REPORT

Advanced Air Mobility on the runway to commercialization

A close look at eVTOL unit economics

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Management summary

This study focuses on the economics of electric Vertical Take-Off and Landing (eVTOL) aircraft in the Advanced Air Mobility (AAM) market. Investment in AAM increased from USD 1.6 billion in 2020 to USD 7.5 billion in 2021 but fell sharply in 2022 and 2023 due to macroeconomic conditions as well as declining investor confidence. Despite this downturn, we believe the industry is experiencing a typical Gartner Hype Cycle, and only AAM aircraft companies offering technically and commercially viable solutions will eventually survive.

The AAM industry needs to achieve both the technical proof of concept, which covers achieving type certification and securing production ramp-up, and the commercial proof of concept, which requires a collaboration from all stakeholders across the AAM ecosystem to ensure an effective and efficient alignment of the ecosystem building blocks as the foundation for commercially viable unit economics.

Our economic model considers the direct and indirect operating costs of three different eVTOL aircraft types to determine ticket prices and unit economics. We analyze three use cases: City Taxi, Airport Shuttle, and Inter City. Our findings indicate that while eVTOL unit economics are higher initially than currently claimed by eVTOL aircraft manufacturers, they can be reduced by considering low-cost vertiports, switching to remotely piloted or autonomous flights, and improving battery lifetime.

Despite facing numerous challenges, we believe AAM can be economically viable for a premium market in the early years, and that eVTOL OEMs, operators, and ecosystem stakeholders should work together to offer the most efficient and effective AAM services.

Looking ahead, it is crucial to build confidence around the pricing and lifetime of aerospace-grade propulsion batteries, and for vertiport operators to find non-aviation revenue streams to keep landing fees to a minimum. This will enable commercially viable AAM services and help the AAM industry take off.

The image used for the cover of this publication is not based on a DLR design.
Cover: XH4D/GettyImages

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Fast Facts

USD 1.3 bn
invested in 2023

Over 10,000 orders placed by the end of 2023

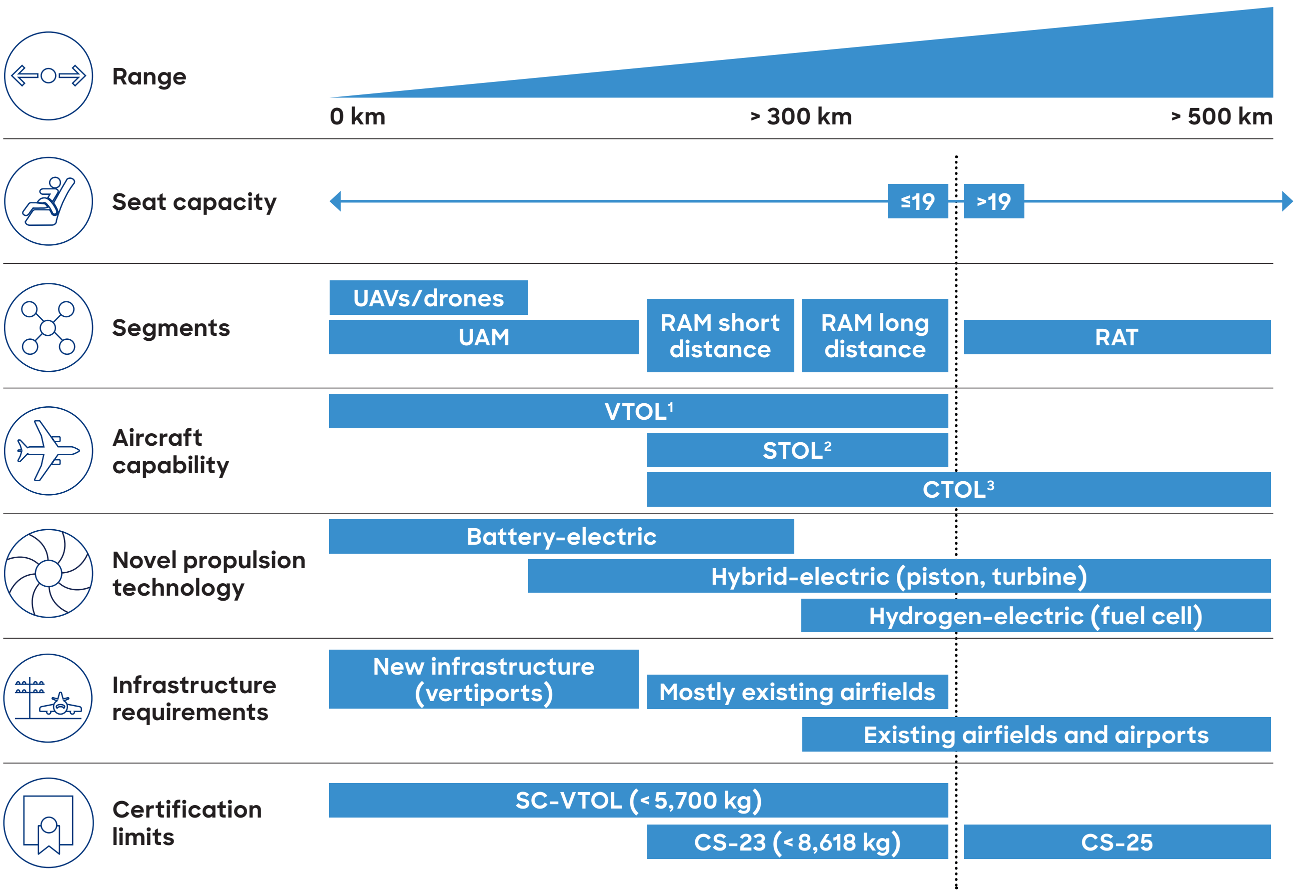
USD 7.7
per passenger mile for airport shuttle use case achievable (depending on scenario)

1 Advanced Air Mobility market segmentation

For the purposes of this study, we divided the Advanced Air Mobility market into four categories

1. **Unmanned Aerial Vehicles (UAVs),** comprising all drones across various use cases besides passenger transport.
2. **Urban Air Mobility (UAM),** comprising both cargo and passenger aircraft including emergency medical services, which carry both passengers and patients onboard, with ranges of up to ~100 km, mainly used in urban environments.
3. **Regional Air Mobility (RAM),** comprising passenger and cargo commuter aircraft with ranges of 100 km to 300 km (short distance) or over 300 km (long distance) and a capacity of no more than 19 passengers.
4. **Regional Air Transportation (RAT),** comprising passenger and cargo regional aircraft with a range of 500 km and beyond and a capacity to carry more than 19 passengers.

A Different types of aircraft and propulsion systems for a variety of use cases
Overview of Advanced Air Mobility market segments



1 Vertical Take-Off and Landing 2 Short Take-Off and Landing 3 Conventional Take-Off and Landing

Source: Bauhaus Luftfahrt, Roland Berger

Each aircraft type requires a distinctive solution in terms of design, propulsion technology, infrastructure, and certification, in particular: ▶ A

