EHANG | 亿航
EH | Nasdaq Listed

The Future of Transportation:

White Paper on Urban Air Mobility Systems

By EHang Jan 15, 2020

Table of Content

The Future of Transportation: White Paper on Urban Air Mobility Systems

Abstract

Urban Air Mobility (UAM) as a concept was defined by NASA as "safe and efficient air traffic operations in a metropolitan area for manned aircraft and unmanned aircraft systems" (Urban Air Mobility Airspace Integration Concepts and Considerations). With governments, enterprises and research institutes paying increasing attention to UAM, this new concept has caught on quickly.

As a disruptive industry, UAM is expected to revolutionize existing transportation modes including on highways, railways, airways, and waterways. A 2018 Morgan Stanley blue paper estimates that the global UAM addressable market would reach US$1.5 trillion by 2040.

As the size of urban populations grows, traffic congestion and air pollution remain as major threats that take a toll on economic growth. It is imperative for governments to seek alternative solutions by making strategic moves to promote UAM system development as an alternative to existing ground transportation.

In this context, our white paper aims to explore the potential of UAM through insights into UAM applications and commercialization based on practical use cases. Starting from the UAM concept, it further explored the way how UAM system can materially change people's lives and impact the existing transportation modes.

If safety, smart cities and cluster management should form the three most fundamental tenets for a modern UAM system, future transportation would become smooth, smart, efficient, and eco-friendly. Given its innovative and disruptive nature, UAM has significant advantages over traditional transportation modes. The advent of 5G networks will further strengthen the function and capabilities of existing UAM platforms, which can remotely command a multitude of versatile AAVs more effectively.

The UAM concept could be further extended into applications in rural areas where the existing ground transportation infrastructure is inadequate. Besides transportation, UAM vehicles can function in specific scenarios in tourism, industrials, emergency medical services, fire control, and other use cases.

As technologies mature, they require the collaboration between governments and enterprises to create new regulatory frameworks to facilitate future development. This is especially critical for UAM, starting now – not in the future. In addition, the ongoing collection of commercial operational data of current and future pilot projects will be necessary for supporting investment decisions in both the private and public sectors.

Overall, our empirical tests and research in UAM have strengthened our belief that UAM is no longer a dream of the future, but is already well on its way here and now.

Chapter 1.
The UAM Concept

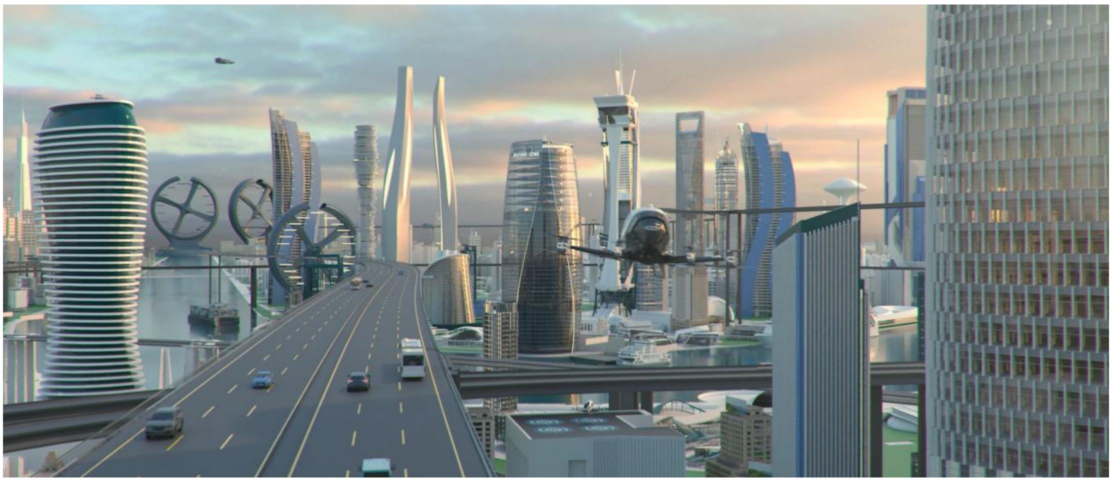
In a research published by NASA (Urban Air Mobility Airspace Integration Concepts and Considerations) on June 25, 2018, it defined UAM (Urban Air Mobility) as "safe and efficient air traffic operations in a metropolitan area for manned aircraft and unmanned aircraft systems". However, existing technologies and regulations only allow the UAM concept be implemented through the use of conventional helicopters now, not as fancy as it sounds. The use of electric autonomous air vehicles (AAV) looks like a futuristic story years ahead of us.

However, based on our experience with AAVs and our research, we believe UAM as a revolutionary idea can be implemented now, yet in a more innovative way. Particularly, it will have the best chance at full-scale implementation if they are focused on safety, operated smartly, and are connected under the command of a centralized platform.

Safety, of course, always needs to be the first priority, so any UAM vehicle needs to be outfitted with power redundancy and backup systems.

"Smart" UAM vehicles to us mean that they are piloted autonomously, which not only obviates the need for an in-vehicle pilot and the associated costs, but also enhances safety and makes vehicle more controllable from the ground.

Finally, cluster management techniques centralized at a ground-based command-and-control center would allow UAM operators to control a multitude of vehicles simultaneously in an orderly and safe manner. This way, all flight routes could be pre-registered and pre-determined so that UAM vehicles can travel only between certified "base points".



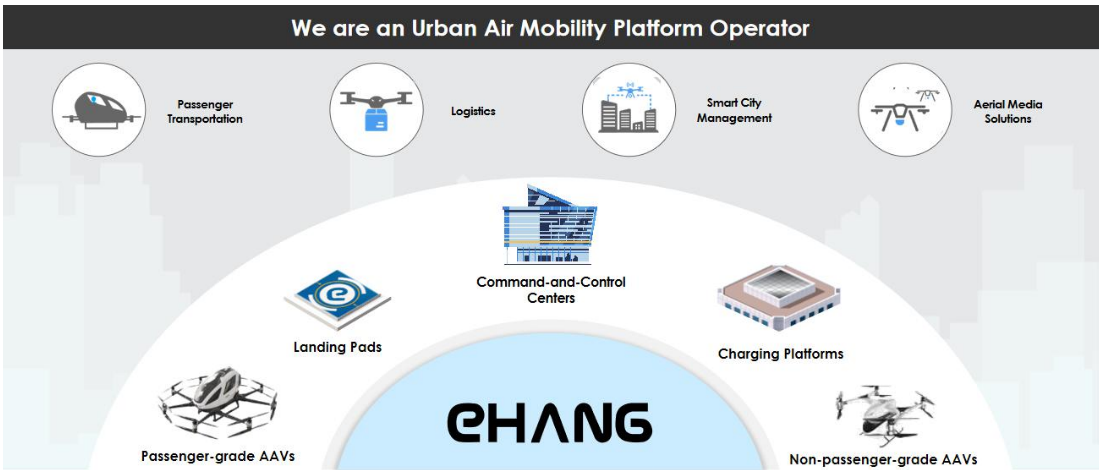
Source: EHang Research

Proposed Basic UAM Structure

As a new mode of transportation, the UAM structure would resemble an on-demand bus system rather than a taxi system, since under the centralized system we propose all aerial vehicles should be registered and controlled by a UAM platform that manages exact point-to-point routes set by its command-and-control platform. Each base point would be a cell of the UAM network that covers a specific zone and would be connected by straight-line routes to other points. A larger base point with higher route density would form a node or hub of the network. The network would grow as new base points and routes are added to satisfy emerging demand.

In a nutshell, a UAM system would consist of the following major components: vehicles (e.g. AAVs, eVTOLs), command-and-control platform, navigation and positioning system, base points (including infrastructure of landing pads, charging ports, etc.), and interface. In general, the key functions of UAM would include the transportation of both passengers and freight within a metropolitan area. Of course, the operations of passenger services are much more challenging given the higher regulatory and societal standards for safety and comfort.

Actually, an active UAM route is no longer just a dream of the future: In May 2019, the world's first UAM passenger service was launched by EHang in China's Zhejiang province. Connecting a harbor to a boutique hotel on an islet, the route has significantly reduced a 40-minute road journey to a 5-minute air ride. This has set a key milestone for the development of the UAM industry.



Source: EHang Research

Key components:

Vehicles

UAM vehicles are flying vehicles that transport either passengers or freight on specific point-to-point routes within urban areas. Due to the constraints of buildings, plants, road traffic and crowds in cities, the ideal vehicle models need to be autonomous, small, efficient, nimble and maneuverable, with the ability to take off and land vertically (as opposed to with a runway).

Safety first – As a top priority, safety should form the very foundation for any designs of UAM vehicles. Simply speaking, we consider the following as the key factors to ensure maximum safety:

1) Power redundancy provided by multiple motors and propellers (e.g. distributed electric propulsion, or DEP);
2) Complete autonomous operations to eliminate human errors caused by the pilots;
3) Backup from duplicate flight control, communication and navigation systems;
4) Centralized command-and-control to ensure safe operations;
5) Intelligent obstacle avoidance capabilities (e.g. millimeter radar, visual positioning, etc.);
6) Intelligent self-detection capabilities to constantly monitor vehicles automatically.

To that end, special algorithms need to be developed and "burned into" hardware systems to make the vehicles safe and smart.
While many prototypes have been built in recent years by firms such as Airbus (A^3 Vahana), Boeing (PAV), Lilium (Lilium Jet), Volocopter (VC2) and Kitty Hawk (Cora), EHang has been the first company to successfully launch serial production of its EH216 and EH116 AAVs for autonomous, manned flights.

● EHang AAVs

The term "autonomous aerial vehicle" (AAV) was first created by EHang, a China-based UAM firm that launched the EHang 184, the world's first AAV at CES in Las Vegas in 2016. Powered by eight 12kw electric motors and remotely controlled by a computer platform, the EHang 184 requires no pilot on board and can carry one passenger for a 20-minute flight. Basically, the AAV was built upon the principles of "safe, smart, platform controlled, connected and eco-friendly".

