Vertical Mobility

The Economics of Vertical Mobility

A guide for investors, players, and lawmakers to succeed in urban air mobility

Porsche Consulting
Strategic Vision. Smart Implementation.

Preface

In 2018 we presented our first market study of the future of vertical mobility [1]. A lot has happened since. Not only did COVID-19 sweep through global markets in the spring of 2020. Vertical mobility projects have received several billion dollars in investments; the first prototypes have taken off for experimental test flights; and a multitude of companies have presented more than 200 concepts and partnerships for electrically powered vertical takeoff and landing aircraft (eVTOL) [2]. Uber Elevate (which originally played an important role in laying the ground for urban air mobility in 2016) has been acquired by Joby Aviation while deepening the partnership with Uber.

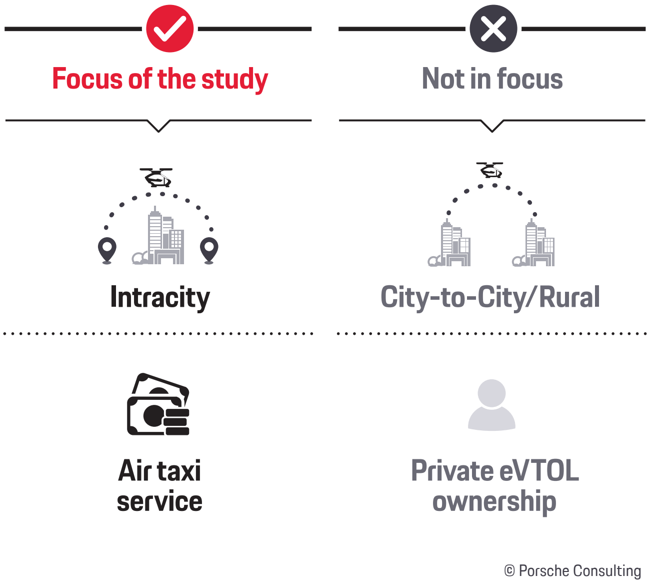

Figure 1. Focus of the study: intracity air taxi service

This second study is not an update; rather, its complementary look at the economics of vertical mobility intends to answer three key questions: Which investments are necessary to overcome the barriers? What is required to build an ecosystem? And what does it take to make this market economically relevant and offer companies and their investors a positive return between now and 2035?

While we have updated our assumptions, we are confident that our originally forecasted scenarios are still accurate. Yet in today's world, forecasting is a more daunting task than ever. Securing financing has become more difficult, but global stimulus programs could also lead to more investments in innovative technologies. Wary consumers may turn away from mass transit and prefer individual transportation. Taken together, we cannot rule out that launch activities pegged for 2025 may be pushed back by a year or two.

"The Economics of Vertical Mobility" is intended as a reality check. We want to give investors, entrepreneurs, regulators, consumers, and society at large the relevant facts so they can make the right decisions to turn the dream of vertical mobility into a reality.

This study focuses on intracity air taxis under a base case scenario until 2035 for two reasons. Cities have a higher population density and face more urgent traffic problems. And we consider intracity flights the necessary feeder networks for vertiports outside the city limits, which could serve as new city-to-city hubs.

Our overarching goal is to drive the debate around vertical mobility forward. After all, our job is to support leaders in crafting strategies for a meaningful future with "Porsche passion." As a strategic consultancy with deep expertise in implementation, we also see our role as developing individual strategies that fit with this particular market.

We welcome your questions, comments, and suggestions.

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At a Glance

The economics of vertical mobility are challenging and fraught with high uncertainty. Players in this space need to show serious commitment and need to take the long view lasting at least 10 years, with no positive return on investment (ROI) in sight before 2030. The ecosystem is also highly dependent on a minimum investment totaling $[1]20–25 billion to make vertical mobility relevant. Only then can we expect a cumulative revenue of $60–65 billion between 2025 and 2035, based on our $21 billion outlook for 2035.

Several preconditions need to be met to make vertical mobility relevant. Technology is one of them, but social acceptance is the key to success. In order to offer everyone the opportunity to use an air taxi in the near future, much like we hail a taxi today, we need a global network of more than 15,000 eVTOLs in more than 30 cities, operating from 1,000 to 2,500 vertiports. If these services are competitively priced, more than half a million people can be expected to use them on any given day. The decisive bottleneck is social acceptance to both sufficiently build out the required infrastructure and offer an attractive service. Only then will there be relevant demand for hardware at viable prices and with satisfactory air taxi performance.

This will not happen overnight but evolve in two phases. Until 2025, players in this ecosystem will make vertical mobility happen by launching first applications that garner a great deal of attention and excitement, yet are neither economically nor socially relevant. This first phase can be summarized as vertical mobility "for some people, sometimes." It will provide the market with the necessary hardware on the ground and in the air to take flight, initially with pilots at the controls. In the beginning vertical mobility will be a service for special occasions.

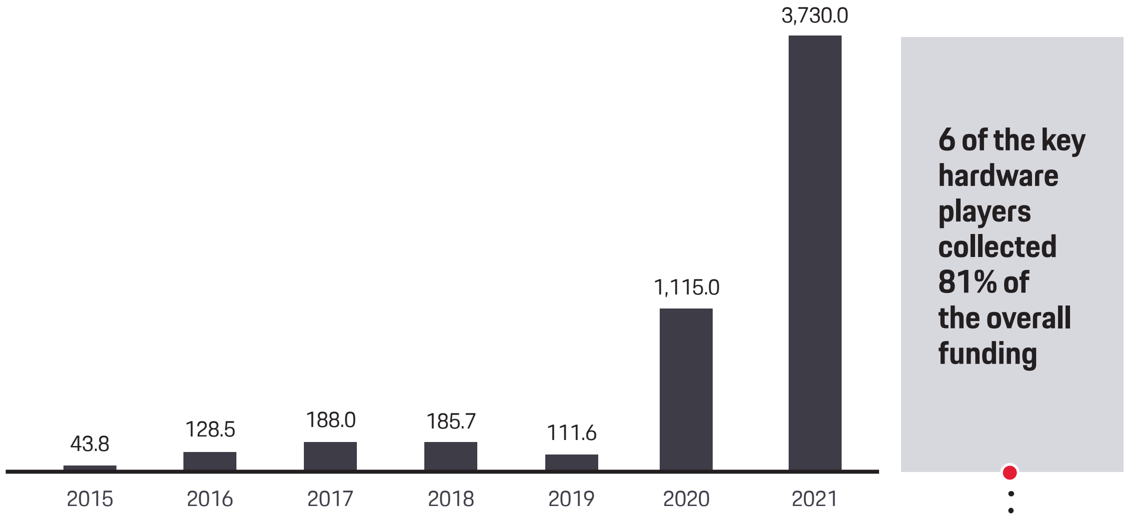
The economics of vertical mobility

Takeoff 2025 secured and funded	Investment required until 2035	Revenue potential 2025–35	Payback period
$5.5 billion funded	**$20–25 billion***	**$60–65 billion****	**≥ 2030**
of an initial investment of 5–10 billion until 2025	to solve ecosystem barriers	from hardware, service, and infrastructure	~10 years for ROI based on operational profits

* Investment volume including initial investment of 5–10 billion until 2025 | ** Cumulative numbers in USD with additional upside potential from private eVTOL.

Figure 2. Investment need, revenue potential and payback period for the vertical mobility market (base case)

[1] $ = US Dollar



	2015	2016	2017	2018	2019	2020	2021
Cumulated funding in million USD	81.2	209.7	397.7	583.4	695.0	1,810.0	**5,540.0**

Figure 3. Funding in air taxi hardware players in million USD [3]

The phased approach forces players to shoulder different burdens and avail themselves of different business opportunities. Hardware companies that lay the technical foundation will carry the biggest risk, as they need 50 to 60 percent of the overall funding and a whopping 80 percent of the initial investments. In order to bring the first generation of air taxis to market, they will have to spend $5–8 billion, without knowing whether and how the public will accept vertical mobility. Six out of more than 100 hardware players managed to collect about 76% of the overall funding of around $5.5 billion until now (Figures 3 and 22). Another $5–10 billion will be necessary to develop the second generation of eVTOLs that hit the mark in terms of price, performance, and acoustic profile. Safety and security are of paramount importance in all those endeavors.

Infrastructure companies and service providers, by comparison, face lower risk and will be able to invest incrementally as acceptance grows. Their upside and investment costs are therefore correlated.

Depending on technological development and social acceptance, we foresee different scenarios with both promising opportunities and high risk. In the conservative case, no ROI will materialize before 2035, if at all. In the progressive case, a positive ROI can be expected by 2028 at the earliest, but we consider this a very optimistic "black swan" case. In our most probable base case we expect an ROI of about 10 years ≥ 2030. Nevertheless in the bullish investment environment for vertical mobility, a financial investment can also be very profitable in the short run (e.g., EHang started with a stock price of $12.90 and reached an all-time high of $124.09). While some investment rounds were undersubscribed in 2019, all investment rounds of key hardware players are currently oversubscribed.

To be sure, the time for vertical mobility has come and the lion's share of around $5.5 billion is already funded. Considering the early stage of vertical mobility, we are sure that the remaining funding to the expected $5–10 billion initial investment will follow. It's closer than you think and the first commercial air taxi services will be reality in 2025.

We continue to believe this market can go one of two ways. It can either remain a dream for most of us, limited to an electric version of a helicopter for the rich and therefore a market that is economically and socially irrelevant, meaning only some customers will use it sometimes. Or it can evolve into a relevant niche market that offers a useful complement to future mobility for all of us, meaning everyone will use these services sometimes. In the final analysis, we believe vertical mobility will evolve in incremental steps rather than take off exponentially. But take off it will.

01 Economic Outlook for Intracity Air taxis by 2035

The vertical mobility market requires companies and their investors to take a long-term perspective when it comes to ROI. In the base case, investments totaling $20-25 billion will be necessary to achieve a positive return in about 10 years.

The vertical mobility ecosystem is an interplay of building the individual business and shaping the overall system. For a relevant market to emerge, we need broad-based acceptance by solving a mobility problem that affects many urban residents, without creating new problems such as noise pollution or additional CO_2 emissions. Only then should regulators and society at large permit air taxi routes and services on a relevant scale.

The combination of technical feasibility, customer interest, and regulatory approval will generate the demand. While a sizable number of investors have already written checks totaling around $5.5 billion, many questions remain unanswered [3]. These include how big this market will be, how quickly it will grow, and how great its inherent risks are.

Investments will flow into the areas of hardware, service, and infrastructure, first to come up with initial solutions and then to optimize vertical mobility around its acoustic profile, range, costs, comfort, accessibility, and integration into today's urban mobility solutions.

As a result, the overall performance of air taxis will improve through iteration, and their benefits will become more pronounced, which in turn will drive additional demand, leading to more approvals for new routes and more unit sales.

Individual mobility has always been a successful proposition, and most cities have suffered the consequences. Congestion on the ground is the price we all pay, no matter how extensively the current infrastructure is expanded. With vertical mobility, helipads are so far the only infrastructural element, and sparse ones at that, so they fall short in terms of accessibility and capacity.

It is worth noting, however, that even a positive scenario of vertical mobility will not solve urban traffic problems. It will be just one piece in the mobility puzzle to relieve specific urban traffic pain points und bottlenecks.

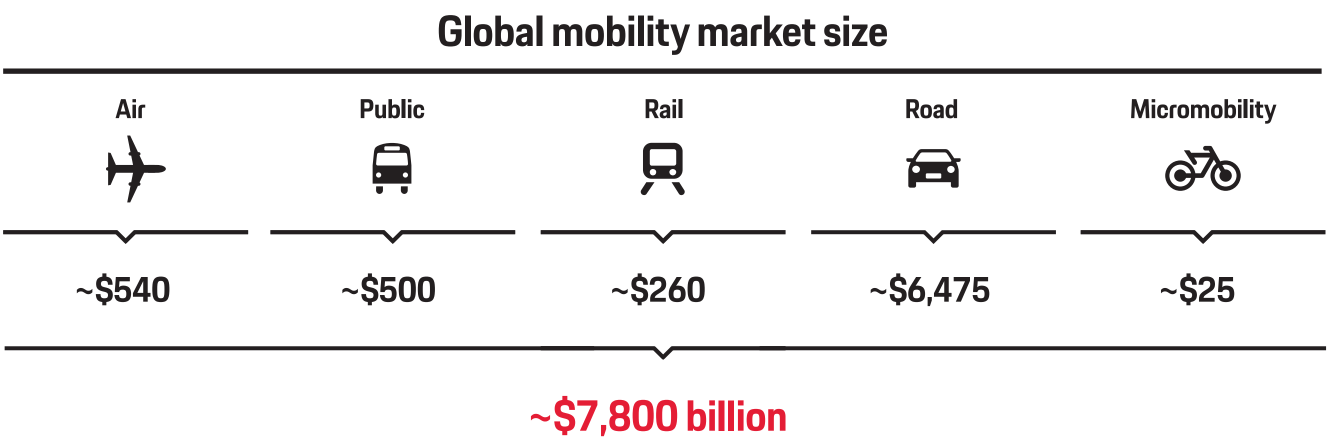


Figure 4. Global mobility market with road mobility accounting for more than 80% (indicative Porsche Consulting figures)

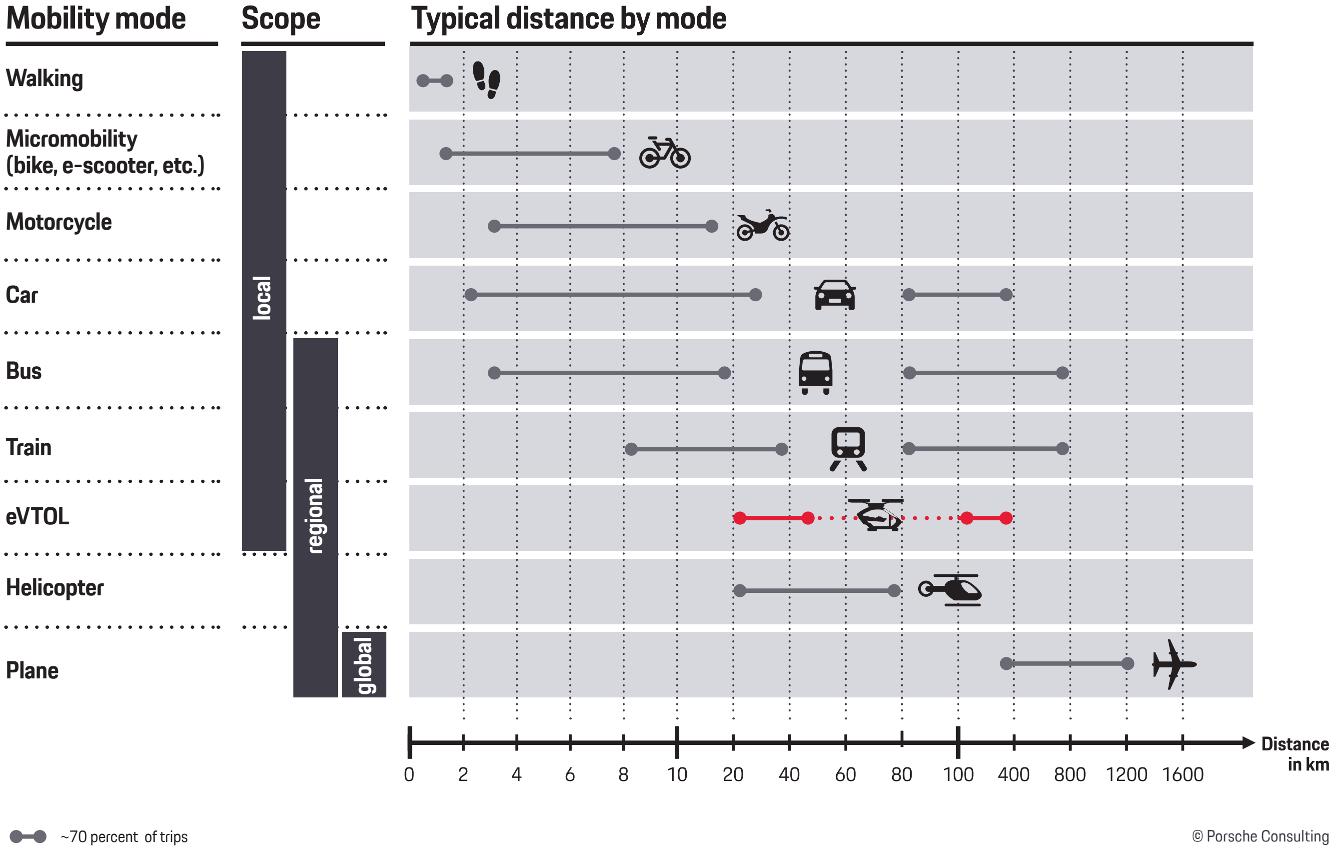


Figure 5. Classification of vertical mobility: comparison of typical distance covered by different mobility modes [6]

The world's total mobility market, including hardware and services, is worth approximately $7,800 billion today, with individual road mobility as its largest segment accounting for 80 percent (Figure 4). By comparison, we forecast that the base case of air taxi services in 2035 will have a market size of $32 billion. It is fair to conclude that vertical mobility will only be a niche in the overall mobility market. Even if the total addressable market of $230 billion and 200,000 eVTOLs were to become a reality, it would still be a niche. By comparison, the world today has about one billion cars on the streets and about 35,000 civilian helicopters in service, with annual sales of 1,000 to 1,500 units. Aside from the mobility sector itself, vertical mobility also holds potential for specialized applications such as emergency services and air rescue, or in the public safety and security sector, which includes police operations.

