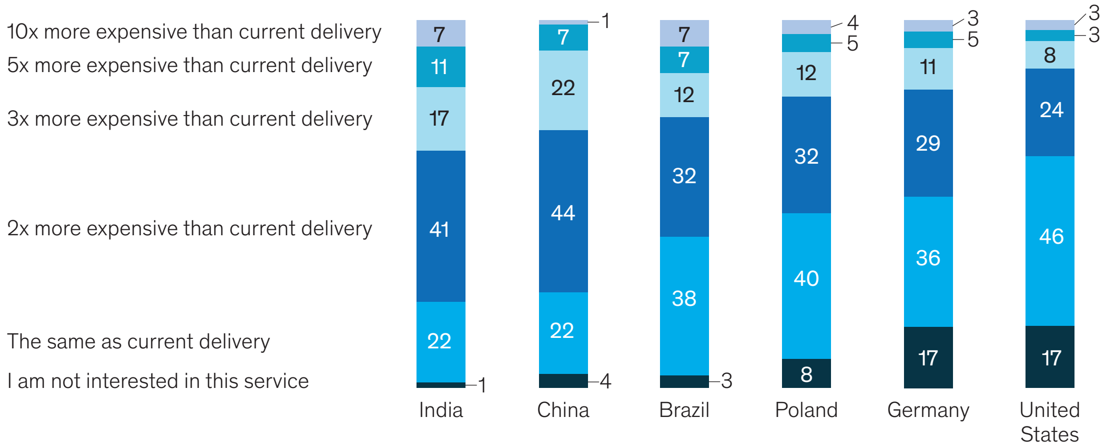


[1]Respondents were asked, "What is the primary factor that drives your choice of which company to select for delivery of a package?"; n = 4,600, with 600–1,000 per country.
Source: McKinsey Advanced Air Mobility Consumer Survey, March 2021

Exhibit 6

Respondents in China and India were most willing to pay extra for immediate delivery with cargo drones.

'If the cargo-drone option were available for a reasonable price, what is the maximum amount you'd be willing to pay to have items delivered within 1–2 hours?'
% of respondents[1]



[1]n = 4,600, with 600–1,000 per country.
Source: McKinsey Advanced Air Mobility Consumer Survey, March 2021

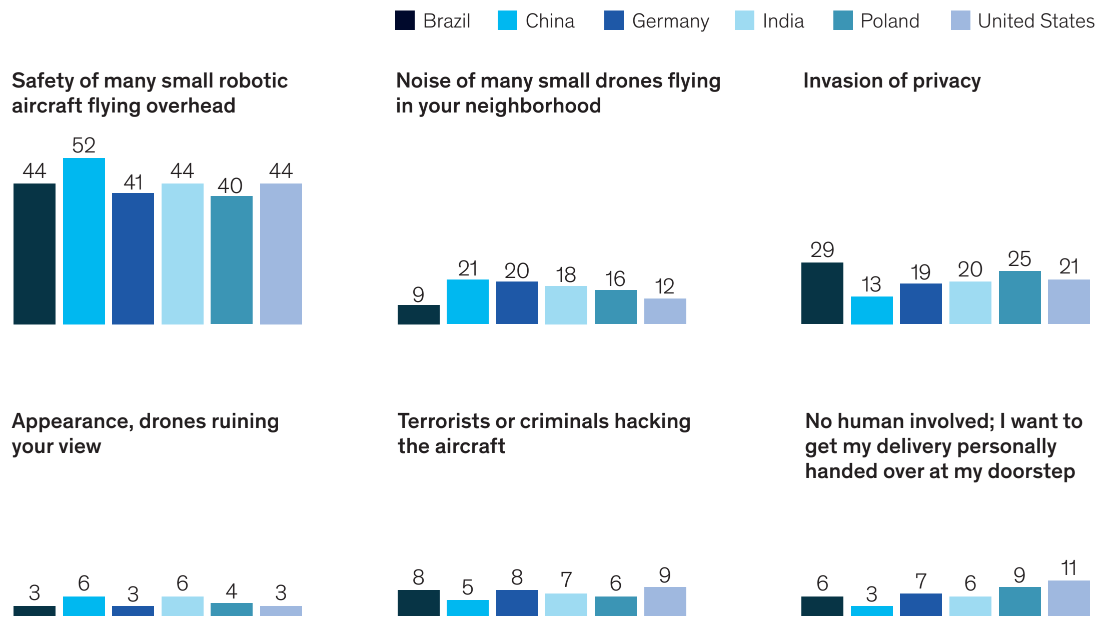
— *Convenience products, such as groceries and prepared food, could become the most promising use case for instant drone delivery.* Across countries, 34 to 49 percent of respondents said they would choose to have convenience products delivered within one to two hours. These products were the top category in every country, which seems intuitive, since the quality of convenience products often decreases over time. Medication ranked second. Entertainment items came in last, with less than 10 percent of respondents indicating that they were interested in instant delivery—possibly because these items can often be accessed online.

— *Safety is key for public acceptance, just as it is with people transport.* In all countries, 40 percent or more of survey respondents had reservations about the safety of many small robotic aircraft flying overhead to make deliveries (Exhibit 7). After safety, the most frequently cited issues were privacy concerns and noise. Respondents tended not to identify the lack of a human to hand over the item at the doorstep as a problem; less than 12 percent in each country selected it as a top-three concern. In fact, during and after the COVID-19 pandemic, contactless delivery might even become a plus.

Exhibit 7

Across countries, respondents cited safety as their main concern about drone deliveries.

Main concerns about use of drone delivery, % of respondents[1]



[1]Respondents were asked, "In order of greatest to least importance, what are your 3 largest concerns surrounding small drones used for delivery?"; n = 4,600, with 600–1,000 per country.
Source: McKinsey Advanced Air Mobility Consumer Survey, March 2021

— *Demographics provide clues about use, with results suggesting that younger people and those in large households are most likely to use AAM.* When we asked survey respondents about their willingness to use drone deliveries (assuming cost parity with other modes and superior delivery times), we found that younger people were most amenable. Willingness to use drone delivery also increased with household size: from 16 percent for those in two-person households to 29 percent for those in households of four people. As with flying taxis, we find the greatest interest in drone delivery among consumers who are 18 to 29 years old and living in a large household. Willingness to use drone delivery was slightly higher for men (26 percent, versus 23 percent for women).

The AAM market remains unsettled at this early stage, but investor confidence and consumer interest suggest strong forward momentum. With the right infrastructure and technology, AAM flights could become a reality. Given the wide country-by-country differences in consumer preferences for people-moving services and drone deliveries, industry players must set different priorities when addressing the opportunities and challenges in each market. They should also identify key customer segments in each country, since these could vary. Our survey findings may help them plan their strategy, as they provide important clues about geographic trends, consumer willingness, in-demand use cases, and key concerns. AAM providers that begin thinking about such issues now may gain a long-term advantage as the industry moves ahead.

Benedikt Kloss is an associate partner in McKinsey's Frankfurt office, and **Robin Riedel** is a partner in the San Francisco office.

The authors wish to thank Dave Gerson, Tore Johnston, Jonathan Li, Klaus Seywald, George Valcarcel, and Andrea Westervelt for their contributions to this article.

Putting the customer at the center of advanced air mobility

The industry has focused on safely getting new types of electric aircraft in the air, but winners in this market will differentiate themselves based on customer experience.

by Benedikt Kloss, Adam Mitchell, and Robin Riedel

Originally published February 22, 2022

Much of the public attention around manned advanced air mobility (AAM) has focused on the development of electric vertical takeoff and landing vehicles (eVTOLs) and short takeoff and landing vehicles (STOLs)—in particular, the challenge for OEMs of getting new designs certified and production facilities ramped up. As the industry matures, however, the emphasis will shift to operations, including strategies for acquiring and retaining customers. As discussed in an earlier article,[1] companies that prioritize customer experience will be in the best position to capture value and build sustainable businesses. That's because about 35 percent to 50 percent of value from AAM comes from segments that involve direct customer interactions, including mobility platforms and infrastructure.

In the series of illustrations below, we've laid out what the AAM customer journey could look like, including researching travel on a mobility platform, traveling to a vertiport, connecting between modes of transport, moving through the vertiport—including boarding—and resolving issues in real time.

As AAM operators think through the customer experience, five elements are worth considering.

1. Time saved could be less important than how people spend their time

Operators in the AAM space need to develop a deeper understanding of how customers are using their travel time and how time saved creates value in their lives. For example, AAM may take less time than a car for many trips, but it might require multiple segments and inter-modal changes (eg, taking a car for a short hop to the nearest vertiport). If the time difference is small, business travelers may prefer ground transportation because that time is relatively uninterrupted. Saving 15 minutes on a cross-city trip may not justify a flight if an executive can sit in a ride-share car and work on her laptop. Operators will need to determine the threshold at which time savings become more important to key customer segments.

2. Inter-modal connection and integration could be critical for a seamless customer experience

AAM flights will require coordination across different modes of transportation, including time buffers between legs of the trip to avoid missed connections. Every time a customer moves from one form of transportation to another, there could be a potential "breaking point" in the customer journey where something could go wrong. Mobility platforms will need to decide whether to build an open ecosystem with connections to a broad range of operators or a closed ecosystem with exclusive relationships. That decision has ramifications for the customer experience, since it affects the number of route choices available, as well as potential recovery options in the event of problems with the trip. Furthermore, software talent to build and maintain these integrations will be critical, not just for mobility platforms but also for operators and infrastructure providers.

3. Vertiports may become havens for omnichannel e-commerce

It may be tempting to think of vertiports as mini-airports, but the experience will differ in key ways, primarily because passengers will spend far less time waiting for departures. Rather than a traditional airport setting with walk-in shops and sit-down restaurants, operators may explore hybrid models that rely more heavily on e-commerce. For example, customers may have the opportunity to purchase meals or amenities via a mobility app and have those products waiting in a "click-and-collect" area when they land.

4. Pilots could become frontline customer reps

Most commercial aviation passengers don't have direct access to the pilot, and flight attendants are responsible for managing frontline customer interactions. For AAM aircraft, which have much smaller four- to six-person cabins, passengers could interact directly with pilots if they are in the same cabin (assuming they are not in remotely operated

[1] *Future Air Mobility*, "Going vertical: How emerging technologies will power a new value chain," blog entry by Tore Johnston, Benedikt Kloss, Adam Mitchell, Robin Riedel, McKinsey, August 31, 2021.

1. Access mobile platform, browse route options, and confirm travel

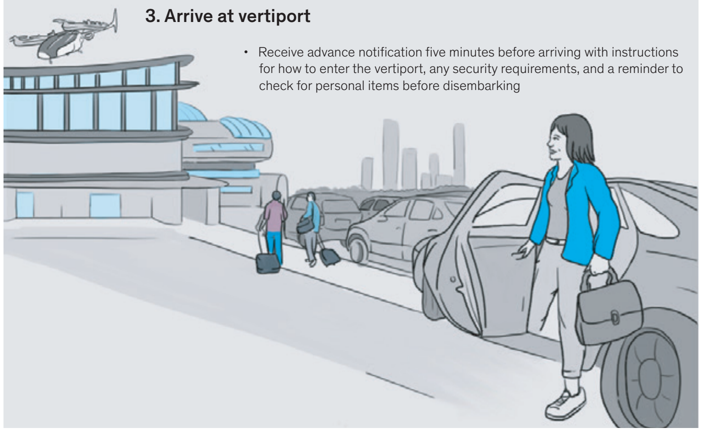
- Log into preferred app offering advanced air mobility (AAM) flights and update preferences
- Review both ground and air options and select mode of transport based on timing and preferences
- Receive confirmation of travel and list of next steps, including baggage allowance and how to prepare for any security at vertiport

2. Travel to vertiport

- Enter rideshare vehicle and begin travel to vertiport
- Receive real-time notifications about traffic delays and options to alter route as needed

3. Arrive at vertiport

- Receive advance notification five minutes before arriving with instructions for how to enter the vertiport, any security requirements, and a reminder to check for personal items before disembarking

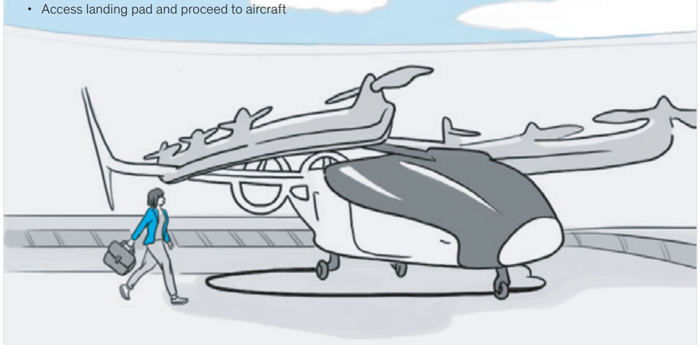


4. Move through the vertiport

- Use the mobile app as guide through terminal
- Grab food/drink from an automated kiosk
- If required, complete security screening, potentially as a simple walk-through process leveraging advanced and automated scanners

5. Board the eVTOL

- Wait in lounge area before being called to the landing pad
- Access landing pad and proceed to aircraft



6. eVTOL flight

- Pilot provides introduction and gate agent helps each passenger on board
- Take off in eVTOL; opportunity to work depending on turbulence
- Order food through mobile app to be picked up at the destination

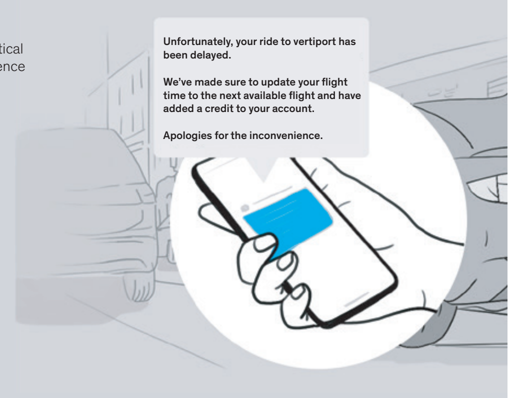
7. Connect to next mode of transportation and travel to final destination

- Pick up food order at click-and-collect station in vertiport
- Meet next ground transport and travel to final destination

Issue resolution

Issue resolution will be a critical part of the customer experience

- Seamless inter-modal experience (eg, quickly adapt to potential delays between modes of transport in a single journey)
- Keeping customers updated regarding delays or diversions due to mechanical issues, weather, etc



or autonomous vehicles). This could turn pilots into important brand and experience ambassadors, and they may require training in how to handle customer interactions. For example, if a customer needs to resolve an issue mid-flight, pilots will need to be able to direct him or her to the right channel for support, while still safety operating the aircraft.

5. Issue resolution could play an outsized role in the early days of AAM

The rapid cadence of AAM operations, along with the number of hand-offs between different modes of transportation, all but guarantees that issues will arise, and operators need proactive plans to resolve these. Early AAM operations may require a more involved, “white glove” service for passengers to resolve issues quickly, which could drive up costs.

As operators and OEMs start thinking about how they will operate AAM aircraft, customer-experience considerations will emerge; these will evolve as the industry shifts from few flights in its infancy to higher passenger volume and more complexity. To date, most companies have focused on certification and manufacturing issues for understandable reasons. But in the long term, companies that have the closest relationship with customers will be in the best position to capture value, drive retention, and build sustainable businesses.

Benedikt Kloss is an associate partner in McKinsey’s Frankfurt office, **Adam Mitchell** is an associate partner in the Toronto office, and **Robin Riedel** is a partner in the San Francisco office.

