HORVÁTH & PARTNERS
MANAGEMENT CONSULTANTS

Urban Air Mobility Study Report 2019

"Business Between Sky and Earth"

Assessing the Market Potential of Mobility in the 3rd Dimension

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Contents

Preface

Dear readers,

The mobility industry is facing its biggest revolution since the invention of the combustion engine. Personal mobility is about to expand. It's going into the 3rd dimension. In particular, concepts for the future of large cities are a decisive anchor point for this new form of mobility. The solution to the most pressing problems of our time lies in sustainable, autonomous, multi-modal and connected mobility. This paradigm shift in personal mobility is particularly evident in the convergence of urban air mobility. Automobile, aircraft and helicopter manufacturing are united in a new form and create a new industry of urban air vehicles.

Numerous start-ups are pushing into the market of urban air mobility and are striving to lift mobility into the 3rd dimension. The necessary integration into the modal split of the future has not remained hidden from automotive or aerospace manufacturers and they are investing in this promising market.

Today's pioneers face similar challenges to Henry Ford, the pioneer of automobile production: "If I had asked people what they wanted, they would have said faster horses." Is that really the case? No, definitively not.

We are experiencing an age of industrial convergence on the basis of the first integrated realization of customers' requirements for mobility from a single source – regardless of the modality. In this future field, the automobile, aircraft, helicopter and two-wheeled vehicle will merge in terms of their emotionality. The customer interface shifts from the manufacturers to the providers of intermodal mobility services.

But who has the best chances for a successful market launch? What are the decisive criteria? How does current public opinion present itself and what are the consequences for companies? How can future profit pools be generated? What does premium mobility actually mean in the future? And what do platforms have to do with it?

We have investigated these questions and, in addition to the industrial evolution, have also carried out measurements of market acceptance, which lead to astonishing insights. I would like to thank all authors of the study, in particular Stefan Schott und Christian Hennes, for their valuable contribution.

We wish our readers an insightful read.

Dr. Daniel Guffarth

Management summary

Mobility will change fundamentally in the years to come due to increasing urbanization, individualization, regulative requirements and new technologies. Instead of owning vehicles, customers will increasingly demand fast, easily accessible, flexible and individualized transportation. Customers' orientation towards mobility as a service will result in a shifting customer interface to mobility platforms, thus presenting a key challenge for traditional players in the automotive and aerospace industry to manage their transition and expand their service portfolio into the mobility world of the future.

Global megatrends – The increasing impact of global megatrends on existing transportation infrastructure necessitates new and innovative transportation concepts. Urban air mobility can help, as part of a multi-modal transportation concept, to manage transportation more efficiently and intelligently and offer an appealing value proposition to customers. Urban air mobility stands for a new and innovative mode of transportation in the 3rd dimension, offering enormous potentials in a world of multi-modal mobility brokerage services. By adding the 3rd dimension of mobility in an electric and autonomous manner, major problems in today's cities can be addressed.

Smart city – As a vital aspect of the smart city concept, urban air mobility can be a great complement to an intelligent and efficient transportation ecosystem, since key parameters in a future transportation system will be efficiency and intelligence, autonomous mobility, multi-modal transportation concepts, and sustainability.

Key promises – Urban air mobility promises faster transportation, flexible and individual mobility, increased security, improved sustainability and eco-friendliness as well as a reduced strain on existing transportation infrastructure systems.

Industrial network – Forming clusters of expertise is a typical phenomena of emerging industries that help transmit knowledge between the actors and share experiences. The analysis of the emerging urban air mobility industry shows a convergence of the automotive and aerospace industry and the rise of independent and visionary start-ups. In order to develop a dominant design, start-ups and established companies increasingly form strategic alliances.

Customer acceptance – Customer acceptance is a key parameter determining the successful market introduction and global rollout of urban air mobility. Interestingly, public perception of autonomous flying is slightly better than autonomous driving and customers value start-ups backed by industry more than stand-alone start-ups.

Market model – With our market model, we expect the global demand for urban air mobility to be 15 million flight hours in 2035, 3 billion flight hours in 2050 and 12 billion flight hours in 2070. In order to meet the projected global demand for urban air mobility, 23 thousand vehicles need to be manufactured in 2035, 3 million vehicles in 2050 and 7 million in 2070 respectively. Our analysis shows the urban air mobility market to be an interesting and important future market for the mobility industry.

Business model – The value chain of urban air mobility offers companies the possibility to engage as a manufacturer and supplier, operator or service provider. However, the biggest profit pools of the future will be the bundling and brokering of end-to-end mobility solutions, making the provisioning of mobility platforms a more favorable business model than traditional manufacturing.

Urban air mobility will play a complementary role to existing modes of transport, as it offers a unique value proposition to customers in terms of speed, flexibility and individualization. However, regulatory requirements and the provisioning of the necessary hub infrastructure is currently unclear. In the future, the mobility industry will be centered around a small number of mobility platforms, where the biggest profit pools can be expected. Strong and well-known brands will be decisive for customer acceptance and will thus pave the way for a widespread and global adoption of urban air mobility. Aerospace and automotive actors should seize the opportunity to establish multi-modal mobility platforms as a complement to their traditional manufacturing business.

1. Global megatrends drive societal change and affect the mobility of tomorrow

Recent developments in the areas of digitalization, individualization and urbanization will considerably impact our future mobility behavior. The effects of this comprehensive change are particularly apparent in urban regions. Cities are not only engines of economic growth, but also the living spaces of today and in the future. Driven by the modernization and industrialization of urban structures, cities have always been the epicenter of change since the beginning of the 21st century with the transformation from an industrial to a technology-oriented service society. Today, they offer a wide range of development opportunities for our highly individualized and networked society. Due to their wide range of living, working, leisure, and shopping facilities, more and more people are moving to urban areas. In the future, this phenomenon – referred to as urbanization or rural exodus – will continue to increase, shaping the global residential landscape even more than before.

As a consequence, the proportion of urban and rural population is shifting considerably: in 1950 less than one third of the world's population lived in urban areas; since 2007 it has been more than half.[1] According to recent UN expectations, the figure will be two thirds by 2050. With additional overall population growth, the number of major cities with over ten million inhabitants is growing significantly. In accordance with those estimates, there will be more than 40 megacities in the year 2030. The number of cities with a population of five to ten million will increase from 417 to 558 over the same period. Especially in emerging economies, cities are growing rapidly into multimillion metropolises. In Western countries, however, population growth is distinctly lower and urbanization is progressing at a much slower rate. Therefore, the major challenge for Western cities lies in the optimization of existing urban structures. However, in both cases, the development of the necessary transportation infrastructure in cities and the accessibility of suburban and rural areas, as well as the provision of favorable ecological and economic conditions are becoming global challenges.

Limiting factors pose new challenges for urban mobility

With increasing urban migration, the less favorable sides of urbanization are becoming increasingly apparent: the lack of suitable living space, significant environmental issues and inadequate water and electricity supply are key challenges for urban development. The most urgent urban challenge, however, is undoubtedly insufficient infrastructure systems and, consequently, road congestion. At this point in time, most infrastructure systems quickly reach their predetermined limits. As a result, a piloted or even autonomous car is becoming more an obstacle than a comfortable mode of transportation in most cities. Particularly in pulsating inner cities and busy main hubs, drivers are often faced with slow and tormenting traffic. Construction sites, traffic jams, red traffic lights and the lack of parking spaces result in gridlock and unpleasant driving experiences. However, this is only the beginning. In a world characterized by population growth and urbanization, the need for mobility will continue to increase. An overall growing demand for mobility in connection with the need for more individual mobility will pose a great challenge for future infrastructure development projects. Without the necessary infrastructure development and expansion projects, many cities are facing imminent collapse.

New technologies and individualization provide impetus for new solutions

On the other hand, new digital technologies can enable stronger connectivity and networking, thus making for more efficient use of resources and infrastructure systems. By networking existing systems and supplementing additional mobility offerings, it will become possible to respond more purposefully to customers' need for a more individual and flexible form of mobility. Originating in the western world, individualization is increasingly becoming the most powerful global cultural principle, having a decisive influence on consumer behavior with regard to mobility services. Therefore, future mobility services will have to be solely focused on the needs and desires of customers, making integrated and continuous end-to-end mobility solutions the central requirement for mobility providers.

[1] United Nations: World Urbanization Prospects (2014)

2. Urban air mobility as vital part of the smart city

Mobility concepts must be intelligent and connected, multi-modal, autonomous and sustainable, thus playing a vital role in the city of the future. In principle, the overarching goal of a city of the future is improving the quality of life for its inhabitants with the help of modern information technologies and additional digital services. The introduction of comprehensive information technology-based communication services enables the synchronization of different layers of infrastructure and the exploitation of synergy effects. Therefore, smart cities use the possibilities of digitalization, for instance to optimize different modes of transportation, energy supply or urban logistics by creating situation-adapted networks. However, every major city has individual shortcomings and faces different challenges. In order to become an essential part of a future urban multi-modal transportation mix, urban air mobility has to comply with different prerequisites. Besides ensuring safe and reliable operation, the protection of privacy, the ecological and economic expansion of existing infrastructure, the reduction of noise and the reduction of environmental pollution are also key issues for customer acceptance.

Driven by these immense challenges for urban infrastructure and its transport systems, different solution options are emerging that change the way we use transportation modes. The increased need for individuality, flexibility and autonomy changes the requirements for mobility and at the same time demands new forms of personal mobility.

Intelligent and connected mobility – The digital net-working of users, services, vehicles and infrastructure is becoming the most important driver of efficient and comfortable mobility. Mobility platforms are a promising solution to efficiently connect users with different mobility offers and improve their mobility experience.

Multi-modal mobility – Although the car will continue to play a key role in the future of transportation, the mobility mix is changing radically in many regards. Different modes of transport will be used flexibly and will be demand-oriented. Especially in urban areas with a high mobility density, owning a car becomes increasingly unnecessary – while access to mobility becomes increasingly more important than owning a vehicle.