The mix of travel time, comfort, distance, price, and sustainability often determines what mode of transport people choose. For short distances, walking is and will remain the default in most cases. The greatest need for mobility is for short distances of two to four kilometers, which can be covered by walking and micromobility options, such as bikes or scooters (Figure 5). At the other end of the spectrum, aircraft are primarily used to cover long distances of 500 kilometers or more. The preferred modes of mobility for the remaining routes in between are motorcycles, cars, buses, and trains.

The most practical distance to cover with vertical mobility is between 20 and 400 kilometers, with 20 to 50 kilometers the sweet spot for intracity routes and 100 to 400 kilometers for city-to-city connections. When it comes to city-to-city routes, vertical mobility will most likely compete with cars, long-distance buses, and trains. The maximum length of these routes is determined by speed and efficiency. If a customer has to cover more than 400 kilometers, trains and planes will score higher on convenience than vertical mobility.

	Innovative mobility mode	Fast trips for >20 km	2nd- and 3rd-tier connections	Flexible and easy to configure	Low infra-structure costs
✓	Air taxis accessible to everyone	Time savings in comparison to road travel	Capacity up to a single-lane road	Demand-driven routing following a city's dynamics	Low costs with regard to benefits of route flexibility
✗	Not the solution for traffic problems	No end-to-end mobility in most cases	Limited eVTOL and vertiport capacity	Limited number of vertiports	Sensitivity to noise emissions

Figure 6. Benefits and limits of vertical mobility

Range limitations are dictated by today's battery technology and accessibility constraints at city-to-city airports; hence, we expect those connections to come online later. At the moment, they can only be serviced by short takeoff and landing concepts (STOL) and/or hybrid technology. This study therefore focuses on the intracity mobility provided by air taxis.

The minimum distance an air taxi can cover is mostly determined by its "setup" time, which includes first- and last-mile connectivity. Depending on those first- and last-mile options, eVTOLs can also be relevant for short distances, but due to the infrastructure limitations in most cities, a distance of 20 kilometers or more offers the clearest time savings. The exception to this is a direct eVTOL connections, when an air taxi can compete with cars, public transport, and trains. Yet compared to cars, regional trains, and buses, eVTOLs offer a considerable time advantage, and compared to helicopters, eVTOLs will be a much safer, cheaper, cleaner, and quieter alternative, especially for urban traffic.
We expect the price point for eVTOLs to be comparable to the price range of today's ride-hailing and taxi services in the medium term and at the same time remain well below today's price for a helicopter service.

Vertical mobility has the potential to generate benefits for both consumers and cities because eVTOLs are a truly novel mobility mode (Figure 6). For one, they feature innovative hardware in the field of aviation due to technical breakthroughs in distributed electric propulsion (DEP) systems. Second, they provide an innovative mobility solution to alleviate traffic congestion on the ground. Compared to helicopters, which are currently a luxury offering for some wealthy customers, eVTOLs operate in the premium segment below it and can make urban air travel suitable for and accessible to all of us. Similar to today's taxis on the ground, they will be a service we can and like to use, but may refrain from doing so every day. While air taxis offer the benefit of time savings, they depend on first- and last-mile accessibility to and from a takeoff or landing site. As vertiports will initially be rare in most cities, this lack of end-to-end mobility can pose a serious constraint.

Use of eVTOLs in cities will mainly apply to second- and third-tier connections that are usually serviced by smaller, "single-lane" roadways. They offer limited transport capacity due to the small number of passenger seats per eVTOL and a limited number of starting/landing slots per vertiport. We expect initial vertiport throughput to be below 100 passengers per hour. Even if Uber Elevate's (acquired by Joby Aviation) vision of megaports with 1,000 takeoffs and landings per hour [4] were to materialize, they could only handle a maximum of 3,000 passengers per hour, based on the assumption of a busy route and of three passengers per air taxi. This maximum throughput capacity is on par with that of a single-lane road that has a throughput of approximately 2,500 to 3,000 passengers per hour [5]. For comparison: a subway can transport roughly 30,000 to 45,000 passengers per hour on a one-way route with 1,000 to 1,500 passengers per subway.

On the upside, eVTOL routes are highly flexible and easy to configure, depending on the number of vertiports, and can respond to demand by dynamically configuring routes. Vertical mobility also comes with low infrastructure costs compared to its benefits in flexibility. It is also worth noting that the infrastructure needed for conventional mobility already exists but is often insufficient. Available land in urban areas is scarce, and new infrastructure projects for ground-based mobility therefore carry a high price tag and negative impacts on quality of life.

Building additional infrastructure for vertical mobility has comparatively fewer downsides. It is easier and cheaper to establish routes between a minimum of three vertiports in a city than to build and maintain a rigid and fixed road or rail infrastructure. Air taxis could also incur lower external costs in terms of environmental impact, accidents, and health effects caused by this mode of transportation.

The market forecast for vertical mobility has to take all these uncertainties into account and is based on three fundamental determinants (Figure 7). First, we estimate bottom-up mobility demand across all mobility modes based on the needs of potential users in different cities, today and in the future. This aggregate mobility demand forms the foundation for our market model.

Second, we gauge the ecosystem performance across the domains of hardware and technology, service, infrastructure, regulation and law, and social acceptance. One underlying assumption here is that specific infrastructure for takeoff and landing spots is necessary and could be a significant constraint on market development. An alternate scenario would assume that eVTOLs can take off and land anywhere, ushering us into a world of "flying cars" whose numbers would approach today's fleet of one billion automobiles on the ground.

Third, we need to analyze the attractiveness of vertical mobility in terms of service accessibility, convenience, its performance and price compared to other modes of transport, and the purchasing decisions customers make. The market will be shaped by the interplay of those three factors.

Applying these three basic conditions to the existing and expected mobility mix of a city, we can then estimate the overall eVTOL potential, and in a next step, use this model to extrapolate how it will scale globally.

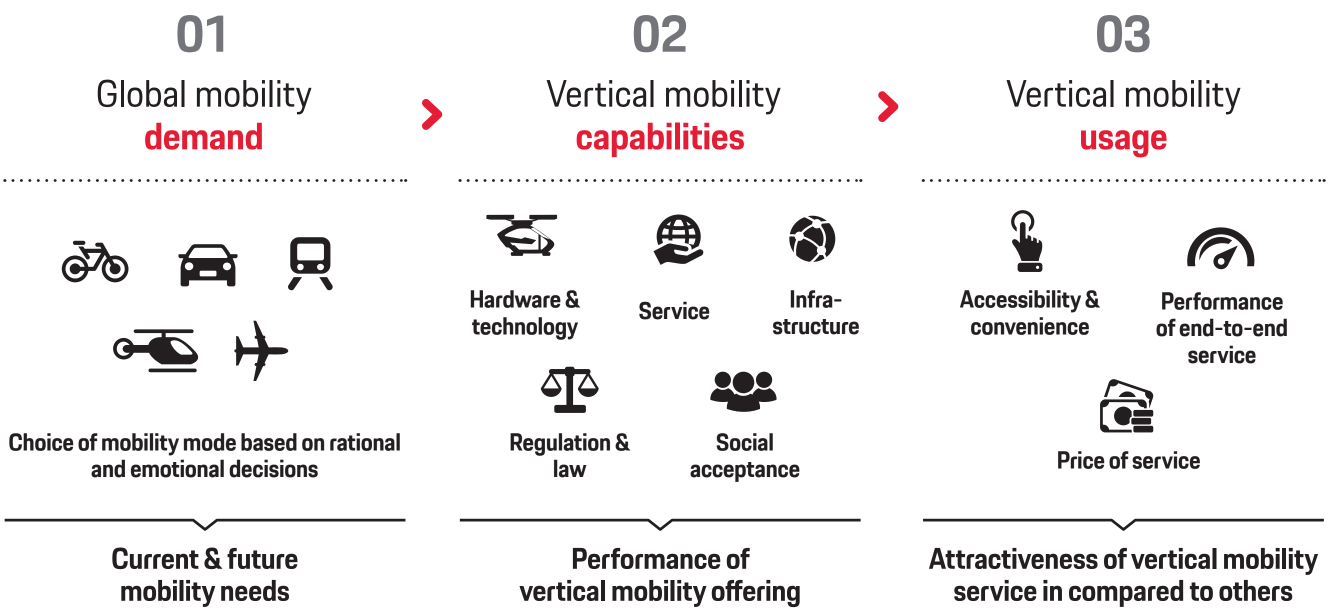


Figure 7. Approach to derive the global vertical mobility market

For passenger eVTOLs, we predict a market potential (base case) of $32 billion in 2035, of which $21 billion come from intracity air taxis. Intracity air taxi service has a cumulative revenue potential of $60–65 billion for hardware, service, and infrastructure in the decade between 2025 and 2035 (Figure 8).[2]

This market potential can be realized by interactively building the business and shaping the system for hardware, services, and infrastructure as well as addressing and removing the barriers of the vertical mobility ecosystem that we will discuss in detail in the following chapter.

Depending on the ecosystem's development speed, we still consider all three cases outlined in the previous study (conservative, base, and progressive) as possible and valid cases [1]. Yet we see the base case as the most likely one (Figure 8).

Positive ROI by 2030 with an investment horizon of approx. 10 years (base case)

Forecasting the vertical mobility market by 2035 is an ambitious undertaking. The investment calculation model put forth in this report is based on our vertical mobility market model with multiple assumptions and uncertainties. Estimates for cumulative revenues from intracity air taxis across the hardware, service, and infrastructure segments range from $7 billion all the way to $240 billion between 2025 and 2035.

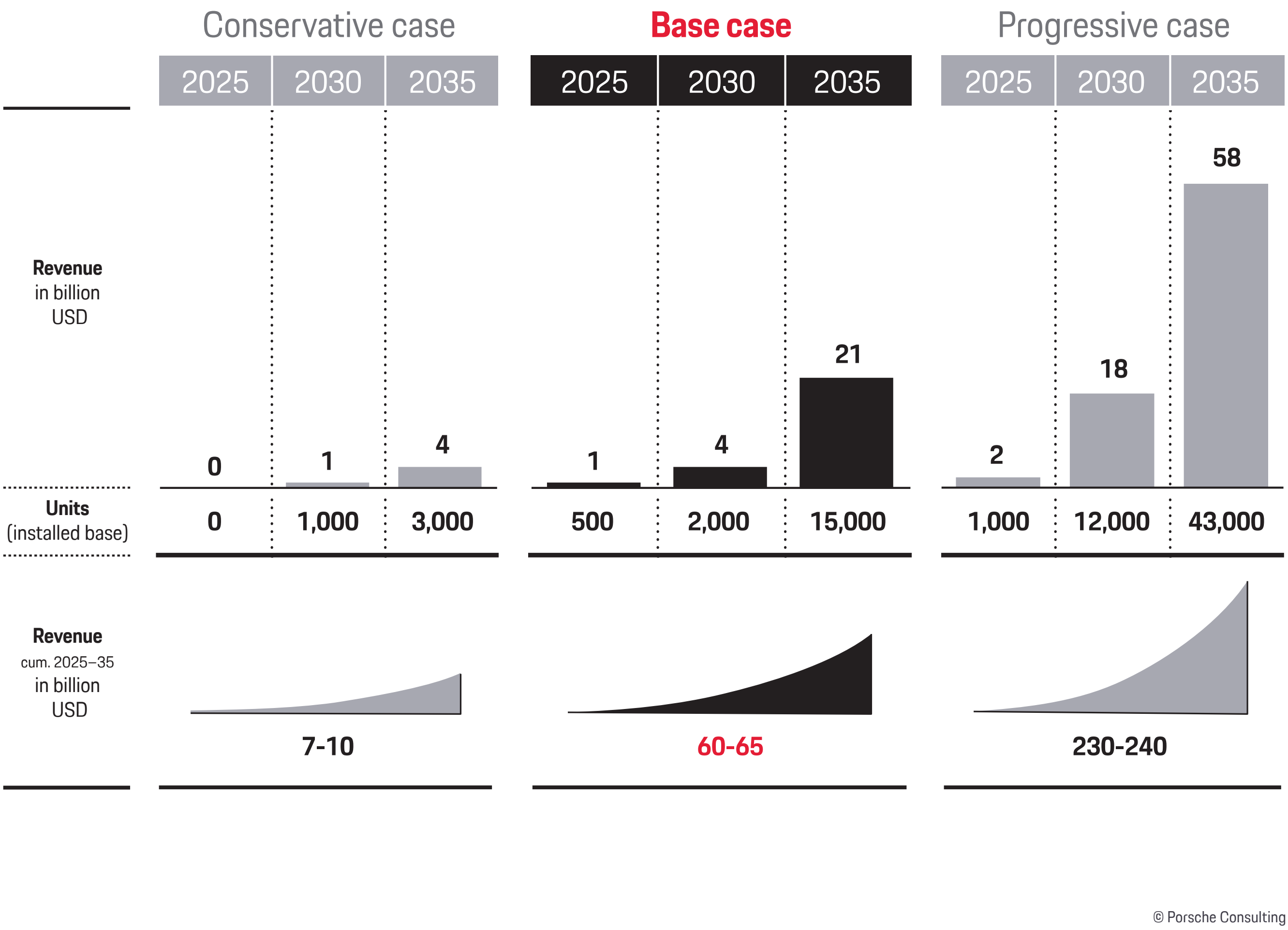


Figure 8. Vertical mobility market revenues (individual and cumulative) between 2025 and 2035 per case

[2] Since we consider investments over time, this report uses cumulative numbers for the economic efficiency calculation.

We believe in a sequential development of the vertical mobility market. One reason is the step-by-step permitting and construction process of vertiports on a global scale. Under the most likely base case, we expect cumulative revenue totaling $60–65 billion between 2025 and 2035, with a potential upside coming from additional private eVTOLs.

The conservative case can still be considered a realistic scenario, as opposed to the progressive case, which we see as a very optimistic black-swan scenario.

Even if hardware and services were to take off exponentially, we do not expect infrastructure and social acceptance to follow the same growth trajectory, let alone on a global scale. Individual geographies such as China might be booming, but vertical mobility will need a global market to become large enough to be profitable.

Developing the infrastructure and establishing social acceptance are time-consuming endeavors. Some cities may successfully address their infrastructure challenges, but the global rollout will remain incremental. To reiterate, hardware makes the vertical mobility market happen, yet infrastructure and broad social acceptance will ultimately determine the social and economic relevance of urban air mobility. The importance and varying impact of the interplay between hardware, service, and infrastructure will be analyzed in more detail in Chapter 3.

Vertical mobility requires players and investors to take a long-term perspective when it comes to ROI. Depending on the case, the required investment needs vary widely: the amount in the base case is in the $20–25 billon range, in the conservative case in the $5–10 billion range, and in the progressive case $35–40 billion.

Each case's assumptions also affect the investment horizon to achieve a positive return. The base case assumes a positive ROI in about 10 years. The conservative case pushes that threshold more than 15 years into the future, while the progressive case will get to a positive ROI in less than a decade (Figure 9).

The investment horizon of about 10 years in the base case might seem far off, but taking into account the market uncertainties observed today, there is still potential for profitability, albeit average.