Operationalizing advanced air mobility

Great expectations: What's required for AAM players to become some of the largest airlines in the world

Future air mobility players could soon rival today's large commercial airlines in size. To get there, they must first overcome some operational hurdles.

by Guenter Fuchs, Ryan Mann, Robin Riedel, and George Valcarcel

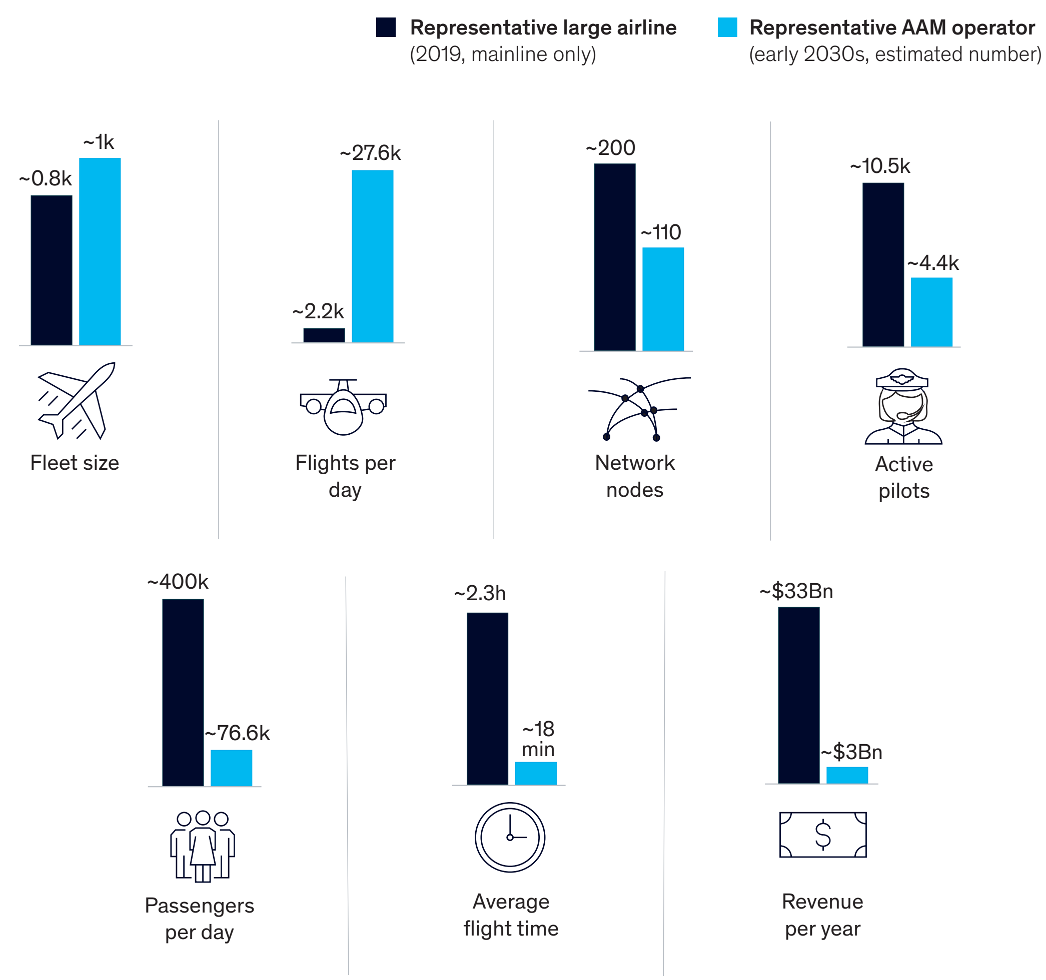
Originally published September 14, 2021

With investments growing and prototypes in development, advanced air mobility (AAM) players have great ambitions. By 2030, they could be similar in size across some dimensions to the largest airlines in the world—according to the announced plans of the major players—with similar complexities. Flights are expected to be much shorter than commercial airline travel today (averaging only about 18 minutes), with fewer passengers (one to six, plus a pilot). Fleet sizes are expected to be bigger than those of a typical commercial airline, and the number of AAM flights could be greater by an order of magnitude—approximately 2,200 per day for the largest airlines versus about 20,000 per day for AAM operators (exhibit).

That kind of accelerated cadence—with large numbers of aircraft flying frequent, short flights—will create operational challenges. Ground processes, flight planning, and other aspects all increase in direct proportion to the number of takeoffs and landings. Thus far, much of the discussion about AAM has centered on aircraft design, manufacturing, and certification. Yet

Exhibit

Passenger advanced air mobility operators could soon rival the largest airlines in terms of fleet size and flight operations.



Source: 2019 BTS; Cirium Diio; investor presentations operations could be a limiting factor to the industry's growth, and stakeholders must overcome hurdles in the following areas.

— *High-throughput vertiports.* To meet aspirations, the industry will need takeoff and landing sites capable of supporting a large volume of takeoffs and landings each day. Existing regional airports and helipads are a start, but AAM operators will likely need to work with the public, city planners, and other stakeholders to build greenfield projects in more accessible locations.

— *Network planning and optimization.* Unlike commercial air travel, AAM passengers won't book months in advance. For that reason, operators need to be far more agile and responsive to short-term changes in demand.

— *Ground operations.* Even though the vehicles are smaller than large airliners, they will still require activities such as cleaning, baggage handling, and refueling (or recharging for battery-powered aircraft) between landing and the next departure. Even with increased automation, manual labor will still be required, even at small vertiports.

— *Passenger experience.* Because the flights are short, passengers will want to spend far less time in terminals. For that reason, terminals need to support a streamlined passenger journey, including access to additional modes of transit, and efficient security.

— *Maintenance repair and overhaul.* Despite being less mechanically complex than conventional fuel powered aircraft, eVTOL will still need both routine and unscheduled maintenance. Operators will have to identify network locations suitable for servicing their fleet—perhaps larger vertiports or existing airport hangers—and may need some level of service at all network nodes.

— *Pilot training.* Attracting and training enough pilots to operate AAM aircraft is also critical, particularly during the early years of operations, when they will be required in the cockpit on every flight. Our modeling suggests that the AAM industry could require about 60,000 pilots by 2028. Longer term, some pilots can advance to remote supervisors capable of overseeing multiple flights from the ground.

Thus far, AAM players have focused primarily on designing and certifying aircraft, but the real question may be this: Can the industry proactively address potential operational issues now to reach its full potential?

Guenter Fuchs is a consultant in McKinsey's Southern California office; **Ryan Mann** is an associate partner in the Chicago office, where **George Valcarcel** is a consultant; and **Robin Riedel** is a partner in the San Francisco office.

To take off, flying vehicles first need places to land

The buzz about vehicles flying above hides the infrastructure challenge below.

by Tore Johnston, Robin Riedel, and Shivika Sahdev

Originally published August 31, 2020

The dream of using new technologies to rise above the ever-increasing urban-road congestion has gained significant momentum. With more than 250 businesses planning to build, operate, or manufacture urban-air-mobility (UAM) vehicles, all at different stages of development, a growing assortment of industry players is working across the value chain to make this dream a reality. Enabled by vertical-takeoff-and-landing (VTOL) systems, electric propulsion, and advanced flight-control capabilities, these vehicles could eventually reach price points rivaling today's terrestrial taxi services.

The resulting flying vehicles will be energy efficient, quiet, environmentally friendly, and eventually pilotless.[1] Although some may question the projected costs involved, their concerns might be misplaced. Adding new transportation capacity in most cities is extremely expensive, especially if it involves tunneling for subways or bypasses. The cost of building a subway in a city can exceed $500 million per mile, for instance.[2] UAM may thus represent a more cost-effective method, in some cases.

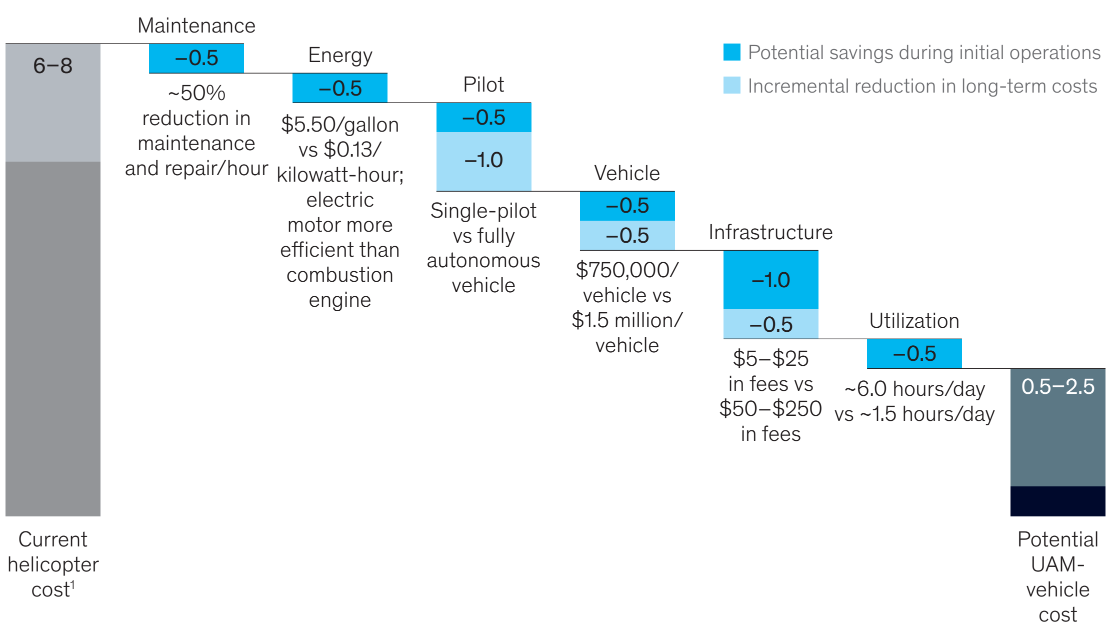
For UAM to be truly successful, trip costs must fall around 80 percent from current helicopter levels for UAM to compete with ground travel (Exhibit 1). In addition to physical infrastructure—places that vehicles take off and land—success will require a variety of infrastructure to support unmanned air-traffic control, aircraft charging and/or refueling, and connectivity.

Although the coronavirus pandemic will inevitably shift market dynamics and influence the adoption rate of UAM, the sector still offers many opportunities for innovators. This article explores how physical infrastructure for UAM could evolve and help shape the market. Our discussion focuses on intracity and metropolitan UAM travel with a distance of under 50 miles. While many other use cases exist for longer trips, they have different dynamics, economics, and infrastructure needs.

Exhibit 1

Operating costs could evolve for urban-air-mobility vehicles.

Potential evolution in operating cost per seat-mile for urban-air-mobility (UAM) vehicles, $



[1]Current costs vary depending on various factors, including number of passengers and helicopter type.

[1] Uri Pelli and Robin Riedel, "Flying-cab drivers wanted," McKinsey, June 2, 2020.
[2] Alon Levy, "Why it's so expensive to build urban rail in the U.S.," Bloomberg, January 26, 2018.

Physical infrastructure provides industry lift

To offer sustainable service, flying vehicles need places to take off, land, receive maintenance, charge their batteries and/or refuel their tanks, and park. Complicating the picture, traffic flows are typically unevenly distributed and highly directional. Mornings and evenings see high demand for travel, while demand is low in the middle of the day and nights. In Seattle, for instance, most travel occurs between 7:00 a.m. and 9:00 a.m. (Exhibit 2). Consequently, infrastructure must support both peak flight needs and off-peak parking needs. That creates a dilemma: infrastructure networks will be larger than needed to support "average" utilization, or else operators must spend money to shuttle empty vehicles between parking and active sites.

The physical infrastructure will be an important determinant for the size of the addressable market, since the only trips possible are between VTOL ports. If only a few ports are available, flying-vehicle transport could follow a pattern similar to that seen in today's helicopter market, where the number of potential destinations is limited. For instance, helicopter trips in cities such as London and New York can only occur between major airports and select locations in city centers—the only locations with available ports. If leaders want to scale the UAM market and not face the limits seen with today's helicopter transport, they must establish many more ports, as well as more routes among them.

The location of the infrastructure will determine market-conversion levels. The closer a passenger is to a takeoff or landing spot, the greater the potential for time savings. If a landing spot is too far away from the origin or destination, the customer might not save enough time for a UAM trip to make sense.

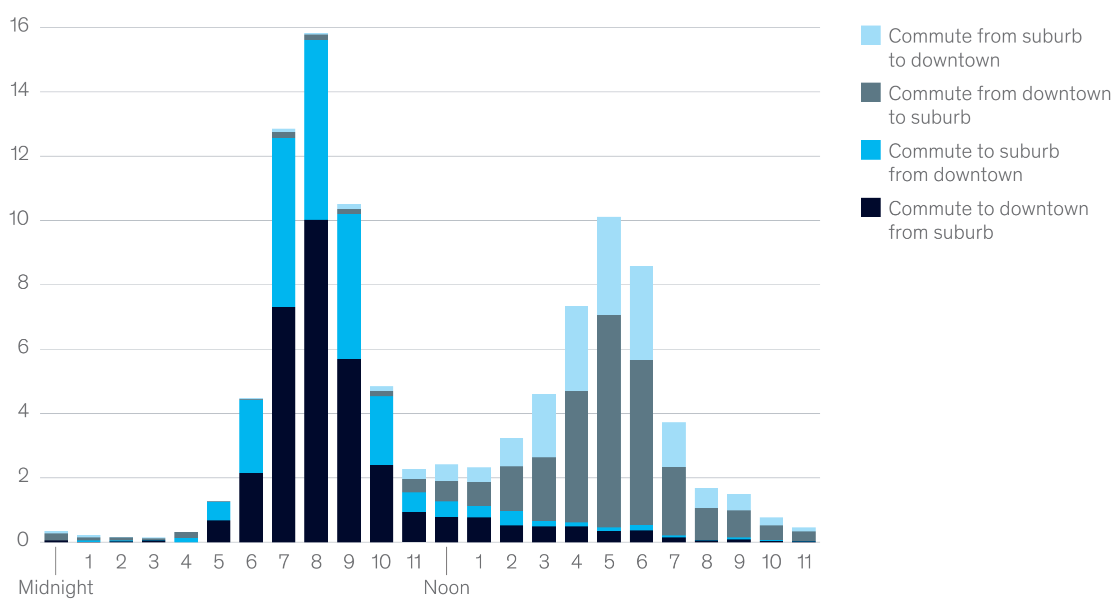
Envisioning an infrastructure network

The specific design requirements for a UAM network will vary by city. We expect that concerns about COVID-19 will increase the importance of safety during travel, and UAM stakeholders

Exhibit 2

Traffic flow varies significantly by time of day, with peaks occurring at commuting hours.

Daily traffic patterns by time of day, Puget Sound, % of total daily trips

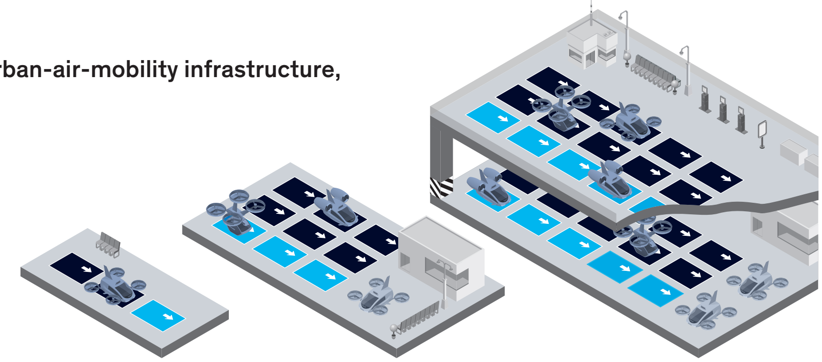


Source: "Household Travel Survey Program," Puget Sound Regional Council, Spring 2017, psrc.org

Exhibit 3

There are three potential archetypes for urban-air-mobility infrastructure.