Modal split interconnectivity will be a decisive factor of future mobility providers' success

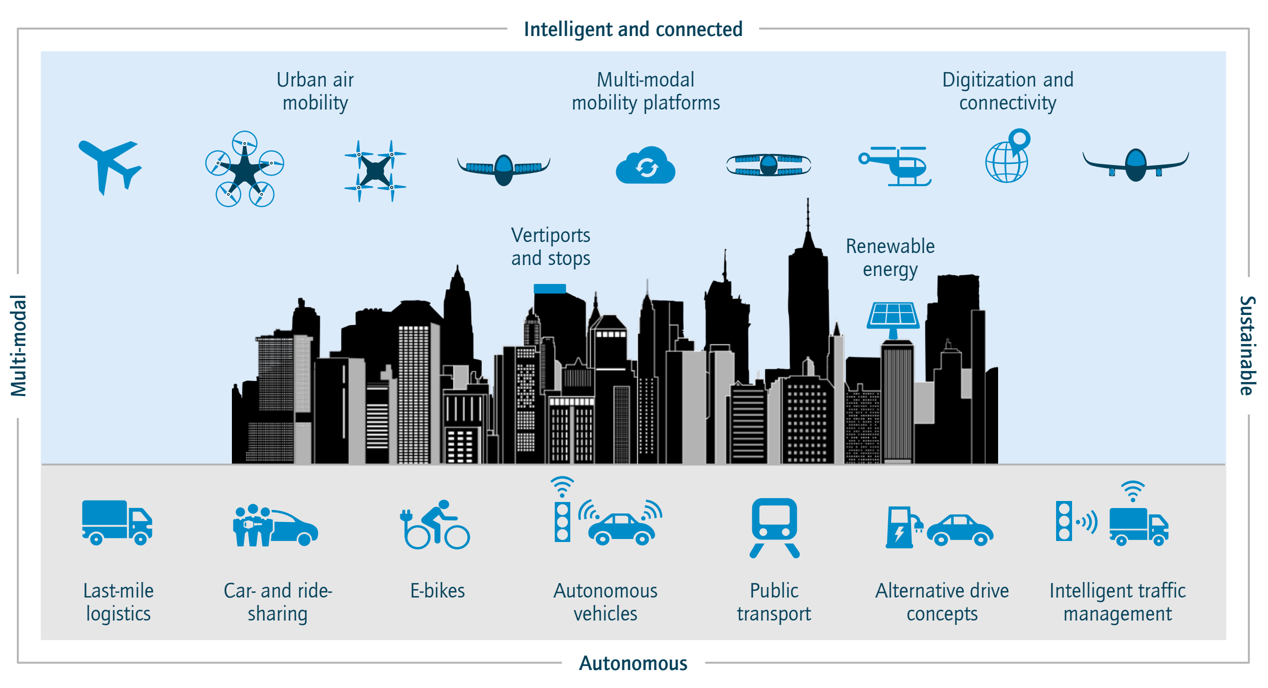

Fig. 1: Mobility concepts and their dimensions in the smart city

Autonomous mobility – If means of transport learn to steer themselves, occupants will have more time and can engage in other activities apart from driving, while at the same time the overall accident likelihood will decrease noticeably. Furthermore, autonomous mobility has the potential to improve the efficiency of current transportation systems by using the fastest routes and adapting instantly to a changing environment.

Sustainable mobility – Future mobility will increasingly take environmental aspects into account. The requirements for a more efficient and emission-free form of mobility continue to increase and will put vehicle manufacturers under considerable pressure. In order to improve living conditions in dense city centers, city residents will continue to push for more sustainable and environmentally-friendly forms of transportation.

The urban commuter of the future will be seamlessly switching between different modes of transport, i.e. choosing between different transportation options on a situational basis. In this context, the Smart City concept offers a suitable approach to meet the described requirements and expectations for efficient, ecological and at the same time individual mobility in the best way possible.

Smart mobility as a way to realize intelligent multi-modal mobility concepts in smart cities

As described, smart mobility concepts are gaining in importance in the context of increasingly networked cities. In the future, it will be more important than ever for people to be able to easily switch between individual modes of transportation. Driven by a digitally sophisticated population and an environmentally conscious mindset, smart cities have the technological, ecological and economic prerequisites to meet all the necessary requirements for future mobility concepts and to enable their implementation. The technological conditions of smart cities pave the way for a direct exchange of information between all road users and with the entire urban infrastructure. Evaluating large amounts of data in real time in order to support ad hoc and intelligent mobility decisions is a decisive factor in the future mobility construct. Hence, the exchange of data between vehicles and the infrastructure surrounding them takes mobility to the next level: real-time traffic planning, on-demand availability and multi-modal mobility will become reality. Smart mobility has the potential to radically change the efficiency of vehicles and therefore ensures the breakthrough of true individual mobility. The motto "Use instead of own" will become reality and residents will buy access to transportation instead of individual vehicles.

The next step: Autonomous mobility replaces piloted driving

Data-based mobility concepts make traffic faster, smoother, easier and more environmentally-friendly. The resulting urban data network also forms the basis for autonomous mobility. Self-driving means of transport perceive their own surroundings in real-time, exchange data with other road users and navigate safely and independently to their destination, making them self-sufficient. By exchanging different data streams, autonomous vehicles inform each other about traffic conditions and warn each other of obstacles in the traffic flow. Autonomous vehicles have the potential to make more efficient use of existing transportation infrastructure and to provide a higher level of safety for passengers and other road users than piloted vehicles.

Mobility as a platform-based solution

To ensure flexible and individual mobility, access to an urban mobility network is becoming increasingly important. Simultaneously, customers expect a comprehensive and holistic approach that bundles the individual transport options in a mobility platform to provide the fastest and most efficient form of transportation available. In addition to autonomous vehicles, e-bikes, buses and trains should be considered while creating a multi-modal transportation platform. In the future, however, the discussion of multi-modal transportation should also take new modes of transportation such as autonomous cars and autonomous air vehicles into account, since they offer different specifications and use cases. In the age of networked urban mobility, it is essential that all modes of transport interact optimally – on land, on water, on rail and in the air.

Mobility in the 3rd dimension – Flying vehicles as a solution for multi-modal mobility

Although new mobility concepts can optimize individual transportation, the lack of space in urban areas remains a major challenge – especially with regard to transportation infrastructure. The multi-lane expansion of roads and new railways is only possible to a limited extent in dense city centers and calls for new alternatives. It is therefore worth looking into the 3rd dimension. The integration of the mobility in the 3rd dimension into tomorrow's mobility concepts should make transportation more comfortable and cleaner, as well as time- and space-saving as compared to conventional transport options. Vertical take-off and landing technology has the great advantage that aircrafts do not need runways to take off or land, which is particularly attractive in dense city centers.

Air taxis thus offer the potential to relieve the burden of congested streets in city centers, while transporting passengers quickly and in an environmentally friendly manner. For city residents, they would provide another mode of transport – a taxi for the air that travels directly to its destination while avoiding red traffic lights and congested streets. In various so-called Volo hubs, air taxis can take-off and land independently and additional services such as maintenance and electric charging can be provided. Volo hubs do not require much space and can thus be installed easily throughout the city. A connected network of Volo hubs then serve as stops at various locations in the city. With such a well-developed infrastructure, air taxis would be much faster than their counterparts on the ground. Similar to other modes of transportation, air taxis should be able to be ordered via a digital platform, as in the case of ridesharing. Air taxis can be a perfect fit to the innovative concepts of a smart city. The core advantage of air taxis is that they are not propelled by fossil-fueled engines, but instead use electrically operated motors. This makes them not only more environmentally friendly, but also almost noiseless compared to conventional flying vehicles. After an initially manned pilot phase, the flying taxis will be controlled autonomously in the long term. They will thus become a networked and integrated component within the overall smart city system. In addition to road, rail and water traffic, air taxis are the next link in a networked mobility chain.

Urban air mobility makes key promises to potential customers

In contrast to other forms of mobility, urban air mobility offers a different set of technological characteristics, which translate into a different value proposition to potential customers. In general, autonomous urban air vehicles will enable a more flexible and individual way of transportation than current mobility offers. Centered around the customer's desire for flexibility and individualization, urban air mobility makes several key promises to customers, including a significant reduction of transportation time on certain routes, improved, flexibilized and demand-oriented mobility, increased security through autonomous systems, improved sustainability through a decrease in pollution and a reduced strain on existing infrastructure systems.

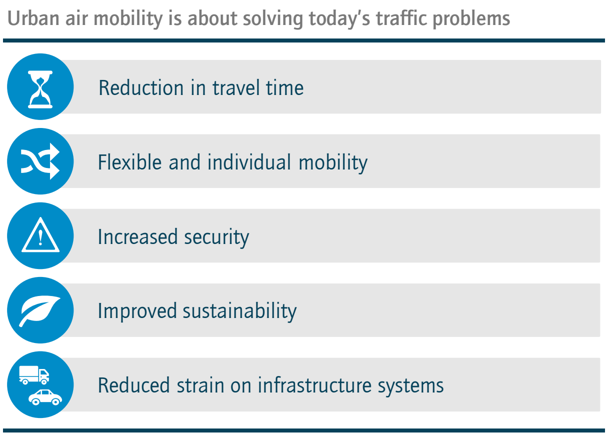

Fig. 2: Key promises of urban air mobility

3. Are we ready to fly autonomously?

3.1 The legal perspective

Legislation for autonomous air taxis is currently not well established and core questions have not been answered, yet the airspace offers a huge potential for individual and fast transportation and provides sufficient space for new mobility concepts. In general, no country or state authority currently has a legislative framework for autonomous air taxis. However, first individual exemptions make initial pilot projects and real-world testing possible. In Dubai, for example, the Road and Transport Authority of the United Arab Emirates intends to work with civil aviation authorities to create a framework for urban air taxis over the next five years. Talks are also taking place in India to discuss the opening of airspace for the commercial operation of air taxis. Interested parties and private citizens can apply for flight rights for unmanned aerial vehicles such as drones for photography, videography and leisure purposes on a new digital platform. In October 2018, the European Aviation Safety Agency (EASA) opened a public consultation for the adoption of regulative standards for the certification of urban air vehicles. In addition, the International Organization for Standardization (ISO) has recently released a draft set of regulations regarding drone operations for public consultation until January 2019. Those standards include regulation articles on classification, design, manufacture, operation and safety management for urban air vehicles.

Restrictive regulation may slow innovation

In Germany, the federal government has recently decided to reorganize its airspace. Under the new regulation, drones with the ability to fly at altitudes of more than 100 m and weighing more than 5 kg require a state-issued permit and adequate proof of knowledge. Initially, this regulation was adopted to regulate only the leisure drone sector, but strict rules also restrict real-world test operations.