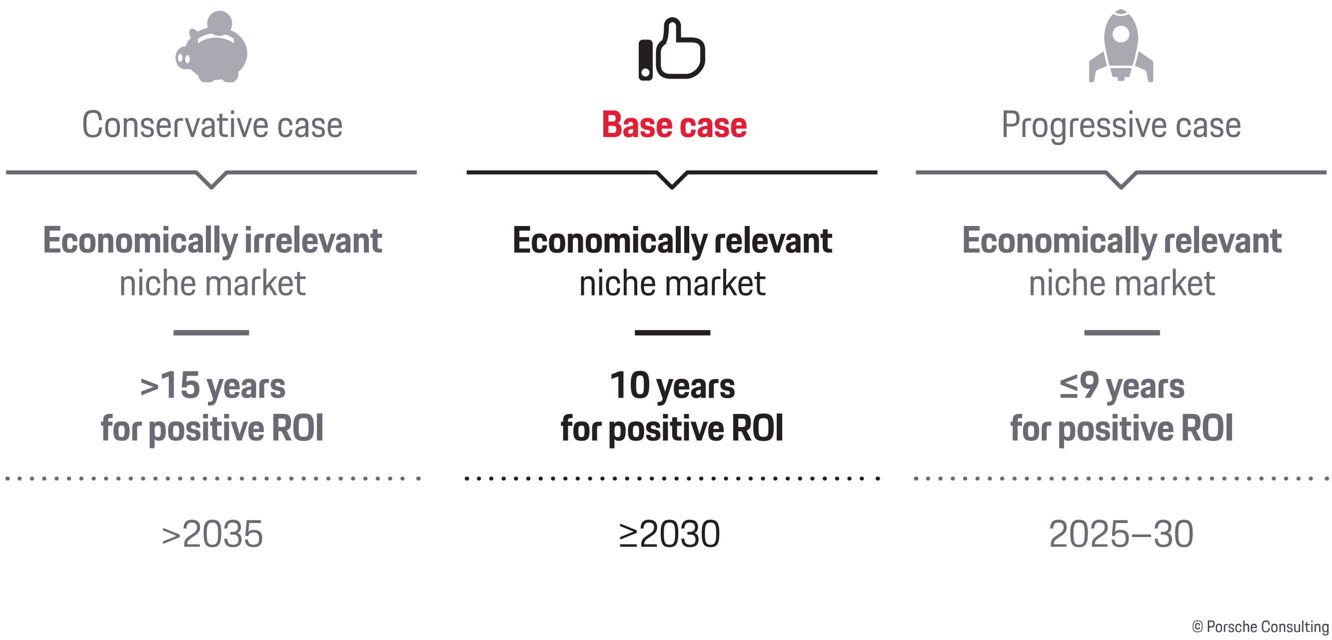


Figure 9. Economic relevance of vertical mobility market for conservative, base, and progressive cases

02 Investment Need by 2035

Players in the vertical mobility space have to bear in mind that it will take $20–25 billion in investments to remove all key barriers by 2035.[3] Around $5–10 billion in initial capital expenditures (CAPEX) are required until 2025 to start air taxi services, while $20–25 billion is the minimum to reach mass market suitability.

Vertical mobility has made great strides in the past few years as many market entrants have presented battery-powered concepts and even begun testing them in real-world environments on an experimental basis. Around $5.5 billion have been dedicated to developing passenger eVTOLs and services [3].[4]

Until 2025, initial investments of at least $5–10 billion are necessary to lay the groundwork that will make intracity air taxis socially relevant. This sum is the minimum, regardless of which case we consider. The lion's share of additional funding has to be secured by the end of 2021 in order to launch the first commercial products and services in 2025.

On top of that, we expect additional investment demand of at least $15 billion between 2025 and 2035, creating a total investment need in the vertical mobility space of $20–25 billion. The largest share—and with it the greatest risk—will go to hardware manufacturers who will have to invest at least $0.5–1 billion each into their systems. Our model is comprised of five to ten players who will eventually be successful, plus many others who will fail.

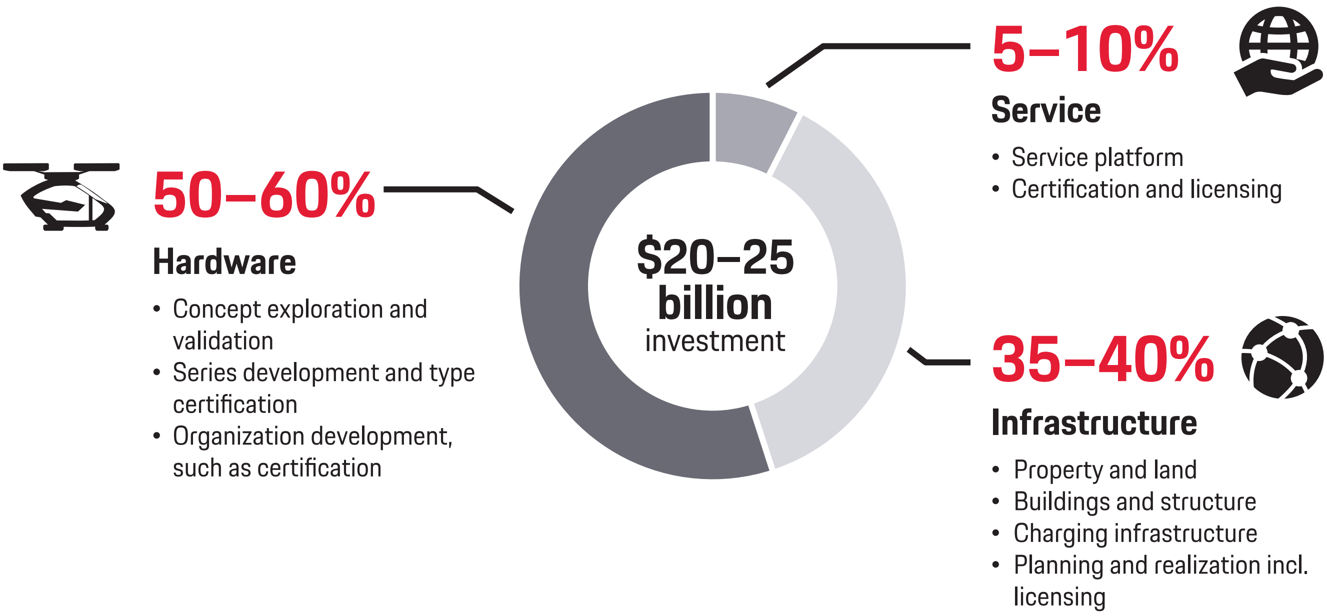


Figure 10. Investment split by 2035: hardware, service, and infrastructure

[3] This number refers to the base case and includes investments already made as well future investments into hardware, service, and infrastructure; investments are given as capital expenditures only.
[4] The entire vertical mobility ecosystem has raised around $7 billion so far, including inspection and goods drones and supporting services such as air traffic management (ATM).

It also includes more than 100 companies that have already invested in hardware development but will not make it to market entry. The funding that has so far been poured into the space is in line with our expectations during the concept exploration and validation phase. For a connected start in 2025 the moment of truth will be from now until 2022, when the capital demands of companies will have increased steadily to finance their series development and type-certification work and infrastructure and service activities will require funding as seen with the consolidation of Joby Aviation and Uber Elevate.

Vertical mobility barriers

The vertical mobility ecosystem rests on five pillars: hardware, service, infrastructure, regulation and law, and social acceptance (Figure 11). In order to evolve, these five components will have to influence each other—first in building the business and second in shaping the system. Hardware, service, and infrastructure are the three economically relevant or business-critical components. Social acceptance as well as regulation and law will shape the necessary framework in which the ecosystem operates.

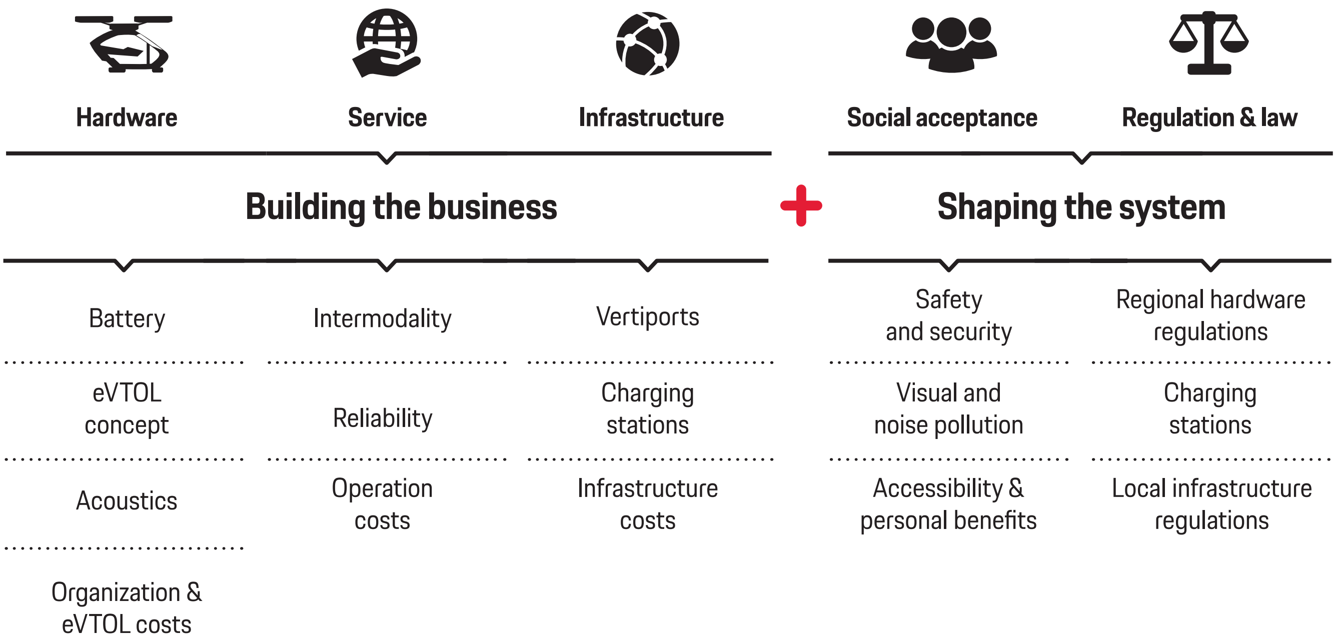


Figure 11. Barriers of the vertical mobility ecosystem: hardware, service, infrastructure, social acceptance, and regulation and law

We have identified a total of 16 main barriers for the vertical mobility ecosystem, comprised of more than 40 sub-barriers, that need to be addressed and overcome. The barriers facing hardware, service, and infrastructure are numerous and deserve to be addressed in more detail.

Successful hardware hinges on a number of factors, among them the right eVTOL concept, battery technology with sufficient energy and power density, acoustic design that minimizes noise pollution, and a cost structure that makes hardware and operations competitive. Hardware costs are strongly determined by the requirements for type certification. Additionally, players in this space have to invest in forging new partnerships to tap into the core competencies of the automotive, aviation, and technology sectors. It will take effort and money to build integrated teams and structures for developing, producing, and certifying new hardware.

The technical development of eVTOLs would not be feasible without leveraging the global trends of digitalization and electrification. The increasing capabilities of actuators and sensors in particular, driven by the overall progress in digitalization, allow us to come up with new aviation concepts. In the long run, this process can also lead to autonomous systems.

Progress on the battery front is also strongly driven by electrification efforts in the automotive industry. Compared to the manufacturing capacity dedicated to automotive OEMs, vertical mobility is a very small market and can exert little influence. Additionally, vertical mobility has its own specific demands on how battery technology must be customized, in particular higher energy density and greater power density, which is critical for higher charging rates to enable takeoffs and landings.

The barriers facing services are threefold. In order to offer customers true convenience and to keep operating costs in check, air taxi service has to be intermodal and reliable. The speed of the service will be essential for its success. Every second counts with an eVTOL, which stands in stark contrast to today's commercial airplanes, where a 10-minute delay is still considered on-time.

Pooling passengers is one way to reduce the price of air taxi services. Utilizing all available seats, however, requires good demand prediction and a sophisticated dispatch system to react to unforeseen events. This aspect is relevant for reducing operational costs as well.

The barriers facing infrastructure build-out revolve around the availability and location of vertiports, as well as the availability and standardization of charging stations, all of which determine infrastructure costs. Quick and reliable security procedures at vertiports are necessary to make air taxi service a reality.

Regulations concerning hardware, service, and infrastructure as well as social acceptance are other important barriers that will significantly shape the system. Hardware regulations are mainly driven and set by regulatory authorities with regional specifications, while service and infrastructure regulations are mostly locally driven and set by cities.

Meeting basic preconditions in the realm of regulation and law as well as social acceptance are just as important as hardware, service, and infrastructure. The openness of politicians and authorities that set the rules depends on the benefits vertical mobility offers and their acceptance among the communities it aims to serve.

All 16 barriers are key for the success of vertical mobility. Due to the large number of barriers, in the following we will only deal very briefly with the topics of battery and energy supply, regulation and law, and social acceptance.

A closer look at selected key requirements

Batteries deserve closer attention because they are one of the crucial technical aspects for the evolution of eVTOLs and have a direct impact on safety, profitability, and acoustics (Figure 12). At a battery energy density in the range of 350 to 400 watt-hours per kilogram (Wh/kg), eVTOLs will begin to show clear advantages over helicopters. Once eVTOLs use batteries with an energy density of 400 to 500 Wh/kg, the efficiency and performance of DEP systems will be superior to combustion engines.

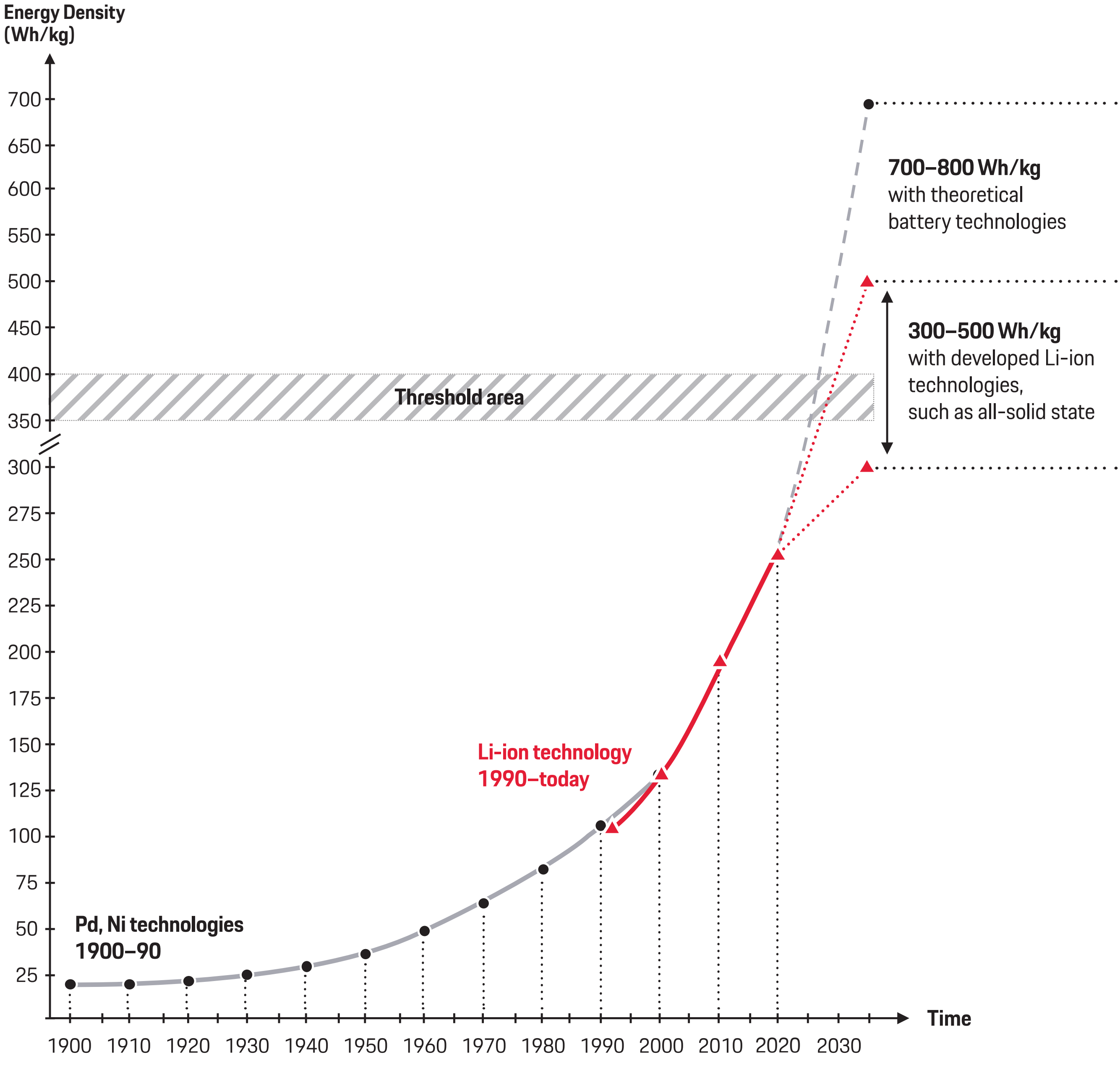


Figure 12. Energy density development of battery technology by 2035 [7]

Regulatory authorities and lawmakers will follow different paths across regions

What is holding up the process of efficiently and smoothly shaping the system? First, regulators in the Americas, Europe, Asia, and the rest of the world need to arrive at standards to certify hardware and operations as well as determine the procedures and regulations for the infrastructure involved.

Regulation is prioritized in aviation to ensure safe air operations since safety is imperative for flying. Statistically speaking, traveling with commercial airlines is on average 167 times safer than driving a car [8]. In other words, driving to the closest airport is more dangerous than flying to another continent, even though our gut may tell us otherwise.

Aviation's currently high safety levels were created in a step-by-step approach, green-lighting one innovation after another. If aviation history is any indication, diverging from this path leads to problems. The step-by-step approach is applied to technical innovations in hardware but also to aircraft use. Whether they operate in a rural, suburban, or urban environment is mainly determined by the aircraft's size and whether it carries passengers or goods.