Potential archetypes for urban-air-mobility infrastructure, illustrative



	Vertipad (new or retrofit)	Vertibase (new or retrofit)	Vertihub (new)
Dimensions	100 × 60 feet	230 × 100 feet	400 × 175 feet (2 floors)
Landing/takeoff pads	1	3	10
Parking/charging spots	2	6	20
Capital expenditures, $ million	0.2–0.4	0.5–0.8	6.0–7.0
Operating expenditures, $ million	0.6–0.9	3.0–5.0	15.0–17.0

will adapt essential infrastructure to meet those requirements. This section defines three potential UAM-infrastructure archetypes that could emerge (Exhibit 3). For each archetype, we estimate costs, and the calculations assume that the land is rented. The following are simply illustrative examples, and the section does not intend to describe all variations or provide a model of what a UAM network must include:

— *Vertihubs.* Vertihubs are the largest structures. Envisioned as stand-alone buildings constructed in central, high-traffic areas, they will have around ten active takeoff and landing areas, plus 20 additional spaces for parking or maintenance. Vertihubs could also include some level of retail and other services for passengers. We estimate they could cost $6 million to $7 million to build and $15 million to $17 million per year to operate.[3] Our operating-cost estimates do not include the cost of power for charging or refueling.[4]

— *Vertibases.* Vertibases are medium-size structures, either newly built or created by retrofitting existing structures such as parking garages and corporate-headquarters rooftops. Located in medium-traffic areas, such as suburbs, or at major work or retail locations, vertibases would have around three active takeoff and landing spaces, plus six additional spaces for parking or vehicle maintenance. We estimate they could cost $500,000 to $800,000 to build and $3 million to $5 million per year to operate.

— *Vertipads.* Vertipads represent the smallest structures and would function as the spokes in the hub-and-spoke network. As with vertibases, they could be newly built or created by retrofitting existing structures. Typically located in suburban or rural locations (up to 50 miles from the rest of the network), they would have one takeoff and landing area, plus two spots for parking or vehicle maintenance. We estimate they could cost $200,000 to $400,000 to build and $600,000 to $900,000 per year to operate.

Every city will have these three structures, but the mix will likely differ. We believe that two

[3] Depending on location and traffic levels.
[4] To allow for easier comparisons, we exclude the power cost from landing fees in subsequent analyses.

Cost remains the critical element in assessing the viability of any proposed VTOL-port strategy.

types of networks could emerge—one for large, densely populated cities, such as London, New York, and Shanghai, and a second for medium-size, less densely populated cities with both urban and suburban neighborhoods, such as Dallas and Düsseldorf.

For large, densely populated cities, there could be roughly 85 to 100 takeoff and landing pads, including the following:

— vertihubs located at one or two major airports, as well as two or three city locations around major commute corridors

— ten to 15 vertibases around commuting-origin and destination areas

— five to ten vertipads at targeted areas of interest or for private use

Building this infrastructure network would cost approximately $35 million to $45 million,[5] with annual operating costs of around $110 million to $130 million per year.[6]

In medium-size, less densely populated cities, there would be around 38 to 65 takeoff and landing pads, including the following:

— vertihubs at one major airport and one or two city locations

— five to ten vertibases to handle workplace commutes and retail districts

— three to five vertipads near suburban commuter stations

Building this infrastructure network would cost between $15 million and $20 million,[7] and annual operating costs would range from $35 million to $50 million per year.

Exhibit 4 summarizes the network structures, network costs, and annual operating costs for both types of cities.

Assessing the economics of flying-vehicle networks

Cost remains the critical element in assessing the viability of any proposed VTOL-port strategy. The following four selected insights on the economics of such infrastructure networks provide some clarity about the costs associated with a flying-taxi network.

Insight 1: The infrastructure network can break even in a small, premium market

Assume that infrastructure charges are about $150 per trip—a figure that excludes charging or refueling costs, just as inner-city heliports do today when calculating their expenses. Under these circumstances, the following scenarios would allow UAM providers to break even on fixed costs[8]:

— *Large, densely populated cities.* The network would require approximately 2,200 trips per day (one trip every 60 minutes when averaged over

[5] Capital costs include the costs of construction, chargers, and integration into the power grid. The total capital cost assumes a useful charger life of ten years before obsolescence and the need for multiple sets of chargers over a 30-year period.
[6] Operating costs include the costs of rent, land use, power, labor, and traffic management.
[7] Capital costs include the costs of construction, chargers, and integration into the power grid. The total capital cost assumes a useful charger life of ten years before obsolescence and the need for multiple sets of chargers over a 30-year period.
[8] Fixed costs include those for rent, labor, air-traffic control, and technology.

Exhibit 4

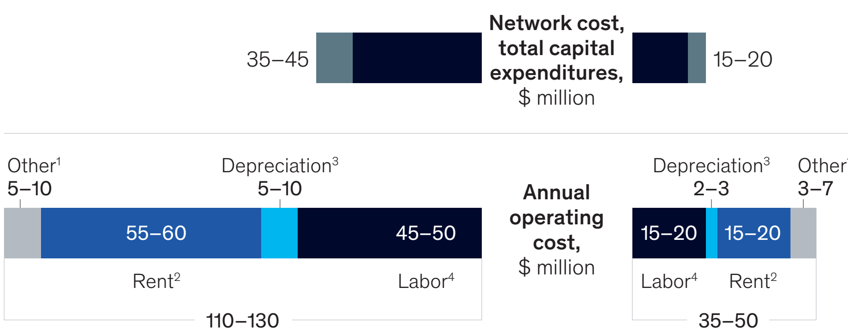
Infrastructure, network costs, and annual operating costs will largely depend on city size and population density.

Vertihub-centered-network specifications and infrastructure cost, illustrative

Large, dense, high-income urban city
(eg, London, Mumbai, New York City, Shanghai, Tokyo)

Medium-size, less dense, medium-income, urban/suburban city
(eg, Atlanta, Dallas, Denver, Düsseldorf)

Large, dense city: location	Large, dense city		Medium-size city	Medium-size city: location
Outposts, areas of interest, and private use	5–10	**Vertipads**	3–5	Major suburban commuting stations, private use for high-net-worth individuals, and wealthy suburbs
Near concentrations of high origin and destination points	10–15	**Vertibases**	5–10	Major corporate headquarters, major retail districts, and major commuting stations
Major airports, city centers, and major commute corridors	5	**Vertihubs**	2–3	Main airports, downtown areas, and major work districts
	85–100	**Total takeoff and landing pads**	38–65	



[1]Connectivity costs and regulatory fees. [2]Cost per square foot multiplied by structure dimensions. [3]30-year useful life for buildings/land. [4]Security, customer service, maintenance, and management.

24 hours). During peak travel times, this would increase to one trip every 20 minutes.

— *Medium-size, less dense cities.* The network would require 750 trips per day (one every 100 minutes when averaged over 24 hours). During peak travel times, this would increase to one trip per pad every 30 minutes.

At this price level, the per-passenger charges would be in the $50 to $75 range, depending on the number of passengers per trip. While this is expensive, the charges are similar to those for other luxury-transport options, such as black-car and helicopter travel. Essentially, UAM in this type of small, premium market would work.

Insight 2: To achieve very low trip costs, the network needs to accommodate very rapid turnaround times

To get to per-passenger charges of $25 per trip—in line with mass-market travel today—the network must generate 10,000 trips per day in a large, dense, high-income city and approximately 3,500 trips per day in a medium-size, less dense city. These trip counts translate to more than one trip every five minutes per landing pad across the network, accounting for peak travel needs. This represents a significant challenge, given the logistics of flight. Landing, deplaning, boarding, transferring baggage, charging batteries or refueling tanks, and preparing for takeoff are likely to take more than five minutes. The increasing importance of ensuring safety in a post-COVID-19 world could also increase the time between flights because of the need for intensive aircraft cleaning and appropriate physical distancing among passengers. It will likely be a challenge for every port to complete all required tasks reliably and consistently in the short time frame available.

Insight 3: Achieving a return on invested capital, excluding charging and refueling costs, could be feasible

While networks can cover operating costs through landing fees, UAM infrastructure will not be cheap to build. Construction at the sites to build the ports, tooling for maintenance activities, and other smaller expenses,[9] such as lighting and emergency preparedness, could cost between $15 million and $45 million. It also would take time to ramp up trip volume (Exhibit 5). Consider the following scenario: infrastructure gets built, and the desired number of trips ramps up over five years, which is likely a realistic time frame. In this case, the infrastructure owners would have to charge a 15 to 20 percent margin on landing fees to achieve a reasonable return on their capital investment. If passenger traffic continues to rise, network operations will increase in scale, resulting in further cost reductions and a larger addressable customer base.

Exhibit 5

Return on investment for urban-air-mobility infrastructure is more difficult to achieve when including costs for charging infrastructure, electricity, and refueling.

Return on infrastructure investment, based on inclusion and exclusion of charging-infrastructure and electricity/refueling costs,[1] %

Excluded

Margin on break-even landing fees,[2] %	Years to ramp-up to steady-state network utilization: 1	2	3	4	5
5	–12.6	–24.3	–35.5	–46.1	–56.2
10	74.7	51.3	29.0	7.8	–12.4
15	162.1	127.0	93.5	61.7	31.3
20	249.4	202.6	158.0	115.5	75.1
25	336.8	278.3	222.5	169.4	118.9
30	424.1	353.9	287.0	223.3	162.7
35	511.5	429.6	351.5	277.2	206.4
40	598.9	505.2	416.0	331.1	250.2
45	686.2	580.9	480.5	385.0	294.0
50	773.6	656.5	545.0	438.9	337.8
55	860.9	732.2	609.5	492.8	381.5
60	948.3	807.8	674.1	546.6	425.3
65	1,035.6	883.5	738.6	600.5	469.1

Included

Margin on break-even landing fees (including energy),[2] %	Years to ramp-up to steady-state network utilization: 1	2	3	4	5
5	–80.2	–82.8	–85.4	–87.8	–90.1
10	–60.3	–65.6	–70.7	–75.5	–80.1
15	–40.5	–48.5	–56.1	–63.3	–70.2
20	–20.6	–31.3	–41.4	–51.0	–60.2
25	–0.8	–14.1	–26.8	–38.8	–50.3
30	19.0	3.1	–12.1	–26.6	–40.3
35	38.9	20.3	2.5	–14.3	–30.4
40	58.7	37.4	17.2	–2.1	–20.5
45	78.6	54.6	31.8	10.1	–10.5
50	98.4	71.8	46.5	22.4	–0.6
55	118.2	89.0	61.1	34.6	9.4
60	138.1	106.2	75.8	46.9	19.3
65	157.9	123.4	90.4	59.1	29.2

[1]Medium-size, less dense city.
[2]Landing fees cover expected operating costs, such as labor and rent; for the case on the right, they also cover energy costs for charging/refueling.

[9] Smaller costs include those for lighting, flags, fire suppression, and emergency-response kits.

Insight 4: The cost of charging or refueling, both initially and ongoing, is significant and will affect the business case

The UAM industry is taking various approaches to vehicle propulsion, including electric batteries (necessitating fast charging or battery swapping), hybrid gas and electric, and hydrogen. The infrastructure required for superfast charging of UAM vehicles does not yet exist. To create it, networks would need to install the necessary physical hardware and then pay utilities for electricity drawn at very fast rates. In such cases, the cost of the charging infrastructure could be between 65 and 75 percent of the total initial capital expense, unlike the cost of fueling infrastructure today. Similarly, the cost of the electricity could be 30 to 35 percent of the estimated annual operating expenses.

What will it take to make this work?

Although infrastructure networks face significant economic and operational challenges, they can evolve to support the UAM market if the following enablers are present:

— *Ancillary sources of revenues.* Infrastructure operators could leverage ancillary sources of revenue beyond landing fees. Airport operators follow this strategy today, obtaining about half of their revenue from nonairline-traffic sources, such as retail, personal services, and integration fees.[10]

— *Private and corporate investments.* Private companies or individuals could invest in ports at large corporate headquarters or personal estates to help support the initial market.

— *Public-sector subsidies.* Cities and states could consider subsidizing network construction to enhance public welfare. In addition to reducing commute times, these efforts would bolster their public image and improve tourism. Cities and states that have undertaken other transport-infrastructure initiatives, such as the Shanghai magnetic rail, have often seen gains in these areas.

— *Small-scale and retrofit projects first.* Rather than starting with large and expensive vertihubs, which must be newly built, stakeholders should initially focus on encouraging trips that use existing helipads or undertaking small-scale projects to retrofit pads and bases. They should also concentrate on routes that are likely to draw the most traffic and passengers with high willingness to pay. As the market takes root and demand starts to grow, stakeholders can invest in the larger new builds.

— *Innovative power solutions.* While this article focuses on the physical space required for the UAM market to take flight, the power/fuel infrastructure required to enable rapid battery swapping, hydrogen refueling, or extremely fast high-power charging—for instance, in a two- to three-minute time frame—is also critical. Infrastructure operators should work with utilities and/or fuel providers to streamline this part of the solution.

— *Modular infrastructure solutions.* In addition to using existing helipads, the early market will benefit from “infrastructure in a box” solutions that can quickly convert the top of a parking garage or building into a functional vertipad or vertihub through a lease, subscription, or revenue-share model.

[10] Airports Council International.

Tore Johnston is a consultant in McKinsey’s Boston office, **Robin Riedel** is a partner in the San Francisco office, and **Shivika Sahdev** is a partner in the New York office.

The authors wish to thank Alex Dichter for his contributions to this article.

Flying-cab drivers wanted

Air taxis are coming. Until they can fly autonomously, this nascent industry will need many pilots.

by Uri Pelli and Robin Riedel

Originally published June 2, 2020

Flying cabs may smack of science fiction, if not of science fantasy. Yet many mobility experts envision a future of small, car-like vehicles that avoid the congested streets of our cities by zipping through the skies above them. More than 250 businesses of all forms and sizes are preparing to manufacture, build, or operate these air taxis in the next five years. These will mostly be multi-rotor or multi-winged electric vehicles that take off and land vertically, seat two to six passengers, and have a 30-to-300-mile range. While some might personally own such vehicles, we expect the vast majority to be operated in a shared fashion. When this urban air mobility (UAM) market reaches scale and its full potential, our latest estimates suggest, the global opportunity will be on the order of hundreds of billions of dollars a year.[1]

But the flight path from here to there is uncertain. UAM needs to overcome a number of challenges—from technology to regulatory to public acceptance to air traffic management to physical infrastructure—to name a few. In addition, it needs to resolve a pilot challenge. These vehicles will eventually fly autonomously, but that could take a decade or more because of technology issues, regulatory concerns, and the need to gain public acceptance. Until autonomous flight of hundreds or thousands of vehicles above cities across the globe becomes a reality, the industry must recruit, train, and deploy thousands of pilots—an important but much less visible challenge than other issues associated with UAM.

Pilots will help the public recognize the value proposition for UAM. Before taking flight, however, they must gain experience with this new mode of transport and help compile data about it. Pilots must also understand broader operational issues and help build confidence in the industry's safety and reliability among regulators and the public.

Although neither the length nor the nature of this transition to autonomy is obvious, we have identified four key phases:

— no automation or human assistance (current capabilities, where computer systems may assist human pilots by reducing workload and providing safety protections)

— partial and conditional automation, in which pilots provide some control from the ground but onboard automation systems control the majority of activities

— high automation with remote supervised vehicles (one supervisor on the ground monitoring multiple aircraft)

— full automation[2]

UAM providers may be able to leapfrog some stages, or some stages could overlap.