With further upgrades, EHang has since launched more advanced versions – EHang 116 and the two-seater model of EHang 216, which are safer and more powerful thanks to eight additional motors and propellers.

Graph of EHang 216

Source: EHang Research

- **Other eVTOLs**

The term eVTOL refers to electrically powered vertical take-off and landing vehicles. Major firms including Airbus and Boeing as well as startups like Lilium, Volocoper and Kitty Hawk are building their own versions of eVTOL vehicles for UAM purposes.

Company	Product	Autonomous	Initial Year of Development	Design	Announce -ment	Validation Tests	Full Size Tests	Manned Tests	Production	Commercial Launch (Estimated)
EHang	**EHang 216 Ehang 116 EHang 184**	✓	**2013**							2019
Volocopter GmbH	Volocopterr 2x Volocopter VC200	✗	2012							N/A
Lilium	Lillium Jet	✓	2014							2025
Airbus	Vahana CityAirbus Pop Up	✓	2016							2020
Boeing (Aurora Flight Science)	Aurora eVTOL	✓	1989							N/A
Bell Helicopter	Nexus	✗	2018							N/A
Kitty Hawk	Cora Flyer	✓	2010							2021
Joby Aviation	S4 / S2	✗	2009							N/A

Source: EHang Research

- **Airbus A³ Vahana**

This is an all-electric, single-seat, tilt-wing eVTOL demonstrator with eight propellers. The full-scale model Alpha was completed and made its first flight on January 31, 2018 in Pendleton, Oregon, reaching 5 meters (16 feet) in elevation. The second model, Alpha 2, was completed in early 2019. According to the company, Vahana has flown over 80 full-scale test flights to date.

General characteristics of the A³ Vahana

Crew	None; autonomous
Capacity	1 passenger; 340kg
Length	5.7-5.86m
Wingspan	6.25m
Height	2.81m
Net weight	726kg
MTOW	1,066kg
Propellers	8 x 1.5m in diameter
Cruise speed	190-220km/h
Range	50km
Service ceiling	1,524 - 3,048m at 35ic

Source: ICAO; Company data

- **Boeing PAV**

The Boeing Passenger Air Vehicle (PAV) is a prototype developed by Boeing NeXt with the assistance of Boeing's subsidiary Aurora Flight Sciences. On January 22, 2019, the PAV prototype completed a controlled takeoff, hover and landing during its first flight test in Manassas, Virginia.

General characteristics of the Boeing PAV

Crew	None; autonomous
Capacity	2 passengers, 225kg
Length	9.14m
Wingspan	8.53m
Height	NA
Empty weight	575kg
MTOW	800kg
Propellers	1 horizontal + 8 vertical
Cruise speed	180km/h
Range	80km

Source: ICAO; Company data

- **Lilium Jet**

This model is a proposed eVTOL designed by Lilium GmbH in Germany. Various subscale models were tested, including a half-scale demonstrator, Falcon (2015), and a full-size two-seater Eagle prototype (2017). The five-seater full-scale model powered by 36 electric motors took its maiden flight on May 4th of 2019.

General characteristics of the Lilium Jet

Crew	1 pilot
Capacity	4 passengers
Propellers	36 vertical
Cruise speed	300km/h
Range	300km

Source: ICAO; Company data

- **Kitty Hawk Cora**

Kitty Hawk, an American aircraft manufacturer of electric aircraft, confirmed its test of an autonomous electric air taxi prototype in New Zealand. The vehicle is called Cora (code named "Zee.Aero").

General Characteristics of the Cora

Crew	None; autonomous
Capacity	2 passengers; 181kg
Length	NA
Wingspan	11m
Height	NA
Empty weight	NA
MTOW	NA
Propellers	12 vertical + 1 horizontal
Cruise speed	180km/h
Range	100km

Source: ICAO; Company data

- **Volocopter VC2X**

Based in Bruchsal, Germany, Volocopter GmbH specializes in the design of electric multirotor helicopters for “air taxi” use. Volocopter 2X is a two-seat version that evolved from an earlier single-seat VC2 prototype flown in 2011. However, this is a not an autonomous aircraft and requires an in-vehicle pilot.

General Characteristics of the VC2X

Crew	1
Capacity	2 (1 passenger + 1 pilot); 160kg
Length	3.2m excluding propeller ring
Width	9.15m including propeller ring
Height	2.15m
Empty weight	290kg
MTOW	450kg
Propellers	18 x 1.8m in diameter
Max speed	100km/h
Range	27km at 70km/h
Service ceiling	2,000m

Source: ICAO; Company data

- **The Opener BlackFly**

The Opener BlackFly is an electric-powered VTOL that was publicly introduced on 12 July 2018 by Opener, Inc of Palo Alto, California, which claims that the design is the world's first ultralight fixed-wing, all-electric, vertical take-off and landing aircraft. However, this is a single-seat aircraft that requires the passenger to have piloting skills.

General Characteristics of the Opener BlackFly

Crew	1
Capacity	1 pilot; 113kg
Length	4.09m
Width	4.14
Height	1.5m
Empty weight	142kg
MTOW	255kg
Propellers	8
Max speed	130km/h
Range	64km

Source: ICAO; Company data

Command-and-Control Platform

Based on existing design concepts of various models and prototypes of UAM vehicles, only the EHang AAV is designed to be controlled by a centralized platform, which we believe is the most promising model for future UAM operations and development. It is difficult to imagine that the safety of an autonomous UAM system can be guaranteed if each vehicle is allowed to fly freely in cities.

Unlike conventional transportation modes like cars or airplanes, a UAM system requires a centralized remote command-and-control platform to perform multiple tasks autonomously. With the help of computer programs and cluster management techniques, the platform is able to control the flights of thousands of UAM vehicles simultaneously. Specific flight tasks are coded, registered, executed and monitored to ensure safety, efficiency and quality. Thus, complex traffic situations become manageable.

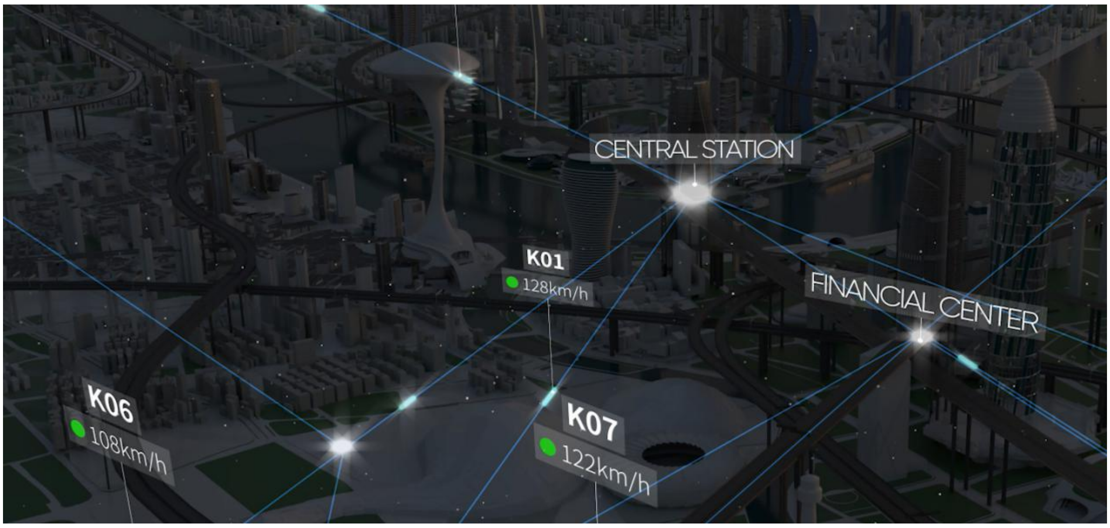
Source: EHang Research

There are also significant city management benefits: a single platform in a metropolitan area would be able to prevent accidents and traffic congestion as well as to improve city operations by integrating various municipal functions like police, emergency response, healthcare, firefighting, forestry, fishing, tourism, etc., forming an instrumental part of a "smart city" urban planning system.

Note that the command-and-control center concept is different from the FAA's UTM (Unmanned Aircraft System Traffic Management) system, which is a "traffic management" ecosystem for uncontrolled operations. According to the FAA, "UTM development will ultimately identify services, roles and responsibilities, information architecture, data exchange protocols, software functions, infrastructure, and performance requirements for enabling the management of low-altitude uncontrolled drone operations." By contrast, a centralized command-and-control platform ensures all air vehicles are registered and controlled to fly on specific routes set by computers.

Navigation and Positioning System

Normal GNSS including GPS, Galileo, BDS and GLONASS are available to provide necessary navigation services to UAM systems. For more precise navigation needs in more complicated situations (e.g. logistics deliveries to office buildings, landing in crowded areas), ground facilities are added to augment the functions of the satellite systems. Moreover, a visual positioning system (VPS) can be added to help the UAM vehicles when GPS signal is poor or lost. So far, the communications between UAM vehicles and the command-and-control platform are conducted through a 4G network. The adoption of 5G technologies will significantly boost the capabilities and functions of future UAM systems.