The aviation business as we know it is a truly global venture, with an international mobility network regulated by international laws through the ICAO. Authorities therefore work closely together and mutually recognize each other's approvals. Today's dominant authorities are the US Federal Aviation Administration (FAA) and its European counterpart, the European Aviation Safety Agency (EASA).

By contrast, vertical mobility will be rolled out as part of regional and local mobility networks, which are subject to regional laws. That is why we expect regulatory authorities to take different approaches and also be beholden to calls for protectionism.

Whether regulatory authorities will enable market entry for companies in the eVTOL space deserves closer attention. Regulators in different geographies will impose their specific requirements to regulate hardware, service, and infrastructure. At the same time, regulatory authorities, policymakers, and society at large are closely intertwined when it comes to shaping and enforcing those frameworks; the desire for progress must be balanced with the demand for safety and security. One can expect that this interplay will lead to different approaches and developmental pace in various geographies.

We see different regulatory approaches for air taxis, either the traditional step-by-step approach mentioned above or a multistep approach that certifies more than one innovation at the same time. Single steps are comprised of electric flying, eVTOLs with DEP systems, and remotely piloted and autonomous flight. Combining those steps can and will lead us down different paths, depending on the respective regulatory authorities.

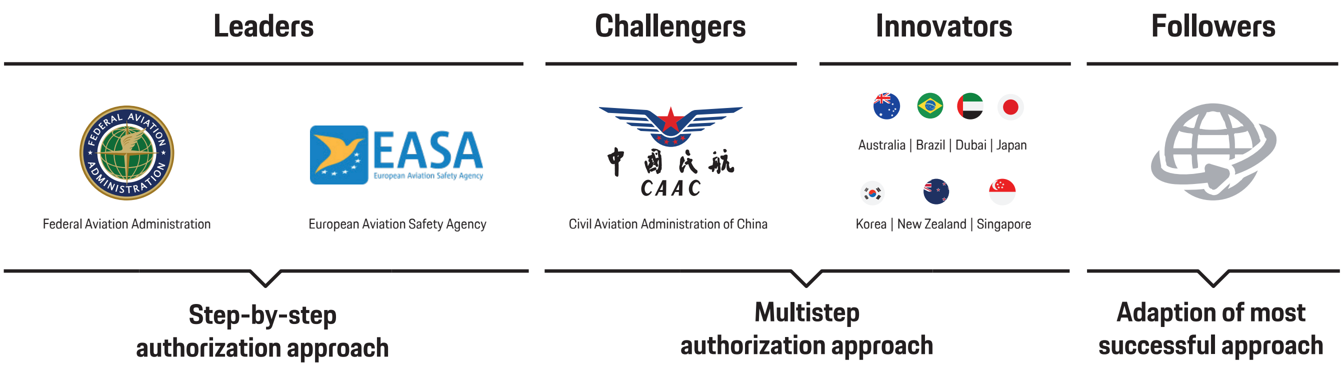


Figure 13. Regionally specific classification of aviation regulatory authorities

We suggest classifying today's aviation regulators broadly into four categories with their own regional differences: current leaders, innovators, challengers, and followers (Figure 13). Having said that, it is worth emphasizing that many authorities have laid out a runway for eVTOLs to take off in 2025 and are generally encouraging progress in this space.

Europe and the USA are today's leaders. They follow a step-by-step authorization approach to certifying hardware, services, and infrastructure. We expect them to act on electric flight, eVTOLs, first as piloted versions and then as autonomous systems. Their regulatory bodies will always weigh innovation against safety, with a clear emphasis on the latter.

China, on the other hand, can be considered a challenger. The Civil Aviation Administration of China (CAAC) could test a shortcut by allowing a multistep approach that would make several new technologies possible simultaneously, for instance pilotless eVTOLs with DEP or remotely piloted eVTOLs. The remotely piloted approach comes with the risk of unstable radio communications, and by extension, the risk of system intrusion. Autonomous control also requires a high degree of intrinsic safety. Nevertheless, challengers like China could exert pressure on the lead markets to follow suit. China has the advantage of a very strictly controlled airspace with no private aviation. Thanks to its high speed of innovation and willingness to take risks, the country is well positioned to leverage vertical mobility as a way to quickly electrify its domestic aviation market.

Yet another category of regulatory authorities are the innovators—major cities and countries with large rural areas that are volunteering to be test beds for the first commercial routes and services. These include Dubai and Singapore as well as Australia, New Zealand, Brazil, Japan, and Korea. Once those first pilots are defined, companies will begin testing new technologies and services. However, innovators are too small to make vertical mobility economically relevant.

The final category of the followers observe others first and only get on board when vertical mobility is proven safe and successful.

Deviating from the tried-and-true stepwise approach can offer a competitive advantage but increases the risk of an eVTOL crash. A catastrophic event like this could seriously threaten or damage the global vertical mobility market, since social acceptance would suffer and investments could be withheld.

The regulatory challenge for eVTOLs lies in how emergency situations are handled when flying over densely populated cities. We can assume that eVTOLs will suffer from similar rates of failure as commercial aviation and that those probabilities need to be factored into the development process early on.

Safety in numbers

What does it mean to apply the expected failure rates of commercial aviation to eVTOL services? Current practice demands a system reliability of 10^{-9}, which estimates the likelihood of a system failure with catastrophic effect per one-hour mission. Assuming an installed base of 23,000 eVTOLs in 2035 with up to 50 million flight hours per year, a system reliability of 10^{-9} translates into one eVTOL catastrophic accident with passengers injured or killed occurring every 20 years (with the proviso that the various phases of flight carry different risks). Lowering the system reliability to 10^{-7} would mean five eVTOL incidents of this proportion per year. Short of catastrophic failure, incidents during intracity flights can cause damage on the ground and create additional congestion. So even in the 10^{-9} scenario, smaller incidents have the potential to negatively affect urban traffic.

Social acceptance as a key requirement

Technology makes vertical mobility happen, but social acceptance makes it relevant. We have developed a detailed framework for the social acceptance of vertical mobility, which is a complex topic deserving of its own analysis.

It is worth repeating that social acceptance is a fundamental requirement for the vertical mobility market to take off. Customer acceptance is strongly influenced by hardware, service, and infrastructure providers. It is their responsibility to satisfy customers and society at large by ensuring their services are available and reliable and offering clear benefits in terms of time and cost. In a similar vein, social acceptance is tied to the standards set by regulators and lawmakers. It is their obligation to address concerns about safety and security, to reduce noise emissions, and to create tangible social benefits, for instance, by having emergency services deploy eVTOLs.

We therefore recommend that lawmakers around the world approve routes only if vertical mobility moves beyond its current status as a luxury niche product and enters the premium niche market. To get there, we need to see attractive and accessible services at a competitive price comparable to today's taxis on the ground.

The end point of this development will be a healthy and growing market for vertical mobility, a market that not only rewards investors but fulfills the bold vision fueling this quest: finally adding a third dimension to human mobility at scale and doing so safely, sustainably, and at an inclusive price point.

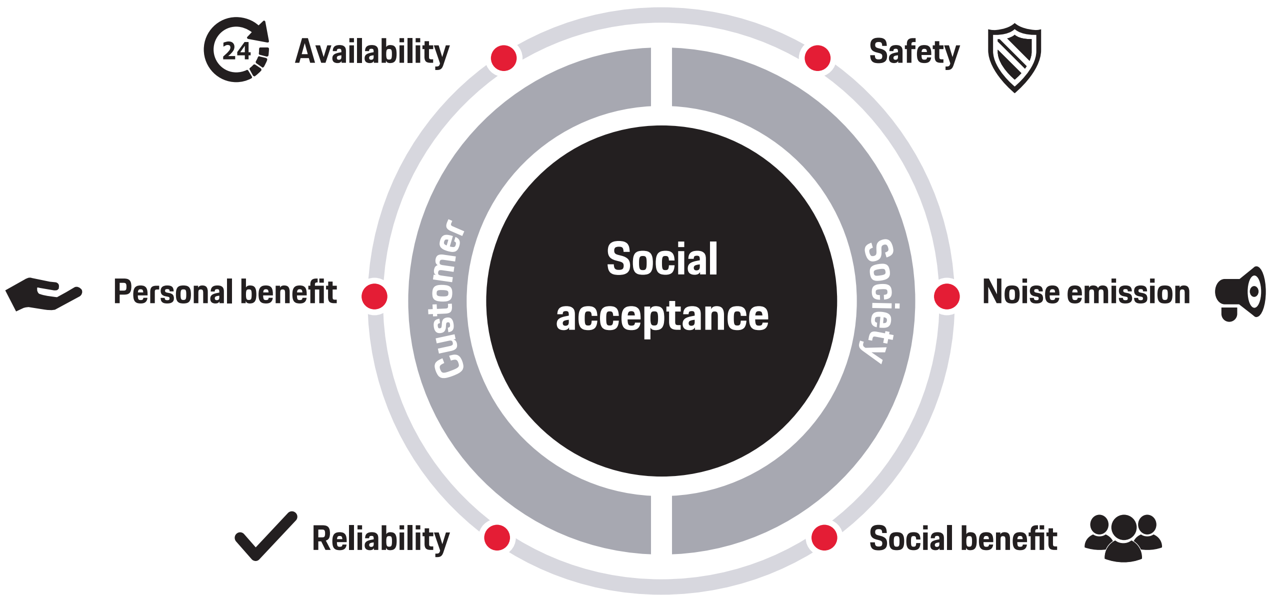


Figure 14. Dimensions of social acceptance for vertical mobility

03 Social and Economic Relevance

Vertical mobility will achieve social and economic relevance in two phases. To make it happen, players during the pioneering phase will have to cooperate on creating and filling the ecosystem with life. In the second phase, which is all about making it relevant, we will see more and more differentiation and competition. While technology makes vertical mobility happen, only broad social acceptance will make it economically relevant.

If vertical mobility is to become economically relevant, it needs to evolve from its status as a luxury offering for the wealthy to an affordable option for wide swaths of the population. One can think of this shift as making helicopters available to everybody. In today's world, helicopters are a small and therefore largely irrelevant niche market, but eVTOLs have the potential to make aerial mobility services a sizable and therefore relevant niche market.

In order to get there, however, we need to see all pillars of the ecosystem—hardware, service, infrastructure, social acceptance, and regulation and law—fall into place and interlock. Disruptive hardware needs to be available for intermodal and seamless services that reach thousands of vertiports. Furthermore, the ecosystem depends on political support and broad social acceptance. The latter can only be achieved if users and lawmakers perceive clear personal and public benefits from vertical mobility.

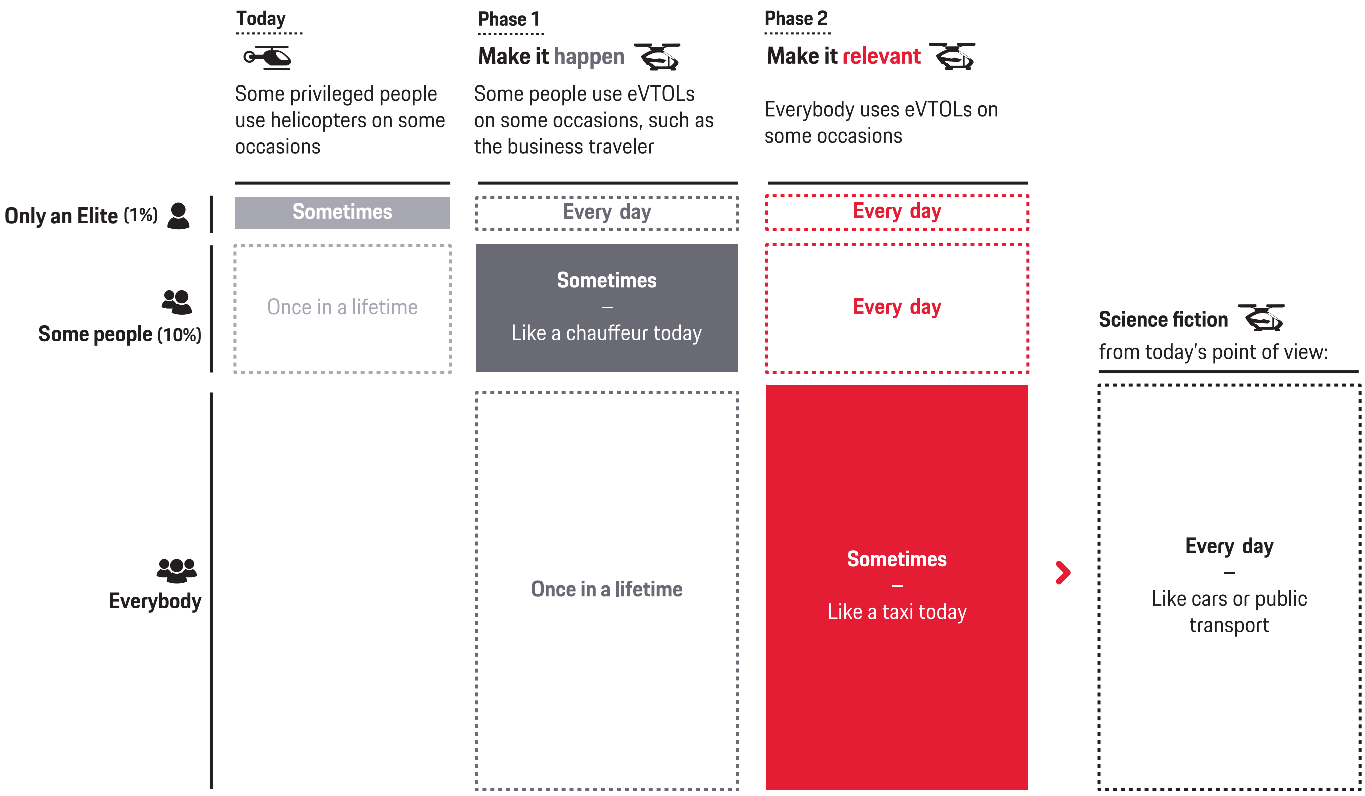


Figure 15. Developmental phases of vertical mobility

Otherwise, this new mode of transportation will remain trapped in a localized niche, since laws and regulations in many countries require broad public consensus. If, on the other hand, only a few pillars of the ecosystem are built and not properly interconnected, vertical mobility runs the risk of meeting a similar fate to present-day helicopter services: being a small niche for well-heeled customers (Figure 15). In this case, eVTOLs may make flights less noisy, safer, and more sustainable but will nevertheless be socially and economically irrelevant—and a very expensive luxury ride.

We see vertical mobility playing out in different phases, with Phase 1 dedicated to making it happen and Phase 2 focused on making it relevant (Figure 15). To make it happen we need to get to the point at which some people use eVTOLs on some occasions. Think of business travelers getting from the airport to a convention center much like they do today with a taxi or chauffeur on the ground—still a premium travel method.

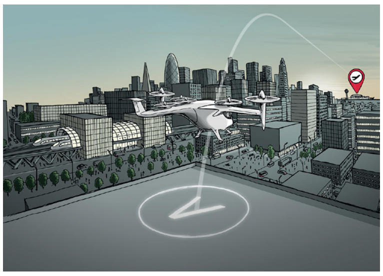
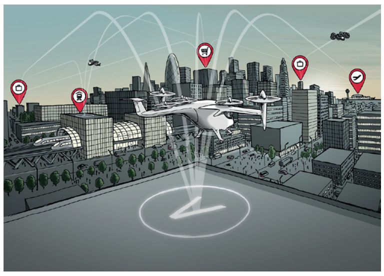
Making this mode of transport relevant will take it to a whole new level. Everybody will be able to use eVTOLs on some occasions, once vertiports are accessible in their neighborhood and the price for an air taxi is attractive enough, or on par with a taxi today. We can also envision some customers using an eVTOL every day, for instance, if they own a private eVTOL, the cost of which would be comparable to driving a current-day premium or luxury car.

Will eVTOLs soon become a new mode of transport that everybody uses every day, like the subway or a car? The short answer is no. We do not think air taxis will be allowed to take off and land anywhere, independent from vertiports, by 2035.

How, then, will a relevant niche market for vertical mobility in 2035 look? It will be characterized by a global fleet of about 15,000 high-performance and reliable airborne workhorses. Hardware players will each manufacture and sell an average of a thousand eVTOLs a year, making it an attractive business. Today's largest helicopter manufacturer, by comparison, sells fewer than 500 units per year.

Those passenger drones will offer higher performance and lower noise emissions than that which is currently under development, implying that we will witness at least the second hardware generation if not the third. On the service side, we need seamless intermodal services in dozens of cities used by half a million people every day. These air taxis have to be integrated with mobility offerings on the ground, creating a holistic transportation grid with many routes and flexible dispatching to ensure a reliable, comfortable, and speedy trip from point A to point B. In addition, we need thousands of air mobility stations in operation. Around 1,000 large or 2,500 medium-sized vertiports are necessary to make this scenario a reality. The relatively high number of takeoff and landing points is essential to guarantee both sufficient passenger throughput as well as easy accessibility to a vertiport.

