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INNOVATIVE GOVERNANCE OF LARGE URBAN SYSTEMS

Airspace is just empty space filled with air. From a different perspective, airspace is a resource subject to national sovereignty, can take different shapes, fulfil functions and be organized into structures and systems. Structured airspace may be even perceived as infrastructure. Structured airspace is increasingly becoming a recognised element of urban infrastructures and urban air mobility an integral part of urban traffic systems. Furthermore, airspace available for use is becoming increasingly scarce. Urban airspace as infrastructure, as a scarce resource and also as urban space needs to be operated and governed.

This issue of the IGLUS Quarterly is dedicated to an introduction to urban airspace, a new focal point for IGLUS. Urban Air Mobility (UAM) is presented both as a concept and a developing new urban system, with important consequences and potential benefits for cities. While UAM-related policy-making and regulation are still in their infancy, it is already clear that UAM has a considerable potential to significantly change the urban landscape including the built environment and how urban spaces may be designed and utilised. New markets are developing as well as novel ways of performing public functions. The timeliness of this IGLUS Quarterly issue is underscored by the recent publication of the world's first guidance material for the design of vertiports by EASA, the aviation safety regulator of the EU.

In the first article, professor Matthias Finger sets the scene by providing a context for the governance of urban airspace and also placing it in the broader IGLUS framework. By drawing parallels with already existing urban systems, several key aspects of the development of urban air mobility are highlighted, including the structure of urban infrastructures, the impact of digitalization and the interrelated nature of urban systems.

In the second article, which is based on both literature and stakeholder interviews, I intend to introduce the evolving concept of Urban Air Mobility and provide an overview of the state of play in the UAM domain. There is a brief discussion of the most important stakeholder groups and their narratives shaping the sector. Use cases for the urban airspace and their potential benefits are presented. A list of challenges Urban Air Mobility is facing is also provided.

The third article by Umut Alkım Tuncer provides a comprehensive industry outlook including a thorough literature review, discussing relevant technologies and ongoing projects - both public and private initiatives. The question of what may be expected in the medium and long run in this industry domain is also addressed.

In the closing article, Mira Bognár compares potential approaches to creating a functioning urban air mobility ecosystem through the experimental projects carried out in Singapore and Hamburg. In effect, both cities acted as laboratories for conducting controlled urban air operations.

While all these articles contribute to the image of a lively UAM sector thriving with investors, technological innovations, public and private initiatives, it should be noted that there are still uncertainties, challenges and obstacles that need to be overcome before a mature UAM ecosystem may be established. Having said that, we hope you will enjoy reading this issue.

Iván László Arnold

Governing Urban Airspace: What are the Problems?

Matthias Finger

Abstract: *In this article, I would like to set the stage for this is IGLUS Quarterly special issue on the governance of urban airspace. In it, I first want to explain what the problem is and then derive from there the different needs for governance. In a third section, I will refer to the broad IGLUS framework, and highlight what one might be able to learn from the IGLUS experience for the governance of urban airspace.*

The rise of urban air transport is in essence the combined result of two separate megatrends, disruptive technological development on the one hand and rapid urbanization on the other. Technological development is easy to understand but nevertheless spectacular: over the past 10 years, unprecedented progress has been made in terms of drones, technically called Unmanned Aerial Vehicles (UAVs), at least originally thanks to military financing. Today, drones come in all sizes and uses, from small toy drones to drones transporting goods, to cruise missiles. Drones are in fact complex technological devices, combining a series of advanced technologies, be they software, sensors, computer vision, artificial intelligence, and of course communication devices. It is the fact that drones necessarily have to communicate with their environment which has led to the term Unmanned Aircraft System (UAS). The term UAS highlights the fact that drones are only one element of a broader technological ecosystem which includes, ground and sometimes satellite control stations, data links and many other supporting technologies. UAS is indeed the more appropriate concept when it comes to the governance of their airspace, be it urban or general. Not astonishingly, UAS is the preferred concept of air navigation services providers and aviation authorities.

The more recent development of UAV and UAS is no longer simply driven by the military, but increasingly responds to demand in various sectors, such as civilian inspection, logistics and perhaps in the future also passenger transport. Let me focus here on the demand in an urban environment. Such demand results of course from rapid urbanization, but more precisely from the consequences of rapid urbanization in terms of congestion. Delivery trucks are stuck in traffic and become unplannable. Especially the delivery of urgent goods (e.g., medical goods, food and other time-critical deliveries) will use UAVs if available at a reasonable cost. Because of e-commerce, deliveries are growing rapidly and challenging cities' logistics operations and planning, thus accelerating the demand for drone deliveries. As a result, UAVs will emerge as a possible technofix to this problem, and, as we will argue urban UAS will emerge and develop in parallel. Finally, sooner or later, a similar demand for UAVs and UASs will appear for urban passenger transport. As a matter of fact, already now rich people use helicopters to get from the city centre to the airport, and increasingly also from one place to the other in cities.

The need for governance

The combined two above-described developments inevitably lead to the need for governance. Two such governance needs have to be distinguished here, namely, on the one hand, the governance of the scarce resource "urban airspace" akin to an infrastructure and, on the other hand, the governance of the UAS in an urban context. Indeed, airspace is a scarce resource, especially in the urban context, but, as aviation in Europe, the USA and China shows, also more generally. Even before congestion problems will arise in the urban airspace of cities and metropolitan areas, rules will have to be set up so as to allocate this scarce resource (or in other words the "air infrastructure") to the different types of users, such as users of leisure drones, delivery companies, the police, public inspection authorities, etc. These rules will furthermore have to take into account already existing users, such as helicopter services for emergencies, but also for VIP transport. But there is more: rules for using urban airspace will not only have to address congestion problems in the air. They will also have to factor in the fact that drones can collide mid-air or simply drop from the sky. Indeed, the consequences of air collusion are probably potentially bigger than two cars crashing on the street. There will therefore have to be no-fly zones, for example over areas where many people gather, or areas that are otherwise sensitive. It is by now well know that drones are dangerous in the vicinity of airports and therefore must be regulated there particularly severely, if not banned. Finally, UAVs, like cars on the ground, can be and probably are a nuisance for city-dwellers, not to speak about the few birds and other animals left in cities (e.g., bats for example). In other words, there exist multiple reasons why urban airspace will need to be regulated, sooner, rather than later. Probably, the governance of the scarce resource urban airspace can and perhaps even must be specific to each city or metropolitan area.

But there is also a second need for governance and regulation, which stems from the above-described broader technological ecosystem, the UAS: UAVs communicate with their owners, with other UAVs and sometimes also with air traffic control. At the least, they have to be monitored in one way or another, using communications services, which can either be dedicated (both technologies or frequencies) or shared with other communications users, such as for example when drones are equipped with SIM-cards. In other words, the entire UAS – that is drones within their broader technological ecosystem – will have to be regulated. And one could in fact go much further here to include also the regulation of privacy and security. All these regulations, unprecedented as they are, will rather take place at the national, if not, as in the case of Europe, at the EU level. Corresponding organizations will have to be set up, be it for managing the urban airspace, as well as for regulating both the urban airspace users as well as the "urban air navigation services" providers. The question will inevitably arise as to whether these two functions – operations and regulation – can and should be provided by the traditional ANSPs (Air Navigation Services Providers) and air transport regulators, or whether new, dedicated bodies will have to created … and at which level? EU? National or metropolitan?

The parallelism with traditional infrastructures: what can we learn?

When devising the governance of UAVs and UASs, especially at the urban and metropolitan levels, one does not necessarily have to start from scratch. Our entire IGLUS endeavour pertains to the governance of large urban systems, in other words metropolitan areas. Such urban systems, for us, pertain to all the infrastructures, namely transport, energy, communications, housing, water/wastewater and green (infrastructures). All these infrastructures are complex and dynamic socio-technical systems, which furthermore are strongly interdependent and interrelated, especially at the urban level, leading to complex governance mechanisms. All these infrastructures make use of scarce resources, and are actually a scarce resource in themselves, something that complexifies their governance further. In addition, contradictory objectives in the different (but interlinked) policy domains may add another layer of complexity.

However, so far at IGLUS, we have never paid particular attention to the governance of urban air transport and urban airspace, as we have focused on ground or even on underground transport. But the rapid development of UAVs and UASs has changed this, and we think that we as IGLUS now also have to become concerned with the governance of urban air transport and urban airspace. When doing so, what can we learn from the IGLUS experience and more precisely from the lessons we have learned? In doing so, we propose to apply our basic IGLUS conceptualization of urban infrastructure governance, namely our layered model. Indeed, we distinguish between three layers of urban infrastructures:

- At the basis, there is the resources layer, as urban systems are built upon scarce resources. These are typically the water and land. As energy is typically imported from outside of the city. And we do think that we can learn from the governance of scarce urban water and land resources, when it comes to governing the urban airspace.
- The second layer pertains to infrastructures, namely roads, urban rail, metro, trams, electricity, gas and district heating distribution grids, water and wastewater pipes, telecommunications infrastructures, but also housing and green infrastructures, such as parks, pocket parcs, urban trees, etc. And urban airspace, in addition to being a scarce resource, is also an infrastructure. These infrastructures need, planning, investments, maintenance and operations. Governance issues for this layer typically pertain to access, pricing and the public interest. It will be only logical learn from the governance of these infrastructures to be applied to the governance of UASs.
- The third layer pertains to the services rendered on the basis of these infrastructures, such as mobility, logistics, energy, water, communications and ecosystems services (in the case of the green infrastructures). Governance issues here pertain competition, accessibility, quality, affordability, equity, etc. Again, it will be possible to draw lessons from the governance of these services for air mobility and air logistics services.