Four major headwinds

The industry will have to recruit, train, and pay thousands of pilots during the next decade or so, before it reaches full autonomy. That reality will beget a range of challenges for businesses eagerly anticipating their automated future.

The cost challenge

Pilots increase costs and the complexity of operation. Our models (using reasonable assumptions about key inputs, such as energy prices, the cost and utilization of vehicles, landing fees, and pilots' salaries) suggest that the cost per passenger-seat-kilometer of a piloted UAM flight could be up to twice the cost of an autonomous one (Exhibit 1).

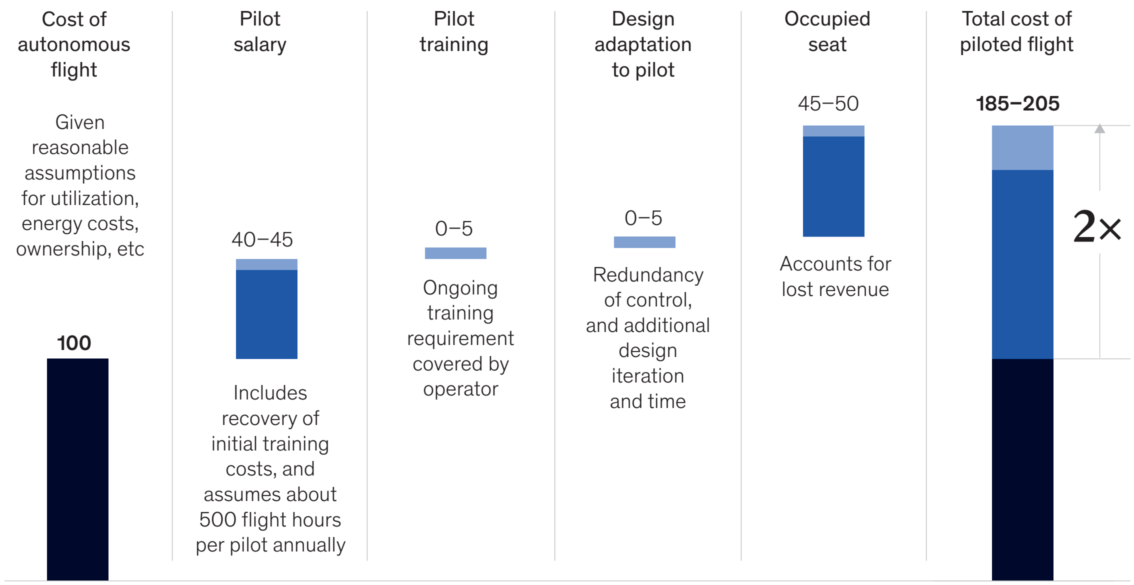
The higher cost will dampen demand for air taxis and reduce the profits of their operators, which might have to accept losing money while they develop their networks, platforms, and customer base. Although this situation may be challenging, operators can hope to recover their losses when autonomy at last arrives.

[1] All financial values are stated in constant 2019 US dollars.
[2] This classification resembles the autonomous-ground-vehicle vision of the Society of Automotive Engineers.

Exhibit 1

The cost per passenger-seat-kilometer of a piloted urban-air-mobility flight could be up to twice the cost of an autonomous one.

Piloted urban air mobility (UAM), cost per passenger-seat-kilometer,[1] %



[1] Constant 2019 US dollars, not adjusted for inflation.
Source: McKinsey analysis

The pilot-sourcing challenge
Finding, training, and retaining enough pilots will be another big challenge. Before COVID-19 brought global aviation to nearly a standstill, operators of smaller aircraft were already having difficulty finding qualified pilots. Projections from before the crisis suggest that the already-tight supply of commercial pilots would become even tighter in the future: at that time, current commercial operations were expected to require 320,000 newly trained aviators over the next ten years.[3] The COVID-19 crisis will defer the need for these pilots by a few years and potentially even lower the number required if commercial aviation does not return to its original trajectory. That said, there will still be a need for most of those new pilots toward the end of the decade. Pilots for UAM would come on top of that.

Before the pandemic, several promising and well-funded players announced that they were aiming to start UAM operation by 2023. Of course, the COVID-19 crisis might slow a few players down and shift the start dates by a year or two. But our modeling, based on announced launch dates and expected delays, success rates, production ramp-ups, and market constraints, suggests the industry could require about 60,000 pilots by 2028, roughly 17 percent of the total number of commercial pilots in 2018 (Exhibit 2).

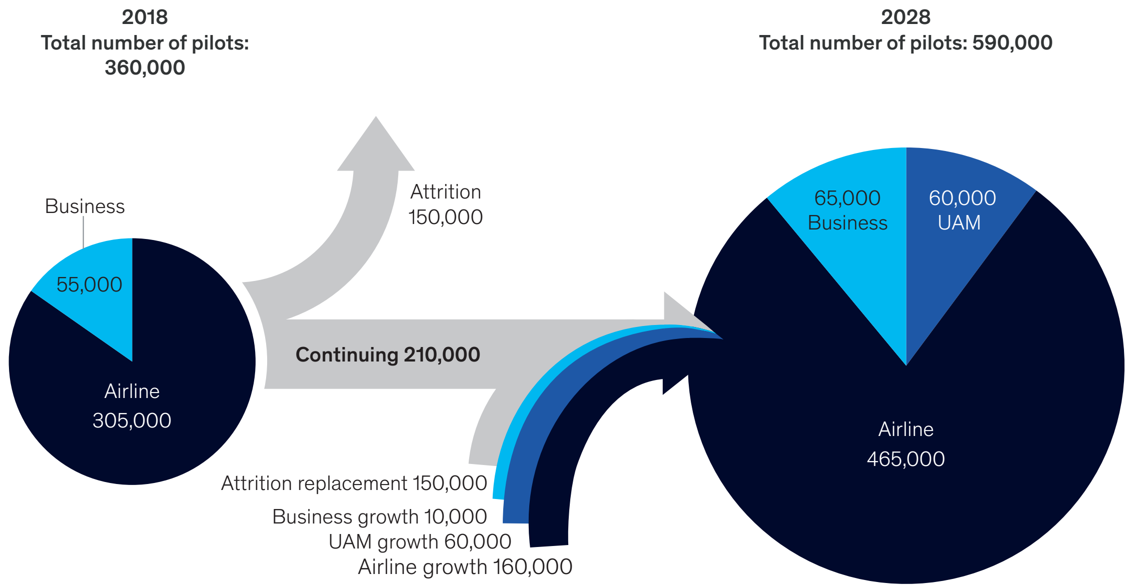
Some efforts to reduce the requirements for UAM pilots,[4] and consequently the training burden, are now under way. Approved programs seem many years distant, however. Until then, prospective UAM pilots will have to take today's training

[3] "Airline and business jet pilot demand outlook: 10-year view, 2018 update," CAE, 2018.
[4] For example, through the concept of Simplified Vehicle Operations (SVO), now being explored by, among others, the US National Aeronautics and Space Administration (NASA), the US Federal Aviation Authority (FAA), and the General Aviation Manufacturers Association (GAMA).

Exhibit 2

Urban air mobility (UAM) will accelerate demand for pilots.

Number of pilots required to fulfill urban-air-mobility (UAM) need in next decade



Note: Numbers are rounded.
Source: "Airline and business jet pilot demand outlook: 10-year view, 2018 update," CAE, 2018; McKinsey Flight Crew Model

programs. Given current training costs, it will take about $4 billion to $6 billion to train 60,000 new UAM pilots. If these aspiring aviators, like the majority today, pay for the training themselves, financial institutions must step in to overcome the tight supply of financing.

Another important challenge will involve creating a value proposition that will encourage people to embrace careers as UAM pilots despite the expense of basic flight training, the 12- to 24-month training period, and—most critically—an uncertain future. The UAM industry is quite vocal about the need to automate, potentially limiting the career of a UAM pilot to a few years. The net present value of a five-year UAM career could be quite low or even negative, given the upfront training cost and the opportunity cost of training time without income, even if compensation levels were in line with current early career pilots (around $40,000 to $60,000 per year). Further, UAM piloting skills and experience may not be transferrable either within or beyond the aviation industry. Many people might therefore believe it would be better to pursue other professions.

Most aspiring UAM operators now focus on technology, employ few if any pilots, and lack experience managing a large operational work-force—whether employed or contracted. All these things will also interfere with sourcing pilots.

The customer-experience challenge

A pilot's presence in a small capsule without a separate flight deck will surely affect the customer's experience of the ride and perceptions of its safety—potentially both positively and negatively—much as experiences with taxi or rideshare drivers do today. In turn, the pilot's presence will influence the willingness of consumers to embrace a new mode of transport. No one quite knows which protocols for customer–pilot interactions will create the safest and most comfortable environment. Will pilots be allowed or even encouraged to converse with passengers? Should they help customers who feel airsick? How will they balance these tasks with safely operating the aircraft? And what kind of behavior by pilots will give passengers confidence in the safety of the flight? Operators will have to find answers to these questions.

The aircraft-design challenge

A pilot's presence further has implications for the design of UAM vehicles. In addition to the pilot's seat, it will be necessary to design controls and interfaces between the pilot and the aircraft. Industry players will need capabilities (for instance, in human factors) that will be superfluous on autonomous vehicles, and the transition from piloted to autonomous vehicles will require significant redesign of the vehicles. The point is not that piloted vehicles will be harder to design or more complex than autonomous ones but rather that they will be quite different. After spending some years designing and producing one kind of air taxi, their manufacturers will have to switch to designing and producing another.

Piloting the transition to autonomy: Four key initiatives

To address the challenge of recruiting, training, and certifying UAM pilots during the early years of UAM, the industry should pursue four key initiatives. All will require collaboration across a range of stakeholders, including vehicle manufacturers, technology players, operators, regulators, and flight schools.

Streamlining the training and certification of pilots

The industry and its regulators must develop a new kind of certification for UAM pilots because the current standard simply does not make economic sense for them or the industry. Certification and training requirements for today's commercial pilots are complex, lengthy, and expensive—an investment, in both money and time, that UAM pilots might not recoup before automation takes over. Therefore, it is essential to redesign the training—without compromising safety, of course. Such new programs would not only streamline training but also increase the pipeline by opening the business to people who lack traditional credentials or want new kinds of jobs late in their careers.

One important area that has to change is the curriculum. For example, commercial pilots study such topics as high-altitude aerodynamics and the technical details of high-bypass jet engines, neither of which will be relevant for UAM. The new industry's pilot-training programs should also expand the scope of digital instruction, both for ground school and practical flying lessons. Relatively low-cost simulators, for instance, could replace a significant portion of the time currently needed for flight training in real aircraft, or artificial intelligence algorithms could help adapt training to the needs of individual students in real time—for instance, by identifying areas where they require remedial training.

To ensure an ample supply of pilots, operators must offer them an attractive career path. Otherwise, high pilot churn might break their business case.

Developing an attractive value proposition for prospective pilots

To ensure an ample supply of pilots, operators must offer them an attractive career path. Otherwise, high pilot churn might break their business case. The career path might, in some cases, extend beyond operating UAM vehicles for a few years. The options could include serving in nonpilot roles within the operators' scope (for example, as remote operators), reskilling for a future outside aviation, or a transition to piloting commercial jets. The latter option would require flow-through agreements with airlines and financing for type-rating training. Operators could also subsidize the cost of basic flight training to improve the economics of a UAM pilot's short career and make it easier to enter.

Managing the pilot workforce

As we have noted, none of the aspiring UAM operators have strong, rigorous employee-management functions to recruit, retain, and direct employees. They will have to develop these capabilities when they scale up. They will also have to build the capabilities specific to managing pilots, such as those required to optimize schedules, ensure regulatory compliance, create an effective safety culture, and manage organized-labor contracts.

Leveraging pilots to provide an excellent experience and increase UAM's public acceptance

Although the need for pilots will increase the costs and complexity of the UAM business, it may improve customers' experience of the ride, as well as perceptions of its safety. This, in turn, will influence the willingness of potential customers to embrace an exotic new mode of transport.

Operators should design their businesses with pilots in mind and use them to improve the customer experience. A pilot, for example, could not only instill confidence among passengers but also greet them and help them load and unload luggage. As we have already noted, only experience will show which protocols for customer–pilot interactions would create the safest, most comfortable environment.

In any case, pilots on board will gradually promote public acceptance of UAM itself. Our research shows that while most people are neutral or positive about the basic idea, they prefer flying in piloted vehicles, and the very notion of a remotely piloted one will deter some potential customers, at least for now. As the need for human controls progressively declines, the market will gradually come to accept full autonomy.

While UAM's long-term future will be autonomous, the industry must initially recruit, train, certify, and manage tens of thousands of pilots. This will likely only be the case for a few years—a problem in its own right, since pilots might not recoup their training investment, including forgone income, during their careers. Stakeholders across the spectrum—manufacturers, operators, flight schools, regulators, and employment agencies—must collaborate to tackle the significant challenges the piloted ramp-up period is certain to pose. They do not have a lot of time to prevent the supply of pilots from becoming the bottleneck that stalls this new industry's development.

Uri Pelli is a consultant in McKinsey's Philadelphia office, and **Robin Riedel** is a partner in the San Francisco office.

The authors wish to thank Alex Dichter, Guenter Fuchs, and Tore Johnston for their contributions to this article.

The emerging AAM ecosytem

Going vertical: How emerging technologies will power a new value chain

As advanced air mobility takes flight, where to play in the value chain will be a key focus for successful companies.

by Tore Johnston, Benedikt Kloss, Adam Mitchell, and Robin Riedel

Originally published August 31, 2021

As advanced air mobility (AAM) businesses move from initial concept to at-scale mobility platforms, a new type of value chain will emerge—one that will be quite different from the traditional aerospace value chain. To capture value in this space, leaders will need a strong understanding of how value pools will shift over time and clear strategies for where to play. The shift could play out in a variety of ways: see the exhibit for one possible scenario. In addition to the revenue breakdown, organizations will also need to understand the margins involved. Some of the points along the value chain will have comparatively lower revenue but higher margins due to higher barriers to entry (for example, batteries).

The AAM value chain differs from the traditional commercial aerospace value chain in several ways. To begin with, pilot expenses are likely to make up a much larger percentage of the value chain, at least initially. AAM aircraft typically have a higher pilot-to-passenger ratio, with most vehicles capable of carrying three to six passengers, while a domestic commercial airliner seats about 160 passengers.

In addition, propulsion systems like engines, batteries, and motors are likely to account for a smaller share of the value chain in AAM than in today's commercial aerospace. AAM has no need for high-temperature combustion engine technology that requires multimillion-dollar rebuilds every couple of years. Electric powertrains have a simpler design and are lower cost than hydrocarbon-based alternatives.

Finally, mobility services could make up a larger share of the AAM value chain, due to the higher degree of intermodal coordination required (that is, ensuring fast transitions between traveling to the vertiport, takeoff and landing, and taking another mode of transport to the final destination). In addition, typical AAM trips will be shorter distance due to initial technological limitations, further increasing the ratio of mode switch to transit time.

Here are three insights that can help leaders prepare for the shifts ahead.

Insight 1: Automation has the potential to substantially reduce costs and unlock a larger market

Pilots are one of the most significant drivers of value and cost for the AAM sector, accounting for an estimated 15 to 25 percent of total value. One way to reduce costs, once regulation and technology allow for it, is to move the pilot from the vehicle to a control center on the ground in 1:1 pilot-to-vehicle operations. This will begin to shift the value chain from pilots to vehicle control centers, and it will allow mobility providers to earn revenues from an additional passenger seat. In the long term, the 1:1 operation ratio may go down to a 1:5 pilot-to-vehicle operation ratio or even more, depending on regulatory developments, potentially reaching close to full autonomy and reducing pilot costs. However, we estimate that 60,000 new electric vertical takeoff and landing (eVTOL) pilots may be required by 2028, which may create a challenge for operators.