On the social acceptance front, the key questions of safety, noise emissions, accessibility, price, and sustainability will have been addressed, and consumers need to have realized the social and individual benefits that come with having a new, reliable service at their disposal. Politicians, for their part, have to draw up fast permit processes for the necessary infrastructure and approval of additional routes as the business scales. Cities finally ought to be interested in quickly adopting this new mode of transportation since it lets them move traffic off their clogged roads and offer additional, environmentally sound mobility options for the masses. Overall, the interplay of social acceptance and policymaking will create the regulatory and legal framework for vertical mobility.

	2025 **Make it happen**		2035 **Make it relevant**	
				
	From local market...	›	... to global market	
	From luxury market...	›	... to mass-suitable market	**Threshold 2035**
Hardware	Provide first commercial eVTOL	›	Develop eVTOL to **high-performing workhorse**	**~15,000** installed eVTOL units
Service	Fly "showcases" on first routes	›	Provide a **seamless intermodal journey**	**>500,000** customers per day
Infrastructure	Use existing infrastructure, such as helipads	›	Provide **multi-use air mobility stations**	**~1,000–2,500** air mobility stations
Regulation & law	Intracity and city-to-city air mobility needs **policy support**			
Social acceptance	Intracity air mobility needs **social acceptance** to lift off			

Technology makes vertical mobility happen, but broad social acceptance will make it relevant

Figure 16. Path to economic and social relevance of vertical mobility

The first phase to make vertical mobility happen is characterized by a few developmental milestones. First will be the introduction of the first commercial eVTOLs that can be deployed on initial routes, even though their performance, measured by operating hours, costs, and acoustic profile, will leave much to be desired. Second, we will see air taxi services in the first attractive routes in a few select test-bed cities, but these showcases will suffer from a relatively high price point due to the small number of cities involved and the low number of daily flights. These pioneering services are hardly ready for the relevant market of tomorrow. Third, those services will rely on existing infrastructure such as helipads, which in most locations are not numerous enough to provide truly relevant service. In addition, the size of the vertiports will limit the number of takeoffs and landings.

Things will change in phase 2 to make vertical mobility relevant. The push to establish a meaningful market will be driven by several factors. High-performance, flying workhorses will lift off, characterized by more than 2,000 operation hours per year, a price range between $250,000 and $1.5 million per eVTOL, and the noise level of a truck, or even lower, providing an overall comfortable sound profile.

This second phase will offer seamless intermodal services that are successfully integrated with ground mobility in more than 30 cities around the world and that will expand their infrastructure, offering up to 30 flights per eVTOL per day at an attractive price. Assuming a more limited infrastructure build-out, smaller air taxi services may spread out over 200 cities to reach critical mass. Passengers will be able to use 1,000 to 2,500 air mobility stations, with the total number of required vertiports needed depending on their size (see also Chapter 4.3). Bigger vertiports will offer a sufficient number of starting and landing points, which in turn drive a higher number of takeoffs and landings. It bears repeating that this type of intra-city air mobility will need broad-based policy support as well as social acceptance to lift off.

There are several key drivers that will influence the evolution of hardware, service and infrastructure as these two phases play out. On the hardware side, the crucial determinants are progress in battery technology and acoustics, the number of innovation cycles, and the amount of targeted hardware investments. On the service front, it is a numbers game—namely, how many cities adopt and launch a service, the number of trips offered as usage becomes more frequent, and the amount of targeted service investments. As for infrastructure, finally, the key drivers are the number and availability of vertiports at attractive locations, their respective size, which will determine the number of takeoffs and landings, and infrastructure investments.

None of those segments will evolve in isolation but are strongly interdependent. When the first eVTOL generation enters service, for example, its less advanced hardware performance could result in lower utilization and also drive up space requirements at vertiports for parking and charging the equipment. As a result, the overall lower hardware efficiency would drive up the price of air taxi service.

The complex interplay of all pillars of the ecosystem needs to happen not only in one city but in many cities around the world more or less simultaneously to create a scaled and eventually relevant market.

Hardware	Service	Infrastructure
Technological progress	Number of cities	Number of vertiports
Number of innovation cycles	Number of trips	Size of vertiports
Hardware investments & costs	Service investments & costs	Infrastructure investments & costs

Figure 17. Key drivers of the vertical mobility market

More than 30 cities in 2035 (base case)

For the base case, more than 30 cities have to establish an intracity air taxi service and the relevant infrastructure by 2035. We have identified more than 60 cities as suitable markets.

Every city suffers from its own operational constraints, for instance, local weather conditions and the number of available slots. Looking at the global landscape, we can draw up a list of potential cities for the progressive case, comprising 64 cities with the most promising conditions (Figure 18). For the base case to become reality, air taxi services have to launch in more than 30 cities, or roughly half of the cities listed, with a sufficiently developed infrastructure for intracity flights. The progressive case, by contrast, requires more than 60 cities, or all cities listed in Figure 18, with a fully developed infrastructure of 50 to 100 vertiports each.

Innovative cities and cities that already have a strong helicopter infrastructure or offer on-demand helicopter services are potential locations for air taxi service. Even though a city might already have infrastructure for helicopter flights, they often lack the facilities for charging. It is a bottleneck similar to what is hampering the broad rollout of electric vehicles today.

Several innovative cities that have already affirmed their intention to offer eVTOL services are Dallas, Dubai, Guangzhou, Los Angeles, Melbourne, and Singapore. They can be considered strong candidates for a successful air taxi service.

In addition, Mexico City, Miami, New York, San Francisco, São Paulo, Shenzhen, and Tokyo look very promising for air taxis, since they already offer on-demand helicopter services and thus have demonstrated their openness to intracity flights.

Already planned as test beds

Dallas
Dubai
Guangzhou
Los Angeles
Melbourne
Singapore

Established helicopter service

Mexico City
Miami
New York
San Francisco
São Paulo
Shenzhen
Tokyo

Further potential cities

Amsterdam
Atlanta
Bangkok
Barcelona
Beijing
Belo Horizonte
Berlin
Bogotá
Boston
Brasília
Buenos Aires
Charlotte
Chengdu
Chicago
Chongqing
Delhi
Denver
Doha
Dongguan
Frankfurt
Hamburg
Hong Kong
Houston
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Cape Town
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Kunming
Las Vegas
London
Madrid
Manila
Minneapolis
Moscow
Mumbai
Munich
Narita
Orlando
Osaka
Paris
Phoenix
Rio de Janeiro
Rome
Seattle
Seoul
Shanghai
St. Petersburg
Sydney
Taipei
Tianjin
Toronto

Figure 18. List of 64 cities to potentially launch an air taxi service by 2035

04 A Guide for Players

This chapter will look at the economics of hardware, service, and infrastructure in more detail, outlining business characteristics, success factors, the developmental path, and the best strategies to succeed as providers in each segment.

4.1 Hardware Player: Solving the Hardware Puzzle

The market for intracity air taxi hardware has the potential to be worth $5 billion in 2035, generating cumulative revenue of $15–16 billion between 2025 and 2035 and requiring a capital expenditure of at least $10 billion in our base case.

If there is one basic precondition for the vertical mobility market, it is the arrival of an eVTOL approved for commercial use. Every system hitherto unveiled, however, can only be considered experimental. Solving the hardware puzzle will require the highest initial investments without clear visibility of this market's evolution. Designing and developing a workable eVTOL will cost anywhere from $500,000 to $1 billion before the hardware can even be introduced and tested in a real market. This path stands in stark contrast to the infrastructure and service components of vertical mobility, with incremental investments occurring while the market is developing and successful offerings are introduced.

In that sense, hardware players are the brave pioneers of vertical mobility. They must brace themselves for tough times, since the market will get started with first-generation systems, but in order to enable the projected market size of $21 billion for the overall intracity market in 2035, hardware players need to roll out at least two generations of air taxis.

Vertical mobility may be a niche of the overall mobility market, but it is a crowded niche, especially on the hardware side, with more than 200 concepts being developed or at least announced (Figure 19).

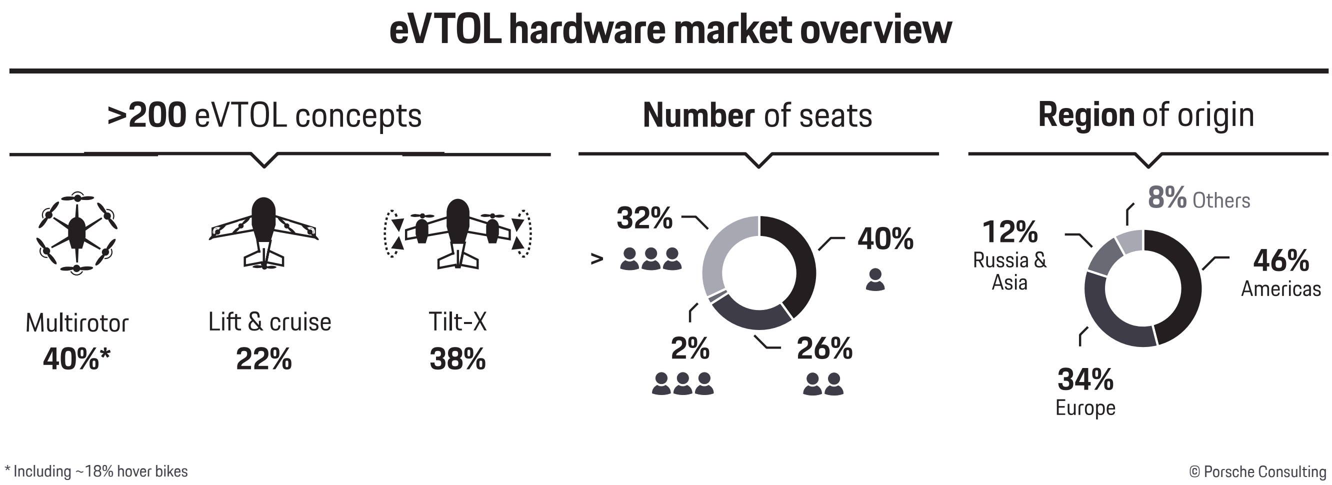


Figure 19. eVTOL classifications: concepts, number of seats (including pilot), and region of origin

There are currently more than 100 companies intending to bring an eVTOL to market by 2025, but we expect no more than five to ten ventures to become economically successful. Because this estimate is market-driven, we consider intracity air taxi mobility to viably include five to ten players—those who can master the triple challenge of access to capital, assembling an A-team, and staying focused on the right products and services (more on that below).

Along the way, we hope to see healthy competition among different concepts. If the market evolves more slowly and if some companies cannot succeed with products for the mass market, we expect to see some of them pivoting, for example, to the more elite segment of private ownership.
Between $5 and $8 billion need to flow into the hardware realm by 2025 for this market to materialize. Whoever wants to play in this space will need to be patient, have pioneering spirit, and secure sufficient venture capital.

But that is only the first phase of making it happen. Assuming five to ten ventures will become successful, the second phase making the market relevant will take at least another $5 billion, maybe even as much as $10 billion, to increase the efficiency and performance of eVTOL hardware. Only then will vertical mobility be able to scale to the projected size by 2035.

Investors have already poured around $5.5 billion of the first $5–8 billion of required funding into developing passenger eVTOLs [3]. While it is conceivable to make vertical mobility happen with significantly fewer funds devoted to hardware development, less capital would curtail competition among the players. The amount of money invested in eVTOL hardware by 2022 will therefore provide a good indication of where the market is headed.

Lower competitive pressure could have several negative consequences. It does not push competing hardware concepts such as multicopter, lift and cruise, or tilt-x designs to face off against each other, resulting in less mature products. It also does not force as much progress as possible when it comes to improving eVTOL sound profiles, costs, or operation hours. And finally, a lack of competition will not help hardware players refine use cases such as intracity or city-to-city flights, including first- and last-mile integration. The progressive case in particular requires highly mature hardware and healthy competition among the various concepts in order to make the market materialize by 2035.

We believe investors in the hardware space have to be patient and accept an ROI horizon of about 10 years for the base case (Figure 9). This is due to the fact that investments need to be flowing today, while the first revenues will not follow until 2025 as the market slowly evolves. One way to generate revenues sooner would be to deploy eVTOLs in the private ownership segment or for transporting goods, since the regulatory hurdles in both cases are lower than for carrying passengers. The question remains as to whether those eVTOLs would really be used in any meaningful way when there is no infrastructure available to take off, land, and recharge them.

The first generation of eVTOLs have already taken to the skies for experimental flights and garnered a lot of interest and headlines. But we are still a long way from commercial eVTOL applications to carry passengers, mainly because safety and security are of paramount importance. First regulatory frameworks, like the special condition by EASA [9], demand that eVTOLs are designed for the probability of a catastrophic failure of just 10-9 per hour when conducting commercial air transport of passengers and flying over congested areas. On the path to this demanding low-risk environment, we expect to see eVTOLs take off as private showcases with a lower safety requirement of only 10-6 per hour. This is due to the fact that an individual is using his or her own eVTOL and not potentially endangering the lives of others. We can also envision special regional use cases, such as leisure flights, that offer vertical mobility as an adventure similar to bungee jumping or parachuting, requiring customers to sign a liability waiver. But these cases will not create a profitable market or hardware business case.

Success factors for hardware providers

Companies that want to earn the right to win in the nascent hardware market for vertical mobility have to master three equally demanding disciplines: secure substantial funding, assemble an A-team, and stay focused on lucrative use cases for their eVTOL.

Depending on the complexity of an eVTOL concept, a company needs to secure at least $500,000 to $1 billion to get from concept drafts to series development. Any market entrant serious about solving the hardware puzzle also needs a deep and broad bench of experts who know how to design aerodynamic concepts, how to get them certified, and how to manage that complex process with various agencies and regulators. Industrial and manufacturing know-how is also a must, with a background in the automotive space as an added benefit to get to production at scale, including UX design. We see success as dependent on the right mix of team members from the aviation, automotive, and tech world. Established companies will have to work on integrating those teams, while startups need to build them from scratch.

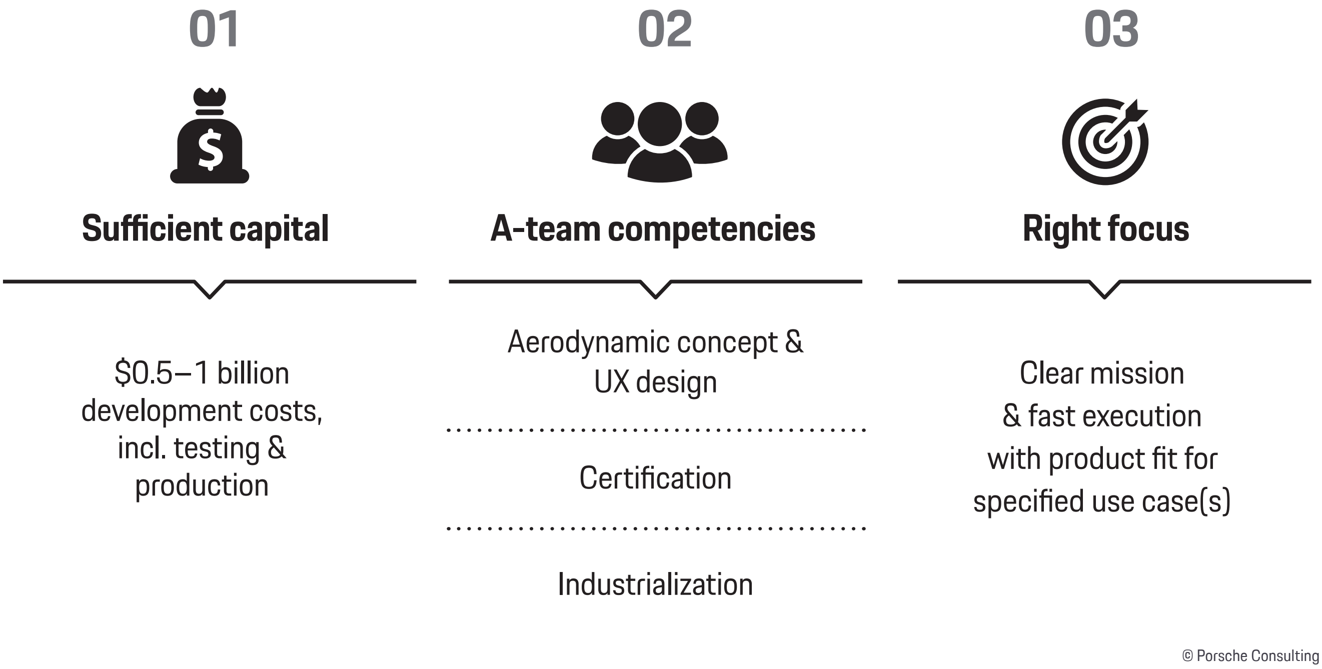


Figure 20. Success factors for eVTOL hardware providers

Third, successful hardware players need to define a clear service mission, focusing on specific use cases and fast execution. Whatever use case they settle on will help them optimize the mission profile for their eVTOL. The specs of their product concept have to be a perfect fit for a particular use case and their intended end users. Furthermore, a player in this space must focus on fast execution of efficient organizational processes and structures. The varying degrees of freedom in large companies and in startups will come into focus here.