But there is more to IGLUS, as IGLUS is not just about the governance of these three layers:

- These three layers are of course strongly interrelated, especially the urban level and particular governance issues arise from such interdependencies, such as for example from the fact that the resource (e.g., water) has multiple uses and can provide multiple services (drinking, cleaning, irrigation, etc.) and that the infrastructure has strong capacity limitations (e.g., aging and leaking pipes). What can one learn from this for the governance of urban air navigation?
- In addition, the different infrastructure systems are strongly interrelated, again especially at the urban level. For example, the layout of the housing infrastructures strongly determines transport, as does the layout of the transport infrastructure determine housing development, etc. This will be no different when adding urban air transport to the picture. Indeed, the governance of (the tree layers of) urban airspace must be conceived in relationship to the governance of urban ground logistics and mobility.
- IGLUS pays particular attention to the role digitalization plays in urban infrastructure systems, that is to the broad topic of "smart cities". Indeed, such digitalization simultaneously strengthens the interrelations and ultimately integration of the above-mentioned three layers, while also creating stronger interdependencies among the different urban infrastructure systems, such as for example by linking the different transport modes into integrated urban mobility systems and services (e.g., "mobility-as-a-service"). This will be no different for urban air transport, which, thanks to digitalization, will become ever more integrated with the other transport modes (e.g., "city logistics"). In this context one also has to mention the fact that digitalization and smart cities can probably best be conceptualized as an additional, fourth layer of urban infrastructures, which in turn calls for additional governance mechanisms and comprehensive data regulation, ideally both at the national and the city level. Such rules could define data sovereignty, access to data, data sharing obligations and the level of privacy protection.

- Finally, let us mention that IGLUS is not only about cities. Rather, urban systems pertain to metropolitan areas which in turn cover multiple jurisdictions, thus raising the most difficult governance challenges. For example, the water resource may belong to the national authority, the water pipes to the different municipalities, whereas the water services may be provided on a metropolitan level. Or the other way round, the pipes belonging to the region, whereas the services are provided by municipal companies. Again, one can probably draw a parallelism with urban airspace and therefore urban airspace governance can probably learn from water, but also energy and transport governance.

Urban Air Mobility: A New Dimension of the Urban Landscape

Iván László Arnold

Abstract: *Based on the available literature and a number of interviews conducted with some of the important stakeholders, the aim of this contribution is to provide a short introduction to the evolving concept of Urban Air Mobility (UAM), providing some context, a brief overview of the state of play and an outlook focussing on the potential benefits as well as the role of cities with regard to a UAM ecosystem.*

Urban Air Mobility (UAM) is not a fully settled concept. Both the concept and the underlying technologies develop dynamically in an increasingly complex, interconnected environment. What the potential benefits and downsides of utilizing urban airspace for mobility solutions and other purposes involving flights are, is still an open question. There is an increasing number of interested stakeholders and ongoing UAM projects worldwide – some of the latter initiated by governments, others by cities or market entities. Tech companies, startups and universities are usually involved. While some use cases are more obvious than others, less visible applications may prove to be more valuable in the future. One of the objectives of this paper is to bring some clarity to what urban air mobility may entail and what cities could do to make the most and best of it.

Context: A brief overview of the history and technology of the UAM vision

From a historical perspective, the 21st century idea of accommodating flying machines in urban airspace is neither new, nor revolutionary. Aerial vehicles have been a defining aspect of the city of the future since the beginning of the 20th century. In the moving picture classic ‘Metropolis’ directed by Fritz Lang in 1927, citizens use flying vehicles to commute. The ‘Futurama’ installation of a future human habitat displayed at the 1939 New York World’s Fair was complemented by a film titled ‘New Horizons’[1], which featured a utopian vision of the year 1960 full of the urban light of Le Corbusier, complete with a highly developed, modern traffic system, fresh air and green infrastructures consisting of interlinked parks. An integral part of this enviable future was urban air mobility with rooftop landing decks, helicopters and autogyros.

Meanwhile, already back in 1929, a decade before the Futurama exhibition, real-world investors had considered some form of urban air mobility in New York City a serious-enough business proposition to finance a 200-foot mooring mast for airships on the top of the Empire State Building. Their vision extended to package delivery by air. A stack of Evening Journals was in fact lowered to the top of the building by rope. Alas, after a few unsuccessful attempts to dock an airship to the mooring mast, the project was abandoned[2] as a result of the apparent difficulty of docking in the prevailing high winds. In the 1920s, Henry Ford developed a concept for flying cars. The first flying car, the Airphibian designed by Robert Edison Fulton Jr. was

1 https://www.youtube.com/watch?v=sClZqfnWqmc

2 https://www.nytimes.com/2010/09/26/realestate/26scapes.html

approved by the Civil Aeronautics Administration of the U.S. in 1950[3]. Between the 1950s and 1980s, early UAM helicopter services were provided in Los Angeles, New York City and San Francisco[4].

Today, as a result of technological developments in the aerospace and digital industries, urban air mobility is potentially facing a new, networked phase, not unlike the vision of the busy urban skies in Fritz Lang's Metropolis. The most relevant technological trends in the aerospace industry are miniaturization of flight, the development of pilotless aerial vehicles (drones), electronic vertical take-off and landing (eVTOL) vehicles (electrical propulsion) and, to a lesser degree, flying cars (some of them already certified[5]). These new developments enable take-offs and landings without a landing strip (air mobility with reduced infrastructure needs), flights piloted from a ground position (flights without a single airborne pilot) and the use of the same vehicle both on the roads and in the air (a convergence between road and air mobility). Meanwhile, the most important development in the digital domain is the convergence of cloud computing, big data analytics, artificial intelligence and the internet of things (IoT)[6]. Developments in satellite-based and mobile communications are also relevant. These new technologies facilitate the establishment of complex networked systems, the collection, transfer, sharing and analysis of vast amounts of data in real time, the capability to dynamically manage infrastructure (including airspace) and to intervene in dynamic processes such as airspace management and traffic flows in real time.

When viewing urban air mobility in the broader context of policy development, it is of course inevitable to also consider aspects such as rapid urbanization, climate change, cyber security challenges and the legal and regulatory framework including data regulation, governance, oversight and liability considerations. It should also be borne in mind that there is a sometimes significant difference between the UAM potential of densely inhabited urban centres and still urban suburban sprawls. Today, while there are examples of pioneering UAM services such as package delivery in urban areas[7], regular, at scale UAM services or operations and the underlying infrastructure do not yet exist. EASA, the European Union Aviation Safety Agency published the world's first guidance for the design of vertiports, the ground infrastructure needed for the safe operation of Urban Air Mobility services in urban areas on the 24th March, 2024[8]. At the same time, there are a lot of pilot projects and demonstrations going on. Investments flow into the sector, according to some beyond the point of no return. While UAM is developed in a fragmented manner today, some signs indicate that the currently isolated pockets of UAM activities may be connected and integrated into a real global network industry in the not so distant future.

Definitions

The first step in establishing a clear conceptual framework for Urban Air Mobility is defining what urban air mobility is. Therefore, it is necessary to briefly look at the existing definitions. There are a number of definitions in use, most of them created by aviation authorities (EASA, FAA), stakeholders (NASA, UIC2[9]) and academia.

UIC2 defines UAM as 'very-low altitude airborne traffic, above populated areas, at scale, that is sustainably

3 Adam P. Cohen, Susan A. Saheen and Emily M. Farrar: Urban Air Mobility: History, Ecosystem, Market Potential, and Challenges, 2021 Bornemouth University ,

4 Ibid.

5 https://www.dw.com/en/slovakia-certifies-flying-car-as-airworthy/a-60551312

6 Vincent Mosco: Becoming Digital – Toward a Post-Internet Society, 2017 Emerald Publishing Limited

7 Wing, an Alphabet subsidiary delivers small packages to selected locations in Christiansburg, VA in the United States, Helsinki in Finland and Canberra, ACT and Logan, QLD in Australia; https://wing.com/about-delivery/

8 https://www.easa.europa.eu/document-library/general-publications/prototype-technical-design-specifications-vertiports

9 Urban Air Mobility Initiative Cities Community; https://smart-cities-marketplace.ec.europa.eu/action-clusters-and-initiatives/action-clusters/sustainable-urban-mobility/urban-air-mobility-uam

integrated with surface mobility systems'.[10] According to EASA, UAM is 'an air transportation system for passengers and cargo in and around urban environments'.[11] NASA has described UAM as safe and efficient air traffic operations in a metropolitan area for manned aircraft and unmanned aircraft systems (UAS)[12].