Insight 2: Mobility services may become a control point, charging fees that are comparable to today's ride-hailing platforms

Connecting vehicle operators with consumers via a mobility platform may be a future control point[1] if platforms can acquire a sufficiently large customer base to achieve network effects and offer intermodal integration. In this case, our estimate of 20 to 25 percent value creation is comparable with today's e-hailing services, which generate value of more than 20 percent. This value varies from city to city, which might be also the case for future AAM offerings.

Furthermore, as our recent global AAM Consumer Survey shows, consumers' top motivation for considering AAM services is to save time. The ability to access vertiports quickly and efficiently will make or break the time-saving value proposition of eVTOL. Thus, integration into the broader mobility ecosystem will be crucial.

[1] A control point is a component of the value chain that most likely will not become a commodity and typically requires specialized capabilities. Owning these control points can give players market power over other parts of the value chain.

Exhibit

As the advanced air mobility sector gains momentum, the value chain will evolve. Here's one way it could play out.

Potential value distribution, 2030[1]

Value chain breakdown
% of total consumer spending

% of total consumer spending	**Value chain categories**	**Underlying categories** (not exhaustive)
1–5	Battery	Batteries and fuel cells
5–10	Hardware and software components supply	Traditional components (eg, airframe), eVTOL hardware, eVTOL software[2]
1–5	Vehicle manufacturer	Research and development, vehicle design, vehicle integration, testing, validation
5–10	Asset provision	Financing and asset ownership, insurance
10–15	Aftermarket	Maintenance and spare parts
15–25	Infrastructure	Starting and landing infrastructure, charging infrastructure, passenger infrastructure, energy sourcing, ground operations, passenger handling, etc
15–25	Pilots	Pilot salary, pilot training
1–5	Tech platforms	Cloud services and data management, flight operations platform, cybersecurity
1–5	Air traffic management	Air control hardware and software, air traffic control center, control center (including fleet management)
20–25	Mobility services	Consumer interface platform, meta or aggregator platform
Total 100		

[1]Distribution scenario is based on the following assumptions: Vehicle base value at $2 million; average vehicle lifetime 10 years; average annual capital expenditures and operating expenditures per operator for vertiport infrastructure at ~$60 million; average lifetime across all "infrastructure devices" of 70 years; annual pilot costs per urban air mobility vehicle at ~$420,000 (several shifts, onboard pilot); annual maintenance costs per vehicle at ~$260,000; share of mobility platform comparable to today's ride-hailing businesses.
[2]eVTOL stands for electric vertical takeoff and landing.
Source: McKinsey Center for Future Mobility

Insight 3: Infrastructure (including charging) may account for a major percentage of the value chain

We estimate that the necessary ground infrastructure in a city such as London or New York could require capital expenditures of $35 million to $45 million, with $110 million to $130 million in annual running costs.[2] Existing funding is unlikely to cover the full cost of infrastructure, so operators and end users might be required to take on these costs (potentially 15 to 25 percent of the value chain). So who will cover the remaining costs?

If operators could make infrastructure profitable by attracting retail stores and restaurants as tenants, it may encourage greater investment in infrastructure. However, if infrastructure cannot be operated profitably and turns out to be an enabler for the overall business, a greater share of investments may fall on manufacturers (in order to sell their vehicles), on operators (in order to provide the service), on the public sector, or on a partnership between them.

As the AAM industry gains traction, organizations that want to capture value in this space will need to evaluate their competitive advantages to determine where they should play on the AAM value chain. Successful players will identify future control points and develop a clear understanding of how shifts in the value chain could affect their strategies.

---

[2] This would include a moderate-size network of approximately 60 to 75 landing pads of different sizes (for example, three "megahubs," eight hubs, and four ports).

Tore Johnston is a consultant in McKinsey's Boston office, **Benedikt Kloss** is an associate partner in the Frankfurt office, **Adam Mitchell** is a consultant in the Toronto office, and **Robin Riedel** is a partner in the San Francisco office.

Final approach: How airports can prepare for advanced air mobility

Advanced air mobility is becoming a reality. Airport operators need to assess the opportunity and integrate it into their planning.

by Florian Brummer, Olivier Chéret, Moira Goulmy, and Robin Riedel

Originally published November 19, 2021

With the COVID-19 pandemic wreaking havoc in global aviation over the past year and a half, the airport industry has been hit hard. The number of scheduled passengers boarded onto planes dropped from about 9.1 billion to 3.6 billion from 2019 to 2020—a decrease of 61 percent—and airport revenues were $129 billion lower than the pre-COVID-19 forecast of $199 billion, representing a reduction of about 65 percent.[1] The year 2021 is set to look only slightly better, with an estimated reduction of about $110 billion in revenues compared with the pre-COVID-19 forecast.[2] Simultaneously, airport operators have had to implement stringent safety protocols to protect passengers and employees. Amid this disruption, they have had little time to focus on the future.

While the industry's short-term difficulties are not yet over, passenger traffic volumes have started to increase in most regions and should ultimately recover. As they do, airport operators face another transformative challenge: the need to integrate a new range of manned and unmanned aerial vehicles into their operations and infrastructure, including battery- or hydrogen-powered conventional aircraft; drones for tasks such as cargo movement, aerial surveillance, or even firefighting; and passenger advanced air mobility (AAM), leveraging electric vertical takeoff and landing (eVTOL) aircraft.

All these aircraft are poised to disrupt the aviation industry significantly. Many of the most significant changes will come from the growth of passenger AAM, which involves smaller aircraft (typically two to seven seats) and a regional range varying from a few dozen to a few hundred miles. Passenger AAM aircraft, which can take off and land vertically without the need for a traditional runway, will initially require pilots. In the future, however, autonomous flights may be possible. These aircraft provide a faster and sustainable option for travelers, since they are powered by electricity or hydrogen, but they also will require new infrastructure and will change long-standing passenger flows.

It is likely only a matter of years before AAM innovations truly take off. McKinsey's AAM database lists more than 250 active AAM projects across the globe with more than $11 billion in disclosed investment over the past five years and more than 5,000 employees globally as of August 2021. Investors, including venture capital funds, special-purpose acquisition companies (SPACs), high-net-worth individuals, and global leaders in the aerospace and automotive industries, are backing specialist start-ups, and several full-scale prototypes are already undergoing flight tests. Around the globe, work is under way to adapt regulatory frameworks and to gain public acceptance. The front-runners are publicly committed to launch commercial operations by the mid-2020s.

The speed and scope of these developments make integrating AAM an issue of high relevance for airports. Owners and operators must begin planning for this emerging transport mode today, given the long timelines for building infrastructure and for making other necessary changes. This article makes the case for action by airport owners and operators to seize this opportunity and examines the key industry developments they should have on their radar. While some operators might be hesitant to move forward now, the experience with another recent innovation offers a cautionary tale. At airports, the unanticipated arrival of ridesharing created confusion at airport curbsides, and many facilities missed revenue opportunities. Because these disruptive new services were not accounted for in the master plans, airports had to resort to patch-up solutions that often irritated travelers, such as busing them to rideshare areas. In addition, airports were not prepared for the loss of parking revenues that occurred as travelers switched from

[1] "The impact of COVID-19 on the airport business and the path to recovery," Airports Council International, March 25, 2021.
[2] Ibid.

their own cars to ride hailing. As AAM takes off, airports will want to avoid similar challenges.

Airports are uniquely positioned to benefit from early AAM growth

Airports are likely to be at the center of the AAM revolution, at least in the beginning. Their prominence will result partly from the fact that more than two-thirds of the 25 largest AAM companies have stated that airports are among their initial target markets. There are good reasons for this focus. First, the economics are attractive because of high, bundled demand for last-mile connections—the vital and currently congested links between airports and the urban areas they serve. Second, some of the basic infrastructure is already in place, both on the ground and in the air, and airport operators have the relevant skills and experience needed to manage facilities. Third, there are obvious customer benefits. AAM flights could save 40 to 60 percent of the time spent traveling to airports on ground transportation within and beyond the city limits. Business passengers would be natural early adopters.

The main use cases for AAM flights involve transport between a hub airport and vertiports in city centers or the broader catchment area, or between a hub airport and AAM landing sites at smaller regional airports. The ease of implementing these use cases will vary. For instance, an AAM connection linking an airport to a city vertiport may be difficult to achieve because of the time, complexity, and cost of developing the downtown infrastructure. Flights to vertiports in a broader suburban and rural catchment area, though less in demand, might be easier to establish and could decrease travel times.

All three use cases will require airports to integrate AAM connections into their infrastructure, investment, and business planning. And each use case will involve distinct challenges, making a "one size fits all" approach impossible.

We project that large and densely populated urban areas, such as London, Los Angeles, and Mumbai, will eventually require networks of up to 30 vertiports or AAM landing sites at small airports. Even medium-size urban areas, such as Atlanta and Düsseldorf, could need as many as 20. These facilities must offer a range of services similar to those found in today's airports, such as passenger processing facilities, waiting areas, and aircraft-handling and maintenance areas. Such "satellite" airports could further reduce door-to-door travel time and enhance the traveler's experience.

Vertiports could be managed by a diverse group of players, including those in rail, public transport, real estate, and aviation ground handling. Regardless of who is in charge, AAM vertiports could serve as physical extensions of existing airports, providing a gateway to flights originating in city centers. Airport operators might be well positioned to manage vertiports, since they already have most of the required capabilities and can capture many synergies with their traditional operations.

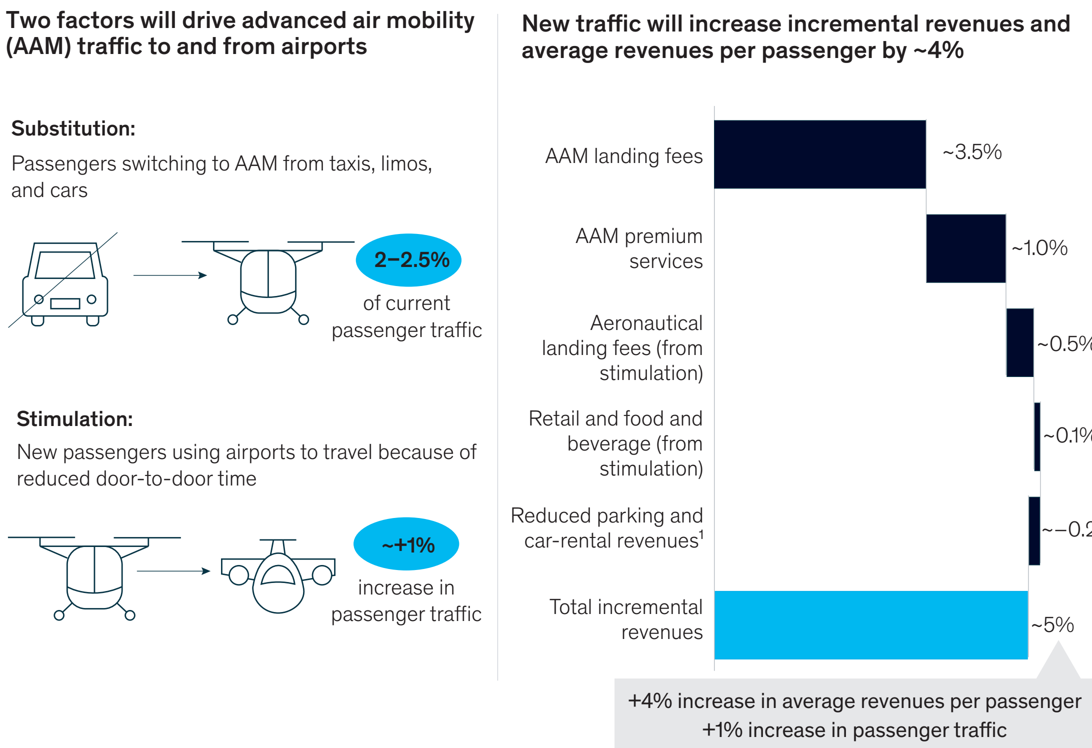
Even a modest AAM offering at airports could generate new revenues. Some business will come from existing passengers who prefer AAM over other types of short-haul transportation, especially if it reduces door-to-door time. Some passengers may even make extra trips because of the greater convenience.

Airports could charge landing fees to AAM operators in the same way that they charge fees to airlines. They could also provide additional services for a fee, such as charging infrastructure or ground servicing. Additionally, the new passenger traffic would increase nonaeronautical revenues from retail or food and beverage. Revenues from ride hailing, taxi fees, parking, and car rentals would slightly decrease, but the overall balance would remain largely positive. We estimate that in a hypothetical airport that serves 45 million passengers per year, AAM may generate incremental revenues of about 5 percent and increase passenger numbers by around 1 percent (Exhibit 1).

The promise of boosting passenger traffic might sound far-fetched, but experience with other novel modes of transportation suggests that it is achievable. For example, in Italy, the opening of the Milan–Bologna and Florence–Bologna high-speed-rail connections, in 2008 and 2009, contributed to the Bologna airport's annual

Exhibit 1

For a typical airport, a modest AAM offering could generate incremental revenues of about 5 percent and increase passenger traffic by around 1 percent.



[1]Includes ride-hailing and taxi fees.
Note: Estimates based on a US airport serving 45 million passengers per year.

passenger-traffic growth rate of 7.0 percent—almost double the average of 3.7 percent in the country. The Bologna airport also significantly increased its market share among air passengers within its 200-kilometer-radius (about 125 miles) catchment area. With similar numbers, AAM vehicles could present an attractive opportunity for airports concerned about revenue growth.

Airports need to integrate the AAM opportunity into their planning

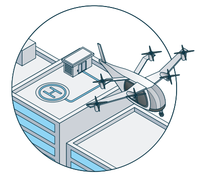
Airport terminals and landside expansion projects are complex, multibillion-dollar undertakings. They require alignment among multiple stakeholders as well as intense environmental assessments, feasibility studies, and many years of planning, assessment, and consultation before construction even starts. With the first commercial AAM routes expected by the middle of the decade and scale-up anticipated near the end of the decade, airports must integrate these routes into their medium-term plans to make them future proof (Exhibit 2).

The challenges of doing so cannot be underestimated. Consider airspace needs. AAM vehicles, analogous to helicopters and drones, likely will require specific air-traffic-control (ATC) pathways and procedures that are independent from standard runway operations. Airports that don't have sufficient capacity could reject AAM traffic altogether. Developing these procedures will take time, especially since there are still multiple uncertainties. For example, the performance characteristics of AAM are not yet sufficiently clear to produce specifications for airspace planning,

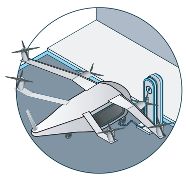
Exhibit 2

Integrating AAM into airport master plans requires a holistic approach.

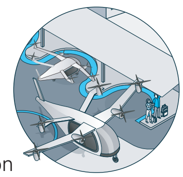
Integrate advanced air mobility (AAM) in airspace
eVTOL aircraft are expected to need procedures that allow independent activity from runway operations



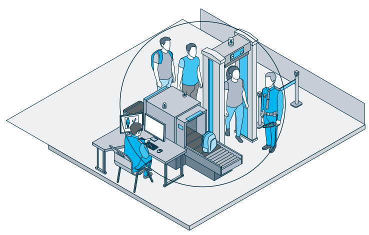
Collaborate with utilities to develop the charging infrastructure
This must enable ultrafast high-power charging



Plan location of AAM landing sites at airports early
An AAM landing site at an airport requires 1–3 acres of land, implying that its development needs to be integrated into the master plan early on



Develop and operate satellite vertiports to increase ecosystem attractiveness
AAM vertiports in city centers or neighborhoods could become physical extensions of the airport, providing a gateway to the terminal



Integrate AAM landing site within terminal operations
This step will be key to enhancing the customer experience and to materially reducing door-to-door time. Important processes include security checks and luggage handling

and in the worst case could differ massively (for example, between aircraft using vectored thrust and multicopters).