Startups are by nature fast-paced, agile, focused, and not averse to risks. As they grow, their challenges lie in building and maintaining structure and secure, continued access to capital. Incumbents, on the other hand, are slower and more risk-averse. Once they embark on a venture, they have sufficient funds and know-how but are hampered by more complex decision-making.

Technology imposes several mission-critical preconditions, starting with the batteries (see Chapter 2). Their design and efficiency define to a large extent whether a planned eVTOL makes sense at all.

We believe that air taxis covering short hops will be the exception, even though the very first applications may just be that—for instance, flying between a train station and an airport that has suffered from poor connectivity. The shorter the distance, the more important high travel speeds become, particularly since customers have to accept detours or delays imposed by vertiport locations and first- and last-mile connectivity.[5]

The sound profile of new hardware directly influences its social acceptance and market success. Companies need to consider noise emissions and what they imply for the routes their eVTOL can service as well as at what locations and how frequently it will be able to take off and land. All those design criteria and product specs need to be defined and fine-tuned according to the specific use case and its intended customers.

One important focus area is operative performance as defined by service time to enable a quicker turnaround, charging time, maintenance, and repair. Excellence in those areas can generate a positive economic case for a service player. We expect that the second and third generation of eVTOLs will feature noticeable technical improvements around noise, mission profiles, and overall efficiency. Those improvements will make eVTOLs reliable workhorses with high operating hours and low downtime for maintenance. And as soon as costs and noise levels come down, this market will be ready to scale. Taken together, these developments are prerequisites for the next phase of making it relevant.

The path to make the hardware business economically relevant

Hardware players need more than good equipment to succeed and make the business economically relevant. Only in an ideal world would an eVTOL be absolutely emission-free in terms of noise and able to start and land anywhere. In reality, we need cost-effective hardware with a low noise profile plus thousands of routes and air mobility stations that serve as the interface for ground and air mobility, with meaningful passenger throughput. Whoever enters this market must be prepared to stay in it for the long run, as at least two eVTOL generations are required to arrive at a fairly silent, high-performance eVTOL workhorse while the market evolves incrementally. We expect no easy shortcuts to get around this timeline.

[5] For detailed information that compares the customer journey and travel time between eVTOLs and cars, see Figures 10 and 11 from our 2018 study "The Future of Vertical Mobility" [1].

Hardware

	2025	2035
	Make it happen	**Make it relevant**
		
	From local market...	... to global market
	From luxury market...	... to mass-suitable market
Performance	**~500–1,000** operation hours per year	**>2,000** operation hours per year
Price	**~$0.5–2 million** per eVTOL	**~ $0.25–1.5 million** per eVTOL
Acoustics	**~65–70 dB** at noise level of a truck/car	**<65 dB** at noise level of a truck/car or lower with comfortable sound profile
Regulation & law	Development of regulatory standards	
Social Acceptance	Acceptance of safety, noise, and sustainability	

Figure 21. eVTOL hardware development path to an economic and socially relevant vertical mobility market

By our estimates, one, two, or a maximum of three eVTOL generations will come to market between 2025 and 2035, depending on the development speed of the underlying technology and the evolution of regulatory standards but also on how investments in the hardware market play out and how team competencies grow.

The first generation of eVTOLs, ready by 2025, will be characterized by limited operation hours of 500 to 1,000 per year due to battery constraints and the relative immaturity of first-generation concepts. The current energy density of around 250 to 300 Wh/kg means batteries are sufficient for first test flights until 2025. Today's eVTOLs have very limited efficiency because of the high battery weight. Taken together, those conditions make sense for showcasing first flights on some routes, but not for operating an economically viable air taxi service for the mass market.

Operation hours are also limited by the respective charging concept. Frequent charging would mean fewer operation hours, while changing battery packs would enable more operation hours. The price of a first-generation eVTOL will range between $500,000 and $2 million, depending on performance, production volume, and the number of seats. We expect its noise level to be between 65 and 70 decibels, comparable to that of a car or truck. Given the increase in road and air traffic, it is critical to reduce noise emanating from both an eVTOL and infrastructure on the ground. Selecting the right locations can make a big difference.

Many players will fail to bring their first commercial eVTOL to market. But they will still have the opportunity to learn from failure and gain more experience to be able to reenter the market with second- or third-generation hardware. By then, some successful concepts may have emerged from today's broad portfolio of ideas. This assessment is based on several key assumptions—namely, that the market keeps growing and additional investors underwrite those players as well as companies having the right A-team, access to capital, and the right focus.

If the market volume for eVTOLs does not grow beyond this initial stage, however, costs will not decrease, leading to a lower number of customers and less social acceptance. Under this scenario, a first-generation eVTOL would be just an electric version of a helicopter and the overall market would merely develop into a very small, economically and socially irrelevant niche (Figure 15).

Several things need to happen to eventually make the market for vertical mobility relevant. First and foremost, eVTOLs have to evolve into high-performance workhorses. Follow-on generations of air taxis will have an increased performance of more than 2,000 hours per year, enabled by increased efficiency, which in turn is driven by battery improvements and more mature systems. By then, we expect batteries to have an energy density of 350 to 400 Wh/kg. The cost per eVTOL will decrease to between $250,000 and $1.5 million as production volumes go up and costs adjust to the improved performance and available number of seats. Noise levels, we believe, will drop below 65 decibels, offering a more comfortable sound profile. Further acoustic improvements are key to raising social acceptance in many regions and will also allow eVTOLs to stretch their operating hours without being perceived as a nuisance.

Possible third-generation eVTOLs could feature new, commercially applicable technologies such as fuel cells or improved batteries, but first those technologies need to mature and be certified. While fuel cells theoretically shine with high energy density and long life cycles, the necessary hydrogen infrastructure needs to be built to use them.

Possible strategies to become a relevant hardware player

The way for a hardware player to achieve relevancy depends on how well that company positions itself along the entire vertical mobility value chain as measured by the environment in which it operates, the competitive landscape, and intrinsic factors for each enterprise. As a strategic consultancy with a strong implementation DNA, we advise companies to develop their individual approach to market success with a clear focus on implementation. We can therefore identify several exemplary strategies to achieve relevancy.

Developing an eVTOL requires significant investments and high sales and production volumes until amortization. Producing many units is in turn predicated on low-cost manufacturing of quiet and socially acceptable hardware suitable for the mass market. This will not happen until the second or even third generation. There is additional risk that first-generation eVTOLs may be a commercial failure plagued by performance issues or a lack of infrastructure for takeoff and landing. As soon as a new generation comes to market, it would no longer make sense to operate the predecessor models.

As a result, hardware players need to demonstrate a solid business case for the first generation of their equipment to ensure a positive ROI and be able to quickly invest in the next generation of eVTOLs. They can pursue several strategies to reach relevant hardware volume. Serving a global market is one very important option, as is focusing on combining multiple use cases (e.g., private air taxis, commercial air taxis, or the fairly small goods market) into one product or product platform. Another approach consists of designing modular hardware that allows for quick upgrades to the next generation.

In addition, hardware players have to work within the regional regulatory frameworks and deal with the risk of protectionism. While this is a delicate balancing act, it promises to open up a larger market that can be successfully served with the right product, leading to a significant global market share and high volume. Unlike traditional aviation, we consider urban air mobility a regional offering that carries the risk of falling victim to the protectionist policies of the big economic blocs.

Players who focus on a regional or local business will have little chance to become economically relevant, given the limited size of the market and the volume involved. That is why addressing and serving a global market is an equally crucial and complex task.

One alternative consists of relying on subsidies to gain a competitive advantage in regional markets, another on keeping prices high, yet both would limit the size of the addressable market. We believe it would be similarly be ill-advised to lower the certification requirements at the expense of operational safety.

It is conceivable that the EASA in Europe, the FAA in the USA, and the CAAC in China will favor local companies to enable them get off the ground faster, and in the process, limit the growth of any one company and prevent vertical mobility from truly scaling. Simple math demonstrates the downside of such a protectionist stance. As we have laid out, large volume sales are necessary to reduce costs per eVTOL. Assuming a company has invested $1 billion in its hardware: if it sells a thousand units during the eVTOL's life cycle, each eVTOL has to carry $1 million of capital expenditure. If unit sales were to go up to 5,000 units, the capital expenditure load drops to $200,000 per eVTOL sold, and with 10,000 units the capital expenditure load decreases to only $100,000.

Market entrants can pursue various possible strategies to succeed. One option is to develop an eVTOL for commercial applications. Reaching a high sales volume could be achieved by diversifying into other applications such as private use, which allows an even earlier start due to lower regulatory hurdles. This approach is also a good way to accumulate valuable flight hours and gain experience.

Players	Concepts	Aerodynamic concept	Lead investors	Funding in million USD
Joby Aviation	 S4	Lift & cruise	Toyota	1,600
Lilium	 Jet	Tilt-X	Tencent 腾讯	1,222
Archer	 Maker	Tilt-X	Atlas Crest Investment Corp.II	1,100
Volocopter	 2X*	Multirotor	Daimler, Geely	335
EHang	 216	Multirotor	Nasdaq	92
Kittyhawk	 Heaviside	Tilt-X	Private funding (Larry Page)	75
Wisk	 Cora	Lift & cruise	Boeing, Kittyhawk	N/A
Airbus	 CityAirbus**	Multirotor	N/A	N/A
Bell	 Nexus	Tilt-X	N/A	N/A
Porsche	 P3	Lift & cruise	N/A	N/A
Hyundai	 S-A1	Tilt-X	N/A	N/A

* VoloCity as major platform; plus VoloConnect (Lift & Cruise) | ** CityAirbus and Vahana (further concept) are vehicle demonstrators

Figure 22. Hardware players with the highest market relevance

A second strategy involves a company's development of an eVTOL exclusively for private use. The private market, however, needs a base layer of infrastructure to function, which poses higher risks with fewer viable business cases. There is a chance to make this happen with investments of just $250,000 to $500,000 for eVTOL development. This approach carries the risk, however, that a direct upgrade for commercial applications will not be possible. Otherwise, we expect investment needs to run at least in the aforementioned range of $500,000 to $1 billion per system.

Should a company want to play it safe, it can choose the third strategy and be a follower. This path would eventually hurt overall market development, however, since daring pioneers are essential to accumulating enough critical know-how and making progress. The entire vertical mobility market would suffer from this lack of experience and expertise. Furthermore, late entry may turn out to be too late if the market has already been divided up among the other players.

A fourth possible path to commercial success consists of a company focusing on a particular niche by becoming a supplier of critical components for eVTOLs, such as batteries, structural components, systems for autonomous flight, and DEP.

We currently see about 11 eVTOL providers on the market that have what it takes to succeed or at least have a good starting position. These companies come from various backgrounds but all have the necessary characteristics to do well in the emerging market for vertical mobility hardware.

As explained above, the expertise and know-how from the aviation and automotive industry lend themselves to facilitating market entry and commercial success with eVTOLs. Similarly, a startup with ties to the tech world can bring important competencies such as software design, rapid iteration, and quick rollout schedules to the table. Overall, we see the landscape differentiate around two major camps: established players with a legacy in product design, manufacturing, and certification versus ambitious startups with a bold vision and high tolerance for risky bets. Our short list of hardware players with the highest market relevance is shown in Figure 22.

4.2 Service Player: Solving the Service Puzzle

The service market for intracity air taxis has the potential to be worth $11 billion in 2035, generating cumulative revenue of $30–33 billion between 2025 and 2035 and requiring an investment (capital expenditure) of at least $1 billion in our base case.

In contrast to the eVTOL hardware business discussed in the preceding chapter, we expect that the eVTOL service business will require much lower capital expenditure investments by 2035, totaling at least $1 billion. This segment of the vertical mobility ecosystem is characterized by high operational expenses driven by running an eVTOL service, locking down funding, servicing those obligations (depending on the financing model), and performing regular maintenance. As a result, it needs significantly less venture capital and carries lower risk in making it happen. The service business also has a shorter ROI horizon, with an investment in a new air taxi service potentially paying off in three to five years. Factors that investors need to keep in mind here are the pace at which the hardware evolves and what that evolution means for the life cycle of the equipment, as well as the speed at which the actual service can be rolled out.

Running a vertical mobility service is a local play, with each urban service depending on the individual needs and particular mobility pain points of a city. Providing the right service on the right routes is key and determined by the interplay of the service itself with the available infrastructure. Service providers must therefore study and adjust for the regional differences and local specifics of their target market. They include geographical and meteorological conditions, population density, the current mobility mix and mobility behavior of its residents as well as existing infrastructure and economic indicators such as the city's GDP and income distribution.

Vertical mobility already exists today in the form of helicopter services in select cities like New York, but the service is still very limited and faces active protest movements because of the noise helicopters cause and the exhaust they generate. To make air taxi service via eVTOL relevant, such services need to gain a large customer base, create broad social acceptance, and improve their safety record.

Broad global customer acceptance is necessary to scale air taxi service, and by extension, make it more attractive in terms of price, routes, and convenience. The overall market will be smaller if social acceptance is only a local phenomenon in a few cities. That calls for eVTOL hardware that is markedly quieter than a helicopter, both for its passengers and residents on the ground, as well as more reliable, safer, and cheaper to operate than a helicopter. We do not necessarily expect every first-generation eVTOL to tick all those boxes.

Furthermore, a successful air taxi service needs to be part of a multimodal mobility chain that delivers a seamless end-to-end journey. A bimodal service brings with it much higher complexity and more risks when it comes to service quality and potential problems. Demand prediction and fleet or capacity management are key success factors to watch in this context. If, for instance, a customer on the way to a vertiport is stuck in traffic, the vacant seat on the air taxi has to be reassigned to another customer to keep utilization high. A second corollary is the responsibility to get a customer from A to B, no matter what. Failure to plan for unforeseen events such as weather or an accident will prompt customers to stop using the service.

Service providers can incrementally scale their offerings city by city. That means increasing the number of routes, expanding their eVTOL fleet as well as slots and frequency for each vertiport, and offering more local maintenance and repair operations. The growth rate of the service market is affected by the development speed of a given number of cities rolling out air taxis and by the number of routes, which in turn depend on city permits for vertiports and the number of eVTOL units in operation.

At the regional level in 2035, we predict a regional market revenue split of 30 percent for the Americas (North and South), 45 percent for the Asia-Pacific region, and 25 percent for Europe and the rest of the world [1]. We can discern varying levels of readiness among cities in these regions:

- **Asia Pacific:** this region includes countries as diverse as Indonesia, Singapore, and China, where especially second- and third-tier cities are generally open to air taxi services.

- **Europe:** the continent has many interesting eVTOL hardware providers, and many cities are generally open to testing, but we expect they could hold back when it comes to actually implementing commercial operations. Compared to other regions, Europe may be more critical in terms of social acceptance.[6]

- **Middle East:** while the region is known for its openness to air taxi service, it is plagued by challenging weather and climate conditions.

- **North America:** cities are more open to eVTOL service. Some US cities, such as Dallas and Los Angeles, are both on track to begin testing in the next few years.

- **South America:** cities in South America and Brazil in particular already offer vertical mobility in the form of helicopter services. While they have the basic infrastructure, it does not offer charging.

[6] Even though we consider social acceptance a critical issue for Europe, a recent poll found that the public would be in favor of using an eVTOL [10]. However, the survey was conducted among 1,200 people who witnessed an eVTOL test flight, so it cannot be considered representative.

Success factors for service providers

Service providers have to be mindful of three overarching success factors: good customer experience by fulfilling the promise of time savings, high operational excellence, and keeping close tabs on local business development. Operators should be prepared to have compelling answers to all of them, above all, regarding customer experience. Users will expect an end-to-end multimodal trip that not only offers them speed, convenience, and good value for their money but is also considered a socially acceptable mode of transport.

01	02	03
Customer experience	**Operational excellence**	**Local business development**
Time savings	"Game of seconds"	Service footprint
Convenience & reliability	Low operational expenditure	Community focus
Competitive price	Efficient multimodal trip	Service integration

Figure 23. Success factors for eVTOL service providers

As for speed, this is a factor of both high service availability and short waiting times, as well as an end-to-end intermodal service that lets passengers seamlessly and quickly get to and from an eVTOL to another mode of transportation. Compared to today's offerings, intermodal air and ground transportation is a complex service that could suffer from multiple issues.

Convenience is defined by highly reliable service that customers can count on for travel, even when last-minute events like bad weather intervene. In such cases, a service provider has to offer alternatives on the ground to make up for the temporary loss of vertical mobility. In addition, convenience and reliability must translate into a simple way to book an eVTOL trip with an one-stop shop or app, and must offer transportation from the start to the very end of the trip. Finally, an air taxi operator should offer additional services around the journey such as a concierge.

Taking an air taxi also has to offer a competitive price and good value for the money. The currency units that enter this highly personal equation are time spent or saved, the safety gained by choosing air travel (depending on the city), and an innovative flight experience people can get excited about.