Advanced Air Mobility (AAM) is a relevant concept endorsed by NASA in 2020, which refers to the adoption of electric and hybrid aircraft to urban, suburban and rural operations[13]. While UAM and AAM are sometimes used as synonyms, AAM is usually considered to be broader than UAM, including transportation extending beyond high-density urban centres[14]. Cohen et al consider that AAM is a broad concept focusing on emerging aviation markets and use cases for on-demand aviation in urban, suburban, and rural communities, which includes local use cases of about a 50-mile radius in rural or urban areas and intraregional use cases of up to a few hundred miles that occur within or between urban and rural areas.[15]

While it may not be obvious from these definitions, both UAM and AAM are closely connected to broader urban mobility systems and infrastructures as well as to carrying out public functions such as the design of urban spaces, buildings and infrastructure. While some definitions only include transport (carrying people and goods from one place to another) or certain types of vehicles in the UAM domain, for the purposes of this paper UAM is considered a broad concept encompassing all potential uses of the urban airspace (extending to functions involving monitoring, planning, surveillance, emergency and other purposes) by flying vehicles including drones, helicopters, dirigibles, blimps, balloons, airships and jetpacks. All these vehicles will be sharing the same urban airspace and will potentially be interacting with each other.

The UAM system

While sometimes urban helicopter services are mentioned as comparable arrangements, UAM at scale involves far greater complexity. The operation of an urban air mobility system needs to be based on reliable and resilient infrastructure that includes vertiports, sensor networks, data transmission facilities and an urban unmanned traffic management (UTM) system. The system is expected to consist of both physical and digital infrastructure as well as a policy- and legal framework. The physical infrastructure would be comprised of structured airspace[16], heliports, vertiports and drone hubs, charging stations, sensors for collecting a wide array of data, data transmission facilities and centres where data is collected, integrated, analysed and stored. The digital infrastructure will include software for integrating and analysing data as well as for increasingly automated operational decision-making processes (granting flight permissions, designing routes, intervening in emergency situations, etc.). A complex legal framework also has to be in place for the system to work including safety regulation, clear rules for the ownership of airspace, privacy, data sharing and access rules, liability arrangements and the designation of the appropriate authorities to exercise oversight.

The creation of a functioning, mature urban UTM system capable of ensuring safe airspace- and traffic management involving large fleets of drones flying be-

10 https://www.eltis.org/sites/default/files/practitioner_briefing_urban_air_mobility_and_sump.pdf p. 6.

11 https://www.easa.europa.eu/sites/default/files/dfu/uam-short-report.pdf

12 https://skybrary.aero/articles/advanced-air-mobility-aam

13 Ibid.

14 https://nbaa.org/aircraft-operations/emerging-technologies/advanced-air-mobility-aam/

15 Adam P. Cohen, Susan A. Saheen and Emily M. Farrar: Urban Air Mobility: History, Ecosystem, Market Potential, and Challenges, 2021 Bornemouth University , p. 1

16 As Paul Cureton points out, „It is critical to understand that airspace is infrastructure, a fundamental aspect of mobility, to which urban design is adapting as cities legislate and develop urban traffic management (UTM) systems for drones and drone architecture." in: Paul Cureton: Drone Futures – UAS in Landscape and Urban Design, Routledge 2021, p. 4.

yond the visual line of sight (BVLOS) of their operator at scale is a highly complex, capital- and data intensive endeavour as it will have to be capable of safely coordinating traffic in low level urban airspace over densely populated areas. In parallel, static and dynamic airspace structures need to be designed (layers, corridors, tubes, etc.). A complex, real time view of the airspace including closed or temporarily closed airspaces, obstacles and the actual traffic situation needs to be established and maintained. Data on ongoing traffic and relevant conditions such as weather, human activity (including construction, events, police or emergency operations, etc.) will need to be collected and integrated. Predictions will need to be made on the basis of historic and real time data about traffic and relevant conditions in order to enable strategic planning and real time decision-making. The airspace needs to be continuously monitored in order to identify potential conflicts, hazards and non-cooperating drones as well as to facilitate intervention where necessary.

Stakeholders and narratives

As Paul Cureton points out in his book 'Drone Futures', 'A vision is a powerful force, which can create consensus, it presents transformation, but is one that can easily neglect critical areas'[17]. This is of course valid with respect to 'vertical urbanism' and the UAM domain. While UAM-related communications often focus on the potential cost- and environmental efficiencies of eVTOL vehicles and unmanned aircraft systems (UAS), there are a range of stakeholders interested in making UAM a reality and they tend to have different views on the need, the potential benefits and the feasibility of UAM. Vendors clearly seem to drive the development of the UAM concept. This situation is even characterized by some as an industry push without obvious demand. Others point to a technological rush in which global cities compete[18].

Governments and the EU usually focus on economic and environmental benefits. They view UAM both as an economic and an eco-friendly opportunity. They consider that a functioning UAM system would create new jobs, support innovation, bring investments, prestige and profits as well as a greater degree of sustainability. Beside the creation of new markets, they expect the termination or at least considerable mitigation of ground congestion and a contribution to greening urban transport. Consequently, several governments have UAM strategies and public funding available for the different R&D projects and demonstrations. In the UK for instance, the Civil Aviation Authority has launched a research and innovation hub[19] to drive innovation in future air mobility and unmanned aircraft systems. The French aviation authority, DSNA is co-operating with Wing[20], the subsidiary of Alphabet to deploy 'OpenSky', its free mobile and web application that provides airspace information to both recreational and commercial drone operators on 'when and where it's safe to fly'[21].

The other major force in the UAM domain is constituted by vendors producing vehicles, sensors, software, infrastructure and services. The most important business opportunity is currently perceived in the development of vertical take-off and landing vehicles (VTOL) that may be employed as air taxis or cargo vehicles. While the legal framework clearly lags behind technology and industry – most obviously in the field of certification – there are products already available on the market. An urban air vehicle capable of transporting passengers may be ordered for 200.000-300.000,- USD. The price of a small vertipad is 200.000-400.000,- USD, a vertiport is sold from 3,5 million USD, a vertihub from 6 million USD. The development of a UTM system is in

17 Paul Cureton: Drone Futures – UAS in Landscape and Urban Design, Routledge 2021, p. 193.

18 ibid.

19 https://www.caa.co.uk/Our-work/Innovation/About-the-Innovation-Team/

20 https://wing.com/resource-hub/articles/somewhere-else/

21 https://wing.com/opensky-faq/#what-is-opensky?

the range of 50-60 million EUR.[22] Some industry forecasts are also available for ticket prices for urban flights. Volocopter estimates that a Central London-Heathrow journey would be available at 100-200 GBP. Archer predicted in 2021 that a Manhattan-JFK flight will cost 50-80 USD (about the cost of the Uber Black luxury car service) and an LA-Santa Monica journey 40USD by 2024. Urban parcel delivery by UAS is estimated at 4,2USD by 2030.[23]

Vendor narratives of UAM are often underscored by futuristic visions of sustainable smart cities with all-encompassing digital ecosystems. These propositions tend to focus on aerial passenger transport such as airport shuttle services between airports and city centres or even as public transport option between urban centres emphasizing sustainability, free movement and new opportunities for exploration, revolutionizing urban mobility through an affordable taxi or sightseeing service, or as a form of public transport between central and peri-urban areas. Package delivery – another dominant business case – seems to have lost some of its appeal in densely populated urban areas due to the technical problems posed by mass air operations and the potential cost of developing the necessary infrastructure such as landing pads and collection hubs.

Municipalities have an interest in bringing about UAM similar to states, but they are more directly concerned. As they have an interest in developing their own strategies, they are increasingly becoming key players in their own right. UAM may provide an opportunity for cities to establish themselves as the masters of creating their own unique airspace arrangements, within the broader context of urban planning, infrastructure, mobility and sustainability. New UAM ecosystems may have the potential to foster economic growth, innovation, enhance the quality of urban planning and to boost cities' reputation. An influential initiative of municipalities is the Urban Air Mobility Initiative Cities Community[24]. Municipalities are ready to endorse commercial applications proposed by vendors and they also see the potential efficiency benefits of carrying out certain city functions relying on aerial vehicles. In the UK for instance, there are at least a dozen ongoing projects initiated by city administrations[25].

Existing authorities such as the police, aviation and security agencies sometimes also influence policy and regulatory developments in the UAM field. National policies or attitudes could for example take a security centred approach, which could considerably hinder advances in the field. A general ban of drone flights over densely populated areas would make developing UAM business cases impossible. Drone use for surveillance purposes could raise privacy concerns as it did in France, even resulting in court proceedings where the Covid-19-related drone surveillance operations of the police were deemed illegal for privacy reasons[26].