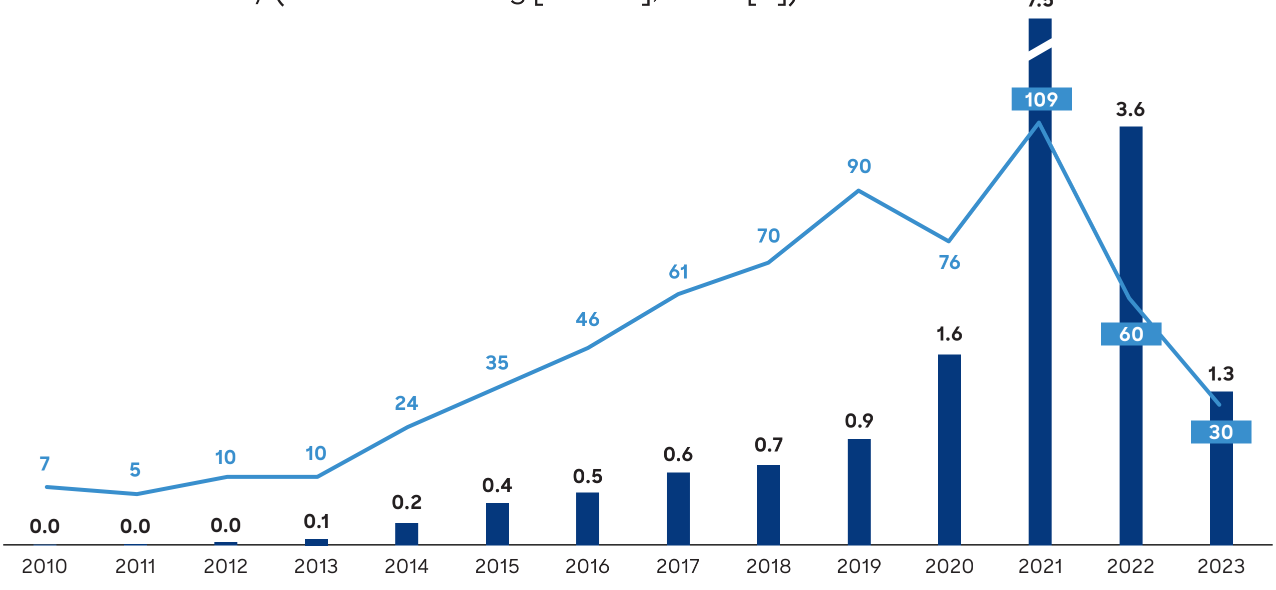
- The design of the aircraft, whether VTOL (Vertical Take-Off and Landing), STOL (Short Take-Off and Landing), or CTOL (Conventional Take-Off and Landing)
- The propulsion technology (battery-electric vs. hybrid-electric vs. hydrogen-electric)
- Infrastructure requirements (new infrastructure vs. existing infrastructure with/without modifications)
- Certification limitations by the respective certification agencies (e.g., European Union Aviation Safety Agency, Federal Aviation Administration).

2 Riding the Gartner Hype Cycle

Having defined what constitutes the market, we now turn to the state of the industry. Investment in Advanced Air Mobility rocketed from USD 1.6 billion in 2020 to USD 7.5 billion in 2021. But in 2022 and 2023 investments fell sharply, although there have still been some large investments in the last two years: Wisk secured USD 450 million in 2022, EVE Air Mobility went public in May 2022 with around USD 300 million in proceeds, Beta closed a USD 375 million funding round in April 2022, Overair secured USD 145 million in June 2022, and Lilium raised USD 119 million post-IPO via a capital raise in 2022, while Volocopter raised USD 182 million in Series E funding in November 2022. In 2023, investment activity reduced to around USD 1.3 billion in light of the macroeconomic outlook.

B Investment in AAM startups reached its peak (so far) in 2021 - Fundraising continues at lower levels in a tougher macroeconomic environment

Investment activity (disclosed funding [USD bn]; deals [#])



Note: Includes all AAM segments, such as the actual aircraft, digital and physical infrastructure, etc.; data as of Dec. 31, 2023

Source: Pitchbook Inc., Roland Berger

Nevertheless, some eVTOL companies have secured additional large funding rounds, such as Lilium from Tencent and others (USD 292 million), Archer from Stellantis, Boeing, and others (USD 215 million), Joby from Baillie Gifford (USD 180 million) as well as Skydrive from the Japanese government (USD 80 million). ▶ B

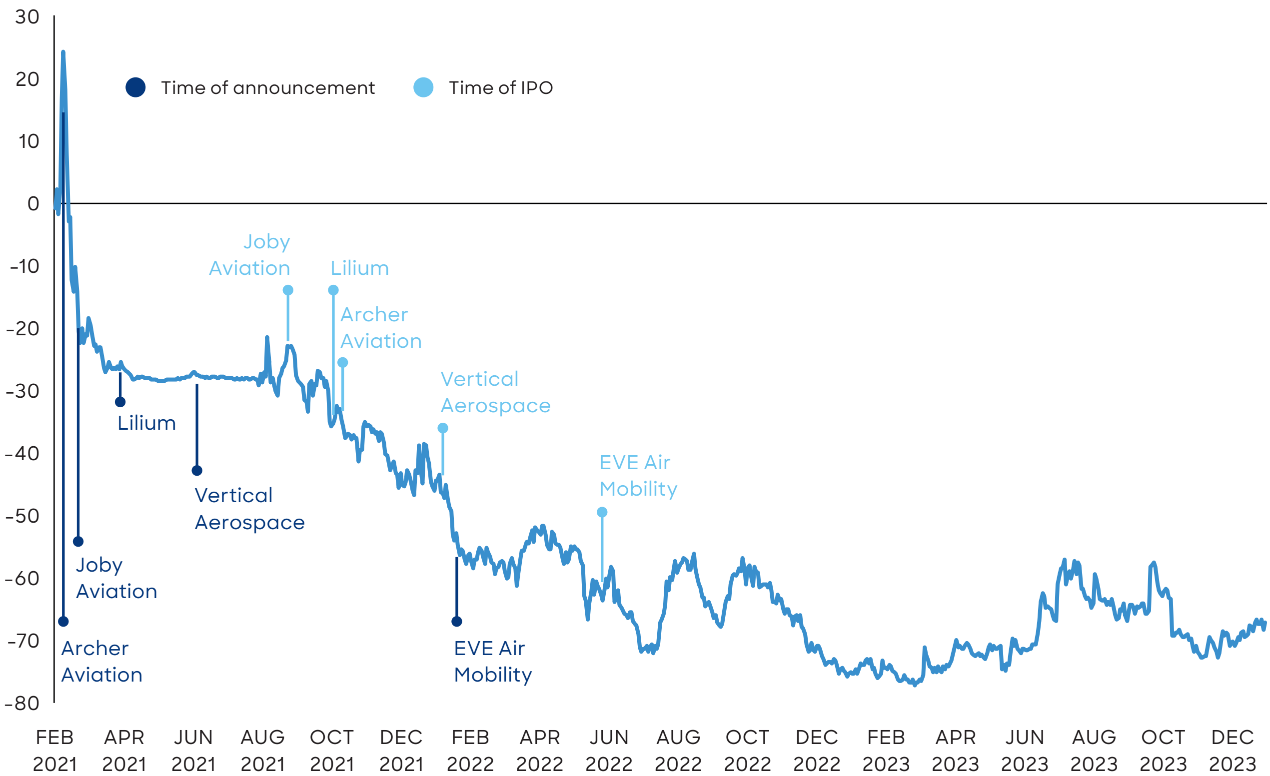
The downturn in investment also reflects slack in the special purpose acquisition company (SPAC) market. The companies that went public using the SPAC route lost more than 60 % of their value in the course of 2021 and 2022, making it more difficult to raise more capital. In addition, it could also be argued that investors have realized the eVTOL market will not be as large as initially anticipated and promoted, and that it will take longer than expected to develop. This is well represented in the Advanced Air Mobility SPAC Index, which reflects (publicly traded) air taxi companies' valuations. ▶ C

However, the drop in investment was not just a referendum on AAM. It also priced in the gloomier economic outlook fueled by the Russia-Ukraine war, the energy crisis in Europe, intensifying climate change, rising inflation rates and with this rising interest rates, as well as further geopolitical tensions between the USA and China and their impact on global supply chains and international trade.