On the ground, airport owners and operators must plan the location of AAM landing sites early, since they will require one to three acres of land. As noted earlier, these facilities will ideally be integrated into terminals if they are built at existing airports. If airports decide to create satellite vertiports to extend their reach, airports must plan where and when to develop them.

Finally, airports need to develop the infrastructure required to enable ultrafast high-power electric charging and hydrogen refueling. Many airports around the world are working toward electrifying ground-service equipment, such as pushback tractors, aircraft-fueling trucks, and baggage loaders.

An AAM agenda for airport CEOs

While several airports have recently announced partnerships in the AAM space, barely any of the top 50 major airports currently undertaking significant terminal and airfield expansions have explicitly stated that they are factoring in infrastructure for passenger AAM use cases. Although designing for an uncertain future is difficult, airports that hesitate to take action now could put themselves at a competitive disadvantage—and they might eventually have to spend more on infrastructure and other changes or risk losing opportunities. To stay ahead of the competition, airports should consider taking the following steps.

Consider the AAM opportunity now, defining how to integrate AAM flights into operations

Airports may hesitate to dedicate money to AAM, but experience shows that winners embrace innovation. Wellington Airport in New Zealand, for example, avoided most of the chaos experienced by airports in other countries when ridesharing became popular because its leaders specified in 2017 that the airport would create dedicated pickup and set-down space for ridesharing in exchange for a $3 fee for every ride. Similarly, some airports reached early agreements with governments and rail operators about the development of airport stations, which allowed them to decrease congestion and increase market share in their catchment areas. London's Heathrow Airport, for example, operates the Heathrow Express as a subsidiary. The rail service transports more than six million passengers a year and achieves an annual revenue of around £120 million.

In addition to exploring passenger AAM now, airports should investigate cargo opportunities, since use cases in this area may gain traction earlier. Cargo AAM may also have many synergies with passenger AAM.

Weigh different business-model options
Airport operators should define their approach to AAM and create a business model based on one of the following options:

— *Light touch.* This model focuses on repurposing existing assets, such as business aviation terminals, and adding electric charging, hydrogen infrastructure, or both to accommodate AAM flights. Airports would invest in larger assets only when demand grows.

— *Dedicated investment.* Under this model, airports would set aside land and provide electric charging, hydrogen infrastructure, or both at terminals for AAM. They would also develop plans to integrate AAM travelers into the passenger flow through airports' facilities.

— *Betting on AAM.* In addition to making dedicated investments in existing facilities, this model requires airports to codevelop and/or operate vertiports in their catchment area, either as an owned business or as a service to third parties.

Set up a planning process based on codevelopment
To manage the AAM journey, airports can undertake a cooperative, staged approach. The first step would involve earmarking locations now and creating concept designs for AAM landing sites at their facilities. As AAM certification efforts continue, airport operators will have access to more robust performance data, as well as greater insight into operational concepts, both of which will allow them to create more detailed designs and specifications.

Airports could also band together to orchestrate discussions with OEMs and regulators on the future performance and infrastructure requirements of AAM vehicles. This collaboration will help them understand whether they can create standard infrastructure elements that will meet the needs of all operators or whether vehicle specifications are so different that customized facilities are needed. If the latter scenario appears likely, airports could strategize and plan for the challenge of developing an AAM landing site that could accommodate AAM providers with different vehicle dimensions, concepts of ground operations, and battery charging or swapping requirements.

Finally, airports need to get ATC authorities on board as early as possible. AAM promises to rewrite the rules concerning airspace around airports. For the past 50 years or so, airports have benefited from operating within restricted control zones. That might change as AAM grows, but current ATC rules do not offer a ready-to-use solution, such as the reservation of specific air corridors for AAM vehicles.

No time like the present

AAM vehicles are already well on their way out of science fiction books and toward commercial service. For airport operators and owners, with their need to plan two or three decades in advance, these vehicles are practically already here. Within the next two years or so, airport operators will inevitably find themselves in discussions on how to integrate new urban aircraft into their facilities, and indeed whether to turn AAM into an important new pillar of their business. The time to consider these challenges and embrace the potential opportunity is now.

Florian Brummer is an alumnus of McKinsey's Munich office, **Olivier Chéret** is an associate partner in the Montreal office, **Moira Goulmy** is a senior expert in the Amsterdam office, and **Robin Riedel** is a partner in the San Francisco office.

The authors wish to thank Axel Esqué, Benedikt Kloss, and Tore Johnston for their contributions to this article.

Apples and oranges: Making sense of the economics of advanced air mobility

As an emerging industry prepares to operate and compete with other forms of transportation, we need a clear understanding of unit metrics.

by Andrea Cornell, Axel Esqué, and Robin Riedel

Originally published October 1, 2021

Flying taxis, passenger drones, electric regional aircraft, and other forms of advanced air mobility (AAM) are a hot topic in aviation. Funding is pouring into the space, and more than 250 companies are working on solutions. And as the industry advances toward the first commercial operations—expected around the middle of the decade—leaders are carefully reviewing and adjusting business plans to understand where they can make profits and see a return on their investments.

An important building block of business plans is unit metrics for cost and revenue. Unit metrics can offer easy benchmarks across business models and time, help AAM leaders evaluate their competitiveness with other modes (such as personal car, public transit, or ride-hailing), and model scaling and growth. But while unit metrics such as “price per mile” seem intuitive and easy to use, they also hold significant risk of misinterpretation. Used incorrectly, they can easily lead to false conclusions—such as making the market seem larger than it is or making an option seem better than alternatives when in reality it is worse—and this in turn can lead to investment in the wrong businesses, development of the wrong aircraft and mobility models, and, ultimately, value destruction.

With unit metrics, the devil is in the details. While it might seem obvious to some, a surprising number of people compare apples and oranges when talking about this industry. To fully understand the economics, we need to clearly define unit metrics and make sure we’re comparing apples with apples. The following discussion aims to provide some clarity about how to properly adjust unit metrics. It does not mean to endorse any absolute price points—that requires a longer and deeper discussion.

Defining unit cost and revenue

Unit cost for transportation is usually seen as cost per unit of distance (for example, dollars per passenger mile), but in the context of AAM, two things need to be clearly defined: the scope for which the cost is assessed, and how the distance is measured (exhibit).

On the scope side, we can look at cost from several different perspectives: cost per vehicle, cost per seat, and cost per passenger. There are also three ways to think about distance: the direct (great circle) distance, which is the most direct path between two points; the road distance, which reflects the indirect nature of road travel; and the air distance, which is the aircraft’s flight path. Air distance tends to be shorter than road distance but longer than direct distance because the aircraft needs to maneuver for takeoff and landing and around other traffic and geography.

To demonstrate the importance of these distinctions, the exhibit shows a unit revenue, or price, comparison between a hypothetical AAM provider and a ride-hailing service. As shown, there are nine different ways to define unit price. If the typical ride-hailing service costs $3 per vehicle road mile and the AAM cost is $2.50 per passenger flight mile, at face value the AAM player appears to have a lower cost. But that conclusion assumes that there’s only one passenger and that both vehicles follow the same route. Because the car will likely take a less direct (and thus longer) route, it is not a fair comparison. A more insightful comparison is to adjust toward a common definition of distance.

In this example, we adjust to a common definition by assuming that the car’s route will be about 33 percent longer than the direct distance because the car has to use roads. Similarly, we assume the aircraft adds 10 percent in distance to allow for takeoff and landing paths and constraints along the route. With that adjustment, the cost becomes $4.00 per vehicle direct mile for the car and $2.75 per passenger direct mile for the aircraft—making the AAM costs look even better. But this is still not an apples-to-apples comparison, because it compares price per vehicle with price per passenger. When the car is carrying two passengers, for example, the price per passenger direct mile drops to $2.00—well below that of the AAM at $2.75 (exhibit).

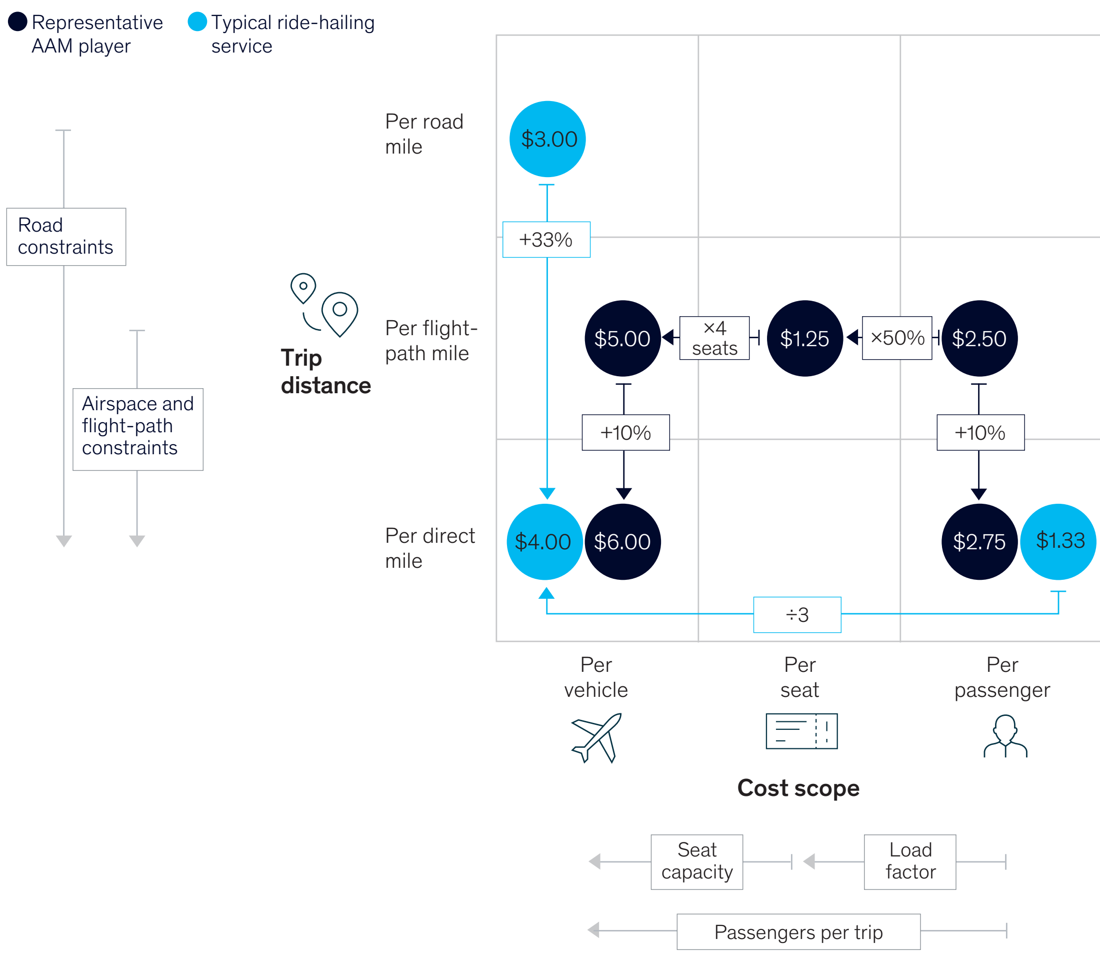
Length of trip matters

We also need to consider the length of the trip. Every transportation mode has both fixed costs per

Exhibit

Understanding the economics of advanced air mobility (AAM) relies on clear definitions of the scope of the cost and the distance of the trip.

Illustrative example



Source: McKinsey analysis

departure (such as landing infrastructure or booking fees) and variable costs (such as energy). Fixed costs are spread across the entirety of the trip, so if all else is equal, shorter trips tend to have higher unit costs and revenues. When comparing business plans and financial reports, it is important to acknowledge this effect and adjust the unit metrics accordingly.

In traditional air transportation, the distance square-root adjustment formula provides a good approximation of the impact of stage length on unit metrics. To adjust, one multiplies the unit metric by the square root of the actual stage length of the metric divided by the stage length one would like to adjust to. The ratios of fixed to variable costs published by a number of AAM companies suggest that the distance square-root adjustment formula will also be a good approximation for this new industry, at least to a point. As the distances grow farther apart, the different design points of each aircraft will start to play an important role and break the validity of the adjustment formula.

As the distances grow farther apart, the different design points of each aircraft will start to play an important role and break the validity of the adjustment formula.

For example, a hypothetical AAM has a cost of $1.75 per seat flight mile at a 25-mile reference stage length, while another hypothetical AAM has a cost of $1.50 at a 35-mile stage length. At first glance, the second AAM appears to have lower costs. But when its path is adjusted to the first AAM's stage length—$1.50 * sqrt (35/25) = $1.77—the two costs turn out to be nearly equivalent and thus quite competitive.

These adjustments, both for the proper definition of unit metrics and for trip length, are necessary to get a proper view of the AAM business. Players that fail to use unit metrics correctly could easily make poor decisions leading to value destruction.

Andrea Cornell is a consultant in McKinsey's Denver office, **Axel Esqué** is a partner in the Paris office, and **Robin Riedel** is a partner in the San Francisco office.

Industry perspectives

Rideshares in the sky by 2024: Joby Aviation bets big on air taxis

Originally published
November 19, 2021

Joby executive Bonny Simi sees a future in which aerial ridesharing is popular, traveling between rural and urban areas is quick and easy, and the pilot workforce is much more diverse.

Bonny Simi

"By 2030, Joby Aviation will be the world's largest airline by departures." The confidence with which Bonny Simi makes this prediction isn't surprising when one considers her background: Simi, who is Joby's head of air operations and people, was a longtime commercial pilot and a US Olympic bobsledder and luger. She was also the founding president of a corporate venture-capital fund. She doesn't shy away from risk, she's accustomed to doing things that others find scary, and she likes to go fast.

Joby, founded in 2009 by entrepreneur and engineer JoeBen Bevirt, has developed an electric vertical takeoff and landing (eVTOL) aircraft that seats five people—a pilot and four passengers—and can travel at speeds of up to 200 miles per hour. And it's gotten the attention of investors and partners: Joby is one of a handful of eVTOL players that went public in 2021. It plans to launch its air-taxi service in 2024.

During a visit to Joby's facilities in Northern California, McKinsey's Robin Riedel—himself a certified commercial airline pilot—talked with Simi about Joby's aircraft, the pilot workforce of the future, and the promise of advanced air mobility (AAM). Edited excerpts of their conversation follow.

Robin Riedel: Let's look ahead to 2030. What do you imagine the passenger experience will be like in a Joby aircraft? What will people use eVTOL aircraft for?

Bonny Simi: Imagine waking up in the morning and thinking you could drive your car to work—but that might take an hour, an hour and a half. Instead, you just open up an app. A car picks you up and brings you to a heliport five minutes away. You ride in one of our aircraft. The flight takes ten minutes. At the other end, there's a car waiting for you. The entire ride is seamless, convenient, and affordable.