Traditional air navigation service providers (ANSPs) have so far been the guardians of airspace. While urban airspace outside the vicinity of airports would not usually fall under the scope of their activities, they view themselves as natural providers of airspace design and traffic management services for UAM. Governments sometimes hold a similar view of the potential role of ANSPs. Such visions are challenged by industry stakeholders being more apt at developing software solutions for ATM as well as the EU which intends to open up markets for data- and service provision in UTM in general and UAM in particular.

22 https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/to-take-off-flying-vehicles-first-need-places-to-land, eHang whitepaper, Unmanned airspace report

23 https://mashable.com/article/archer-maker-evtol-reveal, https://www.flyingmag.com/evtol-air-taxi-passenger-prices/

24 https://smart-cities-marketplace.ec.europa.eu/action-clusters-and-initiatives/action-clusters/sustainable-urban-mobility/urban-air-mobility-uam

25 Philip Butterworth-Hayes and Tim Mahon: The Market for UAV Traffic Management Services

26 https://www.bloomberg.com/news/articles/2020-05-18/paris-police-drones-banned-from-spying-on-virus-violators; https://www.washingtonpost.com/world/in-victory-for-privacy-activists-france-is-banned-from-using-drones-to-enforce-covid-rules/2021/01/14/b384eb40-5658-11eb-acc5-92d2819a1ccb_story.html

City dwellers constitute the stakeholder group potentially most effected by UAM developments in their everyday life, but perhaps least well-represented in the current policy discussions. This is despite the fact that serious privacy issues, negative externalities such as visual and noise pollution, ownership rights over airspace, the design of urban spaces and potential new arrangements for the governance of urban airspace are all closely related to the actual inhabitants of cities.

While collaboration between public authorities and private stakeholders is already a common feature of the UAM domain, all these stakeholder interests need to be balanced between all those involved, but also within the broader context of other urban policies, functions and infrastructures.

Benefits and use cases

When considering UAM as a new feature of the urban landscape, the most important question that arises is what the potential benefits and use cases may be. The previous section has briefly outlined some of the stakeholder narratives which usually include projected benefits. From this paper's perspective, the potential benefits of UAM are mostly related to efficiency, urban planning and providing a new dimension to urban transport and the economy. Drones and eVTOL vehicles are more efficient than helicopters, since they have a reduced infrastructure need, cost less, use less energy and may be piloted remotely. UAM operations can add value to the execution of public functions, facilitating urban planning, supporting the operation of urban infrastructures and authorities, creating new medical and emergency services extending to air ambulances and scheduled public transport. While UAM will not replace traditional means of urban transport (with the exception of helicopters used in urban contexts perhaps), it may become an important element of urban mobility, especially in providing links between airports and urban centres, urban centres and peri-urban areas as well as between urban centres. While urban air operations will probably not resolve the problem of road congestion in the foreseeable future, they may provide a way to avoid them and reduce travel times for those who are willing to pay a premium. UAM also has a potential to catalyse innovation and foster new business opportunities. Having said that, it should be underlined that despite considerable investments, the sector is currently characterized by a vendor push and is lacking well-established demand and robust business cases.

Besides the obvious use cases of passenger transport (making helicopter services accessible to the broader public through the use of eVTOL vehicles according to some) and parcel delivery, integration of drone/eVTOL technology with other technologies (e.g. computer vision and AI) can lead to new use cases. Public use case include the creation of urban data sets through remote sensing and imaging to be used in urban planning, monitoring and operations, disinfecting public places, monitoring and cultivating urban green infrastructures, surveillance of potentially dangerous situations, sensitive infrastructures and public events, identifying malicious or suspicious activities, remote face or gait recognition, hazard detection, emergency response and medical services. Private use cases include air taxis, parcel delivery services, remote sensing, mapping, aerial photography and filming, media services and construction monitoring.

Obstacles and challenges

The evolution of UAM is hindered by different obstacles. The stakeholders interviewed for the purposes of this paper perceived social acceptance as the most important obstacle unanimously. The lack of an up to date legal framework, safety considerations and the level of technological development in certain domains were considered to be major obstacles by the majority. Nevertheless, there are a number of other impediments as well. According to a comprehensive market study, 'The sheer number and complexity of challenges to developing an urban UTM system is so many that we may run out of time and the ground infrastructure will not be in place to meet the business plans of the eVTOL sector'[27]. Obstacles may be categorised as being related to the safety and security, policy, legal, infrastructural, operational and societal domains, all of which may be characterized by fragmented approaches to resolving open issues.

Safety and security challenges are obviously among the most important ones to address. Flying above densely populated urban areas on a regular basis and at scale is a new phenomenon. Safety risks need to be mitigated before operations are permitted at scale. Cyber security is a pervasive and growing concern. Cyber attacks can have the potential to cause harm beyond simply causing a system failure, since pilotless and autonomous flying vehicles can be used as weapons.

There is a gap between the current state of technology, market developments and regulation. First of all, the ownership of airspace is not a settled matter. The situation is somewhat similar to that of the beginning of the 20th century when aviation itself was a nascent industry the fate and evolution of which was not simply impacted, but in fact dependent on legal developments concerning the scope of private ownership and the potential use of airspace over the land.

Privacy is an increasingly problematic aspect of urban air operations as result of drones photography, the possibility of transmitting live video feeds and other technologies including face- or gait recognition. Regulation is needed to ensure the protection of the environment, including addressing visual and noise pollution. Clarification of the rules concerning data sharing, data 'ownership' and access to data will also be necessary. The legal and regulatory framework should include the clear allocation of liability, roles and responsibilities and establishing authorities to carry out oversight and regulation of the safety-intensive UAM sector. Municipalities and in some cases communities or neighbourhoods will need to be empowered to pass decisions or participate in decision-making processes concerning the permissible uses of urban airspace.

The allocation of decision-making powers and the clarification of who is responsible for what with regard to urban airspace is not an easy task. Several legislative layers may be involved including international public law, national (federal) law, state or regional laws and municipal norms. Given the data-intensive nature of UAM, municipalities may need to establish and protect their data sovereignty (e.g. ensuring that data physically stays intra muros). Where private entities are involved, there is a need to ensure that their decision-making powers rest on a clear legal basis and are not simply a de facto result of owning infrastructure, intellectual property rights, developing software or participation in a public private partnership project. Communities on the other hand should be allowed to exercise a certain degree of control over their lives (use of airspace over their homes for commercial purposes, privacy, etc.). In both cases, there is a clear need to develop a proper framework for allocating responsibilities and decision-making powers making sure at the same time that such powers are always complemented by the appropriate accountability and the mechanisms that ensure their integration in the relevant legal system (ensuring appropriate appeal procedures for instance).

While there are technological solutions for certain elements of the system, approaches are still fragmented and there is no agreement on how a complete system would be constructed and operated. As a research paper from Maynooth University points out, it still remains unclear how such urban systems should be designed and operated. The challenges are considerable, since the current architectures do not address key operational aspects unique to urban environments and even where relevant questions are explored, they lack the necessary level of detail[28]. The fact that data streams will mostly need to be processed in real time poses significant challenges in itself. Technologies still need to evolve to

27 Ibid., p. 186

28 Tim McCarthy, Lars Pforte and Rebekah Burke: Fundamental Elements of an Urban UTM, Aerospace 2020, 7, 85; doi:10.3390/aerospace7070085, p. 4

resole a wide range of problems including energy storage, battery life, charging speed. Since the failure of the mooring mast project in NYC weather has not ceased to pose further challenges to technology. Weather phenomena like high temperatures and strong winds still need technological answers. Furthermore, a weather sensing system of high granularity needs to be developed for the urban environment, ensuring the collection of relevant data in real time.

It is currently unclear who will finance the upfront investments needed for the development of UAM infrastructure. Given the fact that demand is not well-established, it is an open question who would bear the risk of the sunk costs necessary for developing new infrastructure. Furthermore, the data intensive, UAM system managing the flows of vast amounts of data in real time (including storage, analysis and automated interventions) will need a considerable digital infrastructure which will in all likelihood have a considerable environmental impact.

This non-exhaustive list provides an overview of the challenges UAM implementation is facing.