C Realism kicks in for investors, bringing valuations down

AAM SPAC Index stock returns, February 2021-December 2023

[%; relative performance to Feb. 2021 = 0 %]

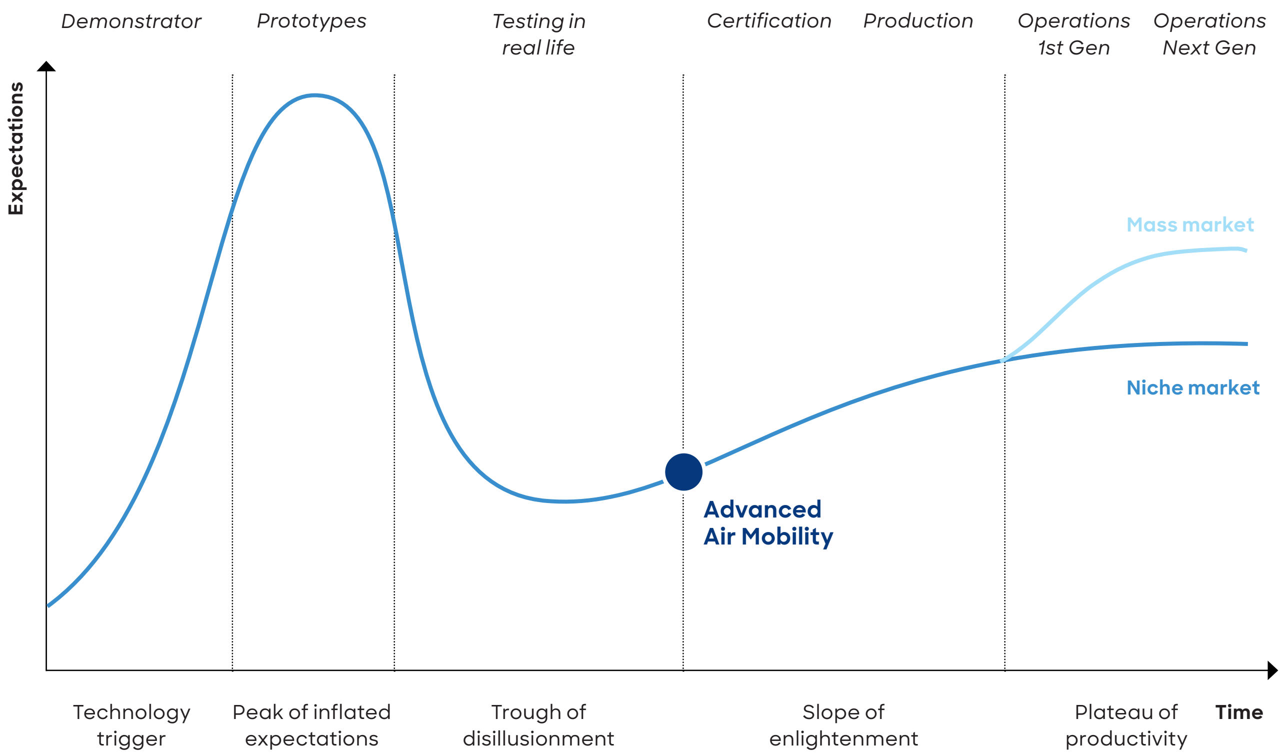


Note: Stock market performance, with new SPACs (incl. those that have announced their intent to list) included the day after their target announcement to exclude the "first day IPO" effect; data as of Dec. 31, 2022

Source: Yahoo Finance, Roland Berger

D **AAM is on the move towards the slope of enlightenment – First use cases have been tested, while certification and production are progressing**

Gartner Hype Cycle for Advanced Air Mobility



Source: Roland Berger

These circumstances imply that some companies will likely vanish from the market in the coming months or years due to either (1) a generally unfavorable investment environment, making it difficult for these players to secure additional funding, or (2) a wave of consolidation that will leave only a handful of Original Equipment Manufacturers (OEMs) in the market. This suggests it is more important than ever for players to reduce their cash burn rate and prepare a solid runway until such time as the overall conditions improve. In this case, fortune favors the cautious, as companies with a solid cash balance will be well positioned.

However, despite the downturn, negative sentiment, and a variety of challenges, there is little to suggest that this is actually the end of the industry. Instead, there is every sign of it being a typical example of the Gartner Hype Cycle as AAM banks out of the trough of disillusionment and recovers some altitude. The giddy, frothy stage of investment is over for AAM. From here onward, the only AAM companies that survive will be those who deliver solutions that are both technically and commercially viable. ▶ D

3 From science fiction to commercial fact

As previously outlined, before Advanced Air Mobility takes to the skies, aircraft OEMs and future AAM aircraft operators must achieve two important milestones: technical proof of concept and commercial proof of concept.

TECHNICAL PROOF OF CONCEPT

The first and most crucial milestone is certification. This encompasses both aircraft and organizational certifications for design and production. Achieving these certifications is essential to unlocking and enabling commercial operations. This deliverable, referred to as the technical proof of concept, requires regulators and aircraft OEMs to collaborate in developing the necessary regulatory framework and validation methods to certify aircraft and organizations to the highest safety standards. Additionally, it involves certifying the production of these aircraft at scale, with the goal of manufacturing up to thousands of aircraft annually – a significant challenge for aerospace supply chains. In parallel to achieving the technical proof of concept, the second key deliverable – the commercial proof of concept – needs to be initiated.

E The commercial proof of concept for the AAM industry requires an efficient ecosystem to deliver the air mobility service at the lowest unit economics

Key deliverables of the AAM industry

1 Technical proof of concept

Responsible: **Regulators** and **aircraft OEMs**

Required building blocks: **Commercial certification** | **Production ramp-up**

Achievement of technical proof of concept **enables commercial operations**

2 Commercial proof of concept

Responsible: All **ecosystem stakeholders**

Relevant cost blocks

eVTOL aircraft	Aircraft acquisition cost	Insurance	Availability/ reliability[1]
Flight operations	Energy costs (charging)	Pilot salaries	Air traffic management charges
Maintenance	Battery replacement costs	Aircraft maintenance cost	Service intervals[1]
Vertiport	Landing fee	Ground handling	Cleaning

Only the **efficient alignment** of all ecosystem cost blocks creates superior **customer value** and the **fastest** travel option at the **lowest unit economics** possible

1 Influencing cost factor

Source: Roland Berger

COMMERCIAL PROOF OF CONCEPT

The development and alignment of the supporting ecosystem for Advanced Air Mobility is essential for the commercial proof of concept. Operators and OEMs must collaborate with a wide range of industry stakeholders to develop a comprehensive supporting ecosystem. This requires investment in additional infrastructure, such as vertiports and urban air traffic management systems, alongside integration with existing ground transportation systems. Most of this infrastructure needs to be built from scratch.

Establishing this supporting ecosystem and efficiently aligning all its components will underpin AAM economic viability and drive unit economics. In regard to eVTOL unit economics, the primary cost drivers are the eVTOL aircraft costs, flight operations costs, maintenance costs, and vertiport costs. Therefore, collaboration between the aircraft OEM, future operators, and infrastructure service providers for vertiports and air traffic management is essential. Effective alignment of these ecosystem cost blocks is crucial for maximizing customer value by providing the fastest travel time at the lowest unit economics in the most convenient way.

Long-term success for AAM depends on demonstrating a clear and convincing business case that proves commercial viability and attracts further necessary funding for industry scale-up. This is particularly challenging as many ecosystem components are currently undeveloped, posing significant uncertainties in building a reliable business case even based on assumptions. ▶ E

Much of this is also contingent on the ability of OEMs to build – and then brand – AAM aircraft as a sustainable and economically viable form of transportation. Many would-be AAM operators believe it can be done – that's why they have placed more than 10,000 orders for eVTOL aircraft – but so far, they are hedging their bets. Many of those orders are contingent on the OEMs meeting multiple licensing and certification milestones, while only a very low single-digit percentage of orders received pre-payment. ▶ F

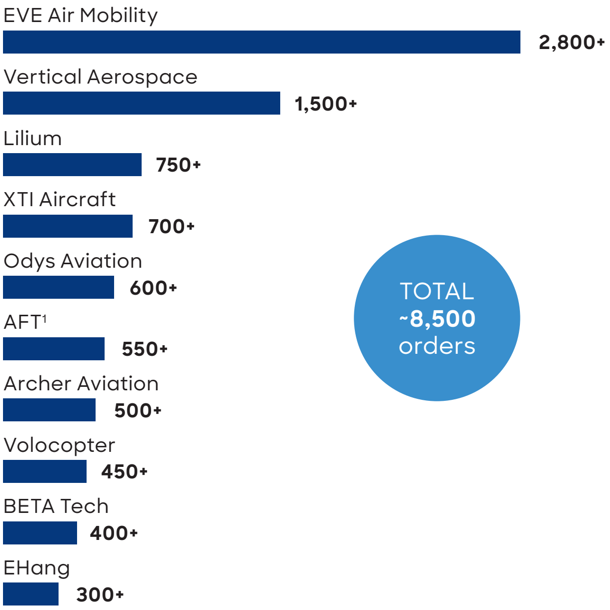
The unspoken concern, of course, is whether such a service can be economically viable. To help prospective operators we conducted an outside-in unit economics analysis of the viability of operating air taxi services using eVTOL aircraft.