Beyond the customer experience lies the challenge of achieving operational excellence. Air taxi services need to optimize costs for operating expenditures (OPEX)—that is, operations, maintenance, and repair. Optimizing the passenger load will require high utilization rates and few dead-end routes plagued by low passenger numbers, all the while ensuring that service is as reliable and available as advertised. Again, we want to stress that predicting demand and managing capacity are crucial in this arena. Last but not least, operational excellence means securing financing to keep the business going and at a price that invites everybody to use an air taxi service, at least sometimes. To achieve this price level, pooling can be crucial.

Vertical mobility is a "game of seconds" where the customer experience is shaped in no small part by operational excellence. The customer may accept a few minutes delay, but operators should plan and time their service down to the second and be prepared to quickly react to any disruptions.

Service providers will have to factor in their passengers' feelings and subjective expectations, similar to how a customer chooses a ride-hailing service today based on ad hoc wait time or the actual (or anticipated) frustration of getting stuck in traffic en route.

Guaranteeing an efficient and reliable air taxi trip from A to B will require a fair amount of smart coordination and dispatching. Which of the current mobility providers, airlines included, can provide that type of satisfying journey today? A delay of 10 to 15 minutes will not be acceptable for urban air taxi services. What's more, a successful air taxi operator has to excel in local business development to secure routes and slots and be a consistently good citizen, creating high acceptance among city agencies and residents. The better the first and last mile is integrated into the service offering, the more attractive vertical mobility will be.

The path to making the service business economically relevant

Service providers will need cities that support them with the approval of test routes and ideally have access to existing infrastructure to accommodate their routes and takeoff and landing slots. We consider the current air traffic management (ATM) system sufficient to get the first air taxi services started and therefore do not expect it to pose a mission-critical constraint.

The first routes for air taxis will be chosen where social acceptance is not of critical importance, for example, by selecting locations that are not overly noise sensitive. Those initial routes will likely be serviced by Uber Elevate (acquired by Joby Aviation) in partnership with Uber Taxi or others in New York via helicopter and will serve only a small minority of people on specific occasions, such as getting to and from an airport.

Service

	2025	2035
	Make it happen	**Make it relevant**
		
	From local market...	... to global market
	From luxury market...	... to mass-suitable market
Cities	**Only a few cities and routes** for first commercial service on selected routes	**>30** with developed infrastructure & service network
Flights per day*	**~15** per eVTOL	**~30** per eVTOL
Service price	**~50%** of today's helicopter services	**Competitive** with conventional taxis
Regulation & law	Allowance of routes	
Social acceptance	Acceptance of service price and reliability	

* Indicative numbers +/- 5 in dependence of use case, trip length, weather, operation hours per city, etc.

Figure 24. eVTOL service development path to an economic and socially relevant vertical mobility market

They will be the test case to gauge consumer interest and acceptance and help build an initial customer base.

During this phase, operators can leverage helicopters to build up know-how in vertical mobility services for various aspects of their business: ground operations from handling to boarding and de-boarding, as well as flight planning and clearance procedures for their air operations. As they implement those services, companies can test and further develop software algorithms that afford a reliable multimodal trip, which is easier to accomplish for single routes than for a complex network of routes.

On the business development side, service providers will by then have secured relevant sites for takeoff and landing and built a functioning rapport with city agencies and other regulatory bodies. Alternatively, they can lay the groundwork for becoming a dominant mobility provider on the ground with the option to add and integrate vertical mobility at a later point.

We predict a rollout scenario in which service will develop from helicopter testing on initial routes to commercial service for attractive routes and finally to a network of routes in the city, with eVTOLs replacing helicopters as a less noisy and safer alternative.

The reliability of eVTOL air taxi services has to be proved with first showcases on initial routes to generate customer acceptance. We expect that only a few cities will start commercial eVTOL air taxi services in 2025, using first-generation eVTOLs and initially covering a few attractive routes, for instance, between an airport and the city center. Trying out and experiencing this novel service will generate customer acceptance for electric air taxis.

On those first routes, we expect each eVTOL will start with about 15 trips per day due to limited performance of first-generation hardware. Social acceptance will grow as the public is subjected to lower noise emissions compared to helicopters. The first eVTOL air taxi services also have to offer personal customer benefits and prove themselves as suitable for the mass market. As for the price point, we forecast that these air taxi services will cost about half of today's helicopter flights. Due to the limited routes, network planning and dispatching will be less critical and a high load factor will be easier to achieve than for bigger networks. This service will only be used by some customers, such as business travelers, on some occasions, like trips between an airport and a city.

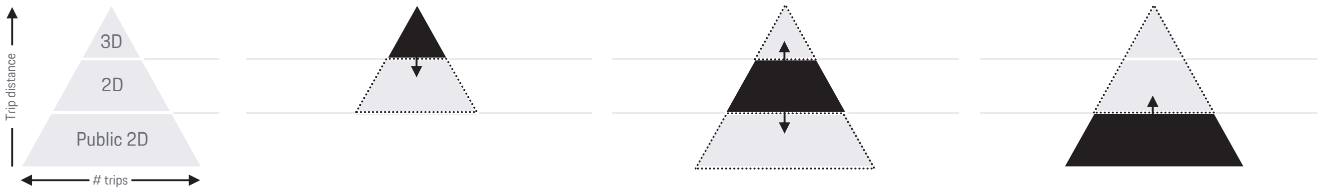
Making eVTOL air taxi service a sizable and therefore relevant market will require quite a few improvements. The new aerial service network will grow by adding more routes and making the first and last mile to and from vertiports more attractive. An increase in routes will result in greater customer benefit due to better accessibility for more people, which will also cause the eVTOL hardware market to scale, lowering equipment costs.

On the flip side, a growing number of routes will drive up complexity for service providers, leading to lower utilization and more dead-end connections. That is why service players have to strive for more operational excellence and rely on more sophisticated pooling algorithms. If they manage to create a network effect that captures many customers, they can eventually achieve high utilization rates and build a profitable service for the broader public. It would be a service available to everybody, like taxis today, to fulfill a specific need: getting somewhere quickly, making a last-minute meeting, or simply splurging now and then.

By 2035, more air taxi services will launch in additional relevant cities. For an economically relevant scenario, we expect to see more than 30 cities with a developed infrastructure being serviced by eVTOL fleets, or more than 200 cities with reduced routes if the build-out were to happen on a smaller scale. It is worth remembering that it took Uber four or five years to launch its ground-based ride-hailing service in 100 cities, but with hardware (cars) and infrastructure (streets) that were readily available.

One also has to take into account the length of a city's permit process for eVTOL service and the time required to build the necessary infrastructure and air routes in many regions. We expect each eVTOL in 2035 to provide up to 30 service flights per day due to the higher performance of next-generation hardware. As the number of flights go up, optimized sound profiles will be essential to building and maintaining broad social acceptance. Next-generation eVTOL hardware will allow price points that are competitive with a taxi on the ground, offering passengers more value for their money and therefore boosting customer acceptance.

	From luxury helicopter service to eVTOL service	From ride-hailing service to ride- and flight-hailing service	From public service to aggregated ride & fly services
Initial role	3D service provider	2D service provider	Public authority
Motivation	Serve premium customer segment	Gain profitability by adding services	Solve existing/upcoming gridlock
Service offerings	Enter flight-hailing service & add client base	Enter ride-hailing service & add other services	Enter public service & aggregate mobility services



Exemplary player	BLADE, voom, UBER* Elevate	UBER, DiDi	BVG, MTA

■ Operator – Initial service offering △ Integrator – Expansion of service offering * Uber Elevate (acquired by Joby Aviation)

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Figure 25. Three possible strategies to succeed as eVTOL service provider

Possible strategies to becoming a relevant service player

Option one is to evolve from luxury helicopter to (premium) eVTOL service: a provider will start with helicopter service to establish its customer interface for the premium segment and later add additional services around the journey on the ground, such as first- and last-mile mobility options and a concierge service. A motivation here is to defend the premium customer segment in terms of customer experience as success factor, as in the case of Blade. With this strategy, the service provider—considering local business development as a key success factor—has to demonstrate safety and reliability to its customers and make sure it can secure attractive locations, routes, and slots in a given city.

The progression from ride-hailing to ride- and flight-hailing service can be summarized as the "enter-and-add" strategy. Providers enter the market with a ground or 2D-mobility offering and then add vertical mobility, as Uber is planning. The goal here is to establish a popular customer interface, a successful customer lock-in, and consumer mindshare by continuously expanding service, ultimately integrating 3D offerings. This approach is driven by the motivation to reach profitability through additional services. It has the potential to increase the profitability of a 2D ride-hailing service provider by adding vertical mobility, because having eVTOLs in the portfolio creates an appealing mobility bundle for attractive distances beyond 20 kilometers. One example of this approach is the integration of premium-priced Uber Black rides into a multimodal experience on the ground and in the air.

Multimodal service is more complex for several reasons. There is a high number of stakeholders and players involved—from service provider, eVTOL operator, and ATM staff to customers and ground operators. Multimodal transport also creates dependencies between ground and air mobility, effectively locking in customers. Operator and customer are compelled to comply with and stay within the multimodal service chain and its boundaries. This differs from today's ride-hailing operations in which drivers often acquire a ride outside the walled garden of the ride-hailing service and app, for instance, when they happen to pick up a passenger at a hotel or airport.

The third strategy entails a provider starting from the public service end of the transportation spectrum and subsequently integrating and aggregating ground and vertical mobility services under one roof. This could be a public transit authority that aims to shape the system early on, providing the usual public transit services while integrating and aggregating private 2D and 3D mobility offerings. The motivation behind this strategy is primarily to solve upcoming or already existing gridlock on the ground.

We believe that cities can, should and will regain control over urban mobility for multiple reasons. It helps them with city planning, expanding tomorrow's infrastructure and optimizing its utilization. It also offers cities the opportunity to steer and guide the evolution of future multimodal mobility, even though private service providers will most likely run parts of this urban mobility network.

Depending on the service starting point, we see different players with varying potential to succeed. Examples for promising providers starting with 3D service are Blade and Voom, while providers starting with a 2D service are Uber and DiDi. Transit authorities that are starting with a public 2D service are Berlin's BVG and New York's MTA.

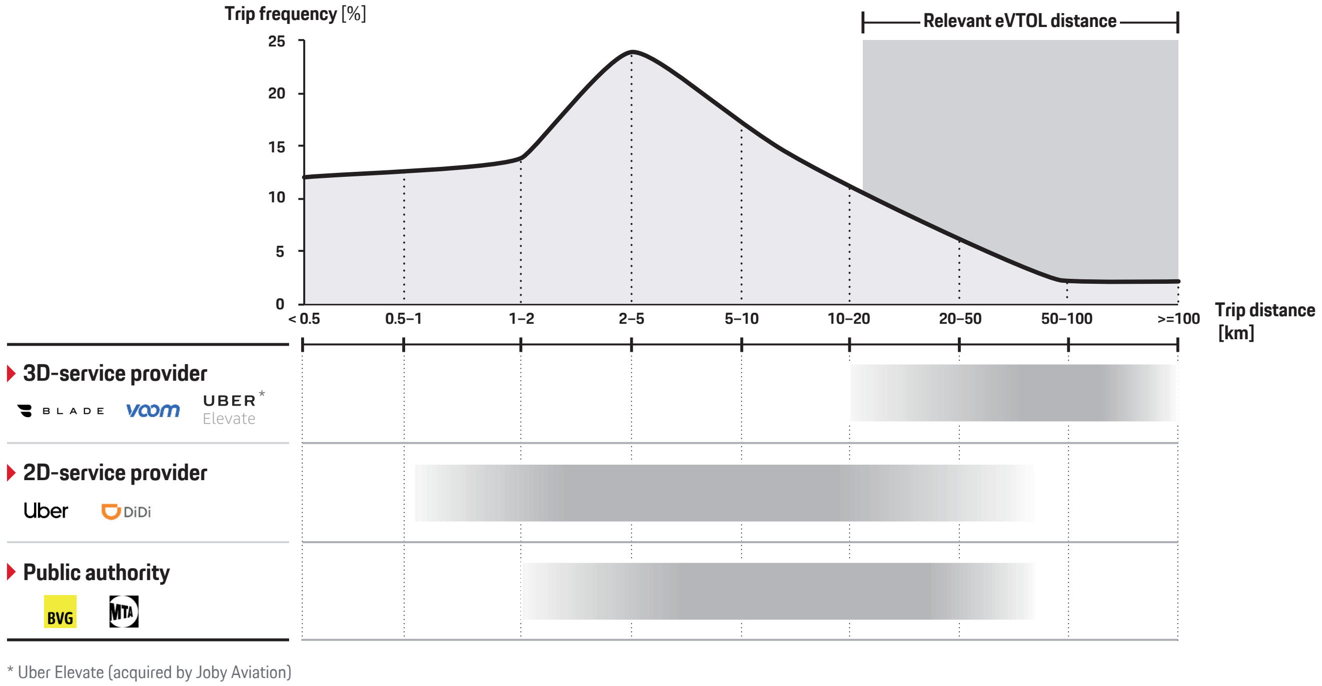


Figure 26. Average trip distance for mobility service providers

4.3 Infrastructure Player: Solving the Infrastructure Puzzle

The market for intracity air taxi infrastructure has the potential to be worth $2 billion in 2035, generating cumulative revenue of $6–7 billion between 2025 and 2035 and requiring an investment (capital expenditure) of at least $7 billion in our base case.

Assuming that by 2035 a minimum of 30 cities launch an air taxi service with a relevant number of flights and routes, we expect minimum investment needs totaling $7 billion. This sum would cover the costs required to enable vertiport operations for eVTOL air taxi service in more than 30 cities with an expansive vertical mobility infrastructure, or more than 200 cities with a lower build-out rate. In the conservative case, only a few cities will have air taxi services in operation, while the progressive case envisions more than twice as many cities. The number of slots is the all-important bottleneck for the infrastructure build-out, as those slots ultimately determine the service capacity in a city.

The key capital expenditure drivers are real estate, depending on the ownership/finance model, and construction costs as well as the charging infrastructure. The drivers for ongoing operating expenses are energy costs, staffing, and ground operations as well as rent, if the buildings are not owned by the operator. The actual sums may vary greatly since construction costs across different geographies have a wide spread. The ratio of CAPEX to OPEX is influenced by the decision to own or rent the real estate required for vertiports. In most cases, we expect the operating model to match that of parking lots or garages. The estimated investments listed above are calculated using a bottom-up investment model, and these funds will be needed incrementally since the required eVTOL infrastructure will not be built out at once but step by step and will involve plenty of refurbishment work.

Investors in eVTOL infrastructure should plan an ROI horizon of 15-plus years, with the actual time frame to recoup their investment determined by the number of vertiports and the specific expansion plans. Investment needs will rise proportional to the maximum number of turnarounds per hour. Our model takes into account three different configurations for vertiport infrastructure: vertistop as well as small and large vertiports (Figure 27). These configurations are characterized by their maximum throughput or their maximum number of turnarounds as defined by the sequence of landing, de-boarding, boarding, takeoff, and potentially charging the eVTOL. (One turnaround in this context means one takeoff and one landing, so 10 turnarounds are equivalent to 10 takeoffs and 10 landings.) The type of batteries or energy systems used imposes a crucial constraint on throughput. Batteries with low capacity and a long charging time will require more space for charging and parking eVTOLs, which in turn will incur additional costs.

Infrastructure is above all a local play that consists of building a unique vertiport network for each city. The given urban infrastructure of houses, skyscrapers, parking garages and the like determines how vertiport infrastructure should be designed, such as meeting safety and passenger security requirements. Building and zoning codes and permit processes vary by city and are also influenced by community acceptance. At the same time, there are regional standards based on product specifications for charging plugs, charging currents, ground handling technologies, and space requirements. The overall business depends on the attractiveness and social acceptance of the total service package, comprised of noise emissions, price, and convenience. Infrastructure players have to strike a delicate balance between making their sites easily accessible for everyone and manage the "not in my backyard" (NIMBY) phenomenon for everybody around them.

Any viable air taxi service using eVTOLs requires very specific routes with clearly defined start and end points to make this market happen. If we were to assume that air taxis could freely take off and land anywhere—much like cars, bicycles, or scooters today—it would constitute a game changer and radically alter the market potential. But this scenario will most likely be science fiction, even in 2035. We strongly believe that vertiports are necessary and yet could represent the bottleneck for vertical mobility's evolution. Customers have to be able to reach them easily, and these start and end points must be permitted and built rather quickly with the surrounding neighborhoods' approval.

The limited number of spots for eVTOL takeoffs and landings means infrastructure planning needs to work under two constraints: planners have to include first- and last-mile access to those vertiports and be aware of the fact that it will limit the overall utility of an eVTOL service. This limitation also puts a cap on the number of possible flights in a given city. After the initial test routes have demonstrated that eVTOL technology is ready to use, this new technology will have to be integrated into existing infrastructure and mobility services to test its commercial usefulness and viability.