Initially, aerial ridesharing will simply replace what people currently do. Perhaps it replaces a long commute on a train or ridesharing on the ground. But we believe adoption of aerial ridesharing will grow as people's lifestyles change. Maybe people will work from home most of the time but go into the office one day a week, and they'll use our aircraft. Perhaps two people in opposite ends of a city can come together very quickly for an in-person meeting instead of doing it over Zoom, and they'd take our aircraft. Over time, people will move out into the more rural areas, because aerial ridesharing will make it possible to have short daily commutes into the city. This technology just completely changes how you think about work.

It can also change how you think about vacations. Getting to an island will be much quicker and easier. Getting from one side of a city or region to another, even over physical barriers—like mountains—will be much easier.

Our focus currently is on passenger transportation. However, our aircraft could also be used in a whole variety of ways. Think about an area that might be devastated from a hurricane or other natural disaster, where the airports are no longer available and the roads are inaccessible. Our aircraft can move in and land pretty much anywhere in an emergency situation to help transport people and medical supplies. That could be one use case. Last-mile transportation of cargo could be another one. It's all about where the economics are going to be, and we believe initially that's in passenger transportation.

Robin Riedel: What geographic areas will likely be the early adopters of AAM? Will it be rural or urban areas? Will it be the Western world or emerging markets?

Bonny Simi: I think the early adopters will be in the large, dense urban centers where congestion is a real problem: Los Angeles, New York, Miami, Singapore, Tokyo, perhaps parts of Brazil. As cities become denser and the roads become more and more congested, trains and buses won't be able to support everyone's transportation needs. Over time, though, AAM will be able to connect large metropolitan areas: San Francisco to San Jose, or Santa Barbara to Los Angeles. You ultimately can connect Nagoya to Tokyo, for example. And eventually, AAM will be bringing people from the rural areas into cities.

What most people get wrong about air taxis

Robin Riedel: What are some of the major misconceptions people have about eVTOL aircraft?

Bonny Simi: One misconception is that these aircraft are noisy. But when we first bring people to see our aircraft fly, the very first thing they remark on is the sound—or the lack thereof. It sounds, even in a hover, like the leaves on a tree. You almost don't hear it.

It isn't just the volume; it's also the quality of sound. When you think of a vertical-lift aircraft, like a helicopter, you hear that "wop-wop." You don't hear that with this vehicle at all. And that's one reason why consumer adoption will be so dramatic.

Another misconception is that aerial ridesharing will be expensive. Joby's vision is to save a billion people an hour a day—so we are planning for mass adoption. If you want to go from one end of town to the other, or perhaps between two cities, the cost of aerial ridesharing will be the same as ground-based ridesharing. Initially, it'll be a little bit more expensive, but gradually, as more people take air taxis and the network effects kick in, we'll get the price point down.

A third misconception is that these aircraft are drones. That's not accurate: a drone is an aircraft that does not have a pilot in it. Our aircraft is piloted—it's very safe and it's easy to incorporate into the existing air-traffic system. Our business model is built to be profitable around a piloted aircraft. Long term, at scale, we think we'll eventually move toward autonomous aircraft. That will take some time, and we're not betting our business model on it. But we are exploring autonomy, because to be truly ubiquitous we'll need to have autonomous aircraft.

Bonny Simi biography

Vital statistics
Born in 1962 in Mount Baldy, California
Married, with one adult daughter

Education
Holds master's degrees in engineering and business from Stanford University and in human resources from Regis University, as well as a bachelor's degree in communications from Stanford University

Career highlights
Joby Aviation
Head of air operations and people
Adviser, JetBlue Airways
(2020–present)

JetBlue Airways
President, JetBlue Technology Ventures
(2016–20)

Held a variety of executive roles overseeing talent, customer experience, and airport and people planning
(2007–15)

Airline pilot
(2003–07)

United Airlines
Airline pilot
(1990–2003)

NBC Sports Group
Expert commentator during the Olympic Games
(1994–2002)

United States Olympic Committee
Three-time Olympian and ten-time national champion in luge and bobsled
Served on board of directors and executive committee
Volunteered as a licensed international luge judge
(1984–2019)

Fast facts
Is a board director of Pebblebrook Hotel Trust and a former board director of Red Lion Hotels

Building the pilot pipeline

Robin Riedel: Tell us more about the pilot experience. In a typical pilot training program, trainees have to learn about high-altitude aerodynamics, jet engines, and other things that don't apply to flying an eVTOL aircraft. How are you thinking about pilot training and building the pilot pipeline?

Bonny Simi: Our aircraft is very intuitive and easy to fly. You can take off and land like a regular airplane on a runway, or you can take off and land vertically—like, on top of a building. It transitions from vertical flight to horizontal flight seamlessly. But our pilots will still need to operate in the regular airspace with other aircraft, so they'll be subject to the same pilot regulations. We're training them to fly in a regular general aviation aircraft first. They'll then transition quickly to our eVTOL aircraft, build up their experience, and launch into commercial operations after they get their commercial license.

As you know, there's a pilot shortage, so we're thinking a lot about building a pilot pipeline. We've partnered with educational institutions. We want to open up access to pilot training to communities that have never even thought about flying as a career. We're determined to make the pilot workforce much more diverse. We see this as a big social enterprise as well, and I'm very excited about the directions in which our pilot academy is headed.

Robin Riedel: You brought up diversity. Our research has shown that, globally, less than 6 percent of airline pilots are female. How does Joby plan to address that?

Bonny Simi: When I started flying a few decades ago, the percentage of female pilots globally was in the single digits. Sadly, it's still the same. Part of the problem is access; another problem is that it's hard to raise a family when you're traveling constantly.

At Joby, our aircraft is easy to operate, so the cost for pilot training is very low—which means we'll be able to open up pilot academies to a diverse population. Also, our focus is on urban air mobility, which means our pilots will be home every night! It makes for a family-friendly operation. We imagine that the workforce of the future for our aircraft will be very diverse, both in gender and ethnicity. So it's not only environmentally sustainable but also socially sustainable.

'Electric is now'

Robin Riedel: What else needs to happen to make Joby's air-taxi service a reality?

Bonny Simi: As we think about building out the entire operation, it's not just building and certifying the aircraft. That's an important piece, and it's what most people are focused on, but we also have to build the infrastructure to run what will be the world's largest airline.

Part of the infrastructure, of course, is the charging infrastructure. We've designed the aircraft for a very quick charge. Our normal stage length—the distance that we'll fly the aircraft—will be about 25 to 50 miles. It takes just about the same amount of time to charge the aircraft as it does for people to get off and for a new set of passengers to get on—so, roughly five to seven minutes. For flights that are longer, like 150 miles, it could take up to 45 minutes to charge the aircraft. By the way, our aircraft completed a 150-mile flight in July 2021 on a single charge. As far as we know, that set the record for the longest eVTOL flight so far.

Robin Riedel: Do you think Joby aircraft will always be electric? Are electric aircraft the future of aviation?

Bonny Simi: A lot of people say the future of aviation is electric. I say, that's not the future—that's now. We're flying electric aircraft now. What comes next? We believe that hydrogen is next; perhaps first a hybrid of hydrogen and electric, and then ultimately pure hydrogen down the road.

If we think about long-haul travel, hydrogen is the long-term future. For urban air mobility—trips of up to 100 miles—I think electric is ideal. As you begin moving out to regional transportation, it might be a hybrid. And then even farther out than that, it might be pure hydrogen. We believe that in the aviation community broadly, hydrogen will be the standard by 2050.

Robin Riedel: What's your biggest and boldest prediction about where AAM can go?

Bonny Simi: At Joby, one of our values is "reimagining possible." So when I think of bold, audacious goals, one is that we will be the largest airline in the world by departures by 2030. Think about that: 1,000 aircraft operating dozens of takeoffs and landings every day. That will make us ubiquitous in the community. Our aircraft will just be a part of people's everyday life.

Robin Riedel: What's scarier to you—getting on an eVTOL aircraft for the first time or going down the luge track?

Bonny Simi: Luge and bobsled are not unlike piloting. I actually see a lot of parallels: it's very much about precision, safety is always paramount, you go fast. But for the riders, trust me: the Joby aircraft is a much smoother ride.

Bonny Simi is head of air operations and people at Joby Aviation. **Robin Riedel** is a partner in McKinsey's San Francisco office.

Comments and opinions expressed by interviewees are their own and do not represent or reflect the opinions, policies, or positions of McKinsey & Company or have its endorsement.

For more from Bonny Simi, see the videos accompanying this article on McKinsey.com.

‘Speeding up everyday travel’: Lilium prepares for takeoff

Originally published
November 19, 2021

Daniel Wiegand, CEO of air-mobility company Lilium, believes that electric passenger aircraft will be commonplace by 2030.

Daniel Wiegand

He didn’t expect aircraft development to cost a billion dollars. When Daniel Wiegand and his team at German aviation company Lilium first set out to make electric flying vehicles a reality, he was “a bit naive” about the cost and scope of such an undertaking. Much has happened since Wiegand and three other graduates of the Technical University of Munich founded Lilium in 2015. Today, Lilium is one of more than 250 entities developing electric vertical takeoff and landing (eVTOL) aircraft.

The advanced air mobility (AAM) industry has been hot lately, attracting more than $5.4 billion in investment in just the first nine months of 2021. Lilium became a publicly traded company in September. Wiegand says that the company plans to offer its first commercial flights to consumers in 2024; locations announced to date include Florida and parts of Germany and Brazil. Unlike many AAM players, which are focusing on urban air mobility—flying passengers and cargo to and from various areas within a city—Lilium is instead gearing up to offer a regional intercity service. Its website describes a world in which a future trip from San Francisco to Lake Tahoe takes under an hour by eVTOL aircraft, compared with almost four hours by car. Traveling from Zurich to St. Moritz, a two-and-a-half-hour drive, would take 29 minutes by air. Wiegand calls it “expanding the radius of life.”

Wiegand recently spoke with McKinsey’s Robin Riedel in Lilium’s hangar near Munich, where the company is constantly testing and refining the technology for its sleek, black-and-white seven-seater electric jet. Edited excerpts of their conversation follow.

Robin Riedel: Let’s start with the name of your company. Why is it called Lilium?

Daniel Wiegand: Otto Lilienthal is believed to be the inventor of aircraft in Germany. We took the Latin version of his second name, which means “lily.” He had a dream that, one day, instead of walking or using horse carriages, we would be flying through the air as our main means of travel. His dream fits pretty well with what we’re doing here at Lilium.

Robin Riedel: When do you think that dream will become a reality? Paint us a picture of what AAM will look like in the coming years and who will be using it.

Daniel Wiegand: I believe 2025 will be the launch phase of this industry, and by 2030 it will really be ramping up—that's when you will see exponential growth, and eVTOL aircraft will become a part of everyday life. I expect that there will be many applications of this new technology. On the ground today, there's everything from sports cars to trucks to buses. We will see something similar in the air: there will be eVTOL aircraft used on intercity shuttle routes, which is what Lilium is focused on right now. There will be sightseeing applications, taxi applications, cargo applications, and so on. We'll see many different products and business models.

Robin Riedel: Will AAM reduce private car ownership?

Daniel Wiegand: Maybe a little. I think what it will truly change is the perception of time and distance. Imagine how different our lives would be today if we only had bicycles. We would have to live very close to our workplace, close to our friends, close to where we want to shop, etcetera. For short trips like these, a bicycle is roughly five times slower than a car.

An eVTOL is five times faster than a car. So think about how that would change things: we'll see different pricing of real estate, for example. We'll be able to live in the countryside and work in the city. What we like to say at Lilium is, this is a different radius of life. Essentially, the radius of our life expands with the speed at which we can travel—especially the speed at which we can do everyday travel.

The passenger experience

Robin Riedel: What will it feel like to ride on a Lilium Jet in five or ten years? Will it be just like flying in an airplane?

Daniel Wiegand: It will be safe, fast, and convenient. We're looking at the aircraft not only as a product—we want to get the whole experience right, from the check-in process to actually getting on and off the aircraft. That means we, along with our infrastructure partners, like Ferrovial [the Spanish transportation infrastructure company], are working hard to make the entire journey seamless, from the first mile to the last.

The Lilium Jet has a spacious cabin. Our jet technology has a very low vibration, so it will be a comfortable ride, with low noise emissions. We want to deliver an experience that corresponds to what customers expect in the 21st century.

It's also important to us that all of this is connected within a network—so we're not only looking at the Lilium flight itself but also at embedding these flights into a bigger transportation network that covers an entire country. That means being connected to ground transportation—taxis, car services, trains—and all the way up to the big airlines, to which Lilium flights would act as feeder flights.

One thing I'd like to clear up is that Lilium won't be an air-taxi service—at least not in the first ten years or so. Instead, we will be providing scheduled shuttle services from one city center to another. The business model is comparable to a high-speed train that connects two cities.

Robin Riedel: You said the aircraft will have "low noise emissions." Noise is obviously a big concern for consumers—not just passengers but anyone who lives or works near takeoff and landing points. How has Lilium been able to solve the noise problem?

Daniel Wiegand biography

Vital statistics
Born in 1985 in Tübingen, Germany

Education
Holds a master's degree in aerospace engineering from Technical University of Munich

Career highlights
Lilium
(2015–present)
Cofounder and CEO

Fast facts
Named one of *MIT Technology Review*'s "Innovators Under 35" in 2017
Won European youth science competition "Jugend forscht" in 2004
Started flying gliders at age 14

Daniel Wiegand: We use ducted electric vectored thrust [DEVT] technology. Our jets have ducted fan engines powered by electric motors. Acoustic liners around the fans capture and dissipate much of the noise. Our tests show that the perceived noise level of the jet, when it's in its initial hover phase, is about the same as a dishwasher from 100 meters away. And when it's cruising, you will barely hear it at all.

We believe low noise emissions is one of the key enablers for the entire eVTOL sector. Low noise is crucial to community acceptance and to accessing the spots in urban environments where we want to take off and land. Helicopters have been able to do vertical takeoff and landing for a very long time, but they are very noisy and costly. The eVTOL industry won't be truly successful unless it solves those two fundamental issues.

Affordability and autonomy

Robin Riedel: So DEVT is your solution to the noise issue. What about the affordability issue? When will most people be able to afford a Lilium flight?

Daniel Wiegand: Initially, we're expecting that the price will be around $2.25 per passenger mile. Over the medium or long term—with higher-capacity autonomous aircraft and lower-cost infrastructure—the price will be comparable to high-speed trains or other ground-based transportation.

From the start, it's been Lilium's mission to create a high-speed transportation system that is affordable for everyone. All our decisions have been made with this goal in mind. The early adopters will most likely be businesspeople, partly because price points will be higher in the early phases. But we think that eVTOL aircraft will eventually become a standard means of transportation for our whole society. In the 2030-to-2045 timeframe, using an eVTOL aircraft will be as normal as driving a car is today.

Robin Riedel: Where exactly will all these eVTOL aircraft take off and land?

Daniel Wiegand: We've designed an infrastructure—and an aircraft—that meets current regulations while also allowing a very high-throughput eVTOL service. We're determined to achieve high throughput because that was the feedback from our partners and customers. They said, "We don't want just 20 people coming in per day. We want hundreds, maybe thousands, per hour."

The infrastructure looks quite simple: each "vertiport" has at least one helicopter pad and multiple gates—typically six to ten—where passengers can board while the aircraft is charging. All these places are connected via a central taxiway. There will typically be some kind of lounge where passengers can check in to their flight on their phones and get some food and beverages. But we envision people flowing through this infrastructure quickly—not spending a lot of time there like we do today in airports.

This can be one of the big advantages of the eVTOL industry: making the airport experience very different from what we know today. We're all annoyed at how much time we spend on the ground and how little time we spend in the air. With eVTOLs, we can have small, distributed, efficient vertiports. It will take two or three minutes—not an hour or more—to get from a car into an airplane.