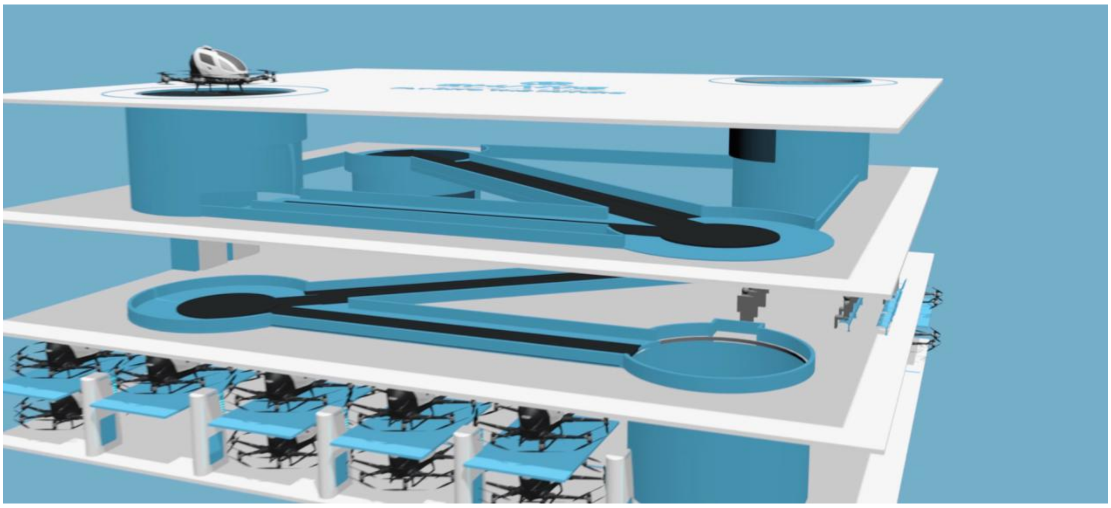


Source: EHang Research

Base Points

We define a UAM base point as a ground site for a UAM vehicle to land and take off. Each base point needs to be identified and registered in the UAM system so UAM vehicles can travel only between the base points, which are the only valid sites for passengers to board and alight. Based on traveling demand, new base points can be created and added into the UAM system continuously, so the overall UAM service network continues to expand.

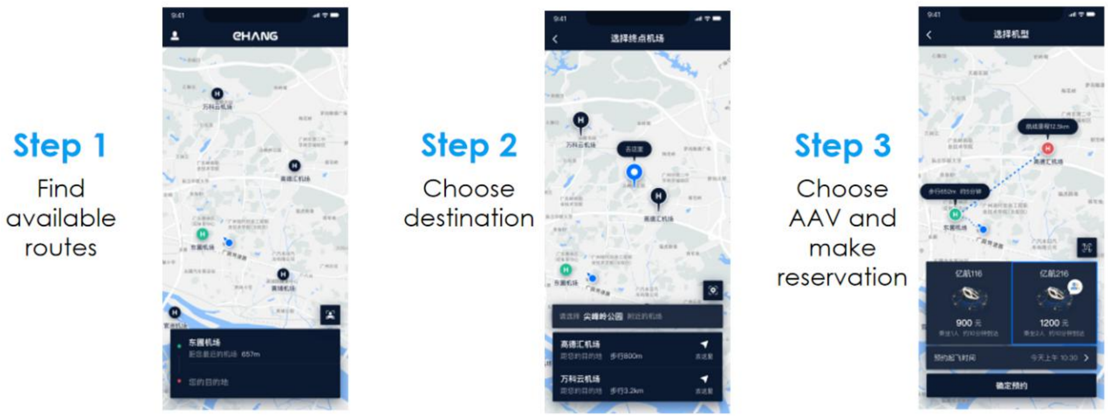
The size and importance of each base point are determined by the density of air routes and traffic volumes. It can be either a single pick-up / landing point or a hub station with multiple landing pads, charging docks, waiting areas and other facilities. Although the UAM routes are linked only point-to-point, further expansion of the network can accommodate the demand for more convenient service locations.



Source: EHang Research

Interface

Based on computer software and programs, a UAM interface takes the form of a mobile app similar to what users are used to from ridesharing apps, which allows customers to place orders and pay for services online. A UAM app would be a real-time information system that connects the front-end platform to the back-end command-and-control system. By sharing the real-time information about passengers and vehicles, it would allow both UAM operators and the customers to locate the nearest base point with available vehicles in specific zones and dispatch traveling orders.



Source: EHang Research

Key UAM Characteristics

Overall, we think a modern UAM system should possess the following characteristics.

1. *Autonomous services* – Full flight automation means that there is no need for pilots on board. Passengers are not required to have any pilot skills or qualifications. Ordering and payments for services are all conducted online through mobile apps. This can maximize efficiency by dramatically reducing staff costs. More importantly, it helps eliminate the risk of accidents largely caused by human errors in current piloted aircraft.
2. *Quick and hassle-free* – Compared with traditional ground transportation, UAM would be faster and more efficient given that it allows individuals and freight to move about a city in straight-line air routes.
3. *Centralized platform* – Today's automobiles, even autonomous ones, travel individually and separately. Accidents and traffic congestion are therefore inevitable. By contrast, a UAM system backed by a command-and-control platform using auto-piloting can eliminate accidents and ensure that traffic flows smoothly and orderly at all times of day and night.
4. *Shared economy* – Since a centralized UAM platform offers a convenient network, it is not necessary for individuals to own their own UAM vehicle. This enables higher asset utilization and a lower waste of resources. It also eliminates the parking problem that dominates so much of city life today. In our view, the difficulty in achieving a truly shared economy for existing automobiles is due to a lack of a centralized command-and-control platform that can automatically control the vehicles.
5. *Green energy* – Electrically-powered UAM vehicles are eco-friendly, with zero emissions, a tremendous advantage over the majority of current land and air vehicles that continue to run on fossil fuels.

Source: EHang Research

What makes UAM a viable new transportation mode?

UAM will dramatically change the existing landscape and dynamics of the entire transportation industry. Below, we compare and contrast UAM to existing transportation models.

Key differences between UAM and the current airline model

- Flight range – UAM provides short-to-medium range (3km – 100km) air services designed for city residents, effectively solving the "last-50km" problem that current airlines cannot offer.
- Flight elevation – The short distances covered by UAM means that vehicles remain at below 800 meters. They therefore will not interfere with airspace trafficked by traditional airlines at an altitude of 8,000-12,000 meters.
- Command-and-control system – A centralized command-and-control platform makes UAM trips completely autonomous. While autopilot techniques are being developed for the airlines, it may still take time for traditional aircraft to be completely autonomous.
- Power system – The fully electrically-powered motors with zero emissions make UAM vehicles more eco-friendly than the traditional aircraft, which run on jet fuel.
- Capacity – One-and two-seater UAM vehicles allow for more privacy and quietness for passengers than normal flights, which carry up to 500 passengers at a time.

Key differences between AAVs and UAVs

UAV refers to unmanned air vehicles, which normally exclude passenger flights. AAVs, however, include passengers.

AAVs vs UAVs

	AAVs	UAVs
	Differences	
1	Can carry both passengers and freight	Exclude passengers
2	Centralized command-and-control	1:1 control or centralized control
3	4G/5G network	Radio frequency, WiFi, or 4G/5G
4	Long remote control range globally	Mostly short-range control at only 100-3,000m
5	Cluster management (easy)	Lack of management (difficult)
6	Sophisticated tasks (passenger flight, logistics deliveries)	Limited functions (photography, video, etc.)
7	Payload up to 200-600kg	Small payload below 10kg
	Similarities	
	Autonomous, remote control, electric-powered, rotary, vertical take-off/landing	

Source: EHang Research

Key differences between AAVs and helicopters

Compared to helicopters, AAVs enjoy absolute advantages in cost, safety and efficiency that make them an ideal choice for UAM purposes.

AAVs vs Helicopters

	AAV	Helicopter
1	Higher safety led by distributed propulsion system (DPS) with multiple propellers	Single propeller with failure risk
2	Full automation to eliminate human errors	Accident risk led by human errors
3	Reasonable vehicle price	High vehicle price
4	No pilot costs	High pilot costs
5	Low repair & maintenance cost	High repair & maintenance cost
6	Low noise	High noise
7	Zero emission, green energy	High fuel cost with pollution
8	Small in size, easy take-off/landing	Larger size requires bigger landing spot

Source: EHang Research

Key advantages of UAM vs. existing ridesharing

Thanks to the arrival of network technologies, ridesharing platforms (e.g. Uber, Lyft, Didi, etc.) throve quickly by leveraging millions of idle resources in terms of both drivers and private vehicles. However, safety issues and service quality remain as main concerns, given the difficulty in managing individual drivers loosely connected to the platforms.

By contrast, a centralized UAM platform carries no safety risks caused by human pilots with it. More importantly, a profitable business model for UAM should make it attractive and sustainable to investors and other participants who have not seen the returns on ridesharing that they had hoped for.

AAVs vs Net cars

	AAVs	Net cars
1	Fully autonomous, auto-piloting	Human drivers
2	Good privacy and safety	Safety concerns
3	Straight-line air routes with no congestions	Ground routes subject to congestions
4	Stable standard service quality	Less stable service quality
5	High margin / low operating cost	Negative / low profit margins
	Similarities	
	Centralized platform, asset light, tech-driven, sharing economy	

Source: EHang Research

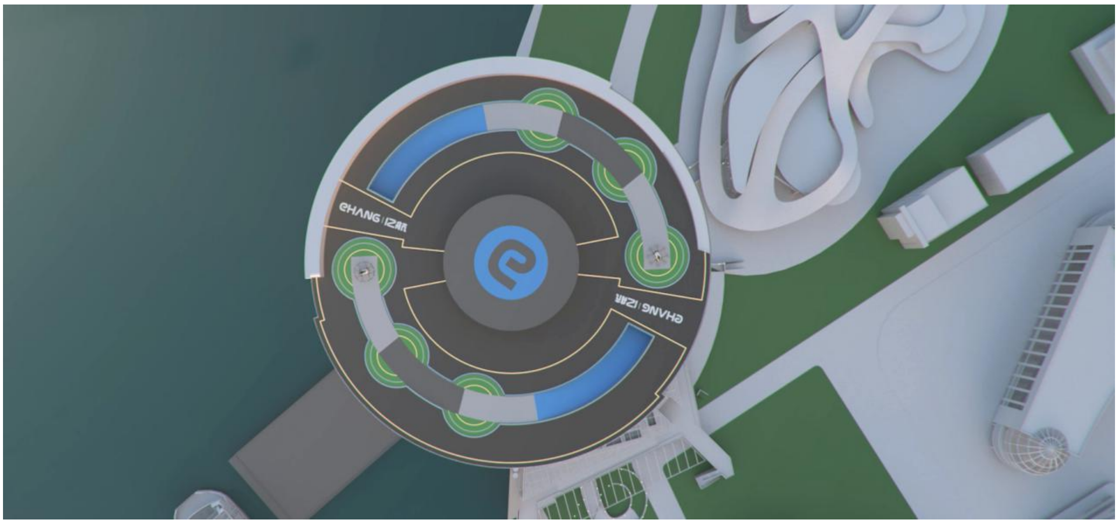
Competition risks from existing ridesharing platforms?