The important aspects to focus on here are establishing open standards for infrastructure and maintaining a sort of "net neutrality" for vertical mobility. That means avoiding vertiports that are either hardware-specific, as in the case of Voloports in Singapore [11], or tied to a specific service player, such as Uber's vision of integrated stations for Uber Taxi, bikes, charging, and the like.

The passenger transportation capacity of an air taxi service is limited by the number of vertiports but also by their type and size. We distinguish between three different types of vertiports: vertistop, small vertiport, and large vertiport (fig. 27). In most cases, we expect a brownfield approach to integrating vertiports into a city by retrofitting existing infrastructure. For a greenfield approach, some players see megaports with a thousand takeoffs and landings per hour (at a rate of 1.8 seconds per takeoff or landing) as a potential fourth configuration, which Uber also envisioned in 2018. We do not expect, however, that such large facilities will become a relevant reality by 2035.

A vertistop is comparable to a helipad and best suited for quick drop-offs, with no or only very limited options to park, charge, or perform maintenance. They would be a good fit for locations near a city center, such as on the roof of an office building. A vertistop has a single TLOF (touchdown and liftoff) area, allowing about six turnarounds per hour, and comes with low space requirements and emissions.

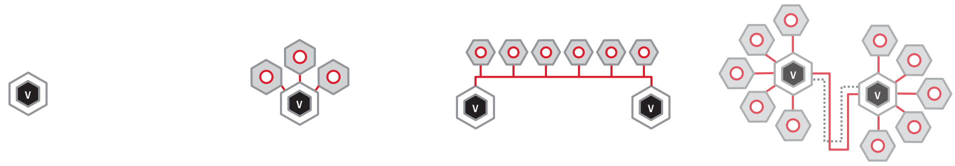
A small vertiport offers the space to park and charge an eVTOL and perform maintenance. It could be located on parking decks since its noise emissions are low. A small vertiport with one TLOF area and three parking spots can handle about 25 turnarounds per hour.

A large vertiport can be considered an enhanced version of a small vertiport, with even more space for parking, charging, and maintenance. Due to increased noise emissions caused by a greater number of takeoffs and landings, a large vertiport would ideally be located outside of a city center or close to high-traffic roads, which already emit high levels of ambient noise. Such large vertiports, with two TLOF areas and six parking spots, can accommodate a total of 50 turnarounds per hour. If a large vertiport is directly connected to ground mobility modes and other services, such as charging plus ancillary offerings like shopping and lounges, we refer to them as air mobility stations.

Megaports, as the potential fourth configuration, could have up to 20 TLOF areas and up to 100 parking spots, which would raise the hourly throughput to a maximum of 1,000 turnarounds. As greenfield buildings, such megaports could cost several hundred million dollars, depending on what other transportation modules are integrated into it, for instance access to ground mobility.

Vertiports could run into the eight figures, including additional expenses associated with enhancements such as lounges, restaurants, retail, parcel center, and ground mobility operations (electric bikes, scooters, vehicles) that will generate additional revenue streams. Depending on the size of the vertiport, the costs for elements required for air taxi service operations (areas for TLOF, taxiway, turnaround, and other facilities dedicated to various aspects of customer convenience) could make up between 10 to 30 percent of the total.

So much for the basics to make the infrastructure market happen. For it to become relevant, a number of mission-critical preconditions have to be met. First is social acceptance of noise emissions and integrating new infrastructure into a city's urban fabric and the daily lives of its residents. Any player active in this market needs to secure sufficient and suitable real estate, which is tied to norms in aviation safety for the approach and departure corridors as well as local regulations and code for issuing building permits. Finally, the length of a city's permit process must be kept reasonably short or it will delay the infrastructure build-out, and by extension, the scaling of the overall vertical mobility business.



Classification (simplified)	Vertistop	Small vertiport	Large vertiport	Megaport
	Starting and landing pad, such as quick drop-offs with no parking possibility	Starting and landing pad, with parking and such operations as charging & maintenance	Further enhancement of small vertiports with more space for parking, charging, maintenance, etc.	Envisions vertiport size that allows operations for 1,000 takeoffs and landings per hour*
Configuration [# TLOF | add. # parking]	1 | 0	1 | 3	2 | 6	≤20 | ≤100
Max. capacity [turnarounds/hour]	~6	~25	~50	~1,000

Touchdown and liftoff (TLOF) area Parking area

* Source: Uber Elevate

Figure 27. Classification and configurations of vertiport infrastructure

Success factors for infrastructure providers

In real estate, location is key. Attractive locations will see higher use, sometimes posing challenges in terms of stakeholder management. Successful entrants into the infrastructure market have to choose wisely where to position their vertiports and their distributed in a city. Greater numbers of well-placed vertiports, for example, make it easier and more convenient for customers to reach them than if they have to travel to a faraway location in an undesirable part of the city. Locations should also be chosen with an eye to multiuse functionality.

If a vertiport offers ancillary services such as parking, electric-vehicle charging, food and drink venues, parcel pickup, or shopping, it becomes more attractive and will draw more customers and create additional revenue streams. The challenge lies in finding a central location for the vertiport that meets all the necessary requirements, including good connectivity to the grid for reliable charging.

Linking the vertiport to mobility services on the ground is another promising approach to turning it into a high-traffic hub and will reduce the dependency on air service alone. Planning for a multiuse location also allows for a flexible and modular build-out of the 3D infrastructure and lowers the investment risk.

There are other aspects of vertiport operations that need to be considered and optimized. Passenger handling includes providing assistance for boarding/de-boarding and finding your way. Next are safety and security-related processes such as security checkpoints, plus ground control. This includes supervision of eVTOL areas, the performance of a ground handling system, and support of the charging process. Finally, there is infrastructure management in the form of monitoring and maintenance of the technical condition and functionality of surfaces, technical installations, and the buildings themselves.

Another success factor concerns stakeholder management. Whoever wants to successfully build and operate eVTOL infrastructure needs to address and satisfy the concerns, needs, and wishes of agencies, residents, and neighbors. It follows that a good corporate citizen ought to aim for a location that provides something for all stakeholders, whether an attractive design or high civic utility as a multiuse hub. Not generating additional acoustic emissions beyond existing ambient noise will promote community acceptance of these locations. Successful stakeholder management also means creating and maintaining a good rapport with city and other agencies to collaboratively develop vertiport locations, which will unlock more routes and slots.

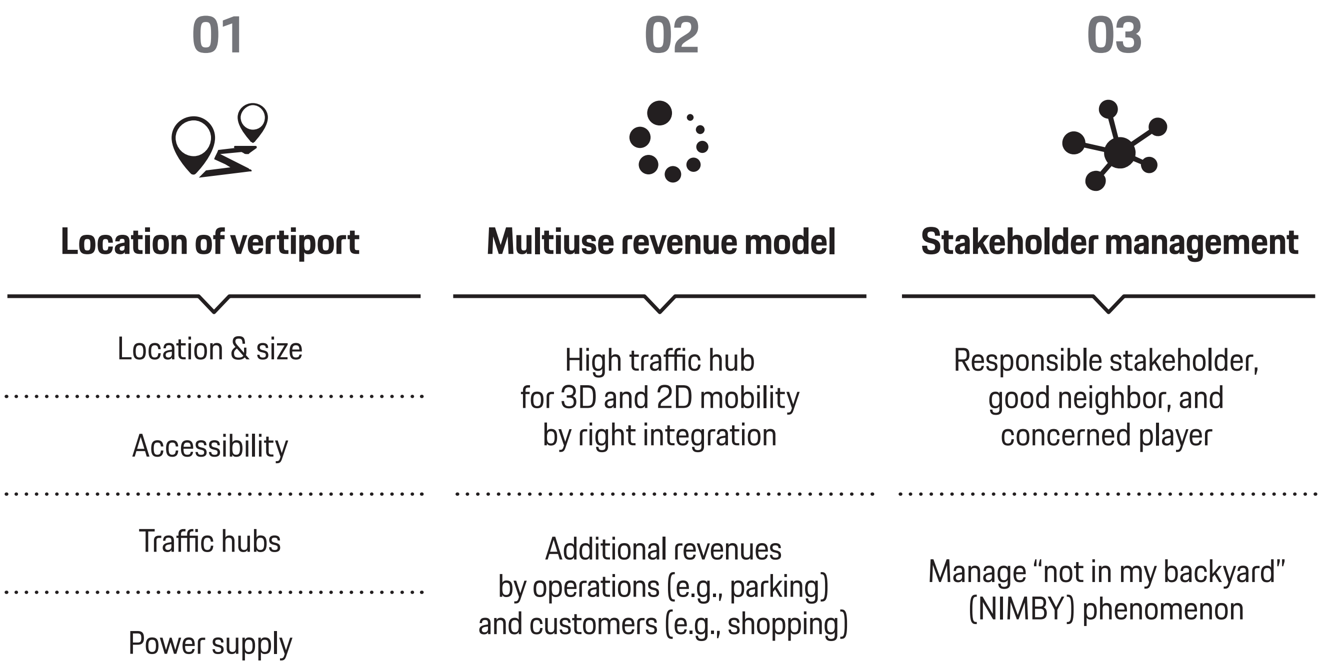


Figure 28. Success factors for eVTOL infrastructure providers

The path to making the infrastructure business economically relevant

Our market model can simulate infrastructure development in three stages per city, from an initial and an extended build-out to a full-blown expansion phase. We expect that existing infrastructure, such as helipads, will be adjusted to meet eVTOL requirements by, for instance, adding charging points to allow first tests by somebody on some occasions. Concurrently, companies in the space will accumulate essential know-how about the infrastructure components essential for vertical mobility. This phase will define common infrastructure standards based on product standards, as well as the standards concerning certification under applicable aviation laws and building codes.

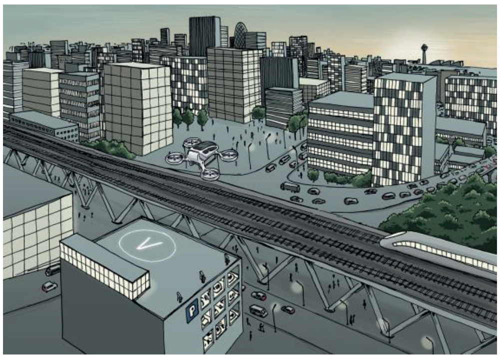
At the outset, the first vertiport networks will only exist in a few cities. The first routes between hubs such as airports and train stations will be serviced, partially replacing existing helicopter routes. Existing infrastructure such as parking garages will be adapted to eVTOL needs to expand the vertiport network and alter its configuration to accommodate more turnarounds per hour.

In 2025 we expect fewer than 50 vertiports worldwide, with about 1,500 takeoffs per hour for the first routes. This total is limited by the number of possible turnarounds per vertiport per hour.

For an economically relevant scenario in 2035, we forecast a need for 1,000 to 2,500 air mobility stations—relevant vertiports that are fully integrated into the existing city mobility. They could be in the form of 1,000 large or 2,500 midsized vertiports in more than 30 cities with developed infrastructure, or alternatively spread out among more than 200 cities with fewer routes if the build-out were to occur at a smaller scale. Existing heliports already have a certain basic infrastructure for commercial operations and therefore lend themselves to this type of retrofit. Looking at global statistics, only the USA with its more than 5,000 existing heliports offers a sufficient number of takeoff and landing sites that could be used for air taxi service, albeit without a charging infrastructure. The growing pains of electric mobility on the ground are a good reminder of how crucial and time-sensitive the build-out of charging stations is. Next is Korea as a distant second with more than 400 heliports; all other countries have significantly fewer than 100 heliports.

As each city builds out its infrastructure, the number of available vertiports will grow and allow more turnarounds per hour. Globally, we forecast a need for more than 65,000 takeoffs per hour by 2035 for the $21 billion intracity vertical mobility market alone.

Infrastructure

2025	2035
Make it happen	**Make it relevant**
	
From local market...	... to global market
From luxury market...	... to mass suitable market

	2025	2035
Number of vertiports	**<50** for first routes	**1,000–2,500** air mobility stations with thousands of routes
Takeoffs per hour	**~1,500**	**>65,000**
Regulation & law	Building permissions for vertiports	
Social acceptance	Acceptance of location and noise	

Figure 29. eVTOL infrastructure development path to an economic and socially relevant vertical mobility market

The costs for air mobility stations will far exceed the expenses of simply retrofitting existing infrastructure with essential eVTOL modules, such as chargers. Air mobility stations will become mobility hubs that offer connectivity to 2D transportation and draw people with their selection of shops, lounges, and other attractions. Building those rich hubs, however, will trigger additional costs before it unlocks new revenue streams.

The infrastructure available to eVTOL services will be unevenly distributed. Most cities will be hampered by their specific and often very lengthy permit processes that could take up to five years and impede a speedy build-out. As a result, we do not expect cities to have a massive network of hundreds of vertiports.

Possible strategies to become a relevant infrastructure player

Companies that want to succeed in this market have different pathways available to them, which are differentiated by an open or closed system. Vertiport sites can either follow the principle of network neutrality or offer exclusive/limited slots for selected service providers. While both are possible and feasible, cities would be well advised to opt for net neutrality when it comes to vertical mobility.

One possible strategy consists of developing a closed infrastructure system, an approach with the advantage of a specific match of hardware, service, and infrastructure. On the other hand, it does create a monopoly that lacks flexibility and runs the risk of high prices and low utilization.

Infrastructure providers can start with the existing 3D infrastructure, such as helipads. This approach lets them gain know-how in operating such infrastructure from ground handling to charging. From there they can develop a vertiport network that makes a difference in urban transport, as long as they always focus on a clear business case.

A second approach consists of building an open system—that is, with no specific match of hardware, service, and infrastructure—creating new meeting points or micro-cities. While they offer the benefit of being flexible, they also risk suffering from a lack of infrastructure standards. This approach focuses on finding attractive vertiport locations by either creating new traffic hubs or integrating vertical mobility into those already present. A company can follow a brownfield approach and adapt existent infrastructure to eVTOL requirements, integrating vertical mobility into parking garages, hotels, and malls. There is also a greenfield option in which operators, such as property owners, holistically plan a new multipurpose infrastructure that includes a vertiport facility.

A third exemplary strategy is characterized by a public-private partnership that integrates vertiports into existing traffic hubs. Companies would have to seek out established nodes like airports and subway or train stations and augment them with vertical mobility infrastructure. This approach must be driven by network neutrality, offering every service provider access to these facilities.

Generally speaking, players like real estate developers, owners of attractive properties, and airport and parking space operators could be successful in this market. Developers are particularly focused on the construction and financing of vertiports. Uber Elevate (acquired by Joby Aviation), for instance, has commissioned real estate developer Hillwood for the city of Dallas and Related Companies for Los Angeles and Santa Barbara to develop vertiports.

Airport operators are mainly specialized in airport operations, but they can also be co-owners of the respective vertiports. Skyports, for example, is developing and intends to operate one of the first vertiports in cooperation with the city of Singapore and Volocopter. FraPort, which operates the Frankfurt airport, also wants to integrate eVTOL operations at its existing airport in Germany. Another potential player is Signature Flight Services, which is already running airport operations for Uber Elevate's helicopter service in New York.

The challenge for airport operators lies in the faster speed of the eVTOL business. A 15-minute delay is almost a given for an airline customer but will be a showstopper for air taxi passengers. Successful operators also need to focus more on the customer journey and less on ringing up concession sales between the security checkpoint and the gate. This shift could also have a positive impact on airport processes for airline customers, motivating the former to optimize their processes.

Whatever comes next—we are ready for takeoff

Whether it is hardware, service, or infrastructure, vertical mobility is a new method of transportation that comes with its own risks and rewards for companies, consumers, and communities.

It will require all market entrants to rethink customer needs and balance them against business demands, regulatory requirements, and social concerns, as this market is poised to evolve from limited experiments to a volume experience. We are optimistic that a future awaits in which flying will be a natural part of our daily lives.

But vertical mobility will not materialize on its own. To make it happen, players will have to cooperate during the pioneering phase to create and fill the ecosystem with life, while we will see more and more differentiation and competition to make it relevant in the second phase. If there is one insight we want to leave you with, it is this: technology makes vertical mobility happen, but broad social acceptance will make it economically relevant.

A future awaits when flying will be a natural part of our daily lives.
We look forward to hearing your thoughts, comments, and questions.

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Appendix

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Glossary

ATM	Air traffic management
CAAC	Civil Aviation Administration of China
DEP	Distributed electric propulsion
EASA	European Aviation Safety Agency
eVTOL	Electrically powered vertical takeoff and landing aircraft
FAA	Federal Aviation Administration
GDP	Gross domestic product
PAX	Passengers
STOL	Short takeoff and landing
TLOF	Touchdown and liftoff area
UX	User experience
Cases	Economic efficiency analysis in which the model is run for three different cases: realistic or base case, optimistic or progressive case, and pessimistic or conservative case.
Scenario	Market uncertainties allow for an indefinite number of scenarios, which can fall into any of the three cases or in between.

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