> **"The efficient alignment of all building blocks of the AAM ecosystem will provide the basis of its economic viability and thus is an important driver of unit economics."**
>
> **Stephan Baur, Partner**

F Airlines have placed most of the ~10,000 eVTOL orders – However, most orders are conditional and non-binding, indicating possible reductions in the future

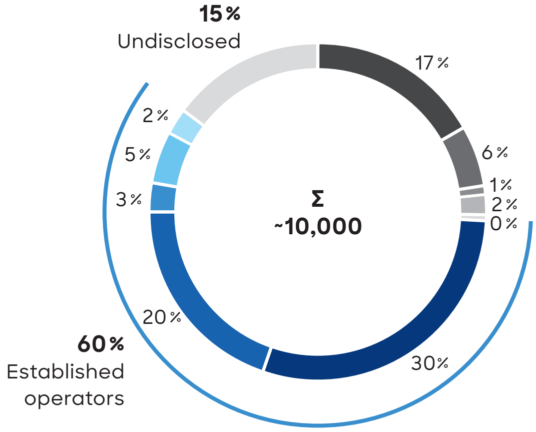
eVTOL aircraft order breakdown

Top 10 passenger eVTOL companies by # of publicly known aircraft orders as of Dec. 31, 2023



1 Ascendance Flight Technologies

Share of aircraft orders in % by type of customer



Established operators
- Traditional airline
- Helicopter operator
- Charter company
- Leasing company
- Cargo

Non-operators
- Other corporate
- Startup airline
- Mobility service provider
- Industry corporate
- Government

Source: Cirium, company information, press research, Roland Berger

4 Unit economics analysis of three AAM use cases

Real-world data about eVTOL air taxi fares is not yet available, as we will see first commercial flights operating by 2025/2026 the earliest. Yet that has not stopped eVTOL aircraft OEMs from announcing their expected prices. Many of these claim that it will be possible to fly passengers for the same amount or even for less money than conventional taxis would cost.

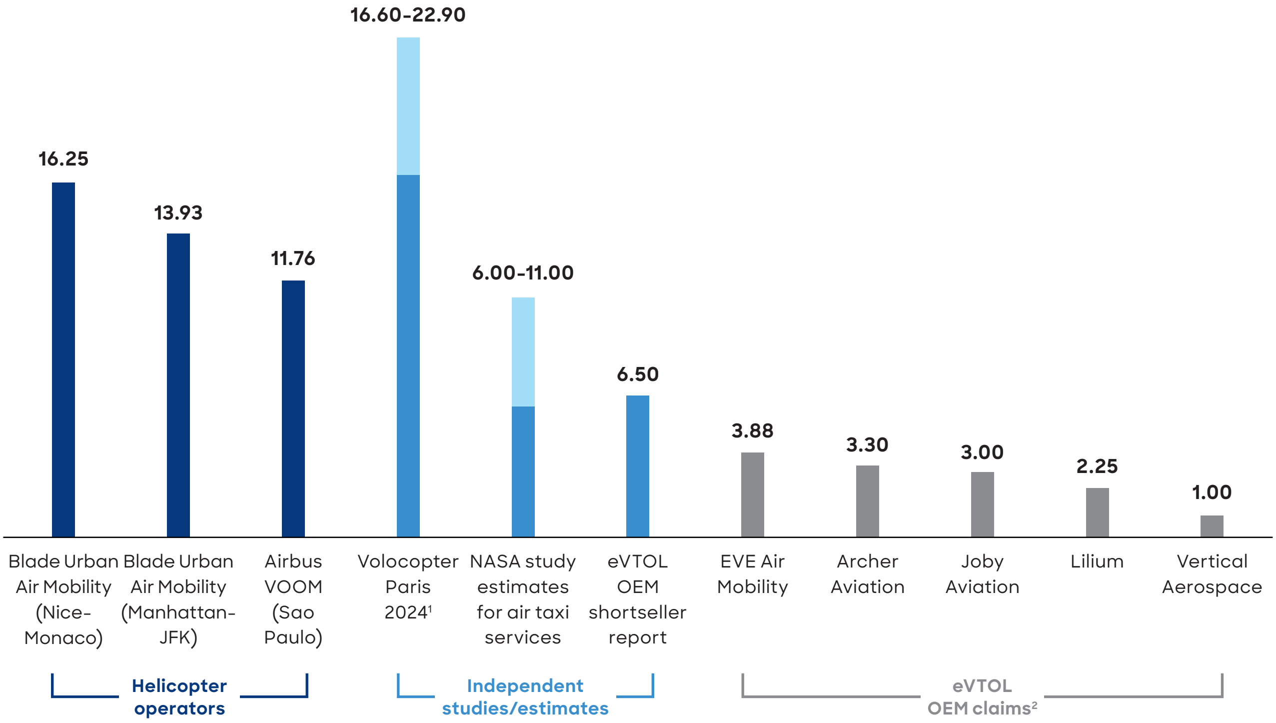
These companies claim that for a 40-mile air taxi service (e.g., from San Francisco to San José), passengers would need to pay between USD 40 and USD 150 for a one-way ticket. Likewise, operators with a Lilium Jet would charge passengers USD 225 for a flight of 100 miles (e.g., New York to Philadelphia). This might be too high for the general public, but eVTOL OEMs argue they would offer a superior value proposition in terms of time saving and convenience.

To date, these projected numbers have not been scrutinized very much, if at all. There are more realistic assumptions from Volocopter for its planned commercial operations in Paris, yet these data points suggest higher unit economics. ▶ G

To shed some light on the actual operational requirements and challenges facing OEMs, we took a closer look at the unit economics of the three most commonly discussed passenger use cases: City Taxi, Airport Shuttle, and Inter City.

G There is still some debate around OEM claims for eVTOL unit economics – Independent studies and estimates paint a different picture

Published eVTOL unit economics studies and price points [USD/passenger mile]



1 Based on targeted price of EUR 10-13 per km incl. subsidies (EUR/USD exchange rate of 1.1) 2 Unit economics in mature market

Source: Investor presentations, company information, press research, Roland Berger