For example, it strictly forbids flying drones over federal buildings, airports, industrial facilities, residential properties, natural reserves, crowds of people and police or rescue teams. Going forward, these flight bans must be tailored more precisely in order to enable test operations and later the implementation and operation of autonomous air taxis.

First initiatives such as the Pop.up concept, a joint test operation of Airbus, Audi and Italdesign in the city of Ingolstadt, are currently being promoted in Germany. The increasing technological maturity and implementation of pilot projects increase the political pressure to formulate and pass legislation for urban air vehicles in a timely manner. At this point in time, pioneer projects for urban air mobility are under way in a total of 50 cities around the globe.

There will be a clear separation supervised by air traffic control

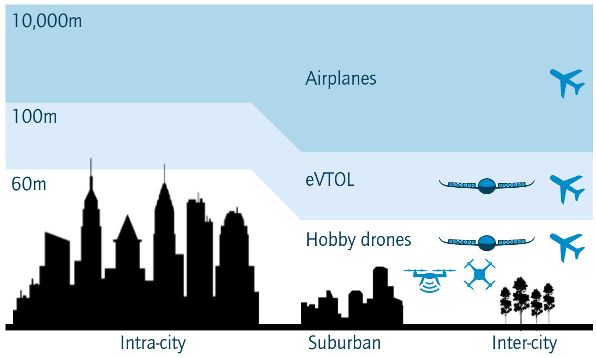

Fig. 3: Conceptual approach to a division of the airspace

Dividing the airspace for different forms of mobility

In the U.S., Amazon and NASA have also given first thoughts to the possible division of airspace over major cities. Due to the technical specifications of drones, air taxis and airplanes, the following distribution is to be made: the drone airspace will be limited to 100 m in altitude with additional layers for air taxis and airplanes above. Additional no-fly zones are required for safety reasons, such as over federal buildings, sensitive industrial facilities and airports. However, it is to be considered how and by whom this divided airspace is to be monitored in the future. In Europe, the U.S., China and Japan, similar concepts are being planned including regulatory authorities, independent service providers, operators and manufacturers. Due to the expected drastic increase in traffic density and increasingly autonomous flying vehicles, new and decentralized traffic management mechanisms need to be implemented to ensure safe and reliable transportation in our airspace. New technological possibilities could pave the way for a self-regulating airspace. However, we expect future regulation to limit urban air vehicles to certain pre-defined fixed routes and corridors through the airspace due to safety concerns, possible intrusion of privacy and the preservation of uncovered skies and high-end living in modern skyscrapers.

3.2 The technological perspective

Different application scenarios for autonomous air vehicles in urban areas and dense city centers are imaginable. Ranging from passenger transportation to the fast and secure delivery of valuable goods, as well as to security surveillance and police measures, autonomous urban air vehicles offer an enormous potential for innovative applications.

Passenger transport is in the focus of this study

Transport ▪ Passengers ▪ Goods	**Leisure time** ▪ Air shows ▪ Hobby
Security ▪ Government ▪ Private ▪ Medicine	**Monitoring and inspection** ▪ Agriculture and forestry ▪ Research ▪ Catastrophes ▪ Infrastructure systems

Fig. 4: Application fields for urban air mobility

Currently, the technological design and implementation of urban air vehicles still leaves plenty of room for innovative concepts and adoptable solutions. All currently discussed designs can be roughly divided into four different categories based on their drive concept: fixed-wing vectored thrust aircraft, tilt-wing aircraft, hybrid concept solutions, and multicopter/ quadrocopter.

Fixed-wing vectored thrust aircraft are equipped with variable-direction fans on fixed wings for vertical take-off and landing. They can achieve a cruising speed of 200 to 300 km/h, achieve a significant range and accommodate up to 4 passengers. Fixed-wing aircraft are the largest vehicles due to their fixed wings, can transport heavy loads and achieve low hovering efficiency and low stability, while generating a lot of noise. This design concept is currently pursued by Lilium. Tilt-wing aircraft concepts are characterized by several propellers or fans that can be tilted at different angles to achieve different flight modes for take-off, landing, hovering and cruising. In comparison to fixed-wing vectored thrust aircraft, they achieve less range, lower speed, lower transport capacity and higher hovering efficiency and more stability, while generating less noise. On average, those aircraft can reach speeds up to 250 km/h and transport 2 to 4 passengers. Airbus's Vahana concept falls into this category. Hybrid design concepts include aircraft with fixed forward-facing propellers as well as upward-facing propellers for different flight modes. Those aircraft will achieve speeds of 150 to 200 km/h and carry up to 4 passengers. In comparison to tilt-wing aircraft they achieve higher hovering efficiency, less noise generation and more flight stability, while sacrificing range, top speed and transport load. The Uber Air concept is falling into this category. Quadrocopters are wingless aircraft with 4 fixed propellers that can reach speeds up to 150 km/h and carry up to 6 passengers. In comparison to multicopters, quadrocopters have a larger range, achieve higher speed and can transport heavier loads, while having less hovering efficiency and overall stability during flights. Examples for this aircraft design are the eHang 184, CityAirbus and Pop.Up.Next. The last aircraft design concept is the multicopter, which is also a wingless aircraft with more than 4 fixed propellers. These aircraft can reach a top speed of 100 km/h and seat 2 to 4 passengers comfortably. Out of all architecture concepts, multicopters achieve the highest stability, lowest noise generation and highest hovering efficiency, while lacking range, top speed and potential transportation load. This design concept is notably followed by Volocopter. In the future, we expect urban air vehicles to have different sizes to match different application scenarios. For hub-to-hub transportation, larger vehicles with seating capacities up to 30 passengers, equivalent to buses, are imaginable. Under the assumption of all-electric propulsion systems and hub-to-hub transportation concepts, we assess the current technological state of the following architecture concepts.

Due to their specific technological characteristics, the aircraft concepts mentioned above respond to different use cases and application scenarios. Especially in major cities and busy hubs, a wide range of factors impact the usefulness and public acceptance of the different design concepts. Since public acceptance is a key variable for a widespread and global rollout of urban air mobility, those design concepts must fulfill a number of requirements to be deemed fit for service. In our opinion, those required factors include regulation aspects, cost-benefit balancing, noise generation, range, vehicle size, integration possibilities in existing infrastructure systems, sustainability, security, and reliability.

So far there is no dominant design – we will observe multi-tech solution environment

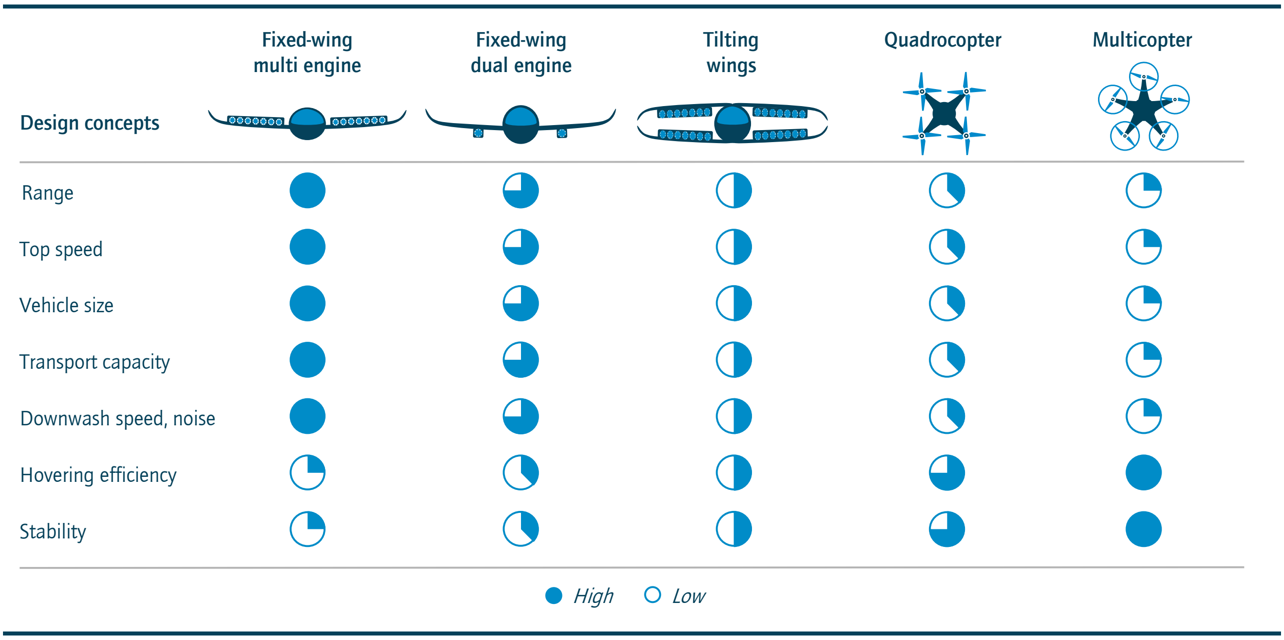

Fig. 5: Assessment of aircraft architecture concepts

Under current circumstances, it remains to be seen which of those technological concepts will prevail for the specific application scenarios intra-city, suburban and inter-city transportation. Furthermore, the integration of urban air vehicles into the existing city infrastructure is heavily dependent on the pursued concepts, ranging from hub-to-hub transportation, individual landing pads on rooftops or completely flexible landing zones. Due to different demands and specifications of use cases such as intra-city and inter-city transportation, applications must meet different challenges and therefore adopt diverse approaches.

To operate purposefully in city centers, vehicle manufacturers have to deal with a wide range of important topics such as performance, background noise, range, downwash, and safety concerns, as well as environmental concerns. Noise generation, in particular, poses one of the greatest challenges. In times of great controversy about night flight bans in urban areas, it is necessary to develop low-noise vehicles to increase the general acceptance of flying vehicles in urban areas. Another limiting factor of urban air vehicles is battery performance. Only with sufficient capacity and energy density can trouble-free and sufficient air traffic be guaranteed. Different application scenarios therefore affect design concepts for the necessary power system of any air vehicle. Batteries with high power outputs and intelligent power distribution systems offer unique opportunities for short travel distances, especially in intra-city transportation.

According to current estimates, quadrocopter and multicopter concepts are therefore more suitable for short distances and fast traffic within a city, while fixed-wing concepts are more conceivable for inter-city transportation. Tailoring innovative solutions to responsibly meet customers' demands will be essential for the successful implementation of urban air vehicles.