We think the success of existing ridesharing platforms in penetrating the traditional taxi market was mainly due to convenient mobile apps that offered instant services to passengers and were supported by a more advanced and centralized dispatch system that leverages millions of individual drivers.

While it is possible to replicate this ground model for the air by leveraging the idle resources of helicopters and pilots, a fully autonomous UAM model is an even better option due to its higher safety, efficiency, and lower cost through smart control. We believe the autonomous UAM system should be more robust and self-sufficient by integrating both manufacturing and operations seamlessly.

Chapter 2.
UAM: Applications and Commercialization

We think the future success of a modern UAM system depends on commercial operations. New technological advancements, especially the development of centralized command-and-control platforms, have made UAM vehicle manufacturers natural UAM operators. This is a different model than that of the traditional airline industry, where hundreds of flight operators globally are in competition with each other, leading to poor margins. By contrast, the UAM industry is likely to be consolidated due to the autonomous nature of its vehicles, which need to be coordinated by a centralized platform. As result, the elimination of unnecessary competitors will lead to sufficient pricing power for the remaining operator(s) to ensure reasonable investment returns.



Source: EHang Research

Ultimate solution to urban problems: eliminating traffic congestion, car accidents and pollution

As the world's urban population grows, traffic congestion has been seriously affecting people's quality of life and taking a toll on general economic growth. For example, according to an article (*Gridlock woes: Traffic congestion by the numbers*, Smart Cities Dive, Mar 27, 2018) by Katy Pyzyk, a U.S. commuter spends 41 hours on average in traffic each year during peak congestion times. An estimate by INRIX (a traffic analysis firm) showed traffic congestions had cost U.S. drivers ~US$305 billion in 2017, implying an average of US$1,445 per driver. Furthermore, the U.S. Environmental Protection Agency estimated an average passenger vehicle emits 4.7 metric tons of carbon dioxide each year.

Economic losses led by traffic congestions

Countries	Loss (US$ bn)
USA	305.0
New York	33.7
Los Angeles	19.2
San Francisco	10.6
Atlanta	7.1
UK	52.0
Manila	18.6
Bangladesh	11.4
Jakarta	5.0
Dhaka	4.5

Source: INRIX 2017 Traffic Scorecard

Top 10 Congested US Cities in 2017

2017 Rank (2016 Rank)	City / Large Urban Area	2017 Peak Hours in Congestion	% of Total Drive Time in Congestion	Total Cost Per Driver in 2017	Total Cost to the City in 2017
1 (1)	Los Angeles, CA	102 (-2%)	12%	$ 2,828	$19.2bn
2 (2)	New York City, NY	91 (+2%)	13%	$ 2,982	$33.7bn
3 (3)	San Francisco, CA	79 (-5%)	12%	$ 2,250	$10.6bn
4 (4)	Atlanta, GA	70 (-1%)	10%	$ 2,212	$7.1bn
5 (5)	Miami, FL	64 (-2%)	9%	$ 2,072	$6.3bn
6 (6)	Washington, DC	63 (+3%)	11%	$ 2,060	$6.1bn
7 (8)	Boston, MA	60 (+3%)	14%	$ 2,086	$5.7bn
8 (9)	Chicago, IL	57 (0%)	10%	$ 1,994	$5.5bn
9 (10)	Seattle, WA	55 (0%)	12%	$ 1,853	$5.0bn
10 (7)	Dallas, TX	54 (-8%)	6%	$ 1,674	$4.9bn

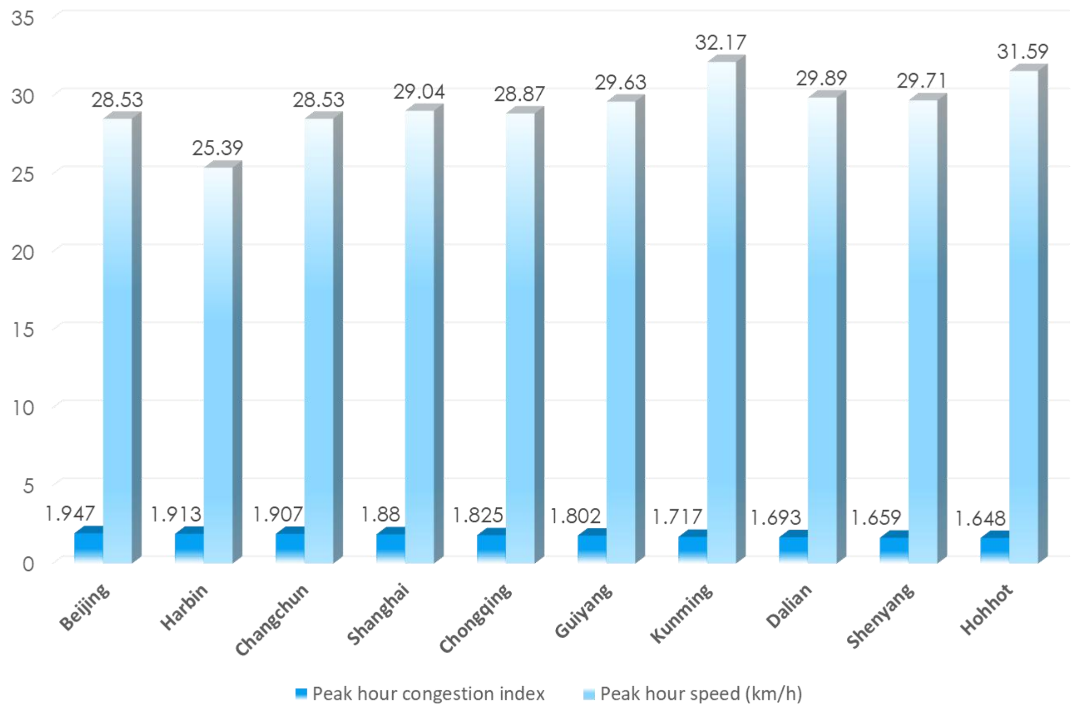
Source: INRIX, 2017

Note: Measured in average hours wasted per vehicle for the year

Clearly, the problem of urban traffic congestion will not be solved by simply building new roads, as researchers from the University of Toronto and the London School of Economics concluded that the number of vehicle-kilometers traveled (VKT) increases in direct proportion to the available lane-kilometers of roadways – i.e. newly constructed roads would only invite additional traffic flows to fill them. This conclusion was supported by a Wharton Faculty Research from University of Pennsylvania that claimed "increased provision of roads or public transit is unlikely to relieve congestion".

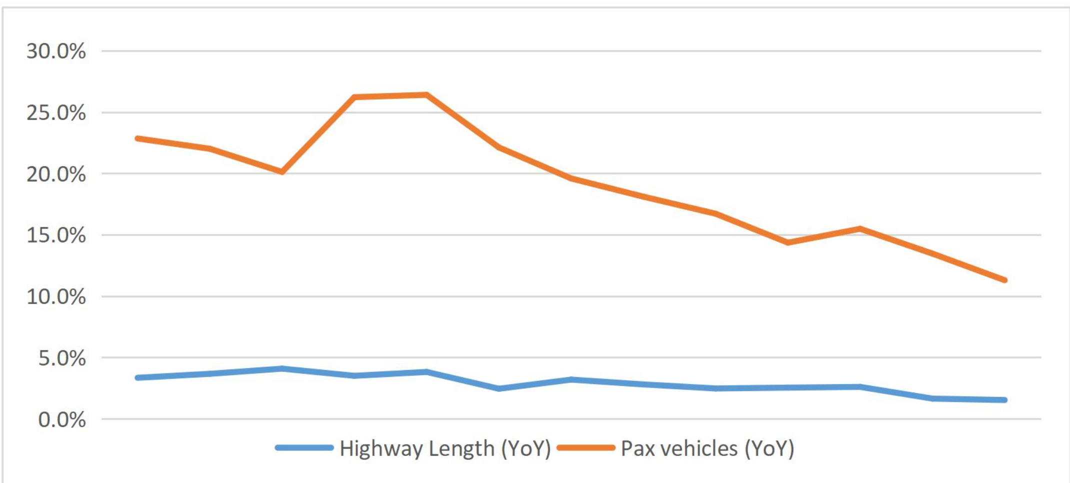
Examples are found in China, where traffic congestions deteriorate along with accelerating road constructions. A 2018 report led by Baidu Map showed the top 10 most traffic congested Chinese cities are Beijing, Harbin, Changchun, Shanghai, Chongqing, Guiyang, Kunming, Dalian, Shenyang and Hohhot. Based on data from 100 Chinese cities, ~53% of the urban population spend 20-60 minutes on their daily commute. As China's urbanization continues, traffic congestion problems will remain a key problem for major cities with ballooning populations.