THE THREE MAIN AAM USE CASES

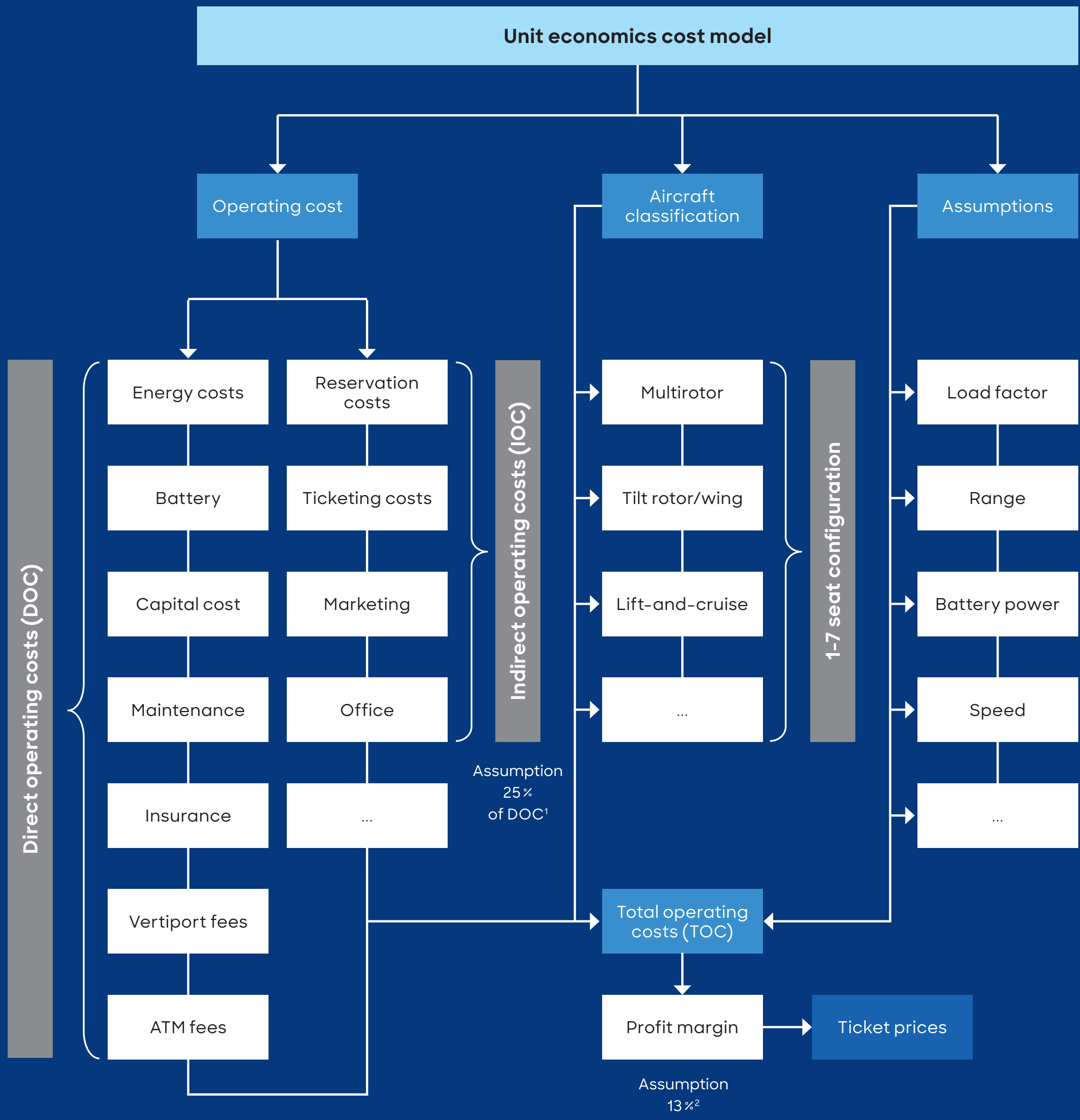
For this analysis, we looked into two UAM use cases and one RAM use case for battery-electric VTOL aircraft, as most eVTOL OEM companies are currently developing such configurations.

If the operational mode is designed in the same way as a conventional taxi service, the service is operated on an on-demand basis without a fixed time schedule, allowing individual passengers to take rides as they prefer. Mobility services in conventional taxi mode are mostly based on cost structures that only take mileage into account. Such a service allocates all costs to the passenger, making it unattractive for the operator to increase the load factor of the vehicle.

However, this is not the case for modern ride-sharing services such as Uber, Lyft, Didi, Grab, or MOIA in Germany. Most air taxi companies are targeting the ride-share business, a pooling service in which rates rise and fall according to load and demand. As the cost structure of this option has some characteristics of a ticket system, like those in commerical aviation or public transport, for instance, it is in the interests of the operator to realize high load factors and utilization.

H Based on the direct operating costs (DOC), we added indirect operating costs (IOC) at 25% of DOC as well as a 13% profit margin for the operator

Methodology (illustrative)



1 Estimate based on ICAO, airline stock analyst reports and financials from regional airlines
2 Average profit of US domestic air routes

Source: German Aerospace Center, Roland Berger

In the subsequent analysis, we assumed that the trips will be offered as a pooled service, making it more economical for the operator in its early years. Setting the scene, we chose three potential but realistic use cases in Northern Germany, with the city of Hamburg positioned as the air mobility hub of the future for our analysis.

THE ECONOMIC MODEL AND COST MODELING METHODOLOGY

For this study, we developed a comprehensive model, which calculates the direct operating costs (DOC) based on a set of operating parameters. To the direct operating costs, we added 25% of indirect operating costs (IOC) to cover overhead costs of the aircraft operator. The sum of both is the total operating costs (TOC). On top of the TOC we added a profit margin of 13% for the operator based on average profit of US domestic air routes. This forms the basis of calculating ticket prices and unit economics. ▶ H

Case 1: City Taxi

Commuter flights from Hamburg central train station to Airbus Finkenwerder campus.

The City Taxi use case is an on-demand point-to-point air taxi service operated by a multicopter eVTOL aircraft. It is designed for one passenger and pilot (or two passengers in case of future autonomous flights) and their light hand luggage for distances of between 10 and 50 km, usually within the metropolitan area of a city. The assumption is that it operates 20 times a day on 330 operating days per year.

The route starts in downtown Hamburg, at the central rail station, and ends at Finkenwerder, where the Airbus facility is located. We selected this use case route as an example of a typical commuter route. The ground distance is approximately 12.4 mi (about 20 km) with an expected travel time by ground-based vehicles of at least 35 minutes and up to more than an hour during rush hour. The air travel distance is calculated at 7.5 mi (about 12.1 km) including a detour factor making use of flying over water, avoiding densely populated areas. The air travel time is calculated at 11.6 minutes.

> **"The long-term success of Advanced Air Mobility depends on demonstrating a clear and convincing business case that proves commercial viability and attracts further necessary funding for industry scale-up."**
>
> **Stephan Baur, Partner**

Case 2: Airport Shuttle

Shuttle service from Hamburg Airport to Blankenese, a suburb of Hamburg.

The Airport Shuttle use case is a scheduled short-range air taxi service between various city landing pads and the airport with distances between 15 and 50 km, operated by a tilt-rotor eVTOL aircraft. It is designed for up to four passengers and pilot, and their carry-on luggage, on defined routes and at set time schedules in a first step. The assumption is that it operates 20 times a day on 330 operating days per year.

The route starts at Hamburg Airport and ends in Blankenese, a suburban district of Hamburg. The ground distance is approximately 15.5 mi (about 25 km) with an expected travel time by ground-based vehicles of at least 35 minutes and up to more than an hour during rush hour. The air travel distance is calculated at 10.7 mi (about 17.2 km) including a detour factor making use of flying over forests and fields, avoiding densely populated areas. The air travel time is calculated at 12 minutes.

Case 3: Inter City

Scheduled service from Hamburg Airport to the island of Sylt in the North Sea.

The Inter City use case is a scheduled medium- to long-range (50-250 km) air taxi service between cities that are too close to be viable for regular aviation links or where no competitive land-based infrastructure or transportation options, such as railroads, exist. It is operated by a vectored thrust eVTOL aircraft with seven seats including pilot seat and cargo space for carry-on luggage. The assumption is that it operates four times a day on 330 operating days per year.

Our route, in which could be served with a vectored thrust vehicle, starts at Hamburg Airport and ends at the island of Sylt. The ground distance is approximately 125 mi (about 200 km) with an expected travel time of at least three hours by ground-based vehicles, including car train transport, and more than four hours during rush hour. The air travel distance is calculated at 140 mi (about 225 km) including a detour factor making use of flying over water, avoiding densely populated areas. The air travel time is calculated at 56 minutes.

RESULTS

We will now discuss the results from two perspectives. First, looking at the share of the different cost blocks in direct operating costs. Second, considering absolute ticket prices, also bringing in indirect operating costs and operator margin.