Policy-related obstacles

- Fragmented legal, technological infrastructural, operational approaches
- Lack of experience and knowledge on the side of states and cities on technical and operational issues
- Lack of aviation knowledge on the side of new start-ups, urban policy-makers and city authorities
- No clear indication of demand
- Lack of robust business cases
- It is not clear who will finance infrastructure
- Lack of market design strategies
- Lack of an ability to manage interrelated and sometimes contradicting policies
- Lack of assessment of the potential environmental impact of an operational UAM system (especially that of the data centres and sensor networks)

Safety and security

- Lack of an overarching framework for modelling risk[29]
- Air collisions and ground damages mitigation (separation and densely populated areas)
- Cyber security (including using air vehicles as weapons)
- Detection and neutralization of non-cooperating air vehicles

Legal & regulatory obstacles

- Legal status and ownership of airspace
- Lack of governance mechanisms for urban airspace
- Lack of clear conditions for certification
- Lack of authorities responsible for oversight and regulation
- Lack of standards (noise, interoperability, etc.)
- Allocation of roles and responsibilities
- Clear allocation of liability
- Gap between technology, market developments and regulation (a constant feature of sectors influenced by exponential technologies)

Obstacles related to infrastructure

- Low level of investment, uncertainties of financing (could also be perceived as policy-related)

29 Tim McCarthy, Lars Pforte and Rebekah Burke: Fundamental Elements of an Urban UTM, Aerospace 2020, 7, 85; doi:10.3390/aerospace7070085, p. 5

- Lack of interoperability
- Lack of prior experience in urban airspace design
- Lack of prior experience in urban traffic management
- Lack of charging infrastructure for air vehicles

Obstacles related to technology

- Battery capacity and life cycle (energy storage)
- Battery charging speed
- Solutions for extreme weather conditions
- Cost and difficulties of retrofitting the built urban environment for UAM

Operational obstacles

- Lack of knowledge and experience on how airspace should be structured
- Lack of knowledge and experience in traffic management over urban environments
- Disconnect between airspace modelling and traffic management[30]
- Lack of a clear altitude reference system
- Lack of suitable protocols, standards or methodologies that address the highly complex environment of dense drone traffic operations over cities[31]
- Urban aerial traffic management of at scale operations is not yet fully resolved
- Challenges of dynamic airspace management
- Flight path allocation in an urban environment
- Establishment of an interface with traditional air traffic management

Societal

- Societal acceptance
- Privacy (French case law)
- Noise

Conclusion

UAM in itself will probably neither solve congestion on the ground, nor make cities sustainable or resilient. While it is possible to define both public and commercial use cases and there are considerable investments flowing into the UAM sector (especially into the passenger transport segment), it is currently difficult to identify obvious demand for the services. At the same time, urban air operations do have the potential to complement existing transport modes and to create added value in a number of public domains. Furthermore, especially in combination with other technologies, hidden benefits and demands may surface. Under such circumstances, the question arises what cities could do to ensure that they benefit from UAM developments.

As a first step, cities could establish a clear vision of their objectives with respect to UAM, namely what they intend to use urban air operations for and what benefits they expect. Such objectives may include enhancing the quality of urban design and planning, carrying out certain public functions more efficiently via airborne vehicles (e.g. medical services, police operations, emergency responses), supporting economic growth through the creation of a new, innovative sector of the urban economy, complementing the existing urban mobility system, or promoting tourism through offering high-end air mobility services such as airport shuttles and sightseeing trips.

Once this vision is established, there is a need to consider the current state of technology, airspace operations, the legal framework and infrastructure (in-

30 Tim McCarthy, Lars Pforte and Rebekah Burke: Fundamental Elements of an Urban UTM, Aerospace 2020, 7, 85; doi:10.3390/aerospace7070085,

31 Ibid. p. 7

cluding the aspect of potential integration into the city digital framework) and to identify the existing gaps on that basis. Planning should also take into consideration all the known obstacles. On that basis a plan may be developed integrating the technological, legal, financial, societal, environmental, governance, safety, security and infrastructural aspects, also taking the interdependences with other city policies in consideration. The most difficult aspects of developing a UAM system are its complexity, its interdependence with other policy and regulatory areas and the need to balance a wide range of stakeholder interests. All of this necessitates a thorough understanding of the implications and avoiding over-reliance on subjective stakeholder narratives.

Urban Air Mobility Industry Outlook

Umut Alkım Tuncer

Abstract: *The need for alternative transport solutions in cities and advancements in drone technologies have recently paved the way for the revival of the Urban Air Mobility (UAM) industry. Even if on-demand helicopter services have a long history, urban air has never been a topic discussed in the past as it has been during the last decade. Increasing populations in urban areas, traffic congestion on the ground, and the lack of alternative transport solutions are some of the incentives for the tech companies which have incrementally invested in research and development activities for urban air transport vehicles and their ecosystem. There have been many pilot projects in different cities worldwide, and the debate for realizing the concept, especially in passenger transport, is more heated. This short article intends to give an overview of where we stand in terms of UAM and elaborate more on what can be expected in the medium and long run.*

The Current State of UAM

Ideas to travel in urban air came up in the early 20th Century with flying car concepts. Not so long after, around mid-century, these ideas were put into practice by on-demand helicopter services (Cohen et al., 2021, pp. 6074-6075). Until recently, it was a small market mainly for high-income people, and the urban mobility sector has been dominated by road or rail transport (Straubinger et al., 2020, pp. 1 - 2). Meanwhile, unmanned aircraft technology and remotely controlled vehicles started to appear and were used for military purposes after World War II. Guilmartin (2020) indicates that modern-day military drones descended from the ones developed and used by Israeli Defense Forces in the 1980s. Drones followed a similar pattern as other military technologies and found use for other purposes. From tiny ones to large ones, drones are now widely used worldwide by individuals, public and private sectors. Coming back to the urban context, it can be said that the scene is about to change with the new aircraft in development. Following the advancements in hardware and software components, drones have become much more capable, and it is not a coincidence that now we are talking about using them for passenger transport or logistics in cities. In this sense, they share the same fate as autonomous vehicles (AV), which are, more or less, at the same stage of development. Although both technologies are in the trial phase, it can be argued that their widespread use is imminent. As a matter of fact, one study concludes that as of February 2020, there were more than 110 cities where drone transport was tested (Hader et al., 2020, p. 5 - 17).

The advantage of such aircraft is their vertical take-off and landing (VTOL) feature, as in helicopters. Cities do not need airports with large runways to have such services. However, infrastructure is still required as drones need a place to land and take off. And it must be noted that not all aircraft in development have VTOL capability and there are also models with fixed wings (Cureton, 2021, p. 8). The areas to be used for take-off and landing by VTOL aircraft are called vertiports. Either VTOL or not, another significant advantage lies in travel time savings, as can be imagined. Even if it is not infinite (for transporting passengers or goods), urban air space has a much larger capacity than roads and railways. So, congestion will be much less critical when urban air mobility is considered. Moreover, it is essential to note that vehicles in development are primarily relying on electric propulsion (eVTOL), and this, in theory, can have positive impacts within the scope of environmental sustainability and reduction of greenhouse gases (Hader et al., 2020, p. 5 – 17; Straubinger et al., 2021, pp. 361 – 362).

Drone transportation also brings challenges with it, as in other disruptive technologies. In order to implement the concept, various stakeholders need to cooperate. One study lists the main actors in the ecosystem: platform providers (that offer UAM services to customers), service providers or operators, vehicle owners, vehicle manufacturers, maintenance and repair companies, insurance companies, ground infrastructure providers, and unmanned aircraft system traffic management (UTM) service providers (Straubinger et al., 2020, p. 7). Looking from this angle, it can be understood that good governance will have an important role in successful UAM operations with new vehicles. According to the literature, there are also other barriers to the concept, and social acceptance will be one of the critical issues. Other challenges are operating in adverse weather conditions, propulsion (electric vs. other energy sources, lifecycle emissions), vehicle mass, battery capacity (in electric propulsion), financing and operating ground infrastructure, fleet management, regulations and vehicle certification, air traffic management, auditory and visual noise, pilot availability (for non-automated models), automation, safety and security, equity, privacy, competition with other modes and affordability (Kohlman & Patterson, 2018, p. 36; Vascik & Hansman, 2018, p. 21; Thipphavong et al., 2018, pp. 3 – 11; Reiche et al., 2019, pp. 1 – 7; Antcliff et al., 2019, p. 15; Gregory I.M. et al., 2020, p. 24; Brown & Harris, 2020, p. 1012; Al Haddad et al., 2020, p. 710; Reiche et al., 2021, pp. 6018 - 6027; Torens et al., 2021, p. 11; Straubinger et al., 2021, pp. 363 – 364; Afonso et al., 2021, p.16; Bauranov & Rakas, 2021, p. 4 – 7; Cohen et al., 2021, pp. 6074-6075; Goodrich & Theodore, 2021, p. 10 - 11). It can be argued that these challenges have further delayed the operations and affected the plans for pilot projects. Nevertheless, the new aircraft in development and considered business models hold enormous potential, and this is demonstrated by the fact the market is already expanding fast with investments from existing companies in the aviation and automotive sectors and the increasing number of startups joining the race. This is promising for UAM because the push from the industry can speed up the processes to address technical, social, and political issues (Bauranov & Rakas, 2021, p. 1).

The novel aircraft that have already been produced or under development are expected to be used for different purposes. Realized or considered business models include personal commuting, air taxi (on-demand transport, route defined by passenger), air metro (fixed routes as in public transport, including airport shuttles, company shuttles, regional public transport shuttles), air ambulance, package delivery, law enforcement, and military purposes (NASA, 2018, pp. 14 – 18; Reiche et al., 2019, p. 1; Straubinger et al., 2021, pp. 365 - 378). As can be inferred from the variety of uses, the developments in UAM will impact the operations and services offered by public and private institutions from different sectors. Naturally, UAM initiatives and trials are not only carried out by the private sector. There are many collaborations and projects in place between different actors listed for various components of UAM. These can be separated into two categories: public sector-led and industry-led initiatives. According to findings from the literature, public sector-led initiatives are listed below in Table 1.