In order to achieve widespread market introduction of autonomous urban air vehicles, improvements need to be made in several key technology areas – in particular the development of battery technology for energy storage optimization. To enable autonomous flying, various improvements in communication technology (e.g. 5G), in artificial intelligence, localization technology, and sensor technology as well as improvements in materials and lightweight construction have to be made. But we are confident, that the convergence of industries will lead to major learning effects, bringing several technologies to maturity that are crucial for success.

3.3 Market perspective

In general, the supply-side of the urban air vehicles market consists of various parties and interest groups. Beside start-ups which follow totally different technological designs and act as lone warriors, we see established actors from the automotive and aerospace industries. A large number of investors, governments and tech companies are also starting to conquer the emerging industry.

The industrial network of urban air vehicle companies shows the emergence of an industry as a convergence of different mobility providers. As of November 2018, a total of 138 prominent players were involved in the industry's emergence, with Airbus the dominant actor in terms of connectedness and acting as a gatekeeper in the network. Uber pioneers the largest network initiative, while Boeing, Audi and Daimler are members of prominent clusters that drive major initiatives.

According to other studies, such as from NASA, more than 400 companies from entrepreneurial start-ups to industrial giants focusing on vehicles, systems and infrastructure are currently engaged in the emergence of the urban air mobility market. As it is often the case with prototypical exploration networks in an early industrial development phase, this particular network possesses a great heterogeneity and distinct clusters of firms focused on industry leaders.

The graph, depicted as Fruchtermann-Reingold-Representation, for this network shows a considerably large diameter of 9, an average path length of 3.6, a centralization coefficient of 0.084 and a cluster formation coefficient of 0.123. Consequently, this industrial network shows clearly distinguishable clusters that represent independent business ecosystems, in relationship to a large number of unconnected actors.

The urban air mobility industrial network shows distinct clusters

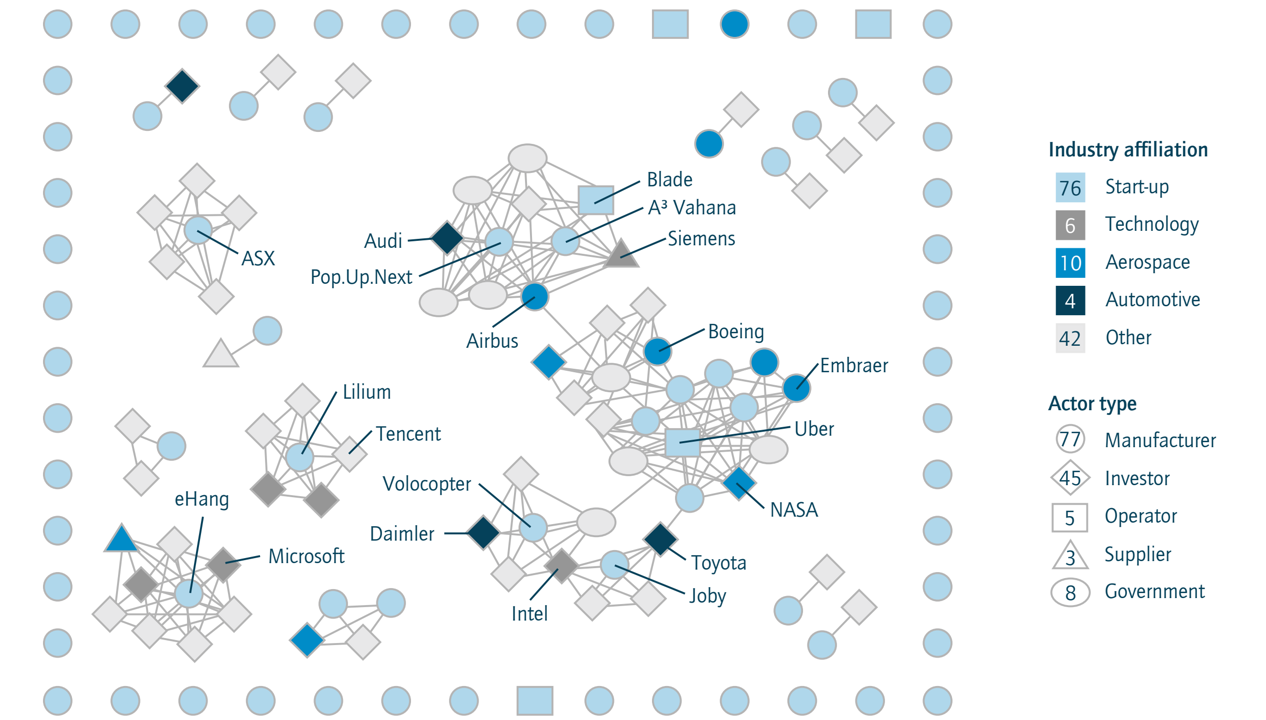

Fig. 6: Urban air mobility depicted as Fruchtermann-Reingold network

Each cluster possesses a center of gravity, represented by a leading company who drives the development and implementation of urban air vehicles. Major clusters are arranged around key players like Intel, Uber, Airbus, Audi, Microsoft, Tencent and Daimler. Characteristically, every major cluster consists of at least one mobility provider, one or more tech companies and different start-ups specializing in urban air transportation concepts. Since the development and implementation of urban air transportation requires extensive knowledge and expertise from different industries, including aviation, information technology, and service providers, those collaborations need to be interdisciplinary. While nearly all these alliances are closely tied, only few connections are made between different clusters. Most clusters consist of closely networked sub-areas and therefore enable strong and efficient knowledge sharing as well as an intelligent pooling and allocation of resources. This aspect suggests that every cluster will present a unique air mobility concept. At the end of this race of ideas, a dominant design will likely emerge. Due to its better adaption and applicability, the dominant design will replace other design concepts and consequently will take a major stake in the global air mobility market. Therefore, every cooperation has a great desire to be able to offer an attractive design concept as early as possible.

Many well-known players in the aerospace and automotive industry are currently exploring the concept of urban air mobility and start developing early industrial applications. For example, Boeing has recently announced that it will work with various start-ups to allocate and manage flight corridors for autonomous urban air vehicles using artificial intelligence and blockchain technology for implementation. Therefore, Boeing is building a research centre in Massachusetts that is scheduled to open in 2020. Another example of this shift to mobility in the 3rd dimension is Frank Stephenson, who is considered to be one of the most influential car designers of recent years. Stephenson drew the new edition of the Mini and designed McLaren sports cars, and now he is working at a start-up called Lilium and is developing concepts for autonomous urban air vehicles. Another industry leader is the company Volocopter, which can currently be referred to as the pioneer of urban air mobility.

3.4 The human perspective

Customer expectation and acceptance is a key prerequisite to a successful introduction of mobility in the 3rd dimension in urban areas. Similar to electric vehicles, the market introduction of urban air vehicles is strongly dependent on the willingness of potential customers to switch from conventional means of transport to air vehicles. Any concerns of potential customers and residents regarding the safety, practicability, and favorability of this new transportation method will result in a slow rate of adaption. In a recent study conducted by the industry association BITKOM in Germany, a total of 8 percent of participants reacted unambiguously favorably to the idea of flying with autonomous air vehicles, whereas 90 percent remained doubtful.[2] Most concerns were centered on the responsiveness and reliability of algorithms in unanticipated situations and security concerns such as cyberattacks. On the other hand, participants clearly acknowledged the potential of autonomous air vehicles to rule out human mistakes by automating air transportation.

In order to measure the general market acceptance of urban air mobility, we performed a comprehensive market acceptance assessment with our Horváth & Partners Radar Suite. The radar extracts information from a daily growing database of more than 100 million text documents. Trends and recurring patterns in the semantic structure of those texts are analyzed and monitored in real time. Through machine learning and semantic analysis, we identify trends and signals, which we use to analyze the public opinion on specific topics and identify trends with sentiment analysis. For our market acceptance assessment of the urban air taxi industry, we conducted a pre-selection of texts with relevance for autonomous flying. This approach resulted in a reduced set of approx. 16,000 documents from 3,350 sources. Based on our database, we conducted a comprehensive analysis of semantic patterns in articles and texts using machine learning algorithms and semantic analysis.

Autonomous flying vs. autonomous driving

The first question we try to answer with this analysis is how autonomous flying is perceived compared to autonomous driving. The results of our Horváth & Partners Radar Suite show that autonomous flying is slightly better perceived by the public than autonomous driving. With an average sentiment value of 0.2, autonomous flying is reported slightly more favorably than autonomous driving with a sentiment value of 0.18 – but overall the reporting is very similar. The possible reasoning behind this is the immaturity of both concepts. Since perfect autonomous driving or flying (i.e. level five of autonomy) is not yet technically mature, negative headlines cannot be reported. On the other hand, more articles are written about the potential advantages of urban air taxis, such as reduced traffic jams or fewer accidents. The overall reporting on autonomous flying increases visibly over time. The media presence is increasingly picking up speed, which is why more mainstream media outlets are reporting on the upcoming air taxi industry. More extensive reporting brings urban air mobility closer to potential customers and influences customer perception. The sentiment of the reporting has remained largely the same over time. The impact (the weighted sentiment) is slightly better for autonomous flying than for autonomous driving. However, it must also be noted that the sentiment has a relatively low variance overall: this means low volatility and therefore little contrary reporting.