Top 10 Congested Chinese Cities in 3Q2018



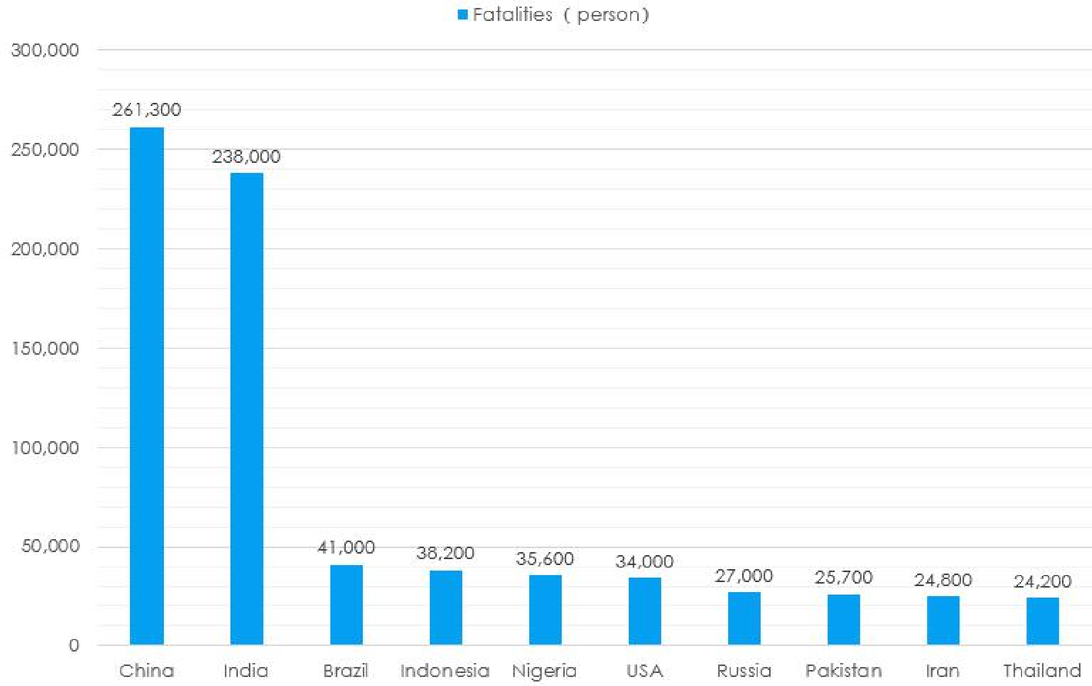
Source: China Urban Traffic Research Report, 2018

China: Auto ownership outgrew highway lengths (2006-2018)



Source: China Ministry of Transportation

Furthermore, car accidents have surged along with booming vehicle ownership in developing countries such as China and India. According to the WHO, about 1.25 million people are killed in car accidents each year, leading to about 3,400 deaths per day. This does not account for the millions of injuries incurred in non-fatal accidents. Human error was the major cause of accidents.



Source: WHO

To find the way out, we believe a 100% autonomous system will provide the ultimate remedy to these urban traffic safety problems.

Finally, an electric-powered UAM system that replaces existing gas-powered cars will significantly reduce carbon emission and improve air quality in urban areas. Based on our estimates, a sedan with a 1.6L engine would consume 1,000 liters of gasoline per year, resulting in an emission of 2.7 metric tons of carbon dioxide. Official statistics showed that China's total carbon emission reached 103.57 million metric tons in 2018, causing serious smog in major cities.

UAM - How realistic is it?

Given the ever-increasing problems of urban traffic congestion, car accidents, and air pollution faced by cities, we are looking to the skies for solutions.

What we now consider to be UAM entered the popular imagination under the guise of "flying cars" as early as the 1950s. For example, a 1957 edition of *Popular Mechanics* predicted the emergence of flying cars in "the next 10 years." However, we are still waiting. In fact, a 2018 blue paper by Morgan Stanley estimated the UAM industry will only start to develop significantly from 2030 given both technological and regulatory uncertainties.

Source: POPULAR MECHANICS

However, we believe a reality of flying vehicles that carry people around cities could arrive sooner than people's expectations.

The launch of the EHang 184, the world's first autonomous air vehicle (AAV) at CES in Las Vegas in 2016 set the stage for the development of UAM industry – not in the future, but now.

With a one-person cabin and eight propellers on 4 axes, this AAV can carry a passenger with a weight up to 200kg for 20 minutes at a cruise speed of up to 100 km/hour. EHang has since expanded its product line to a two-seater model. With over 2,000 unmanned and manned flight tests, EHang AAVs are ready for commercial operation – now, in 2019.

Source: EHang Research

What will it take for UAM to become a viable industry?

In our view, the development of UAM systems should serve as a key strategy for urban transportation in the next 30-50 years. Governments around the world should make serious efforts to implement UAM plans to boost their cities' competencies.

Some governments have taken a first step in this direction. The government of the Chinese megacity of Guangzhou recently entered into a strategic agreement with EHang for UAM development. This cooperation may make Guangzhou the first city to launch real passenger UAM services in the world.

Meanwhile, Volocopter said in May 2019 that it was bringing its first-ever air taxi "vertiport" to Singapore by the end of 2019, with test flights already planned.

In October 2019, Volocopter launched a test flight in Singapore using its Volocopter 2X model. The flight was reported to cover a distance of approximately 1.5km within 2 minutes. Meanwhile, the company also unveiled a new air taxi vertiport called VoloPort to serve as the take-off and landing of its vehicles.

In general, we see three key factors as critical in determining the success of the UAM industry: regulations, technology and capital.

1. Regulations

Below is an overview of the current regulatory environment for UAM in various geographies.

China – CAAC. In fact, regulatory approvals in China need to be granted by three levels: military (PLAA), civil aviation (CAAC) and local government.

- PLAA – Approval for airspace

Any UAM flight requires approvals from local divisions of the PLAA for proposed routes. The approvals from the PLAA are usually granted on a one-off basis or are only valid for a limited period of time.

- CAAC – Approval on airworthiness

The UAV Airworthiness Guidance recently published by the CACC has established a UAV airworthiness framework that is based on the assessment, classification and management of operational risks of UAVs.

Under this framework, a written approval needs to be issued by the CAAC for trial flights of passenger-grade AAVs in certain locations in China for the purpose of evaluating their airworthiness and formulating industry standards on airworthiness of passenger-grade AAVs.

According to the UAV Airworthiness Guidance, the detailed rules and regulations on airworthiness are expected to be promulgated by the end of 2019. Pursuant to the Interim Rules, a prospective operator of certain classes of UAVs must submit an application for pilot operation. In February 2019, EHang submitted an application for pilot operations of the EHang 216 AAV in Taizhou, Zhejiang Province and have passed the preliminary examination by CAAC.

- Local government – Approval for commercial operations

While there are no detailed rules or regulations with respect to commercial operations of passenger-grade AAVs, it is unclear whether the relevant regulators in China would permit commercial operations under the current regulatory framework. A potential launch of UAM services in Guangzhou based on the latest strategic partnership agreement may set a precedence for future operations.

Europe – The EASA (European Union Aviation Safety Agency) is the regulatory body in charge of airworthiness certification. Of particular relevance to UAM, the Council of the European Union adopted new aviation safety rules in June 2018, which included a new mandate for EASA. This formalizes the EASA's role in the domain of drones and UAM and enables EASA to prepare rules for all sizes of civil drones and harmonize standards for the commercial market across Europe.

On October 15, 2018, the EASA opened a public consultation on its proposal of airworthiness standards which will enable the certification of small vertical take-off and landing (VTOL) aircraft. The objective was to develop the first component of the regulatory framework to enable the safe operation of air taxi and electric VTOL aircraft in Europe.

Further progress was made on July 2, 2019, when EASA issued "Special Condition for Small-category VTOL Aircraft"- a complete set of dedicated technical specifications in the form of a special condition for VTOL aircraft. This special condition addressed the unique characteristics of the new VTOL products and prescribed airworthiness standards for the issuance of the type certificate, and changes to this type certificate, for a person-carrying VTOL aircraft in the same category.

US – The FAA (Federal Aviation Administration) is the regulatory body in the US focusing mainly on aviation safety and efficiency. Specifically, it has established an Unmanned Aircraft System Traffic Management (UTM) for uncontrolled operations that is separate from, but complementary to, the FAA's Air Traffic Management (ATM) system. UTM is how airspace will be managed to enable multiple drone operations conducted beyond visual line-of-sight (BVLOS), where air traffic services are not provided. According to FAA, the purpose of UTM development is to ultimately enable the management of low-altitude uncontrolled drone operations.

With UTM, there will be a cooperative interaction between drone operators and the FAA to determine and communicate real-time airspace status. A distributed network of highly automated systems via application programming interfaces (API) serve as the major means of communications between the FAA, drone operators, and other stakeholders.

So far, the FAA, NASA and industry are coordinating the UTM initiative, with the aim to enable safe visual and beyond visual line-of-sight drone flights in low-altitude airspace. Specifically, the Low Altitude Authorization and Notification Capability (LAANC) supports air traffic control authorization requirements for drone operations. Through LAANC remote pilots can apply to receive a near real-time authorization for operations under 400 feet in controlled airspace around airports.

On the other hand, NASA is conducting research at UAS Test Sites to further explore UTM capabilities that will accommodate rulemaking as it expands opportunities for drone integration.

Worldwide – JARUS (Joint Authorities for Rulemaking on Unmanned Systems) is a group of regulatory experts from all around the world, with the purpose to recommend a single set of technical, safety and operational requirements for all aspects linked to the safe operation of the Remotely Piloted Aircraft Systems (RPAS). By taking consideration of existing regulations relevant to manned aircraft, it draft material to cover the unique features of RPAS through the analysis of the specific tasks linked to RPAS.