	Initiative	**The Region, Country, or City**	**Purpose**
1	Urban-Air-Mobility Initiative Cities Community (UIC2)	EU, UK	Policymaking for transition to vertical transport
2	AURORA	EU	Autonomous UAM demonstration for primarily emergency applications
3	CLASS	EU	Developing a pre-operational prototype of a UAS Traffic Management System (UTMS)
4	CORUS	EU	Developing a reference Concept of Operations (CONOPS) for UTM (UAS Traffic Management)

5	DREAMS	EU	Contributing to the definition of the European UTM Aeronautical Information Management operational concept
6	DroC2om	EU	Contributing to the definition of integrated cellular satellite data link specifications for UASs.
7	PODIUM	Denmark, France, and the Netherlands	Large-scale drone operation interacting with manned traffic
8	SECOPS	EU	Mitigating security risks in drone technology
9	SKYOPENER	EU, Switzerland	Increasing the use of Remotely Piloted Aircraft Systems (RPAS) for civilian applications
10	TERRA	EU	Producing a technical architecture to support VLL RPAS operations
11	USIS	EU	Demonstration for technical and operational feasibility
12	AIRPASS	EU	Researching on-board technologies for UTM
13	IMPETUS	EU	Researching 'micro-services' in UAM
14	MoNIfly	EU	Proposing a drone traffic management system based on mobile network infrastructure
15	PercEvite	EU	Developing technologies to autonomously detect and avoid "ground-based" obstacles and flying objects
16	SAFEDRONE	EU	Acquiring practical experience in Very Low Level (VLL) operations
17	VUTURA	Rotterdam, Enschede	Demonstrating U-space in the Netherlands
18	STEP2DYNA	EU	Developing an innovative bio-inspired solution for collision detection in dynamic environments
19	GAUSS	EU	Fast and thorough achievement of acceptable levels in terms of performance, safety, and security for both current RPAS and future UTM operations
20	5G!DRONES	EU	Trialing several UAV use-cases covering eMBB, URLLC, and mMTC 5G services and validating 5G KPIs for supporting such challenging use-cases
21	COM4DRONES	EU	Researching safe software and hardware drone architectures
22	DELOREAN	EU	Guaranteeing safe navigation to UAM aircraft
23	GEONAV IoT	EU	Development and delivery of precise ubiquitous positioning and navigation applications and services
24	ADACORSA	EU	Strengthening the European drone industry and increasing public and regulatory acceptance
25	BUBBLES	EU	Developing algorithms to compute collision risks
26	ICARUS	EU	Integrated common altitude reference system
27	FACT	EU	Increasing the safety, security, and efficiency of air traffic management (ATM) systems by updating CNS technology
28	LABYRINTH	EU	4d path planning technologies for drone swarm to enhance safety and security
29	XTEAM D2D	EU	Seamless integration of ATM and Air Transport into an overall intermodal network
30	DACUS	EU	Development of a service-oriented Demand and Capacity Balancing (DCB) process for drone traffic management
31	INVIRCAT	EU	Safe and efficient integration of RPAS (Remotely Piloted Aircraft Systems) into the existing Air Traffic Control (ATC) procedures and infrastructures
32	METROPOLIS 2	Vienna	Providing concrete solutions to enable air traffic in high-density urban areas
33	SAFIR Med	Aachen	Demonstrating ways to achieve safe and socially accepted urban air mobility
34	AMU-LED	Amsterdam, Rotterdam, Enschede, Santiago de Compostela	Demonstrating U-space capabilities to enable UAM
35	CORUS XUAM	EU	Demonstrating U-space capabilities to enable UAM
36	GOF 2.0	EU	Demonstrating operational validity of serving combined UAS, eVTOL, and human-crewed Operations using existing technology
37	USEPE	EU	Exploring potential separation methods to ensure the safety of drone operations in urban environments
38	TINDAIR	Toulouse, Bordeaux	Demonstrating through real flights the proposed technologies for automatic Tactical Conflict Resolution and Strategic Deconfliction
39	FlightAI	EU	Integrating the Artificial Intelligence (AI) technology generated by the FET-OPEN GOAL-Robots Project into the web solution by EUSC
40	OASyS	EU	Forecasting future scenarios for UAM vehicles and supersonic aircraft
41	ODESSA	EU	Obstruction detection sensor for surveillance on aircraft
42	HEAVEN	EU	High power density FC system for aerial passenger vehicle fueled by liquid hydrogen
43	FF20	Zaragoza	Developing a new UAM ecosystem aligned with the Digital Government Transformation (DGT) program of European countries,
44	AIRMOUR	Stavanger, Helsinki, the region of Nord-Hessen, Luxemburg	Increasing awareness among different actors for necessary near-future actions in UAM

45	Uspace4UAM	EU	Tackling issues of operational concepts, regulation, and standards, while building confidence in safe and orderly integration of UAM in everyday air traffic
46	FAA-NASA UAS traffic management (UTM)	USA	Facilitating small, unmanned aircraft systems (sUAS) to safely access low-altitude airspace beyond visual line of sight
47	FAA UAM concept of operations	USA	Creating a roadmap for UAM including various stakeholders
48	NASA UAS traffic flow control (UTFC) in urban areas	USA	Creating a traffic management conflict model
49	SESAR U-SPACE	EU	Supporting the EU aviation strategy and regulatory framework on drones
50	DLR USpace4UAM	Germany, EU	Large scale UAM demonstrations with different partners from the industry
51	ONERA low-level RPAS LLRTM	France	Researching RPAS LLRTM
52	Singapore Nanyang Technological University UTM Concept	Singapore	Researching and developing air traffic management solutions for Singapore and the Asia Pacific region, including UAV traffic management
53	China's civil UAS Aviation Operation Management System (UOMS)	China	Developing regulations and standards
54	JAXA UAS	Japan	Developing UAS traffic management system
55	Ensenada Pilot Law Enforcement Project	Mexico	Monitoring crime and police dispatching using drones
56	Ministry of Interior of Turkey Law Enforcement Applications	Turkey	Monitoring crime and police dispatching using drones

Table 1. Global UAM Projects Initiated by the Public Sector

Source: Table compiled by the author, sources: (European Commission, 2021; UIC2 – UAM Initiative Cities Community, EU's Smart Cities Marketplace, 2021, p. 73-91; Bauranov & Rakas, 2021, p. 8 – 19; Butterworth-Hayes, 2019; T.C. İçişleri Bakanlığı Bilgi Teknolojileri Genel Müdürlüğü, 2019)

The table above and listed completed or ongoing projects demonstrate that international, national, and local authorities are pretty proactive when it comes to UAM. They are preparing for possible disruptions by trying to involve other relevant stakeholders. It must be noted that there can be other projects, and the above table is not a final list. One of the key findings is the European Union's more comprehensive and balanced approach with many different projects addressing technical and social issues.

The other category we defined is the industry-led initiatives. Because of the competition, transparency may not be a priority for these actors. Therefore, our list will only include information from sources selected and already available. Table 2 below is a catalog of industry-led initiatives on a global scale.

	Initiative / Company	**Country**	**Purpose**
1	Amazon Prime Air	USA	Package delivery using drones
2	Airbus Urban Mobility	France	Production of eVTOL aircraft, ground infrastructure, regulatory studies, and UTM
3	Boeing	USA	Production of eVTOL aircraft
4	Embraer-X	Brazil	Production of eVTOL aircraft
5	Joby Aviation	USA	Production of eVTOL aircraft, national and international partnerships for UAM system design
6	Beta Technologies	USA	Production of eVTOL aircraft
7	Lilium	Germany	Production of eVTOL aircraft
8	Wing (Alphabet)	USA, Australia, Finland	Production and development of eVTOL aircraft and UTM system; drone delivery services for customers by linking them with local businesses
9	EuroDrone UTM	Poland	Software and mobile applications for procedural control of drones
10	Cezeri	Turkey	Production of eVTOL aircraft
11	Volocopter	Germany	Production of eVTOL aircraft, UTM software, and vertiport design
12	Wisk	USA	Production of eVTOL aircraft
13	Archer	USA	Production of eVTOL aircraft and related software development
14	EHang	China	Production of eVTOL aircraft and components
15	Elroy Air	USA	Production of hybrid VTOL aircraft
16	AirMap	USA	Development of UTM platforms and applications
17	AiRXOS	USA	Providing UTM solutions
18	Kitty Hawk	USA	Production of eVTOL aircraft