Autonomous flying shows a better rating than autonomous driving

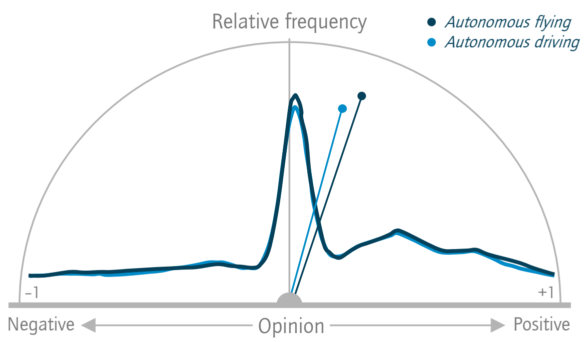

Fig. 7: Public perception of autonomous flying vs. autonomous driving

[2] Bitkom survey on market acceptance of autonomous flying (July 2016)

Automotive industry vs. aerospace industry vs. start-up

Many manufacturers of urban air vehicles have a traditional industry background, often in either the automotive or the aerospace industry. It is therefore important to analyze whether the public perceives differences between manufacturers from different industries. Our research has shown that urban air vehicles are perceived more positively in connection with automotive investors than with aerospace investors and independent start-ups. On average, urban air vehicles from automotive investors are reported more positively (0.23) than those from aerospace investors (0.19) and start-ups (0.17) – however, the volatility of the reporting in case of automotive investors is also significantly higher. Overall, the smaller data set is probably responsible for the generally greater volatility in reporting (opinion variance), which increased significantly last year. It should also be noted that reporting on start-ups is much more controversial. What could be the reason for this discrepancy in technology reporting? On the one hand, one should consider that automobile manufacturers have a more direct line to their customers than aviation companies. As a result, a customer is more aware of the quality features of an automobile brand and can identify with it. The opposite is true for aviation companies. Therefore, it can be fairly assumed that only a small portion of the total population identifies directly with an aircraft manufacturer, such as Airbus or Boeing, and is able to assess the quality they offer. Obviously, flight enthusiasts may be familiar with individual aircraft models, their capacities or other specifications, but most of the population is not. Rather, they have experience with flight providers such as the aircraft operators Lufthansa and American Airlines.

Manufacturers supported by the automotive industry show a better rating

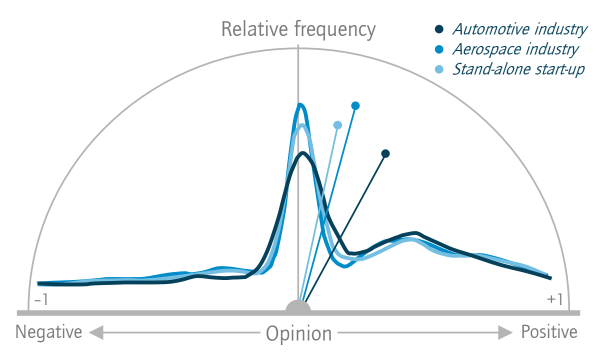

Fig. 8: Public perception of start-ups with automotive or aerospace background or independent start-ups

Perceived differences between individual start-ups

Besides looking at players with a traditional industry background that are investing in the future of mobility, it is also important to examine urban air mobility start-ups.

As we could see during our analysis, prominent urban air mobility start-ups are perceived differently in the public eye. Both Lilium and Vahana currently pursue a fixed-wing concept, but Lilium is reported more positively with 0.24 than Vahana with 0.19 average sentiment. In the field of quadro/ multicopter concepts, Ehang competes with 0.24 and Volocopter with 0.19 average sentiment values. With a special focus on intra-city concepts, Airbus A3, Vahana, and Volocopter have the most media presence. In addition to the sentiment analysis (positive or negative reporting), we also carried out a source bias analysis. The result shows that the reporting is consistently positive or neutral and that factual reporting is more frequent than hypothetical coverage. This is highly unusual for new technological products and their fields of application, as positive and negative exaggerations are stimulated as scenarios. The question arises as to whether conclusions can be drawn from this analysis concerning the development of a dominant design out of current design concepts. However, we firmly believe that different design concepts are more suitable to different fields of application. Different designs need to be developed in order to better match use cases such as intra-city, inter-city and suburban transportation.

4. Assessing the market potential of mobility in the 3rd dimension

4.1 The potential acceptance of urban air vehicles differs by global region

Since the process of urbanization and infrastructure development is at different stages depending on the region of the world, the goals and objectives for the use and market adaption of autonomous air taxis in different world regions also differs. Micro- and macroeconomic factors of individual world regions have a decisive influence on societies and determine the mobility needs and requirements of the urban population.

Within the scope of this study, a market model was developed that measures the market penetration of autonomous flight taxis per world region based on different influencing factors. In this context, several main drivers for the market adaption of regional urban air vehicles were used and examined in more detail. Each of these weighted factors is composed of further sub-factors and results in a cumulative overall result:

Asia is at the forefront of global potential market acceptance

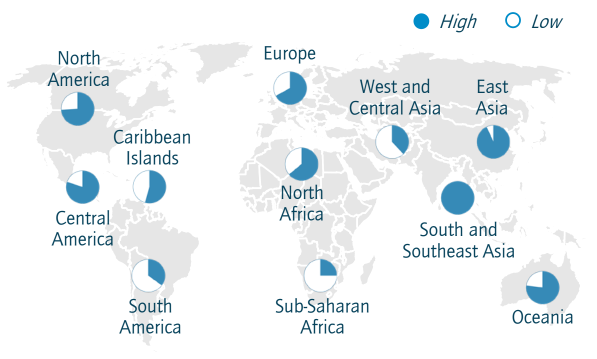

Fig. 9: Potential market acceptance levels of urban air vehicles

Congestion level

In order to determine the pull momentum towards autonomous air vehicles, information on the current congestion and traffic situation in the individual regions was considered. The congestion level is an indication for an increase in overall travel times when compared to a free-flow situation. The higher the congestion level in a region, the more likely the population is open to new mobility concepts with the purpose of reducing travel time.

Annual cost for public transportation in relation to annual income

The index is an indication of the likelihood that city residents will prefer public transportation to private vehicles. The lower the ratio, the more frequently public transport is used.

Technology affinity

The push momentum to an increasing use of autonomous air vehicles was considered by an in-depth analysis of the urban technology affinity and the willingness of potential customers to pay for vertical transportation as a percentage of the annual household income of the urban population. A technology-oriented population exhibits a greater acceptance of innovative mobility concepts.

Availability of latest technologies

Furthermore, the external framework conditions for the development, implementation, and overall availability of new innovations and technologies were examined. In detail, this was measured by the availability of the latest technologies in a specific world region.

Global Innovation Index

The Global Innovation Index 2018 provides detailed metrics about the innovation performance of various countries and economies around the world. It consists of 80 indicators, including political environment, education, infrastructure, and business sophistication. The Index analyses the energy innovation landscape of the next decade and identifies possible breakthroughs in fields such as energy production, storage, distribution, and consumption. It also looks at how breakthrough innovation occurs at the grassroots level.

Political stability

The index of political stability measures the likelihood that the local government might be destabilized or overthrown by unconstitutional forces, including politically motivated violence and terrorism. Political stability is a basic requirement for the development and implementation of new technologies and innovations.

The consolidation of these main factors provides information about the general market adaption of mobility in the 3rd dimension in different world regions. The analysis shows the world regions in which inhabitants would be most willing to use autonomous air taxis as a possible means of mobility in urban areas and which regions, states, or cities can provide the necessary conditions for their implementation. The results of the study show that especially the regions Asia, Europe, Oceania, and North America are attractive markets for the introduction of autonomous air taxis. In addition to the high volume of urban traffic caused by public transport, as well as private vehicles, the above-mentioned regions are characterized by a population with a distinct affinity for technology. A relatively high degree of political stability and the corresponding innovative capacity of the respective states provide the necessary framework for the development and market introduction of mobility in the 3rd dimension.

4.2 Mega metropolises will be at the forefront of change

As discussed, urban mobility will change dramatically in the coming years. Due to the introduction of urban air vehicles, urban mobility will become more flexible and mobility in the 3rd dimension will contribute as an integral part of multi-modal transportation platforms. Between 2010 and 2035, cities will grow globally by an average of 51 percent, making multi-modal mobility platforms in urban areas a necessity. The current increase in total travel times compared to a free-flow situation of 33 percent on average will continue to worsen worldwide – especially Mexico City, which with 66 percent must be named as the front-runner in this regard. Current challenges are the networking of traffic, the creation of new and more efficient transport routes and the necessary transportation infrastructure.

In order to assess the market potential of urban air mobility, the overall demand for urban air mobility fares, as well as the demand for add-on services, must be quantified. In this study, we calculated the usage volume based on the estimated population development in all world regions. The urban population in the relevant set is determined based on publicly available statistics and, subsequently, propounded until the year 2070. As described in more detail above, we developed a market acceptance index for urban air vehicles for individual world regions. This index shows the regions' market acceptance for urban air mobility based on traffic, innovation, and technology metrics. Due to different conditions and prerequisites, we expect a different adoption behavior in the various world regions. The first commercial operations will likely be conducted in mega cities with a high population density and a high market acceptance for urban air vehicles.

Mega and progressive metropolises will be the first to adopt

Fig. 10: Clustering of exemplary target cities according to market acceptance and population density

Combining our index with a derived, realistic adoption rate based on widely-discussed adoption theory principles, the total potential market was derived. Of course, the adoption rate will increase over time as more and more potential users are convinced of the added value of the urban air mobility. This particular estimate builds the baseline for any further discussion about the implementation of urban air vehicles in this study.

Our market model takes the gradual implementation of urban air mobility in the respective world regions or cities into account. Thus, we propose a three-phase approach to reflect a gradual implementation pattern of mobility in the 3rd dimension in all world regions. In the first phase of our model, from 2025 to 2034, urban air mobility will only be available in mega metropolises and major cities where urban air vehicles can contribute the most to solve shortcomings in the existing transportation infrastructure. Out of all cities worldwide, urban air mobility will likely only be available in the 47 cities with a population exceeding 10 million inhabitants. Due to a gradual rollout of urban air mobility, more cities will be adopting in the second phase from 2035 to 2049. For this time frame, we include 120 cities with more than 5 million inhabitants into our considerations. Since adoption curves tend to behave exponentially, we expect a drastic surge in adopting cities from 2050 to 2070. We expect a market potential for urban air vehicles in a total of 1,267 cities worldwide that have at least 600,000 inhabitants. At the end of our observation period, a total of 784 million people will have access to urban air vehicles as a common and widely accepted mode of transportation.

4.3 Our methodology

This market potential assessment focuses solely on passenger transportation – with dedicated focus towards the intra-city passenger segment. Therefore, this study covers the traffic volume occurring within cities in addition to resident traffic resulting from direct neighboring and suburban areas. However, before diving deeply into practical potentials and implementation phases of urban air mobility, a theoretical driver tree was developed to represent different factors that affect the implementation and adoption of urban air mobility in population centers across the globe. Based on this theoretical consideration, a quantified approximation for the urban air mobility market from 2025 to 2070 has been developed. For this purpose, all above mentioned drivers were taken into account and approximations were estimated with currently available figures or, if necessary, suitable premises were established in order to derive potential market volumes.