In March 2019, JARUS issued "Guidelines on Specific Operations Risk Assessment (SORA) Issue 2.0 (Annexes)", followed by another "SORA Standard Scenario STS-01 for Aerial Work Operations"in May 2019. The purpose of the Specific Operation Risk Assessment (SORA) is to propose a methodology for the risk assessment primarily required to support the application for an authorization to operate an Unmanned Aircraft System (UAS) within the specific category when an operator/applicant desires to operate a UAS in a limited or restricted manner.

Particularly, given the new and innovative aspects of UAS, the traditional approach to aircraft certification (e.g. approving the design, issuing an airworthiness approval and type certificate) may not be appropriate.

ICAO – International Civil Aviation Organization. As a United Nations specialized agency on global civil aviation affairs, ICAO is increasingly focused on innovative technologies that could revolutionize the existing status of civil aviation industry. The latest ICAO Innovation in Aviation Fair held on September 22-23, 2019 featured technological start-ups including Loon, EHang, Wing, as well as larger firms such as Airbus, Bombardier and Thales which showed strong enthusiasm about technological innovations.

2. Technologies

The product of AAV is a combination of cutting-edge technologies in aviation, aerodynamics, material science, mechanic engineering, computer science and software engineering, etc. Given the very nature of auto-piloting, computer algorithms form the soul of an AAV while composite materials form the skeletons.

Moreover, the widespread implementation of UAM systems requires a solution provider with technological know-how and R&D capabilities. The solution provider needs to be a cross-sector expert who is not only able to manufacture UAM vehicles, but also able to construct a centralized platform to support commercial operations. Cross-sector skills from various fields need to be combined for practical purposes.

In practice, a strong supply chain is also critical to both R&D and manufacturing activities. In EHang's case, we owed our fast progress in launching our passenger-grade AAVs partly to our close location to China's PRD area, a global manufacturing hub.

3. Capital

Compared with traditional transportation models such as airlines, railways and highways, UAM is likely to be less capital intensive in the long run. On an individual vehicle level, the price for an EHang 216 AAV is currently only RMB2 million (US$0.3 million), comparable to the market price of a luxury car in China. On the infrastructural level, the construction costs of highways, bridges and traditional airports are significantly higher than those of building UAM base points.

Comparison of AAVs vs Luxury Cars and Low-End Helicopters

	EH216	Mercedes S600	BMW 760	Tesla Model X	Robinson R22
Vehicle cost (RMB)	2,000,000	2,200,000	2,000,000	890,000	2,450,000
Road cost (Mn RMB/km)	-	60-100	60-100	60-100	-
Airport construction (Mn RMB)	30	-	-	-	80
Driver/Pilot (RMB/year)	-	100,000	100,000	100,000	525,000
Maintenance cost	Low	Medium	Medium	Low	High
Emission	-	6L	6L	-	5.24L

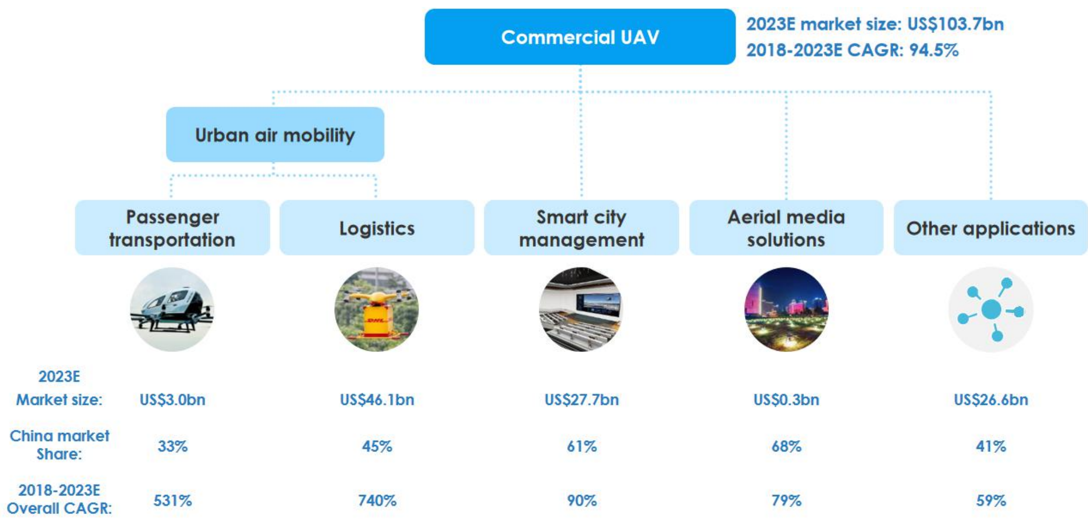
Source: EHang Research

Moreover, operating costs of UAM will be significantly lower due to lower staffing needs, lower maintenance costs and lower energy / fuel costs.

How big could the UAM market be?

According to Frost & Sullivan, the total revenues of the global commercial UAV market will grow into US$103.7 billion by 2023 from US$3.7 billion in 2019, representing 95% CAGR in the period. Specifically, the revenues from passenger UAM will surge at 531% CAGR from US$0.3 million to US$2,995 million, versus 740% CAGR in freight / logistics UAM (from US$18 million to US$46,046 million) in the same period. Thanks to China's liberal policies that support innovations, as well as EHang's industry leadership, China will account for material market shares in various segments of UAM applications.

Exhibit – Frost & Sullivan Research



Source: Frost & Sullivan

Morgan Stanley | RESEARCH

BLUEPAPER

December 2, 2018 10:00 PM GMT

Urban Air Mobility

Flying Cars: Investment Implications of Autonomous Urban Air Mobility

If you're bullish on autonomous cars, it's time to start looking at autonomous aircraft. To make this complex topic accessible, we collaborated across sectors and regions, using scenario analysis to size the addressable market – ~ $1.5tn in our base case by 2040. Logistics is leading the way.

alphawise

Furthermore, recent research by Morgan Stanley shows the industry revenues could grow to US$1.5 trillion by 2040.

However, we think both estimates are on the conservative side in their analysis of the UAM industry, especially for passenger services. Full commercial operations of EHang AAVs are on the verge of being realized in 2019-20 and could trigger a potential explosion of market demand sooner than expected.

UAM – Who will be the main participants?

Government / regulatory bodies: Relevant organizations may include military authorities, civil aviation regulators (e.g. the FAA, EASA, CAAC, etc) and local-level entities including police, security and public transportation management services.

UAM organization: To promote the construction and application of UAM systems globally, an industry organization needs to be established to ensure proper communication among the participants. Similar to global organizations such as IATA and JARUS, UAMS will function as an international organization to set industry standards, monitor industry development, and promote the construction of a global UAM network.

Network partners: Business or government entities may invest to build a regional UAM platform to serve as UAM service providers to its customers or the public. Working under a national or even global network, these network partners may enjoy the benefits of sharing customer resources. They may also contribute to the construction of regional UAM systems by ordering vehicles and building infrastructure.

Vehicle OEMs: Besides EHang, which has successfully launched the world's first commercial AAV flight, there are other firms which claim to be testing their models for UAM purposes. Similar to the mobile handset industry, the UAM industry need to have more transparent and specific industry standards to ensure different vehicles are compatible for the existing UAM platforms. Ultimately, all vehicle models need to comply with the industry standards before joining the network.

Commercial operating model

Given the strong advantages of EHang AAVs over both helicopters and automobiles, we estimate the unit operating cost at roughly Rmb10-12 / ASK (available seat-kilometer), or US$1.43-1.71 / ASK, which can be covered by a reasonable fare level that is slightly above the normal taxi fare levels in New York City (Base rate: US$2.5 plus US$1.56/km). Considering significant savings from straight-line air routes vs. the zigzagging ground routes, the total trip cost of the AAV from point A to B may be even lower than that of an NYC cab. More important, the AAV passengers will enjoy a faster and smoother trip led by higher cruise speed with no traffic congestions. Therefore, we believe the AAV model should prove to be highly competitive and profitable, with an expected payback period below 2 years.

Our financial model is based on the following key assumptions:

- Capacity: 1-2 seats for passengers with no pilot needed
- Load factor: 90% or above
- Vehicle cost: US$300,000
- Battery life: 500 cycle life
- Depreciation period: 10 years
- Electricity cost: $0.2 per kWh electricity cost
- Operating hours: 20 hours per day, 6,000 hours per year
- Unit fare: US$2.5 per passenger-kilometer

Based on our model, an EHang 216 (2-seater) could generate an annual revenue of US$352,174 (Rmb2.5 million). After deducting operating costs, over 60% of which are for batteries, it implies operating profit at US$138,000, putting OP margins at 39%. We believe this model is highly conservative and does not capture efficiency gains potentially led by scale economies. Furthermore, improving battery technologies could lead to lower battery weight, longer battery life and cheaper battery prices, which would directly boost operating results.

Sensitivity analysis

Batteries – As batteries are the single largest cost item for EHang AAVs, a sensitivity analysis shows every 1% decline in battery cost will add over 2% to the operating result.

Pricing – We see strong pricing power led by a lack of market competition in the near term. On our estimate, every 1% increase in unit fare level would boost operating profit by 3%.

Chapter 3
UAM Operations and Implications

The invention of cars led to profound changes to the world in the twentieth century, significantly improving people's quality of life. Billions of dollars have been spent on infrastructure of the highways, tunnels and bridges that have reshaped the appearance of cities and countrysides worldwide.

Yet automobile transportation has become more challenging as cities have become more crowded. We believe that UAM has the power to do for cities of the twenty-first century what automobiles din in the twentieth century – and to do so in a safer, smarter, more efficient and more eco-friendly manner.

How will UAM change people's life?