19	Pipistrel	Slovenia	Production of hybrid VTOL aircraft
20	Vertical Aerospace	UK	Production of eVTOL aircraft
21	Supernal	South Korea	Production of eVTOL aircraft
22	Eve Urban Air Mobility Solutions	Brazil	Production of eVTOL aircraft
23	Honda	Japan	Production of hybrid VTOL aircraft
24	REGENT	USA	Production of eVTOL aircraft
25	Overair	USA	Production of eVTOL aircraft
26	Dufour Aerospace	Switzerland	Production of hybrid VTOL aircraft
27	Electra	USA	Production of hybrid VTOL aircraft
28	Sabrewing Aircraft Company	USA	Production of hybrid VTOL aircraft
29	Ascendance Flight Technologies	France	Production of hybrid VTOL aircraft
30	Airflow	USA	Production of hybrid VTOL aircraft
31	Jaunt Air Mobility	USA	Production of eVTOL aircraft
32	Bell	USA	Production of eVTOL aircraft
33	ANRA Technologies	USA	Developmental airspace simulation
34	ARINC INC	USA	Developmental airspace simulation
35	Avision INC	USA	Developmental airspace simulation
36	Ellis & Associates	USA	Developmental airspace simulation
37	GeoRq LLC	USA	Developmental airspace simulation
38	Metron Aviation	USA	Developmental airspace simulation
39	OneSky Systems	USA	Developmental airspace simulation
40	Uber Technologies	USA	Developmental airspace simulation
41	AMU-LED Project	Multinational	Safe interaction of UAM with other airspace users and safe UAM flight

Table 2. Global UAM Projects Initiated by the Industry

Source: Table compiled by the author, sources: (Bauranov & Rakas, 2021, p. 8 – 19; Joby Aviation, 2022; Beta Technologies, 2022; Lilium, 2022; Butterworth-Hayes, 2019; BaykarTech, 2021; Volocopter, 2021; Wisk, 2021; EHang 2022; Elroy Air, 2022; AirMap 2021; General Electric, 2018; SMG Consulting LLC, 2022; NASA, 2020; AMU-LED, 2022)

The table above is meant to be extensive but does not mention all the projects and firms from the industry. On the other hand, it can be understood that the UAM sector has numerous existing firms entering the market and as many startups to provide for components of the UAM ecosystem. In addition, it must be noted that the concept has been realized in goods delivery. It can be expected that goods delivery will become viable sooner than passenger transport because the latter brings in complex problems to be solved. On the goods delivery side, Wing, a subsidiary of Alphabet, is providing this service in Australia, and it is highly probable that some of the initiatives mentioned are also mature enough. Relatively recent developments in the sector make it harder to track the progress of these initiatives.

The increasing number of projects and investments have already created a sizeable UAM market. Although the figures vary, existing research indicates that the market size was USD 3.1 billion in 2019 and USD 7.1 billion in 2021 (Emergen Research, 2020; Valuates Reports, 2022). According to another study, investments in passenger UAM startups were USD 907 million for the first half of 2020, and this figure is twenty times higher than for the same period in 2016 (Hader et al., 2020, p. 5 – 17).

Future Projections for UAM

The research conducted for this article indicates that academic studies have mainly focused on challenges and constraints in the UAM ecosystem. Possible business models and technical modeling are also common in academic literature, which can be attributed to the lack of operational data. However, it is also observed that many pilot projects have been completed or ongoing. A look at the timeline suggests that there is a compounding effect. When the details and location of projects are taken into account, it can be understood that the EU is much more organized and prepared with projects addressing technical, social, and political challenges. On the other hand, the USA dominates industry-led initiatives. It can be expected because the aviation and automotive industries have a long history and are much more advanced in this part of the world than others.

When we look at the current state of UAM, it can be seen that the goods delivery sector will mature sooner than passenger transport, and there are already existing services in cities that are not very dense. Relatively easier operations and the absence of passenger safety concerns can be among the reasons for this phenomenon. Nonetheless, we can expect an increase in passenger transport pilot projects because many vehicle manufacturers have their novel aircraft ready, and some of them have already received orders in relatively high volumes. Moreover, it is observed that the push from the industry is creating pressure on public authorities to work on regulations and vehicle specifications for certification.

UAM already has a significant share within the overall drone market, but most of the sectoral reports estimate a further boost until 2030 and even more for 2050. Studies we referred to estimate that the UAM market size will reach USD 12.9 billion in 2028 and USD 15.5 billion in 2030. Another source assesses the viability in different segments of UAM. It concludes that last-mile delivery with drones can have a viable market in 2030 and passenger transport with fixed routes in 2028. However, the same study projects that on-demand passenger services may still not be viable in 2030. Finally, it is expected that the passenger UAM industry will generate around USD 90 billion a year by 2050 (Emergen Research, 2020; Valuates Reports, 2022; Hader et al., 2020, p. 2 – 10; Reiche et al., 2018, pp. 12 – 20).

In conclusion, we are looking at a sector that has recently been swarmed by public authorities and the private sector alike. The scene in cities is subject to change with goods delivery drones and bigger vehicles that carry passengers. Apart from the constraints and challenges listed in the literature, there are still questions about what to expect from UAM when the whole urban mobility system is considered. At the current stage, it is hard to estimate passenger UAM's impact on public transport and traffic congestion in cities created by cars. In addition, as in other technologies, the public's reaction remains unclear.

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Urban Air Mobility - Where Do We Stand?

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Abstract: *This article aims to briefly discuss the state of play in urban air mobility (UAM) through the examples of Singapore and Hamburg. Both cities experimented with sandbox projects – UAM laboratories – in an attempt to identify problems and solutions on the way to implementing urban air mobility. The brief introduction and comparison of the two projects provides a snapshot of where urban air mobility solutions stand today.*

The trends placing urban air mobility in the focus are technological innovation in the field of aircraft with vertical take off and landing capabilities, rapid urbanization and climate change. UAM is expected to resolve or at least mitigate some of the problems cities are facing while creating new business opportunities and bringing about a range of societal benefits. Therefore, an increasing number of governments and cities begin to develop policies and design projects to study and clarify the concept and applicability of UAM.

The question is of course far more complex than that of technological advances and how a flying car may be manufactured. In fact, an entire UAM ecosystem needs to be developed, encompassing a legislative framework, physical and digital infrastructure, energy sources, supervising authorities, community aspects and comprehensive links to the urban mobility framework and other urban systems. While many electronic vertical take off and landing vehicles (eVTOL) manufacturers are planning to begin operations in the next few years, several essential elements and aspects of the ecosystem are still missing or are not yet fully resolved. Hamburg and Singapore have taken considerable steps to integrate UAM into their urban reality.

UAM in Hamburg and Singapore

The two cities we have examined represent two different continents, two different approaches, different geographical aspects, regulatory frameworks and processes, as well as public attitudes and acceptance, but the same objective. Singapore is a leading example of urban air mobility in the making. Its relatively small and dense national airspace is an ideal context and testbed for developing a new ecosystem. Its characteristics make Singapore especially interesting and relevant. It is a city-state with many cross-border connections. Singapore is a transport hub with large ports, intermodal transport. Furthermore, it is an eminently innovative state, well prepared to take advantage of cutting-edge technologies. Singapore has already begun working on the implementation of some services and has already concluded trials (to be detailed below). The state stands at second place behind the United States on KPMG's Air Taxi Readiness Index from 2021.[1] In general, the air taxi market is expected to be dominated by the Asia-Pacific region by 2035 (China, Singapore and South Korea).[2]

The other project we examined was the U-Space sandbox project in the Port of Hamburg, a demon-

1 https://assets.kpmg/content/dam/kpmg/ie/pdf/2021/10/ie-aviation-2030-air-tax-readiness.pdf

2 Unmanned airspace forecast report edition

stration project of the U-Space concept of the EU[3]. The trial took place over the span of seven months, from May to November 2021. The U-Space concept of the EU – a set of services enabling the air traffic management, and a safe and effective access to airspace for drones – was developed by the European Aviation Safety Agency (EASA). The application of the first requirements is to be implemented in the EU from January 2023. The Port of Hamburg, although not an inner city environment, has the characteristics to be ideal for a U-Space test-run. A large area with more then seven thousand hectares, several industrial installations, tall ships, terminals and more than 120 bridges; it is a complex, intermodal environment. There are 300 kilometres of railroad tracks in the port area. Besides the industrial environment, residential areas are also included, making the sandbox an ideal laboratory for testing advanced UAM technologies.[4]

Inspiration, expected benefits

The objectives of the Hamburg port sandbox project were rather clear and practical: putting into practice and testing the viability of the EU's U-Space regulation before its implementation; to identify gaps or places for improvement and serving as a blueprint for implementing U-Spaces in Europe. In conclusion, several proposed actions for successful future implementation were identified. The port was an ideal scenario for all parties, as it was already using drones for transporting goods, and due to high traffic and the many physical obstacles in the air (like tall ships and bridges), U-Space implementation had a very practical aspect. The benefit for the port includes increased productivity and efficiency, lower costs and reduced need for human labour. Testing the concept together with the partner companies and city stakeholders provided an opportunity for the preparation of the eventual introduction of UAM in the near future.