In order to assess the market potential of urban air mobility, we followed a two-fold approach. The first approach takes the Greenfield Approach and projects the market development of urban air mobility in an ideal world – free from limiting factors and restrictions. In this model, we include parameters such as population growth, market acceptance, modal splits, adoption behavior and technology characteristics to project annual flight hours in the various world regions. To assess different market adoption scenarios, we differentiated between a progressive (100 percent adoption rate achieved by interested consumers in 2070), a realistic (50 percent adoption rate) and a contrary (25 percent adoption rate) market adoption scenario. This approach lets us quantify the total market potential for the urban air mobility, which can be achieved by clearing the way from current technological restrictions, economic constraints and social barriers.

The second, more realistic, approach takes numerous restricting factors into account. Due to economic and technological reasons, we expect the global rollout of urban air mobility to start in mega metropolises and spread out across the globe to cities with fewer residents. Therefore, we account for three different implementation phases, instead of resorting to total populations per world region. In Phase 1, which lasts from 2025 to 2034, the technical feasibility of urban air vehicles is still relatively limited. Technology-induced capacity bottlenecks only allow a maximum of two passengers per vehicle. In addition, the implementation of urban air vehicles is planned only in megacities with a population of more than 10 million inhabitants. In Phase 2, which runs from 2035 to 2049, seat capacity in urban air vehicles is expected to expand to four passengers and further large cities – with more than five million inhabitants – are taken into account. In a final phase, all cities with 600,000 inhabitants or more will be included from 2050 onwards. Phase 3 is also characterized by an increase in vehicle seating capacity to a maximum of 8 simultaneous passengers. In addition, we assume an average urban air vehicle lifecycle of 10 years and sufficient battery capacity to meet the requirements of global intra-city transportation with a maximum range of at least 150 km. Since the 8- or 4-seater concepts are technologically and economically superior to the first 2-passenger variants, one has to assume that the latter models will move into a phase-out period at the end of Phase 2. In our projection, we also accounted for climatic restrictions, regulative flight restrictions with regard to noise and overcrowded airspaces, the development of purchasing power, vehicle utilization rates, and the demand-stimulating effects of advertising and positive public perception.

Fourteen parameters have a decisive influence on the market potential of UAM

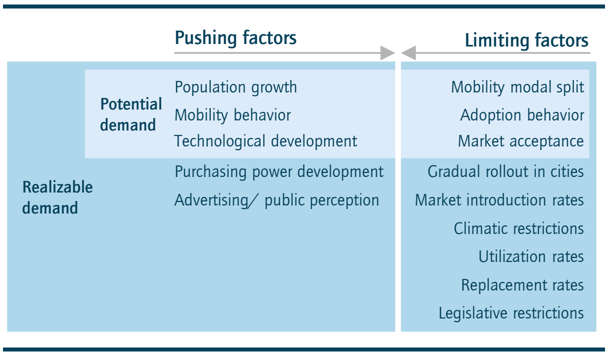

Fig. 11: Overview of our modelling parameters

4.4 Market model results

Based on our market model analysis, we can unequivocally state that urban air mobility will play an important part in future multi-modal mobility concepts and offer huge value for customers and mobility actors alike. In the following, we are going into more detail and present the results of our market model analysis. Following our custom two-fold approach, we first present the market potential in an ideal world, where no limiting factors and conditions apply.

With our first approach, we project the maximal market demand for urban air mobility in the form of annual flight hours per world region. The results we obtained show that the market demand for urban air mobility will strongly increase over the years, reaching its sharpest increase by mid-century. While we project a global demand for 423 thousand flight hours in 2025 under the realistic scenario, the number of annual flight hours reaches 125 million in 2035, 9 billion flight hours in 2050 and 22 billion flight hours in 2070.

With continuing urbanization, demand for UAM rises on a global scale

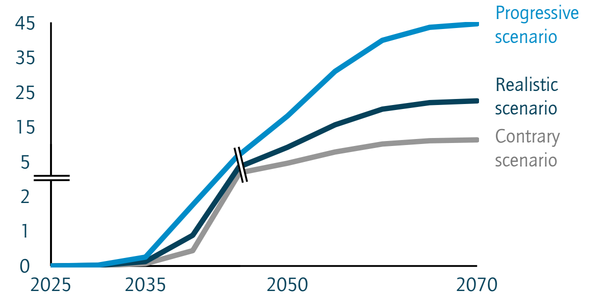

Fig. 12: Global demand for urban air mobility (in billion flight hours)

The most attractive markets by market size are East Asia, South Asia, and Southeast Asia due to their strong population growth in combination with high market acceptance rates. Furthermore, we also find Europe, North America, and South America to be attractive markets for urban air mobility operators. As we can show, the potential market sizes vary greatly due to different population growth, different market acceptance levels, different adoption rates and the availability of the latest technology. We can also acknowledge that the adoption behavior as a function of personal perception and willingness to act affect the market potential of urban air mobility immensely. (cf. Fig. 14)

In order to assess the total number of flight hours per year, we calculated the personal flight time of an average person per world region. While an average person in East Asia exceeds 6 flight hours per year, the average European or North American will use urban air vehicles on average 2.5 hours per year. In addition to an enormous population growth, East Asians use urban air vehicles most often, making East Asia a very attractive market for mobility companies.

In our second approach, we discounted the total market potential for limiting factors and included a gradual global rollout of urban air mobility in urban areas worldwide. Under the three-phase implementation approach, approximately 15 million flight hours are requested in 2035, increasing to 3 billion flight hours in 2050 and 12 billion flight hours in 2070 under the realistic adoption scenario.

Breakthrough as consumer-ready product in 2035

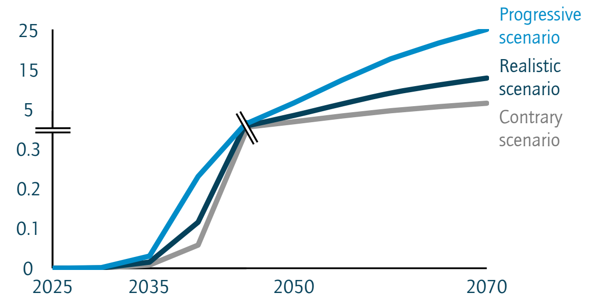

Fig. 13: Realizable global demand for urban air mobility (in billion flight hours)

Since the supply-side of the market will need time, effort and additional technological advances for a global rollout, the total market demand cannot materialize. In Phase 1, which lasts from 2025 to 2034, we expect urban air mobility services to be offered in only 47 cities worldwide that have more than 10 million inhabitants. Following this logic, in 2050 a total of 120 cities will have urban air mobility services operating within the city bounds. After 2050, a total of 1,267 cities with more than 600,000 inhabitants will offer urban air mobility solutions to their residents. We therefore propose to look closely at our market model approach, which accounts for this difference.

Due to structural factors Asian regions show the highest potential market penetration

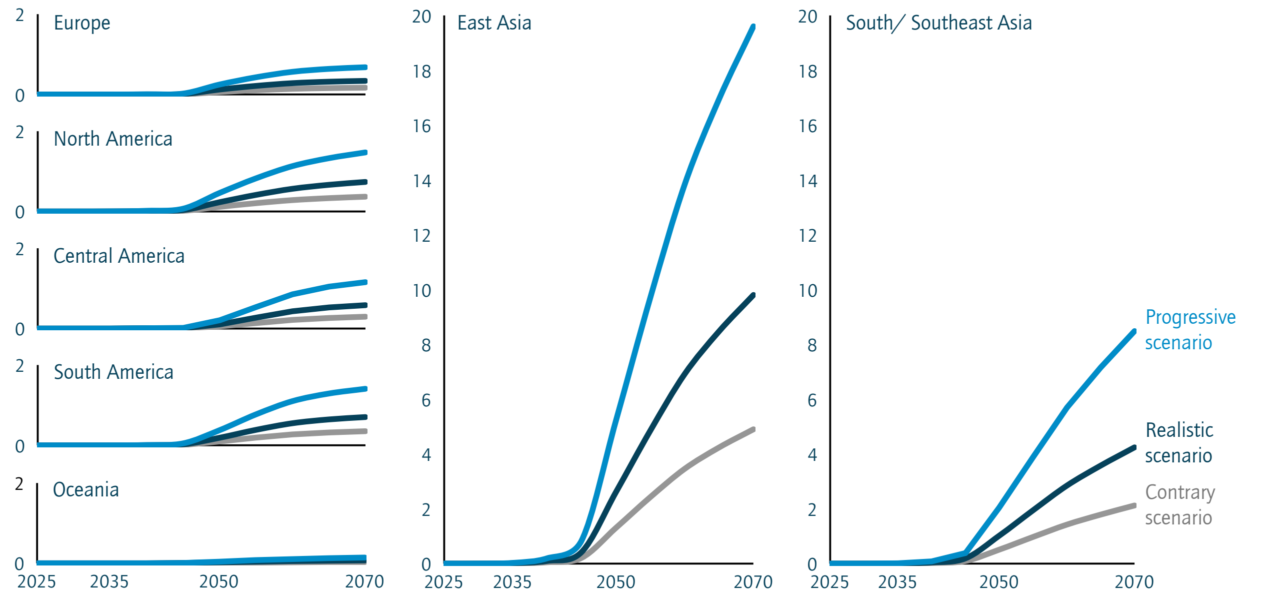

Fig. 14: Realizable demand for urban air mobility (in billion flight hours per world region)

In order to provide the necessary supply of urban air vehicles in rush hours, adequate numbers of vehicles must be manufactured and operated in a meticulously planned flight rhythm. Therefore, it is essential to take the progressing technological progress into account, because in the first years, urban air vehicles can be expected to carry two and later four – then up to eight – passengers. To provide full availability of urban air mobility services during rush hours, the number of vehicles must cope with the maximal demand for air fares during rush hours.