By 2030, there will probably be a lot of infrastructure created in a very distributed way, from private garages and vertiports in small villages to hotel rooftops and downtown vertiports in big cities. Beyond 2030, Lilium could potentially shift from providing shuttle services only for larger groups of people to also providing on-demand services for individuals, where you can maybe take a two-seater airplane from a vertiport next to your house to a village somewhere. Again, with autonomous aircraft and low-cost infrastructure, we could get to the price points and throughput that will make sense for an on-demand air-taxi business model.

Robin Riedel: So the price will drop when the vehicles become autonomous—but Lilium flights will be piloted at first, right? How do you expect that to evolve?

Daniel Wiegand: Yes, Lilium will initially have pilots on board. Each of our pilots will hold a commercial pilot license and get the full training of an airline pilot, plus an additional "type rating," or certification, for the specifics of the Lilium Jet.

Over time, we'll develop autonomous technologies. People often ask, "What will happen to the pilots training on these aircraft today?" We think we'll need them for a very long time. The pilot will be on the ground, acting as a supervisor of five, ten, 20, or 30 autonomous aircraft flying at the same time. So we're envisioning a gradual shift from a fully piloted service to a more or less autonomous service. As we shift to autonomy, the number of aircraft that one pilot can operate will simply increase.

Making aviation more sustainable

Robin Riedel: What about sustainability? Is it good for the environment to have so many Lilium jets in the air?

Daniel Wiegand: Sustainability is part of our core mission. From day one, we made our aircraft all electric and battery powered. We didn't even go for any hydrogen options, because hydrogen consumes roughly three times more primary energy to make the same trip.

The eVTOL sector is also serving as a catalyst for the entire aviation industry to become more environmentally friendly. Lilium aircraft are jets—just like the airplanes flying in the air today—so the technologies and processes we're using aren't just for eVTOL aircraft. They can also be used for "normal" electric jets. The regulation to certify batteries for our aircraft, for example, can be used to certify batteries for other electric jets. So, in this way, eVTOL is helping to bring sustainability into the wider aviation community.

Leadership lessons

Robin Riedel: You cofounded Lilium before you turned 30. What are some of the biggest leadership lessons you've learned as a young founder and CEO—and one who has been building not only a new company but a whole new industry?

Daniel Wiegand: One lesson that's probably independent of this industry—it's a lesson for founders—is that whenever something goes great in the company, it's linked to your people. And whenever something isn't going so well, it's also linked to either your people or the structure in which you put them. It's all about the people.

There have been challenges along the way, of course. One of the challenges we faced was that we were initially a bit naive about the scope and cost of developing something like this. I think our first estimate was for a smaller sports aircraft in the $50 million to $100 million range. But now that we're designing against the same safety standards as an airline, we've discovered that the development cost will be $1 billion or more.

With this recognition comes the need for more fundraising, which means you need to spend much more laser-focused time on making sure that you have a compelling business case. Otherwise, the whole thing will just fall apart.

Thankfully, at Lilium, we started early. More than four years ago, we began looking systematically into the business case—the costs, what customers expect from such a service, and so on. One thing we found, for example, was that an air-mobility service needs to reduce passengers' travel time by at least half an hour. Otherwise, they won't think it's worth the trouble to switch from a car to an aircraft and back to a car; they'll just take the longer car trip.

Robin Riedel: It's an exciting time in AAM, and there are now so many companies hoping to compete in this space. How do you think the AAM ecosystem will evolve? Is there room for everyone?

Daniel Wiegand: We think there's room for at least five to ten players—both big companies and independent companies—because the demand in the medium and long term is going to be so high that one company alone would never be able to meet it. We're excited that there's a whole sector growing up around us, because when there's an ecosystem, investors are more comfortable with investing. Your partners are more comfortable because they know that if you fail, someone else can take your place. And there is more infrastructure being built, more supply-chain developments happening, more politicians pushing for state funding. If we were the only company in the entire sector, most of these things would not happen, and we would have a very hard time making progress. So we welcome the competition.

Daniel Wiegand is a cofounder and the CEO of Lilium. **Robin Riedel** is a partner in McKinsey's San Francisco office.

Comments and opinions expressed by interviewees are their own and do not represent or reflect the opinions, policies, or positions of McKinsey & Company or have its endorsement.

For more from Daniel Wiegand, see the videos accompanying this article on McKinsey.com.

Will VoloCity transform urban transportation?

Originally published
November 19, 2021

Electric air taxis such as the VoloCity, made by Germany's Volocopter, are poised to revolutionize not just city travel but also the global mobility industry, says CEO Florian Reuter.

Florian Reuter

Both the bicycle and the automobile are said to have been invented in Southern Germany, near the city of Bruchsal. Soon, another transportation game changer could emerge from that part of the world. So says Florian Reuter, CEO of Bruchsal-based aircraft manufacturer Volocopter. His company is building multirotor electric vertical takeoff and landing (eVTOL) aircraft, which it plans to offer for commercial use in 2024.

Volocopter is working on three types of eVTOL vehicles: the VoloCity, a two-seater urban air taxi; the VoloConnect, for traveling between cities and suburbs; and the VoloDrone, for transporting cargo. VoloIQ, the company's digital platform, is designed to connect all of these services and allow consumers to book flights easily. Volocopter is one of several eVTOL companies that have recently gotten considerable traction in the investor community; the company has raised more than $350 million in equity and has formed partnerships to bring its services to a number of cities, including Los Angeles and Paris.

Reuter recently discussed his views on the future of air mobility with McKinsey's Kersten Heineke. The following are edited excerpts of their conversation, which took place at a hangar in—where else?—Southern Germany.

Kersten Heineke: If Volocopter sticks to its announced timeline, just three years from now your aircraft will be flying above metropolitan areas, carrying people and products. How do you envision advanced air mobility [AAM] changing over the next decade? What will people be able to do in 2030 that they can't do today?

Florian Reuter: I envision that by 2030, there will be a wide range of AAM options, for both passengers and goods. As a consumer, I will be able to simply tap my smartphone and it will show me all the different options. And I can choose the one that best meets my specific needs at that time—whether my priority is the lowest price or the shortest trip or something else. The options will have to be 100 percent sustainable, there's no doubt about that.

I think urban air mobility—for example, air-taxi applications within cities—will start a profound transformation in the air-mobility sector overall. Specifically, the digitization and the electrification in urban applications will spread to other, longer-range missions until eventually we develop the means to fly, with 100 percent sustainability, from continent to continent. In 30 years, AAM will be as ubiquitous as any other transportation mode.

I can say that with confidence because this technology isn't just promising—we've actually already shown that it works. We've had public demonstrations and test flights in many places, including Helsinki, Singapore, Paris, and Oshkosh, Wisconsin, so thousands of people have seen our vehicle fly. They've also *heard* it fly, so they've witnessed that this technology is extremely quiet. Our test flights have helped dispel the common misconception that these vehicles will be noisy.

Kersten Heineke: Which cities do you think will be the first to adopt AAM?

Florian Reuter: Mobility is a constraint in every city; that's why we see a huge global market demand for AAM. The more prone to congestion a city is today, the larger the impact of the air option will be. The biggest needs are certainly in the megacities that have an underdeveloped infrastructure—particularly cities in Asia, which is why we are putting a lot of emphasis on scaling our services in that region.

Kersten Heineke: You've mentioned sustainability a few times. Did you consider other energy options besides electricity?

Florian Reuter: It was clear to us that if we want to be part of the mobility options of the city of the future, 100 percent sustainability is a must. The only way to head in that direction today is by going all electric. Over the longer term, fuel cells might play a role, but we're certainly not there yet.

And it's not enough to just have rechargeable batteries that use 100 percent renewable energy. The production of your vehicle—not just the operations of your vehicle—must be fully sustainable as well. We still have a long way to go on that front. But I'd say the entire industry, and society at large, is searching for the right solutions.

A $300 billion market?

Kersten Heineke: Many AAM players have been getting significant funding recently. How many will still be in business in 2030?

Florian Reuter: We are talking about an overall $10 trillion mobility market potential. If AAM can get $300 billion of that in the next ten to 15 years, that is a gigantic market opportunity, but it still represents only a very small fraction of the total market. So I see tremendous opportunity for growth for Volocopter and for many other players out there.

I predict there will be multiple players. But there probably won't be as many as there are in the automotive space right now, because it takes an investment of almost $1 billion just to meet the initial safety criteria and get over the certification hurdle.

Kersten Heineke: Many stakeholders would all need to cooperate before air taxis can start flying over cities. What types of partnerships is Volocopter pursuing?

Florian Reuter: We want to transform the way that people move about our planet—and we can't do that alone. This is a massive undertaking. We're forming partnerships along the entire value chain so that we can bring urban air mobility to life.

On the supply-chain side, we have a very clear make-or-buy strategy, and we're partnering with parts suppliers who have a huge legacy in the aviation domain. On the ecosystem side, there are certain elements that need to change before we can unleash the full potential of AAM: those have to do primarily with the availability of landing sites—or what we're calling VoloPorts—as well as the availability of charging infrastructure and the implementation of next-generation technologies for managing airspace. We are

Florian Reuter biography

Vital statistics
Born in 1979 in Aachen, Germany
Married, with two children

Education
Holds a diploma in industrial engineering from the Karlsruhe Institute of Technology, studied management and economics at the University of Barcelona, and wrote his thesis with Daimler in Japan

Career highlights
Volocopter
CEO
(2015–present)

Siemens Novel Businesses
Venture manager
(2009–14)

Contrium Consulting
Project manager
(2005–09)

Fast facts
Speaks German, English, French, and Spanish
Enjoys skiing, mountain biking, reading, and pioneering new technologies

happy to start with existing airspace-management technologies, but in order for our services to truly scale up, a technology shift—from traditional air-traffic management to universal traffic management—will need to happen.

We have partnered with numerous companies to help make this a reality, and we involve them in our test flights. For example, at the airport in Helsinki, we flew alongside legacy helicopters and large commercial airliners. We were demonstrating that we can integrate a Volocopter flight into the existing landscape, but also that we can work with partners to move toward universal traffic management.

The advent of autonomous aircraft

Kersten Heineke: What other cutting-edge technologies will you need in order to be successful in the next ten years?

Florian Reuter: We want our aircraft to be as lightweight as possible. At the same time, we want it to be as "performant" as possible, which directly relates to the energy and power density of the battery and the efficiency of the entire electric drivetrain. So we're pushing hard on those two elements and exploring what is possible, always with an eye toward meeting the highest standards in aviation and getting the aircraft certified.

After that, the next technology frontier is autonomous aircraft. Autonomy will free up an additional seat in the aircraft and it will make AAM much more affordable and scalable. When you talk about autonomy, most people think of sophisticated computer sensors and algorithms on board the vehicle, but if we want to ensure that we can provide our services at a safety factor of ten to the power of minus nine—or one incident in one billion flight hours, which is the safety target that the European Aviation Safety Agency [EASA] has given us—then we can't think only about the vehicle. We have to think about a system of systems. That has implications on the infrastructure that we use; it has implications on the reliability of GPS satellites, mobile-phone technology, and so on. So there are a host of technologies that we need to tie together to make sure that, ultimately, we can capture the full potential of AAM.

Kersten Heineke: How long will it be before we see autonomous aircraft? Five, ten, 15 years?

Florian Reuter: Many people were expecting that self-driving cars would exist by now. But there are two reasons why I believe we'll see much faster adoption of autonomous capabilities in the air than on the ground. First, airliners have been flying on autopilot for decades, so there's a level of autonomy that we're already very used to, and have mastered very safely, in the air. Second, the air is a much easier space to control than the ground. Of course, we have to be aware of "noncooperative members" in the airspace—like birds or illegal drones—so we need to have a plan for how to deal with those. But, generally speaking, participants in the airspace are much more technology-equipped and much better educated than those on the ground, simply because there's not much traffic up there.

Besides, the autonomy road map is being pushed not just by Volocopter and other members of this industry—it's also being embraced by regulators worldwide. They know it's coming and they see its advantages, so they are actively encouraging industry players to participate in the working groups to make autonomous aircraft a reality. I expect to see the first adoptions of fully automated flights within the next five years and, on a global scale, in five to ten years.

Kersten Heineke: What would you say to pilots who want to work for Volocopter but worry that in just a few years they'll be unemployed?

Florian Reuter: When we talk about the maturation of this industry, we think of it in phases. In phase one, we put a pilot in the aircraft to fulfill the traditional regulatory requirements. We make it easy for the regulator to simply accept the VoloCity and VoloConnect as aircraft that resemble a helicopter, to a certain degree, and can integrate into existing air-traffic-management systems and can use existing heliport infrastructure. That's how we can get started tomorrow.

For phase one, we have partnered with [pilot-training-services provider] CAE to make sure that we can train the necessary numbers of pilots to support our business expansion. But we want to scale our services, so, eventually, we want to take the pilot out of the aircraft. But we'll still need trained pilots to oversee the operations of passenger aircraft as well as cargo drones.

It will be a natural progression from being a pilot on board—which will become more boring because the vehicle will be much more automated—to being a pilot on the ground. I believe this offers a compelling career path for pilots; it gives them tremendous opportunity for growth in a tech environment.

No ordinary start-up

Kersten Heineke: What's the most difficult part of your job?

Florian Reuter: In this industry, you need an incredible amount of capital before you can start generating meaningful commercial revenue. This is a marathon rather than a sprint. Many of the start-up best practices—like A/B testing, "fail fast," and all that—don't really apply to this industry. Keeping everyone engaged—the team, the public, investors—on this very long-term journey has been a challenge.

I always saw the potential for it; otherwise, I would have never left Siemens to join what was at the time a four-person start-up. But it was difficult to predict how fast the vision would come to fruition. And we had a lot of internal debate over the years because we saw other companies applying very different approaches. We constantly asked ourselves, "Do we need to be more aggressive in our timelines? Should we put more pressure on regulatory authorities? Should we stay with electric power or go hybrid? Do we need to go after longer-range missions?" and so on.

Looking back, I think staying true to our original DNA has served us well. It's been very rewarding to live through the emergence of this whole new industry that, today, no one is contesting anymore. Everybody's just asking, "How exactly is it going to unfold?" Where we are today is an extremely exciting point in time.

Kersten Heineke: In 2017, Volocopter changed its corporate language from German to English. Any advice for CEOs who are thinking about doing that in their companies?

Florian Reuter: We made that transition when Volocopter had about 15 employees; we now have more than 400. I recognized that even if we hired best-in-class talent in Southern Germany, we would not be good enough to compete on a global scale. We needed to attract the best talent from all over the world. It was obvious to me that the company language was one element that we had to change to support our growth ambitions.

But language is just one element—it's a highly visible one, but it's not enough. You then need to change many other things: organizational structures, internal policies, IT systems, and so on. And in our case, we also needed to expand geographically. The city of Bruchsal is around the corner from where the automobile and the bicycle were invented, so we think of Volocopter as writing the next chapter in that history—but how many people have heard of Bruchsal? Probably not that many. So we've opened additional sites in Munich and Singapore, and we're about to open an office in Paris.

Any company that has global ambitions must go through these kinds of transitions sooner or later—and I think there is great merit in doing it sooner. If your vision is to become a multinational company, start acting like one from the outset.

Florian Reuter is the CEO of Volocopter. **Kersten Heineke** is a partner in McKinsey's Frankfurt office.

For more from Florian Reuter, see the videos accompanying this article on McKinsey.com.

This McKinsey Practice Publication meets the Forest Stewardship Council® (FSC®) chain-of-custody standards. The paper used in this publication is certified as being produced in an environmentally responsible, socially beneficial, and economically viable way.

Printed in the United States of America