Singapore is running multiple UAM related projects in parallel. The government is actively facilitating the use of UAS both in the private and public sectors. Partnerships have been established to achieve related policy objectives. These are comprised of authorities (including EASA, the EU regulator), universities and commercial companies. Their activities cover several important aspects of UAM, including the development of safety standards and regulatory requirements and testing drone delivery networks, managing multiple drone operations in low-altitude airspace. Drones had already been used for smaller tasks such as infrastructure inspection, but a greater potential is foreseen for other services and urban air mobility. Evidence of that are the rather recent announcements of the extensive cooperation of the city-state with eVTOL manufacturer Volocopter, with plans to make Singapore one of the first cities in the world where UAM is a reality and establishing the state as a flying taxi hub including for cross-border operations[5]. Apart from that, the port of Singapore is also a testbed for drone operations in ports, with a consortium of seven stakeholders testing their operations to launch drone transport in the large port area[6]. According to Volocopter, their cooperation with Singapore is set to massively benefit the city, by providing 4,18 billion SGD in economic benefits, while also creating up to 1300 local jobs by 2030[7]. The expected benefits include greener transport in line with Singapore's plan for a greener economy.

Planned services

Singapore has plans to integrate UAM solutions

3 Described in Commission Implementing Regulation (EU) 2021/664 of 22 April 2021 on a regulatory framework for the U-space

4 Practioner briefing, Urban Air Mobility

5 https://www.volocopter.com/newsroom/vc-generates-sgd-4bn/

6 https://bitport.hu/szolgalatba-lepnek-a-dronok-az-oria-si-szingapuri-tengeri-kikotoben?mc_cid=7a26291f8c&mc_eid=2650215ea3

7 https://www.volocopter.com/newsroom/vc-generates-sgd-4bn/

into its urban mobility system. Operating beside or within the context of the already well established and functioning public transport system, air vehicles in Singapore could transport passengers into, out of and within the city; on private, business and sightseeing trips, including cross-border operations. With Indonesia and Malaysia relatively close by, UAM provides an easily accessible and unique transport option for affluent travellers wishing to save time, or just to be among the first ones to experience this futuristic way of getting around. Potential new services also include last mile deliveries as evidenced by the Skyways[8] project, which is building on artificial intelligence and focusses on autonomous operations.

While the Hamburg sandbox project is focussing on U-Space airspace, being a member of the UAM Initiative Cities Community (UIC2) and the Smart Cities Marketplace initiative, Hamburg considers realizing UAM in the not so distant future a priority. Applying a bottom-up approach, the city fosters close innovation-driven interactions between three groups of stakeholders, namely the research community, the business community and the city and federal authorities[9]. While the envisioned future use cases aim to serve the public interest (e.g. medical deliveries), it is acknowledged that such services have a great potential to support the public acceptance of commercial drone operations.

Timeline of implementation

For Singapore, starting UAM operations is a reality. Volocopter seems determined to begin operation in the next couple of years (2024-26 are the current target dates)[10] and use Singapore as a positive example and model state of a functioning UAM ecosystem. The U-Space sandbox project in Hamburg lasted seven months, with the all-out simulation taking place in the last two months, from September to November 2021, leaving plenty of time for reflection and planning before January 2023, the date of the entry into force of the U-Space implementing the regulation.

Infrastructure

A crucial element of a well-functioning UAM ecosystem is a robust supporting infrastructure. This means both physical and digital components. The most important physical infrastructure would be vertiports for take-off and landing and charging stations, while high-speed digital communication networks, traffic management software and data bases would also be needed, just to mention the most important elements. Partnering with Volocopter, Singapore is poised to develop a network of vertiports (Voloports, as they call them). While the Hamburg U-Space sandbox produced a firm basis for a well-developed digital background, according to the KPMG readiness study Singapore scored relatively low in the infrastructure element, leaving ample space for improvement. With respect to the digital infrastructure, a consortium, together with the aviation authority, CAAS, completed a two-year UAS and UTM trial in 2021. The project operated with both live flights and simulations, focusing on handling drones flying Beyond Visual Line of Sight, while also studying the operational suitability of 4G and 5G networks to adequately support UAS. While the trials were completed and rated successful, it is accepted that they serve as only a starting point for the long process of developing a regulated UTM system[11]. Both cities seem to have acknowledged the important role of new technologies such as artificial intelligence and machine learning in the development of a mature UAM ecosystem.

An important role for the infrastructure underlying UAM is the coordination of traffic flows, vehicles and

8 https://skyways.com/

9 UAM Pracitoner Briefing

10 https://aamrealityindex.com/

11 https://www.suasnews.com/2021/03/singapore-deploys-first-successful-trial-utm-system-creating-the-foundation-for-urban-air-mobility/

potentially a lot more: requests and airspace closures from authorities, priority traffic, etc. The Hamburg sandbox project proposes the designation of a single central data consolidator at the national level (SCISP), which would act as a 'single point of truth' and provide a firm basis for coordination, parts of which role could be executed by multiple U-Space service providers (USSPs). In Singapore, the coordinative role could belong to the air navigation service provider authority (CAAS).

Legal framework

For the establishment of a functioning UAM ecosystem, a number of legal questions need to be resolved. These involve privacy, liability, safety and data regulation. There are some uncertainties both in the legal framework of Singapore and that of the Hamburg project. Safety, liability and governance issues surfaced in Hamburg, including the lack of liability rules for U-Space operations. In Singapore, the UAM legal framework is currently under development. The Hamburg project has identified certain areas of necessary legislative change. The test runs and sandbox projects have provided invaluable practical experience, basis and facts to inform policy-making and legislation. CAAS is also working with EASA and Airbus on the development of safety standards and regulatory requirements for UAS in urban environments, exchanging information and sharing technical expertise.

Some major challenges

Public acceptance of UAM remains a major issue. This was well illustrated by the Hamburg project, where concerned citizens often called the police to report the drones flying in the port area. The project needed a close cooperation with the local police and an awareness campaign to inform the local community of the ongoing project was also conducted to address concerns. For Singapore, in contrast, consumer acceptance scored rather high in the KPMG study, at third place among all the states observed. The EASA study on societal acceptance of UAM examined the public's attitude in the EU, finding privacy, safety, noise, security and environmental impact major concerns[12].

Designing airspace and operations for UAM is a challenging task with countless factors to consider. Safety is one of them. With several no-fly zones established, such as above certain infrastructure elements or above a kindergarten, the Hamburg project proposed several actions in respect of the design and operation of U-Space. In line with EU policy, the integration of manned and unmanned traffic was proposed. In order to facilitate dynamic reconfiguration of airspace, a sectoral approach was proposed, with a single U-Space sector that can be switched on and off in accordance with the traffic demand as the preferred option. As for the interactions between manned and unmanned aircraft, the findings called for clarification of the rules, such as minimum separation distances, right of way and prioritization. In Singapore, the operation in the urban airspace is thought of as one of the biggest challenges segregating an already small and contested airspace, with many no-fly zones and high buildings and an airport in the vicinity.

Conclusion

Both Singapore and Hamburg have conducted promising projects that have already provided valuable insights and a good basis for the further development of UAM. While some skeptical voices fear that UAM might just be an empty façade, calling eVTOLs rebranded helicopters,[13] considerable investments flow into the concept, with more than five billion dollars invested in urban air transportation in 2021.[14] At the same time, it needs to be acknowledged that we are not there yet.

By looking at two vastly different use cases in two dif-

12 EASA Study on the societal acceptance of Urban Air Mobility in Europe, 2021

13 https://www.bloomberg.com/opinion/articles/2022-02-20/electric-flying-cars-are-just-dirty-old-helicopters-rebranded

14 https://www.ft.com/content/d12b3b28-5472-4905-bc4e-4e116b2ff498

ferent continents and diverse cities, some general conclusions may be drawn. There certainly are use cases serving the public interest such as emergency operations and medical deliveries. These could potentially be among the first services to take off, as stated in the findings of the Hamburg project. For this to happen, UAM ecosystems still need to be established. The optimistic promise of providing something truly revolutionary and an alternative for urban congestion in the near future might be a long shot. There are definitely useful and important use cases, but to see much of the road transport transfer to the sky seems unrealistic. The examined use cases tend to focus on niche markets such as high end travel options and providing cargo services in the port area. Anything else seems to be further down the road for now. Nevertheless, some industry players clearly believe in the potential of air taxis to revolutionize urban mobility at scale. Time will tell.

At the current state of UAM, co-operation of all stakeholders seems to be essential, including local authorities, municipalities, as well as industry players from all spectrums in the development process. The value of this approach is clearly demonstrated by both cities we have examined. Another important point is that to manage urban air traffic safely, U-Space, as well as similar concepts will need to be strengthened and further matured. The UAM market development is still in the early stages for a credible assessment of the proposed benefits and the possible disadvantages. In any case, preparations are well under way.

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We are proud to announce that IGLUS Almaty Smart City Lab was inaugurated on 01.04.2022. This is a partnership between the City of Almaty, IGLUS and Kazakh-British Technical University. The lab will organize training programs and conduct research activities for the region. Stay tuned!

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