A significant manufacturing sectors is in sight

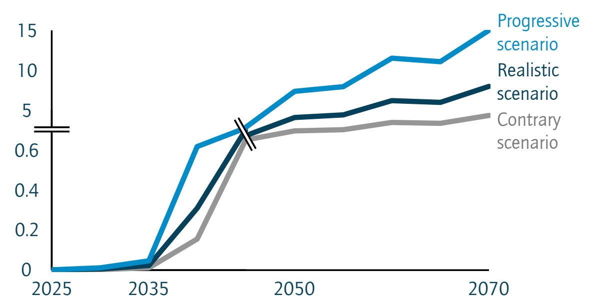

Fig. 15: Annual production demand for urban air vehicles (in million vehicles)

Keeping those parameters in mind, several of the approximately 23 thousand urban air vehicles need to be manufactured in 2035. This number rises by 3 million vehicles in the year 2050 to 7 million urban air vehicles in 2070. Due to technological advances and vehicle deterioration, we expect an average vehicle lifecycle to be 10 years, after which it needs to be replaced. Compared to current annual production figures of about 93 million automobiles worldwide, which include passenger cars, trucks and buses, our estimate seems fairly reasonable.

The projected urban air vehicle stock will reach approximately 130 thousand vehicles in 2035, 13 million vehicles in 2050, and 52 million vehicles in 2070 under the most realistic adoption scenario.

5. Business models shape the urban air mobility landscape

Value creation in the future urban air mobility market can essentially be divided into four business models: service providers, vehicle operators, vehicle manufacturers, and suppliers. In principle, those business models can be implemented individually (stand-alone) or consolidated in a single market player. By consolidating add-on services, as well as operating and manufacturing activities, a single built-to-operate player can be established. Depending on the position of a firm in the shared value creation network, different challenges must be addressed and taken into consideration to strengthen the respective competitive position.

Manufacturers and suppliers

Manufacturers and suppliers provide the necessary number of urban air vehicles to satisfy market demand. Since urban air vehicles are complex product systems, manufacturers must have profound knowledge and expertise in the field of aeronautics to develop safe and reliable vehicles for passenger transportation. Therefore, industry players from the aerospace, aviation and automotive industry have an initial edge in terms of technological expertise and manufacturing experience over mobility start-ups. It is therefore to be seen, whether start-ups can build safe and reliable urban air vehicles by themselves or whether they enter into cooperative ventures with experienced players possessing the necessary industry background. In the value creation chain of urban air vehicles, several suppliers will have the opportunity to establish themselves as providers of different system components. The components and the current levels in the supplier chain include structural parts (e.g. chassis, runners and propellers), propulsion (e.g. battery and electric motor) and the flight system (wiring harness and sensors).

Operators

The next node along the value creation chain are the operators. Operators are tasked with executing passenger transportation along predetermined routes with their urban air vehicles. For the operators of urban air vehicle transport routes, the key challenge lies in minimizing costs and attracting as much customers as possible. The critical success factors for this business model can be summarized in a well-defined target group, an attractive pricing model and a balanced cost structure.

In contrast to the pricing of Uber or Google, premium services can be established by additional operators. While it must be assumed in the long term that freemium offers will expose users to advertising on the route – for example on built-in flat screens, on billboards along the route, or passing through advertised points of interest – a lower or zero airfare can be established. At the same time, the Spotify model is also imaginable, in which users can enjoy free transport, but are exposed to advertising. In contrast, corresponding premium offers can be established. The aim is to justify a higher fare through freedom from advertising, direct routes and greater comfort. Nevertheless, two different pricing structures can also be thought of in this premium model: On the one hand, the classic pay-per-mile approach could be mentioned here. In this case, the customer pays for the mileage actually used in the same way as for taxi rides. On the other hand, the premium component can also be easily combined with a flat-rate service. A variety of pricing models would be conceivable, for example, reminiscent of today's data volume packages for mobile phone contracts. A customer could thus book a certain total mileage per month but add additional packages such as daily flat rates or resetting the statistics. In the event that a global urban air vehicle platform prevails, the business case would have to be thought through in the same way for roaming charges in the various regions of the world. This clearly indicates an immense operating scope for urban air vehicle operators.

Depending of the integration into mobility service platforms pricing strategies can diverge

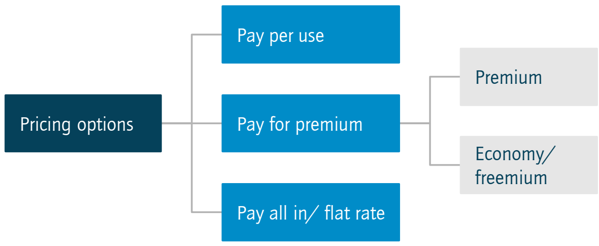

Fig. 16: Pricing models for urban air transportation

Service providers

Individual and flexible transportation through urban air mobility provides different options for service providers to offer a wide range of add-on services to customers. While customers are using autonomous urban air vehicles, they are receptive to additional services that make their trip more entertaining, more productive, more convenient, and relaxing.

Since customers are relieved from piloting autonomous vehicles, they have more time during the flight to organize their personal and professional life and to take time to relax. Service providers can take this opportunity and offer individualized services to generate new business and contribute to a pleasant customer experience. But what are potential add-on services that a service provider may offer to customers itself or with the help of third-party suppliers? The research results of Horváth & Partners in the field of autonomous driving ("Enabling the Value of Time") can partly be transferred analogously to the urban air mobility industry.

Based on this particular study, we can predict that service providers will offer a wide range of services around different functional areas such as sleep and relaxation, work and productivity, eating and drinking, entertainment and beauty, along with well-being and fitness. However, the implementation of each additional area of service is currently still uncertain. In general, the integration of services for sleep and relaxation, as well as work and productivity, seems most feasible. An urban air taxi may, thereby, be equipped with massage chairs, additional meeting tables or screens, which can be pre-booked or activated during the ride. Other add-on services may include individualized advertising, or promotions and shopping offers during the rides. In addition, it is of course also possible to adopt already tried and tested business models from the aviation industry, for example, in the form of freight and chauffeur services. Especially in the cargo sector, it is important to match any cargo load with the passenger weight on the corresponding route. Additionally, already established services can be offered in urban air vehicles: shuttle services can be operated on highly frequented routes and link important hot spots and important sights in major cities. The service offer may also include individualized fares for different routes, day times and travel durations. For this purpose, a basic distinction can be made between premium and economy class offers, whereas premium customers will get the fastest route to their destination while economy users will have to accept detours through the city whilst passing shopping opportunities.

Highest business potential lies in the service integration

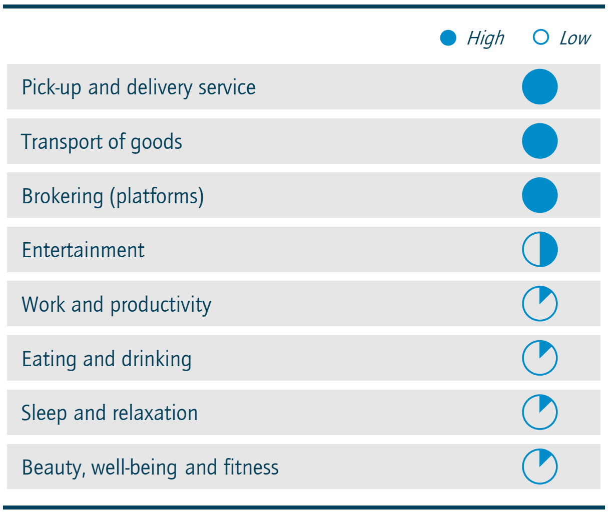

Fig. 17: Portfolio of add-on services and their estimated relevance

In addition to the provisioning of typical add-on services, the subject of mobility platforms is constantly evolving and gaining in importance. The most basic service those platforms provide to customers is the connection of individual mobility demands with an aggregated supply of mobility options. Operating these two-sided platforms represents a huge economic potential for service providers. For some years now, we have seen a cross-industry trend towards more centralized access points and marketplaces. This phenomenon initially began in the media industry (see YouTube or Netflix) and has now extensive effects on the mobility and transportation sector. In Germany in particular, we see Daimler as a pioneer with the integrated Moovel mobility platform. At present, various on-the-ground transportation options are listed on this platform, but Daimler's investment in Volocopter will also contribute to the vision of integrated multi-modal mobility platforms. From an international point of view, Uber Air has already announced a launch of operations in major cities in Japan, India, France, Australia, and the U.S. This announcement is accompanied by the partnerships described in the third chapter with prominent start-ups from the urban air mobility industry and the established players from the aerospace and automotive industries. It can therefore be concluded that the importance of mobility platforms is increasing continuously.

The decisive question, however, must be asked as follows: Is the integration of urban air vehicles the driving factor for a stronger regionalization of platforms? It is important to find an answer to this question in the near future. It therefore remains to be seen which role existing platforms such as Uber will play and which role can be complemented by players from the automotive or aerospace industry. The cards have not yet been laid, as each stage of the value chain can still be occupied by suppliers, manufacturers, operators, and service providers.

Profit pools of the future

In the future, customers will not own individual transport vehicles, but rather make use of various mobility services. Therefore, the market demand for mobility solutions will shift to service platforms that bundle various transport options and can make tailored and highly individualized offers to customers. Due to this compelling value proposition, customers will increasingly make use of mobility platforms and the customer interface and thus the future profit pools will shift towards more and more powerful mobility platforms. From a customer's perspective, the largest value share is created by brokering demand and offer, thus the biggest future profit pool will lie in the service brokering and bundling in multi-modal mobility platforms. The differentiating criteria for customers to choose one mobility service over another will predominately be the broker or platform, while the name and image of the manufacturer will lose importance. Due to an increasing distance from the customer interface, the business models of manufacturers and suppliers will become less profitable and thus more and more unattractive. In the future, we will see that vehicles will become interchangeable for a majority of customers, since the value for them lies more in offering flexible and individualized mobility solutions and not in the possession of automobiles or helicopters.

On the other hand, brokering mobility platforms will gain importance and power, making them very compelling and attractive business models for all industry actors. Since platforms heavily profit from economies of scale, only few players will prevail in this position, while most platforms will vanish over time. Due to the increasing shifting of profit pools to other positions in the value creation chain, the mobility industry will undergo a profound change, creating several losers and few winners. Traditionally successful manufacturers will have to decide on which side they would like to wake up when the music stops.