1. *Safe transportation* – Power redundancy with centralized computer control will eliminate accidents caused by human errors.
2. *Smart transportation* – Autonomous online booking improves convenience, while a pre-determined route increases certainty. Moreover, smart transportation is a critical component to the general "smart city" concept, which aims to improve overall transportation experiences in speed, convenience and efficiency.
3. *Improved efficiency* – The time-saving benefits of UAM are invaluable. UAM improves travel efficiency not only through its higher cruise speed compared to cars, but also by using shorter, more direct routes that do not get congested. Furthermore, a shared economy of AAVs means higher asset utilization and eliminates the need to find parking.
4. *Greater mobility and accessibility* – Thanks to UAM, travelers are able to reach new destinations that were less accessible, such as islands, mountains, swamps and forests. It will also minimize the impact on nature that would have otherwise occurred due to transportation infrastructure construction.
5. *Disperse living areas* – Improved mobility means people can more easily live in remote suburbs or regions. This may alleviate the cost pressures in major cities that are suffering from ever-increasing property and rental prices.
6. *Sustainability* – The adoption of low-carbon or zero-carbon energies for urban transportation helps improve air quality by reducing carbon emissions, which is critical to population centers globally.

Source: EHang Research

How will UAM impact existing transportation modes?

As a new disruptive mode, UAM will reshape the existing urban transportation system by elevating the dimensions from 2D into 3D, as normal airlines are unable to offer short-haul urban services. We are trying to analyze potential impact on specific industries as follows.

Airlines

We view UAM system as a perfect extension to the existing air services by offering seamless “last 50-km” flight connection to the passengers’ homes. To remain competitive, traditional airlines should act quickly as a partner to the UAM system to offer value-added services to their customers. For the Top 2 aviation markets in the world, US and China are boasting 893 million and 612 million air passenger volumes in 2018. Suppose only 10% of such passengers would choose to take UAM for their “last 50-km” transit, it implies 150 million passenger volumes in US and China alone.

High-speed Rail

Similar to the airlines, HSR operators should find UAM complementary to existing services. While subways and bus services are the natural transit options from HSR stations, AAVs can serve as a good choice for high-end passengers who are more time-sensitive rather than cost-sensitive. According to CRC, China’s HSR carried ~2 billion passengers in 2018. Assume only 5% of such passengers would transit by UAM from HSR stations, it implies ~100 million passenger volumes annually.

Highway

As a substitute to the cars, UAM may ultimately erode the shares of the roads within cities. Indeed, traffic congestions and high infrastructure investment and maintenance costs are impeding the long-term growth of major cities such as New York, Los Angeles, London, Tokyo, Hong Kong, Beijing and Shanghai. Statistics showed China’s number of passenger sedans reached 205.6 million by 2018, including ~1.4 million taxicabs that had carried ~36 billion passengers in 2018. This implies a huge market for UAM.

Waterway

UAM will prove to be a highly valuable transportation mode for transit between islands and offshore areas, by providing faster, more comfortable and enjoyable experiences through straight-line routes. It could be even combined with some boating services as landing pads can be easily added to the decks of some large cruises.

Chapter 4.
Key Application Scenarios

Looking beyond cities, we find the term "urban air mobility" to be limiting, given the abundance of opportunities for non-urban applications. Many of these applications are currently being serviced by helicopters. According to AsianSky, an aviation consultant, the Asia Pacific civil turbine helicopter fleet size reached 4,265 by the end of 2018, an increase of 4.6% YoY, with an estimated replacement cost of US$30.9 billion. Based on the market price of the EHang 216 (US$0.3 million), this is equivalent to the market value of 103,000 AAVs. Key application areas include oil and gas (onshore / offshore), forestry, firefighting, aerial photography, agricultural and pest control, power-line repair and surveys, media, offshore operations, search and rescue, emergency medical services and law enforcement.

Exhibit – Helicopter Fleet and Replacement Cost

By AsianSky Group

Mission	Fleet Size (Units) / Market Share	Replacement Cost ($M) / Market Share
MULTI-MISSION[2]	2,248 (53%)	11,950 (39%)
CORPORATE	377 (9%)	2,228 (7%)
OFFSHORE	343 (8%)	5,971 (19%)
SAR	311 (7%)	3,903 (13%)
LAW ENFORCEMENT	307 (7%)	2,512 (8%)
EMS	267 (6%)	2,323 (8%)
CHARTER	266 (6%)	1,439 (5%)
PRIVATE	87 (2%)	374 (1%)
TRAINING	59 (1%)	199 (1%)
TOTAL	4,265	$30,899

Note (1): "Replacement Cost" figures are based on the assumption that existing helicopters are replaced by the latest versions of their particular OEM variant and at 2018 list prices.

Current applications of normal UAVs (also known as drones) to such scenarios are limited mainly due to 1) insufficient capacity, as normal UAVs can carry only a payload of 10kg; 2) small sizes, as normal UAVs are designed for consumer use such as air cameras; 3) lack of a centralized command-and-control platform to ensure large-scale operations safely and accurately.

Given the strong advantages of UAM vehicles over normal UAVs, it is more realistic to envision UAM penetrating into various fields that are currently dominated by traditional helicopters. We examine a few of these applications below.

Tourism & recreation

UAM can provide aerial tourism services at designated locations including scenic spots, amusement parks, tourist attractions, etc. A ride on a UAM vehicle will help tourists explore new areas that were previously difficult or impossible to reach, such as deep valleys, mountain tips, vast jungles, desert islands and waterfalls.

Source: EHang Research

In China alone, there are 259 "AAAAA-class" and 1,528 "AAAA-class" scenic spots nationwide. According to CTA (China Travel Agency), China's domestic tourist spending reached RMB 5.54 billion in 2018, with total spending over RMB 5.13 trillion (US$743 billion). Assuming only 893 (50%) of these scenic spots were to introduce UAM services by deploying only 10 AAVs each, it would imply a near-term demand of 8,930 AAVs in China.

As tourists may be less price conscious when taking UAM for fun than travelers who take UAM for transportation, tourism applications could prove to be more attractive to operators from a commercial perspective.

Emergency medical services

The fast-moving nature of emergency medical services makes UAM an ideal solution that provides "air ambulances"," especially when ground traffic congestions may seriously jeopardize the emergency missions of normal ambulances.

Source: EHang Research.

China currently has approximately 110,000 ambulances and 365 first aid emergency centers, which are deployed mainly in urban areas. Given the large population size, this implies only 127 ambulances per 100,000 people. Considering that over 40% of the Chinese population (580 million) lives in rural areas where emergency services are less available, huge gaps exist for the government to boost medical conditions for rural residents.

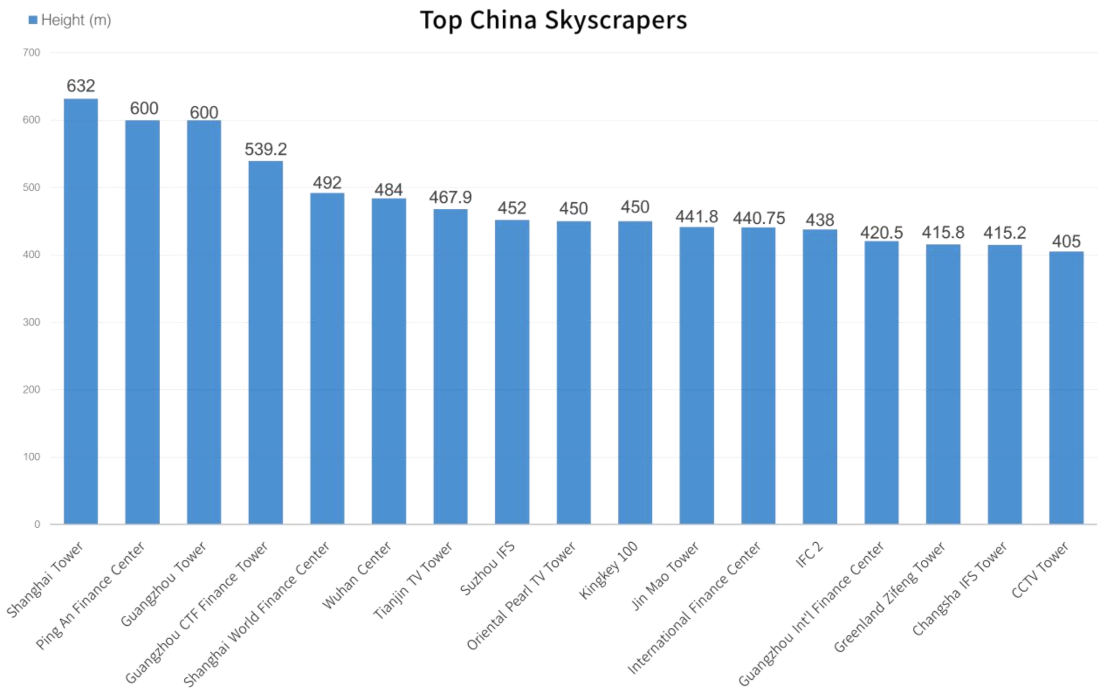
Given that the more dispersed rural population living in mountains, islands and plateaus, the construction necessary for emergency systems requires significant infrastructure investment , which can be expensive and time-consuming to build. The clear advantages of UAM vehicles over normal ambulances suggest that UAM can be a quicker, more effective and less expensive solution to improving China's rural emergency systems.

Assuming China were to provide air ambulance services to cover the 580 million rural population at a similar ratio of only 10 / 100,000, this implies a potential demand of 58,000 AAVs.

Similarly, this could prove to be a solution for under-developed but populous countries in South Asia and Africa, where infrastructure and medical conditions are lagging.

Aerial fire apparatus

In recent years, skyscrapers are mushrooming in China. Statistics show China has the majority of all the world's tallest buildings in late 2019 and many more than any other country. The tallest 15 buildings in China are all above 400 meters high, among the world's 26 tallest skyscrapers. Yet, these do not count so many "mid-level" ones built throughout major Chinese cities.