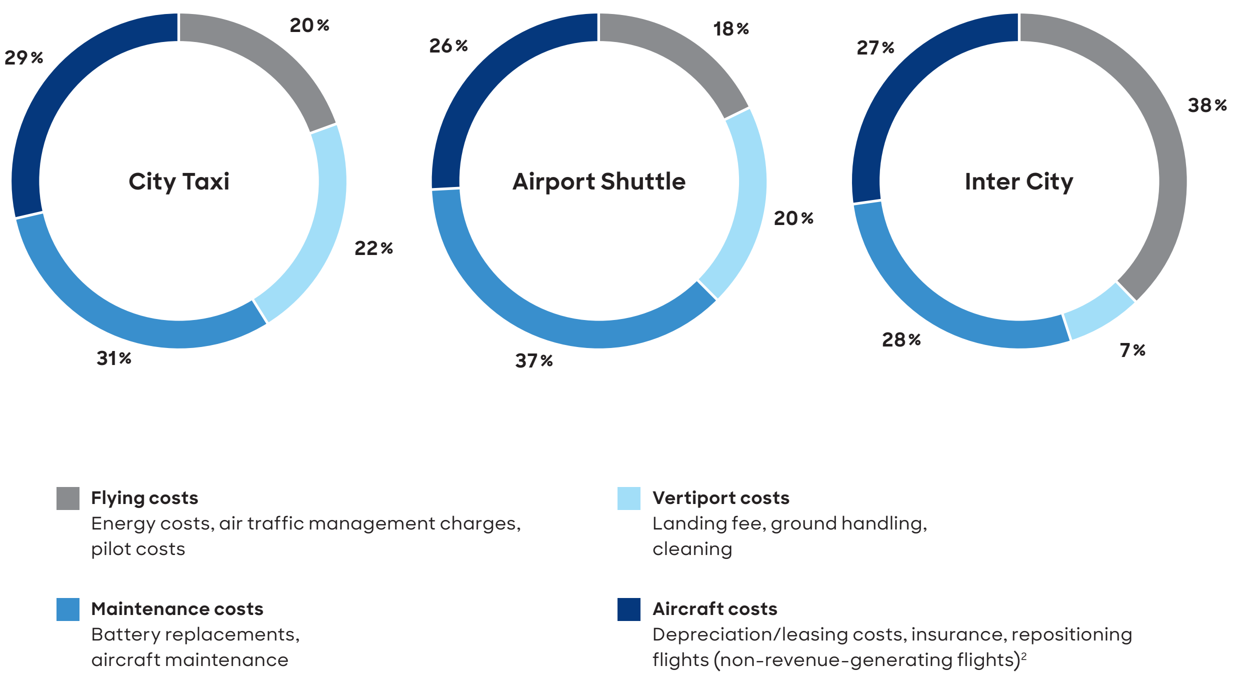
DIRECT OPERATING COST DISTRIBUTION

We clustered all our direct cost blocks into four categories: ▶ I

- **Flying costs** include energy costs, air traffic management charges, and pilot costs.
- **Vertiport costs** include landing fees (including passenger handling fee) at the vertiport, ground handling of the eVTOL aircraft, and aircraft cleaning.
- **Maintenance costs** include general aircraft maintenance costs and battery replacements. Here, battery replacement costs are the main driver.
- **Aircraft costs** include aircraft depreciation or leasing costs, insurance, and costs associated with repositioning flights for the City Taxi and Airport Shuttle use case to pick up new passengers (non-revenue-generating flights).

I Direct operating costs split differently across use cases provide interesting considerations for operators on how to improve unit economics

Direct operating costs[1] [%]



1 Rounded percentages might not add up to 100% 2 Repositioning flights not considered in Inter City use case

Source: German Aerospace Center, Roland Berger

In a direct comparison across the three use cases, we observed a different distribution of these four cost block categories, which allows us to draw conclusions on how to improve unit economics:

For the City Taxi use case
· Operate low-cost eVTOL aircraft
· Consider low-cost vertiports to minimize landing fees
· Switch to remotely piloted or autonomous flights to free up one additional revenue-generating passenger seat and cut unit economics in half
· Improve battery cycle time to reduce battery replacement costs

For the Airport Shuttle use case
· Operate low-cost eVTOL aircraft
· Consider low-cost vertiports (minimize landing fees)
· Switch to remotely piloted or autonomous flights
· Improve battery cycle time to reduce battery replacement costs

For the Inter City use case
· Ensure low-cost energy supply
· Improve battery cycle time to reduce battery replacement costs
· Guarantee high utilization of aircraft (longer flights, shorter turnaround times)

It should be noted that some of our assumptions may have been overly positive or negative – see our disclaimer at the end of the study. For example, the air traffic management charges calculations are based on commercial aircraft weights and distance flown. The calculation logic will most likely change to consider much lighter AAM aircraft and account for more complex urban or suburban aircraft navigation.

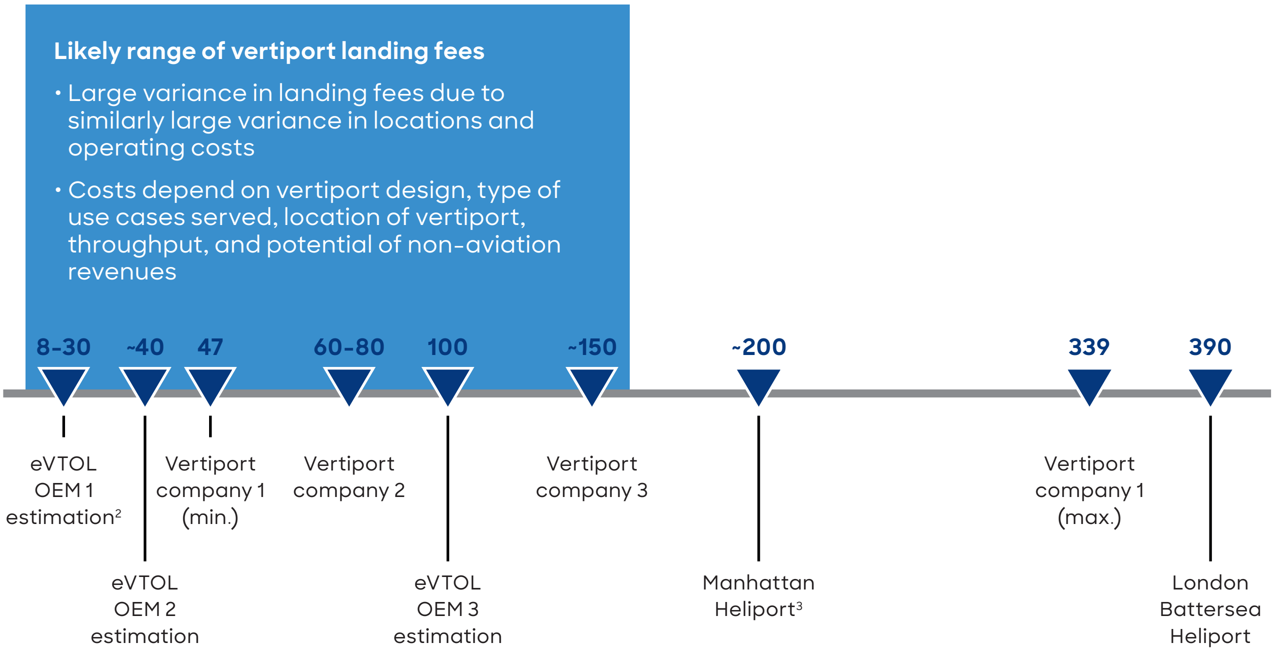
Vertiport costs, especially landing fees, are dependent on vertiport design, type of use cases served, location of vertiport, throughput, and potential of generating non-aviation revenues. We observed a large variance in landing fees due to similarly large variance in locations and their operating costs. In addition, battery costs for AAM applications remain uncertain. ▶ J

There are currently no aerospace-grade propulsion batteries available at a large scale, making it difficult to estimate future supply prices at volume manufacturing levels. Further, a large cost driver of unit economics are battery replacement costs, as high utilization of eVTOL aircraft coupled with high discharge rates during vertical flight maneuvers takes a toll on battery cycle life. When replacing batteries, there is still debate over whether the whole battery pack needs to be replaced (cells and battery management systems) or whether just the cells can be exchanged in battery packs. In the latter case, battery replacement costs could be significantly decreased.

For these reasons, we decided to vary vertiport landing fees as well as battery costs and battery lifetime to account for the uncertainty when discussing the results of the unit economics analysis in USD value.