Integration into services and brokering platforms has the highest potential for opening up new profit pools

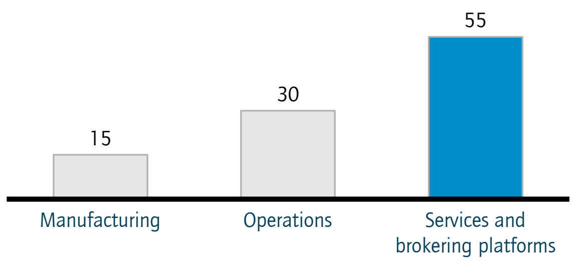

Fig. 18: Profit pools (in percent)

6. Quo Vadis mobility of the smart city – Pitfalls and opportunities on the way to multi-modal mobility platforms

In the future, urban air mobility will complement traditional modes of transportation and will be a vital part of multi-modal mobility platforms. It will especially contribute to a more individualized and flexible form of transportation that is customer-centered and adapts on a situational basis to changes to its environment. Beyond that, urban air mobility has a great potential to change our daily mobility behavior through fully autonomous vehicles. Currently, one might consider that autonomous air vehicles will establish themselves in the marketplace even before autonomous vehicles hit the road. This presumption may sound implausible at first, but we can state several arguments why this development could materialize in the near future. Since a mostly empty airspace offers a huge potential for the relocation of mobility into the 3rd dimension and this less frequented space reduces the complexity for learning algorithms in autonomous vehicles, autonomous air traffic may establish itself earlier than autonomous driving. On the other hand, autonomous air traffic must be able to solve current problems concerning noise generation and the intrusion of privacy to win the acceptance of customers and regulators. Furthermore, regulators must provide stringent legislative frameworks to enable a widespread implementation of urban air mobility in major cities. In conclusion, it remains a possibility that autonomous air transportation will be available sooner to customers than autonomous road transport. Nevertheless, we expect both forms of autonomous mobility to exist simultaneously in the market as they complement each other and contribute to multi-modal transportation concepts.

On the way to a global rollout of urban air mobility, additional issues and problems, which are critical to success, must be addressed. In this context, one has to ask which players might provide the necessary infrastructure for urban air vehicles to operate in densely populated city centers while conventional infrastructure systems have already exceeded their predetermined limits. First, we have to remind ourselves that urban air vehicles will not need massive runways – in contrast to airplanes – but rather many landing sites throughout the city where urban air vehicles can take off and land vertically on a small platform, the way helicopters do. In order to operate on different predetermined routes through the city centers, urban air vehicles need a network of landing sites and platforms as well as charging stations and places for maintenance and service. Since these sites will likely not occupy much terrain, we expect that they can be integrated easily into existing infrastructure. Possible locations for landing sites and ports might be on top of buildings, on the upper deck of parking garages and on free-standing areas within a city's boundaries. To ensure the maximum availability, those sites should be widely distributed within the districts of an urban agglomeration. By positioning hubs alongside main roads, railways, tunnels, and bridges, switching between different modes of transportation becomes accessible and guarantees the fastest possible mobility through a public transportation network. Those hubs are likely to be automated and will have minimal equipment, such as a single landing and take-off pad and no charging station to save costs. The more interesting question, however, focuses on the provision of this infrastructure and the financial resources necessary to own them. Do mobility operators need to possess the necessary infrastructure to operate their transportation business? Or will public investors provide the infrastructure systems in order to support innovative and beneficial mobility concepts? From our perspective, different mobility concepts require different financing concepts ranging from private investment by individual companies and public-private partnerships to pure public investment from the national or state level.

Another important issue to consider is the further development of the urban air mobility industry. At the moment, we can observe a convergence of industries developing and designing urban air mobility concepts. Players from different industry backgrounds team up in small alliances to share resources and knowledge in the pursuit of a dominant design in the urban air mobility industry. This convergence of industries becomes most apparent at customer interfaces and on mobility platforms where players from different industries compete against each other and position themselves to be part of new mobility solutions. One prominent example in this regard might be the cooperation of Airbus and AUDI to develop their Pop.up concept. Since the customer interface becomes vital for their economic success, mobility companies are trying to get a solid foothold in the provisioning of mobility services. In the future, only the mobility-mediating platforms and the mobility operators will have direct contact with customers, while traditional manufacturers will be cut off from the customer interface. This development poses a serious risk for manufacturers such as Airbus, Boeing, or AUDI. Due to the vast experience of Airbus and Boeing in manufacturing flying vehicles, we expect them to get a strong market position in the urban air vehicle market. Mobility platforms will likely profit from the expertise of digital technology companies such as Google and Uber, which will probably establish themselves as strong players in the mobility mediation business. That leaves manufacturers of conventional modes of transportation such as railway companies and automotive companies in a tough competitive situation. The essential assets of those companies are probably their brands, which are recognized by most customers. However, if they do not act fast and face those challenges with courage and perseverance, they risk that others will eat them for lunch.

Urban air mobility will be integrated into holistic mobility platforms

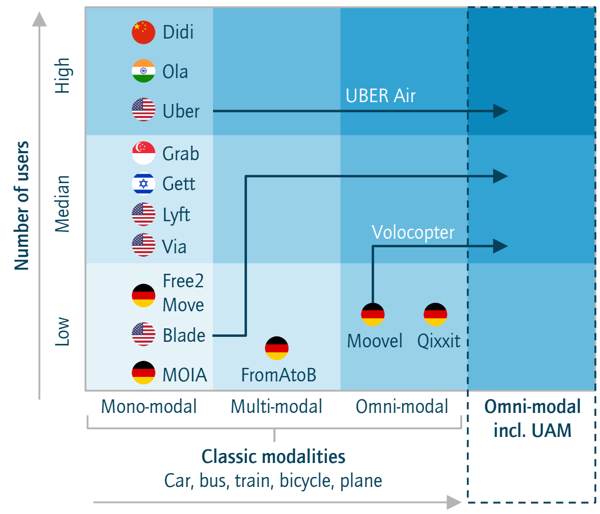

Fig. 19: Forming of omni-modal mobility platforms

In addition to individualized and flexible transportation, urban air mobility has the potential to contribute to the preservation of rural areas and structures by connecting those areas with nearby cities. The improved connection to urban transport infrastructure systems means that rural structures can be maintained and revived, as they remain attractive for commuters and families as places to live. Therefore, the European countries are very much engaged in maintaining the structure of rural areas by making it a central element of different support initiatives.

For instance, over the period 2014-2020, the European Union is providing a total of 100 billion euros for rural support and development from the European Agricultural Fund for Rural Development (EAFRD). The funding provided is used to foster 118 different rural development programs in the 28 member states of the European Union. In the future, urban air mobility may contribute as a vital part to the further development of rural areas. This not only benefits the smart city as a multimorphic work and living space through the integration of urban air mobility into intelligent mobility concepts, but also enables the rural regions to achieve dynamic economic development through urban air mobility, which preserves the structure of their private living space.

At last, one may ask how urban air vehicles can be integrated meaningfully into future intelligent urban mobility concepts. To that end, it is important to consider the different modes and types of transportation that urban air vehicles might substitute or complement one day. Since individual, high-end transportation is already covered by helicopters and private aircrafts, we suppose that urban air vehicles will rather take over certain portions of public transportation. The development of inner-city flight route concepts between important locations in major cities, which the initial players in the urban mobility industry focus on, also fits in with this assumption. The design of the necessary infrastructure in the cities in the form of conveniently located landing sites and hubs also supports our thesis. In combination with other forms of mobility, urban air vehicles will therefore primarily assume the role of public transport as part of integral multi-modal transport solutions.

Conclusions

In order to make urban air mobility a reality, the automotive and aerospace industries increasingly converge to form the new urban air mobility industry. Since urban air vehicles are technologically complex products and high standards apply for safety reasons, the extensive expertise and broad technological knowledge base of automotive companies is presently highly sought after. Therefore, as can be shown with the current urban air mobility industrial network, visionary and idea-driven start-ups often turn to automotive companies to help them with the manufacturing of urban air vehicles and the implementation of operations. This way, clearly distinct network clusters emerge on the industrial landscape which are characterized by close strategic alliances of players with complementary knowledge, expertise, and skill sets. Therefore, the current evolution stage of the urban air mobility industry offers various possibilities for automotive actors to position themselves in the emerging industry and make use of their distinct set of abilities and knowledge.

Urban air mobility as a meaningful addition to mobility platforms

In the future, urban air mobility will at least partially substitute automobiles and helicopters, and as a result, corrode the economic foundation of automotive companies. Following the current trend towards integrated and holistic end-to-end mobility solutions, automotive actors might be inclined to increasingly understand themselves as mobility providers rather than as traditional manufacturers of automobiles. Some automotive actors have already taken this path and started the transformation into an integrated mobility provider or established spin-offs to that end. From understanding mobility as a service, it is only a small cognitive step for mobility providers to start building an integral mobility-as-a-service ecosystem by bundling different mobility offerings together and offering end-to-end mobility solutions to interested customers. Due to its technological characteristics and the resulting value proposition to customers, urban air mobility could become an integral part of a multi-mode mobility chain. Therefore, automotive companies may be inclined to secure a favorable stake in the urban air mobility industry to integrate this mobility form into their mobility platform.

Commitment and speed are decisive for success

As customer acceptance is a key determinant in the widespread and global adoption of urban air mobility, strong and well-known brands are an important asset to influence public perception. Therefore, established automotive and aerospace players have a considerable advantage compared to independent start-ups in the formation of the urban air mobility industry. Furthermore, they have a technological advantage compared to independent start-ups in terms of safety, production technology, product development and implementation, which is currently very strong but will decrease over time due to learning effects and knowledge building in the start-up community. By joining forces, start-ups might have higher rates of learning, thus posing a serious long-term danger for traditional automotive players. The race of ideas towards a dominant design in the urban air mobility industry is decided by the speed and commitment of leading players. Early commitment and rapid development are therefore decisive for success.

Finding future profit pools and positioning in the emerging value chain

Future profit pools will likely shift over time as the value creation in the future mobility industry will lie in the bundling and brokering of end-to-end mobility solutions. Automotive actors in particular have to find new profit pools to balance declining margins from automobile sales. Furthermore, they need to discuss how future profit pools can be addressed with suitable market offers and how the course should be set in today's transition phase. The management of the transition into tomorrow's mobility world will become a key challenge for all automotive players, but a clear vision and set of objectives can guide the way. In order to stay successful, automotive companies must decide which position in the emerging value chain might be best suited for them and which benefits might be attached to each position. Traditionally, companies in the automotive industry understand themselves as manufacturers or suppliers, but the greatest value creation and thus the profit pools of the future might lie somewhere else. It is therefore essential to make a holistic assessment of the emerging value chain for a strategic positioning in the new mobility industry.

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