Source: EHang Research

Years	No. of new buildings
2003-2004	133
2005-2006	125
2007-2008	126
2009-2010	127
2011-2012	105
2013	83
2014	149
2015	137
2016	127
Total	1112

Source: EHang Research
Note:number of buildings >150 meters high

However, considering fire safety, it creates a real challenge for normal fire apparatus such as aerial platforms and turntable ladders that can reach only limited heights. Equipped with a deluge gun with water pumps onboard, a normal EHang AAV can be modified into an aerial fire apparatus that allows access or egress of firefighters and fire victims at a height above 400 meters. Moreover, it can provide a high-level water point for firefighting.

According to statistics, in 2018, over 237,000 fire reports were received in China, causing 1,407 deaths, 798 injuries, and Rmb3,675 million worth of direct damages. There were over 12.73 million man-times and 2.193 million vehicle-times dispatched for firefighting tasks. We believe the modified aerial fire apparatus will prove to be an effective tool with great potential values.

Source: EHang Research

Industrial applications

There are many possible industrial applications for UAM. For example, in the offshore marine industry UAM vehicles may serve as effective alternatives to helicopters, which are heavily used to carry staff and supplies between offshore rigs and onshore headquarters. UAM vehicles would be more effective given their higher safety, lower cost, and around-the-clock working schedules.

Source: EHANG Scandinavia AS

A helicopter fleet report by AsianSky showed there were 343 turbine civil helicopters dedicated to offshore oil and gas operations in the Asia Pacific region as of the end of 2018, with an estimated replacement cost at US$5.91 billion. This is equivalent to the market value of ~20,000 EH 216 AAVs.

Furthermore, we see potential opportunities from the development of offshore wind farms. AsianSky estimates that the Asia Pacific offshore wind capacity would rise 20x within the next 10 years, which could dramatically boost the transportation demand for both passengers and logistics.

In other industrial fields such as power grid maintenance and pipeline inspection, UAM vehicles can prove to be desirable tools as well.

Chapter 5
Development of a UAM ecosystem

The development of a UAM ecosystem requires the contributions from various participants. While a UAM network provides individual vehicles (capacity up to 2 passengers) for urban transportation, it differs from the existing taxi network mainly in: 1) UAM vehicles need to travel point-to-point via pre-determined air routes, which is similar to the bus system; 2) UAM vehicles are all autonomous with no need of pilots or drivers.

Comparison of UAM vs. Taxi, Bus, Ridesharing

	UAM	Taxi	Bus	Ridesharing
Autonomous	Yes	No	No	No
Speed (note)	130km/hour	60km/hour	40km/hour	60km/hour
Effective routes (note)	Very short	Long	Very long	Long
Dimensions	3D	2D	2D	2D
Predetermined routes	Yes	No	Yes	No
Cost	High	High	Low	Medium
Congestions	No	High	Medium	High
Online booking	Yes	Yes/No	No	Yes

Note: 1. The speed estimate is based on speed limit in urban areas;
2. Effective UAM routes are very short mainly due to the direct path enabled by air travel.

Network developer

The UAM network developer is a technology enterprise responsible for designing, constructing and operating an UAM network, including the command-and-control center. For security reasons, the command-and-control center fulfills a unique role in a city, similar to the operators of existing ridesharing platforms. It receives orders from passengers through mobile apps, processes the information promptly and executes the orders by dispatching UAM vehicles automatically.

Vehicle manufacturers

These are OEMs which manufacture UAM vehicles fully compatible to the UAM network. High quality standards need to be met to ensure operational safety.

Network partners

A network partner is defined as an operator who owns a certain number of UAM vehicles to cover designated urban areas. As an effective investor, it acquires UAM vehicles from the manufacturers and is responsible for all related issues including battery charging, maintenance and repairmen, etc. Depending on its financial strengths and operating capabilities, the service area of a specific network partner can stretch to a whole city.

Infrastructure

It mainly includes base points, maintenance and repair centers, charging facilities, passenger service facilities, etc.

Supply chain

It includes relevant suppliers of electric motors, batteries, battery management systems (BAM), speed control, flight control, avionics, composite materials, etc. The success of new product development depends on the accessibility of a well-established supply chain network.

Regulatory bodies

These are mainly official organizations or government entities (e.g. JARUS, the FAA, EASA, CAAC, etc.) While regulatory approval is the first step for the development of a UAM ecosystem, government may find it a challenge in making laws to accommodate this whole new industry. Both enterprises and government need to collaborate closely and extensively on emerging issues related to safety, traffic control, sound control, airspace planning, etc.

Chapter 6
The Path Forward

As an emerging industry, UAM has attracted attention from governments, enterprises, research institutes and investors from all over the world. With sufficient input of resources, we expect the industry to take off soon.

Looking forward, we expect the UAM industry to be boosted by potential technological breakthroughs in the following areas.

Battery technology

Our operational analysis shows battery is the single largest cost item that accounts for over 60% of total operating costs for EHang 216 AAVs, based on a 500-charge life cycle. We estimate a 1% decline in battery cost will boost operating profit by over 3% for the operator, while a 1% increase in battery life will also increase operating profit by 2%.

Moreover, as battery weight accounts for about 1/3 of total empty weight of the AAV, further reduction in battery weight would significantly increase the AAV's flight range.

Finally, from a commercial perspective, a reduction in battery charging time would lead to higher asset utilization and increase operating results.

Source: EHang Research

New materials

Similar to traditional aircraft, UAM vehicles are highly weight sensitive. Composite materials are ideal for aviation due to their lightness and firmness. Key components such as electric motors are made of metals. New materials or designs that can further reduce the weight of the vehicles would help improve flight range and overall performance.

Source: EHang Research

Aerodynamics

Despite many advantages of eVTOLs, a lack of natural lift by fixed wings means inefficient power consumption and limited flight range. An improvement in designs to combine the benefits of both eVTOL and fixed wings should help. A good example is Bell Boeing's V-22 Osprey which has a higher cruise speed, altitude and range than normal helicopters.

Source: EHang Research

5G network

The imminent launch of 5G networks will enhance the connectivity of UAM vehicles and capabilities of the command-and-control platform.

Specifically, 5G networks enable real-time high-resolution image transmission, remote control and precise positioning for multiple UAM vehicles operating simultaneously. It also broadens the communications loop from just being between a single UAM vehicle and the command-and-control platform to also running between the vehicles.

Source: EHang Research.

Noise levels

Although the noise level of EHang's AAVs is significantly lower than that of helicopters, there is ample room for improvement so the vehicles can travel unobtrusively within communities. Ideally, we think the vehicles should be even quieter than an engineering vehicle operating in the neighborhood. Adjustments for noise (e.g. propeller size / shape, etc.) need to be carefully studied to further reduce the current noise level of AAVs.

Source: EHang Research

Conclusion

As the ultimate solution to city problems of traffic congestions, accidents and air pollution, UAM is a promising industry with huge market potential ahead. For cities to be more efficient, smarter and competitive, it is imperative for governments to adopt effective UAM strategies to construct complete ecosystems based on centralized command-and-control platforms.

Future UAM systems should be safe, autonomous, efficient, ecofriendly and centrally controlled, shared by public customers. With potential benefits from future technological advancements, we believe the cost of UAM services would be as low as normal taxi services nowadays, and affordable to the general public. So this new urban transportation mode would ultimately replace automobiles and free up most land areas occupied by the roads.

As a leader in global UAM industry, EHang is committed to offer safe, autonomous and ecofriendly air mobility to everyone. Besides manufacturing AAVs for UAM purposes, the company aims to build a complete platform that supports the operations of the UAM ecosystem. To that end, it seeks collaborations with various parties including governments, regulators and business organizations. With expertise in both aviation and autonomous command-and-control, it explores various fields for potential applications such as tourism and recreation, emergency medical services, fire control, and other industrial applications.

Contributors

Author

Edward (Huaxiang) Xu	Chief Strategy Officer

Contributors and Reviewers

Huazhi Hu	Founder & Chief Executive Officer
Derrick (Yifang) Xiong	Co-founder & Chief Marketing Officer
Richard (Jian) Liu	Chief Financial Officer
Shang Hsiao	Co-founder

References

Uber Elevate	Fast-Forwarding to a Future of On-Demand Urban Air Transportation (Oct 27, 2016)
NASA Urban Air Mobility	Urban Air Mobility (UAM) Market (November, 2018)
Morgan Stanley	Flying Cars: Investment Implications of Autonomous Urban Air Mobility (Dec 2, 2018)
Roland Berger GmbH	Passenger Drones Ready to Take-off (Dec 21, 2018)

About the author

Edward (Huaxiang) Xu is Chief Strategy Officer at EHang Holdings, a global leader in urban air mobility solutions. Specifically, Edward supports the CEO in managing group strategy, operations and financing activities for EHang.

Prior to joining EHang, Edward was Executive Director at Morgan Stanley Asia Limited, serving in the Equity Research Department. He headed MS Asia-Pacific Transportation team which was consistently ranked among All-Asia Top 3 by Institutional Investor magazine through 2012-19. His broad research coverage included airlines, airports, logistics, railways, aerospace and defense, etc. During his 15-year professional experience as an equity research analyst at Morgan Stanley, he participated in major IPOs, such as those of ZTO, BOC Aviation, AirAsia X, BTSGIF, Kerry Logistics, etc.

Edward is a CFA charter holder and has an MBA from the University of Illinois at Urbana-Champaign.

About EHang

EHang(NASDAQ: EH) is a world's leading autonomous aerial vehicle ("AAV") technology platform company. Our mission is to make safe, autonomous and eco-friendly air mobility accessible to everyone. EHang provides customers in various industries with AAV products and commercial solutions: urban air mobility (including passenger transportation and logistics), smart city management and aerial media solutions. As the forerunner of cutting-edge AAV technologies and commercial solutions in the global Urban Air Mobility industry, EHang continues to explore the boundaries of the sky to make flying technologies benefit our life in smart cities.