J Besides battery costs and replacement cycles, the vertiport landing fee is another uncertain cost block with various industry estimates

Overview of vertiport landing fees [USD per take-off/landing][1]



1 Assumption: Includes the landing fee for the eVTOL and passenger handling fee charged by the vertiport. Does not include additional aircraft parking fees (e.g., overnight parking, electrical charging fees)
2 Based on 11-40 cents per passenger mile on a 25-mile flight with 3 passengers
3 Blade Urban Air Mobility landing fee

Source: Company information, expert interviews, press research, Roland Berger

TICKET PRICE PERSPECTIVE

In the following section, we present and discuss unit economics from a USD/per passenger mile perspective as well as from an overall ticket price perspective. ▶ K

We displayed our results across the three use cases of City Taxi, Airport Shuttle, and Inter City, and in two scenarios, one low and one high.

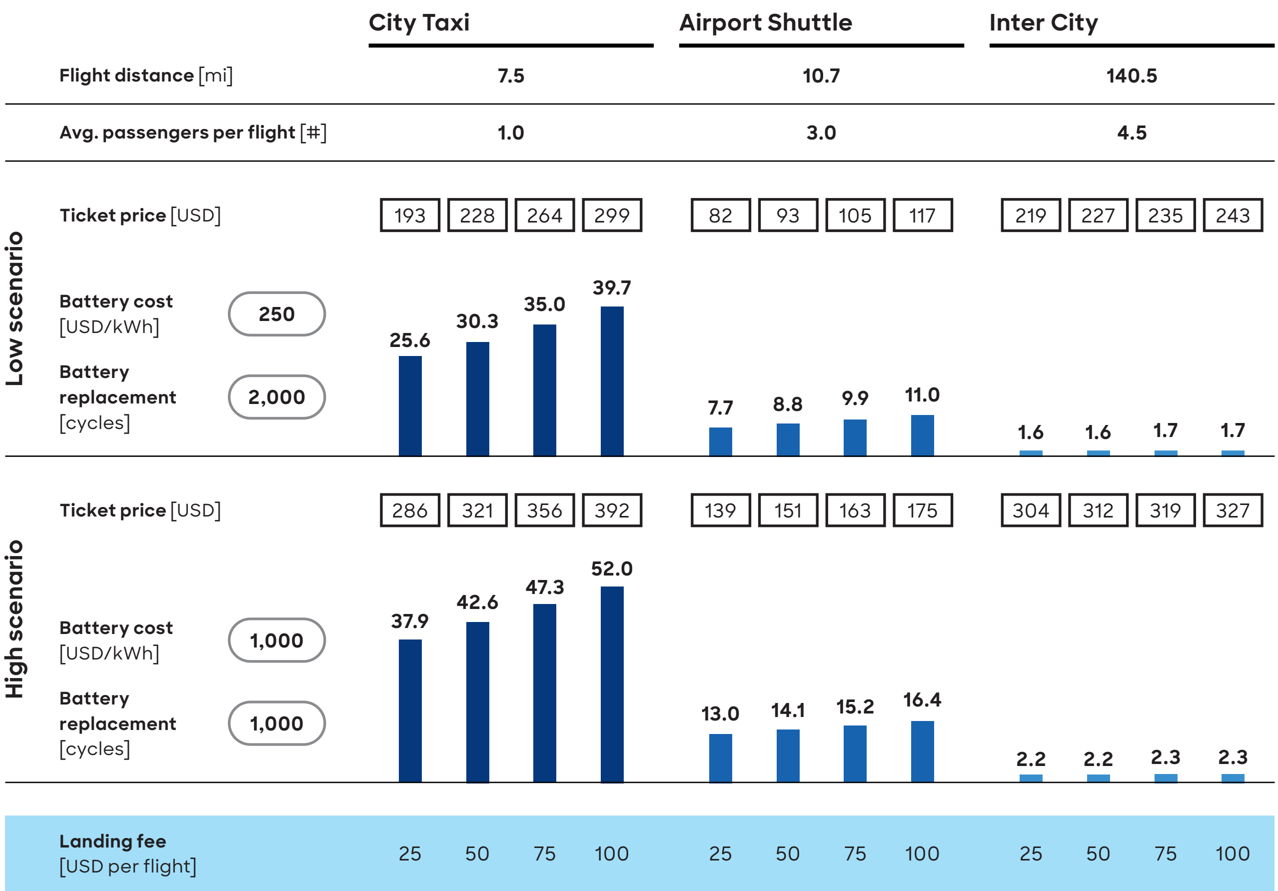
The low scenario assumes more favorable development of battery costs and battery lifetime, with USD 250 per kWh as the battery price (on pack level) as well a battery lifetime of 2,000 flight cycles before replacement is necessary.

Meanwhile, the high scenario assumes less favorable development of the two battery parameters, with USD 1,000 per kWh as the battery price (on pack level) and a battery lifetime of 1,000 flight cycles until replacement.

In addition, we vary the vertiport landing fees between USD 25 and USD 100 per flight in USD 25 increments.

K By varying the landing fee as well as battery costs and battery lifetime, unit economics differ between use cases

Analysis results: eVTOL unit economics [USD/passenger mile]



Source: German Aerospace Center, Roland Berger

Figure ▶ K show the results on a USD/passenger mile perspective, which we calculated based on the flight distance in miles and the passenger load. We assumed a 100 % occupancy rate for the City Taxi use case and a 75 % occupancy rate each for the Airport Shuttle and Inter City use case, in order to provide a realistic operational environment.

In addition, we also calculated the respective ticket price of the flight based on the USD per passenger mile value, as this is the price the end customer (i.e., passenger) is charged when booking or, earlier in the booking process, is offered as a basis for deciding whether or not this is an attractive price for the AAM service.

DISCUSSION AND INTERPRETATION OF OUR UNIT ECONOMICS ANALYSIS

First, it seems interesting for the City Taxi use case that the unit economics, at USD 25-52 per passenger mile, are more expensive than existing helicopter services. A resulting ticket price of USD 193-392 hardly justifies any time savings in the majority of use cases. However, this is related to having only one paying passenger onboard. If the onboard pilot could be replaced with a remote pilot, the freed-up seat provides space for another paying passenger, cutting the unit economics in half to USD 13-26 per passenger mile. In this case, the unit economics favor the eVTOL air taxi service over current helicopter services - while being more sustainable and less noisy.

Second, the Airport Shuttle use case shows higher unit economics than claimed by eVTOL OEMs in their investor presentations, albeit not differing by orders of magnitude. It must be noted that we chose a rather short route for this use case, thus the unit economics will be better when flying longer routes (i.e., 20-40 miles). Nevertheless, our unit economics are still reasonable when looking at business travelers as the most likely end customers to take these services. Ticket prices of USD 82-175 for an 11-mile flight are still a significant premium over existing ground mobility services. However, time savings are valuable to business travelers, as is the certainty of arriving on time at the airport by air mobility instead of ground mobility (due to unforeseen traffic jams), making this use case attractive. In addition, these ticket prices undercut existing helicopter air services, making eVTOLs an attractive helicopter replacement for such use cases. We assume that the unit economics can reach USD 4-10 per passenger mile for longer Airport Shuttle routes.

However, our chosen route might be out of reach for such seven-seater battery-electric eVTOLs, targeting an operational range of around 110 mi (175 km), meaning the aircraft data might be too conservative (e.g., battery capacity too small, energy consumption too low). In addition, while the unit economics seem attractive at first, the long flight distance and thus the full ticket price needs to be taken into account. Here, ticket prices of USD 219-327 per passenger for a regional air mobility service make it most probably not an everyday travel option for the average citizen. Interestingly, a Sylt Air Shuttle already flies from Hamburg to Sylt twice a day for USD 300-350 per passenger one-way. This would be in line with our calculated Inter City ticket price. However, the service is used by only a tiny minority of Sylt travelers, supporting the argument that an air taxi service will be of interest mostly to more affluent passengers.

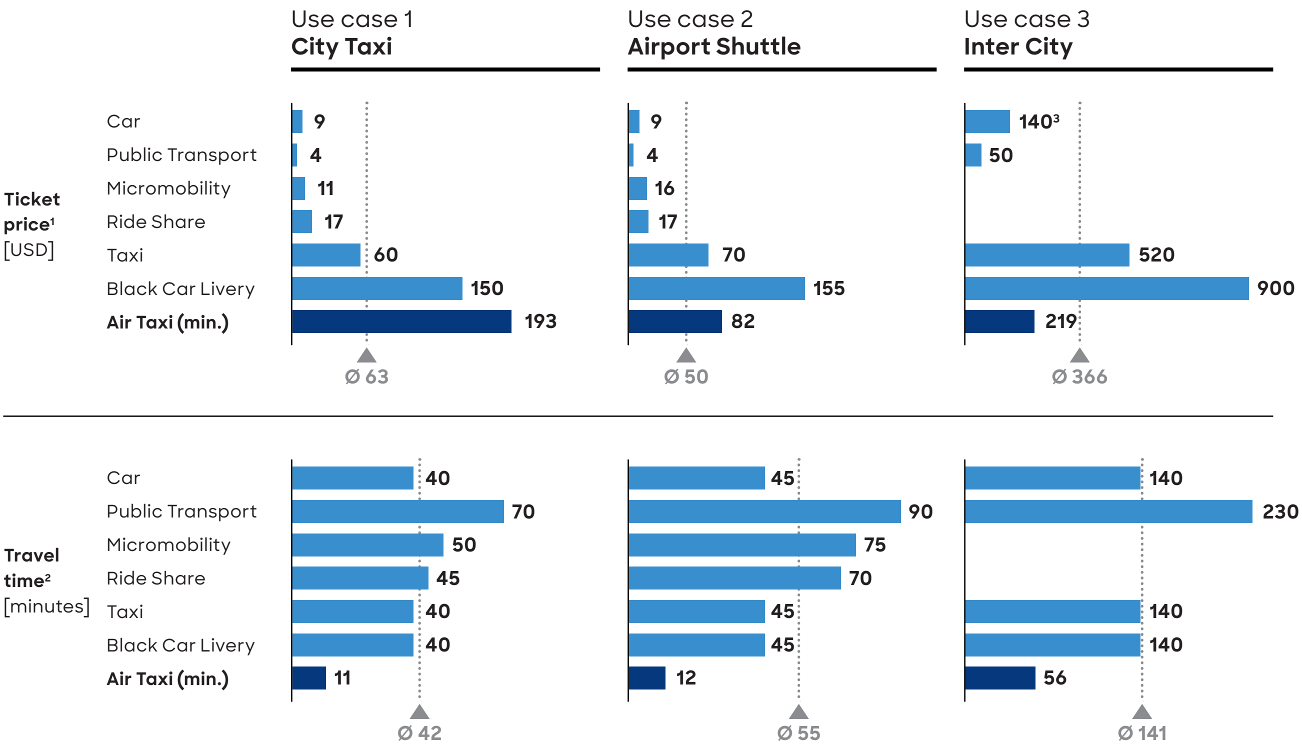
We can see a similar price pattern when we compare our hypothetical Hamburg use cases of City Taxi and Airport Shuttle against existing local and regional ground mobility options: These two use cases would be more comparable to a black car livery service, not a basic car ride share service or a regular taxi ride. ▶ L

"eVTOL use cases will remain a premium niche market in the early years, with some successful but limited use cases and routes in commercial operation."

Manfred Hader, Senior Partner

L Existing ground mobility services vs. new air taxi service: Air taxi is always the fastest travel option, in some use cases more affordable than ground transport

Comparison of air taxi with other transport modes



1 Rounded data points due to currency conversion from EUR to USD of 1.1. Car costs are calculated using the German tax deduction calculation of the commuter tax allowance of 35 eurocents/km
2 Average travel times during weekdays 3 Incl. Sylt Shuttle (train service)

Source: Company information, internet research, Roland Berger

Compared to a regular taxi or black car livery service, the air taxi service seems to be price competitive and thus, for the less price-sensitive traveler, a suitable alternative option. It must be noted, however, that taxi fares are on a per-vehicle basis and thus offer more privacy, while for the Airport Shuttle and Inter City use case the ticket prices are on a per-seat basis, so the flight would be shared with other passengers. This might be less problematic for solo travelers, but it diminishes the attractiveness of the air taxi service for groups or families of three or more people traveling together.

These results lead us to believe that such eVTOL use cases will remain a premium niche market in AAM's early years, with some successful but limited use cases and routes in commercial operation. For eVTOLs to be successful in the long term and aim for a wider market, eventually achieving broader market adoption, eVTOL OEMs, operators, and AAM ecosystem stakeholders must collaborate to enhance the efficiency and effectiveness of the ecosystem building blocks, thereby reducing unit economics for air taxi services incrementally.

5 Conclusion

This study on eVTOL unit economics has several key takeaways and implications for aircraft OEMs, operators, and investors:

- AAM can be economically viable for a premium market. The willingness to pay will be there as helicopter services are demonstrating and eVTOLs will offer even more convenience.
- eVTOL OEMs might see their aircraft unit economics in a favorable light, yet this analysis showed no major deviations, resulting in realistic, albeit premium ticket prices.
- Operational economics will not be influenced by the aircraft alone but by the whole ecosystem. eVTOL OEMs and operators should work together with ecosystem stakeholders to be sure to offer the most efficient and effective AAM service.
- The unit economics of the Inter City use case indicate even more favorable unit economics for eSTOL and eCTOL aircraft in the RAM segment (under the assumption of sufficient range through advanced battery technologies) or with hybrid-electric or hydrogen-electric propulsion systems as alternatives.
- More confidence is needed around the pricing and lifetime of aerospace-grade propulsion batteries, as the replacement of batteries has a significant impact on unit economics.
- Vertiport builders and operators should find non-aviation revenue streams to keep landing fees to an acceptable minimum.

With this study, we hope to have achieved our original goals and motivation for conducting this unit economics analysis:

- To provide an independent/third-party view on AAM economics
- To initiate discussion for potential future AAM operators considering entering this market
- To raise awareness beyond the AAM aircraft: There is a whole ecosystem to be built, which is part of the economic equation and which will eventually enable only commercially viable AAM services. Aircraft OEMs, operators, and investors should not neglect the build-up and efficient management of this supporting ecosystem to enable attractive unit economics.

While it might be true that widespread adoption of (urban) air taxis and individual air mobility is likely to remain a fantasy for this decade, we remain confident that the AAM industry will take off at its own pace, certification stage by certification stage, use case by use case, and ecosystem by ecosystem.

Disclaimer

This unit economics study is based on an outside-in analysis in the early stages of AAM market introduction (i.e., with the year 2030 as a reference). We, the German Aerospace Center (DLR) and Roland Berger, have jointly conducted this study and have collected data from various sources including expert interviews, databases, and from previous (research) project experiences.

It is a complex challenge to estimate costs for eVTOLs without precise information on the future ecosystem design and efficiency. Therefore, it must be explicitly mentioned that the calculation of economic viability is still based on multiple assumptions that might change in the future, and with them the results.

We have thoroughly checked and challenged every data point and assumption and will provide the full set of input parameters on request. We are happy to discuss our parameters and look forward to your feedback.

In particular – and we want to point this out in the interests of transparency – uncertainties in vertiport landing fees (and any associated taxes and fees), the lifetime of the eVTOL aircraft, and especially battery lifetime and battery replacement costs, can have a large impact on AAM unit economics. In addition, the current air traffic management charging fee models might not be applicable for AAM aircraft, especially in urban environments. This might also change in the future, with the rise of Unmanned Traffic Management (UTM) systems.

Finally, we wish to point out that this study has been in preparation since 2022. Due to the war in Ukraine, Europe is experiencing record energy prices. Our assumptions regarding energy prices therefore do not reflect a benchmark price for other countries. Nevertheless, this also shows that the AAM industry is dependent on geopolitical developments. A high energy price in the long term influences the economics of AAM, meaning operators may need to rethink their business case.

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Further reading

- → *TRANSFORMING THE AVIATION INDUSTRY*
- → *PRICING SUSTAINABILITY THE RIGHT WAY*
- → *AVIATION'S ROADMAP TO TRUE ZERO*

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