EDITORIAL

Urban aerial mobility: Reshaping the future of urban transportation

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Urbanization causes concentrated economic and social activities in urban areas, leading to high living standards, e.g., better economy, food, education, housing, healthcare, and entertainment. However, such a concentration comes at some costs, e.g., traffic congestion, pollution, overcrowding, and fast spread of disease, and among these, traffic congestion is a growing problem that is neutralizing the efficiency of urbanization. Indeed, traffic congestion leads to tremendous costs for large cities. For instance, INRIX estimated that the annual economic losses from traffic congestion in New York City and Los Angeles were $11.0 billion and $8.2 billion in 2019, respectively, and on average for each traveler, the annual wasted hours are 140 and 103, respectively.[1] Situations are much more serious for cities in China, e.g., Beijing and Shanghai.[2]

Plenty of attempts have been made to alleviate traffic congestion, spanning congestion pricing, public transportation promotion, traffic signal control, high-occupancy driving lanes, road space rationing, recent vehicle-sharing and ride-sharing models, etc.[3–5] However, all these cannot essentially solve the problem because the root cause is the imbalance between ever-growing travel demand and fixed traffic capacity. Any strategic planning of the transport infrastructure cannot be based on the worst-case demand, and the traffic capacity of any road network is always capped by its bottlenecks, e.g., intersections of roads. Travel demand has increased steadily over the years because of urbanization, but large cities in the world have limited space to expand road capacity. Thus, traffic congestion cannot be solved on the ground, on the traditional two-dimensional surface.

Since the road capacity on the ground cannot accommodate the travel demand, we turn to explore unused traffic capacity from the air, i.e., leveraging the three-dimensional cubic space. Such a solution has been recently revealed due to the rise of electric vertical-takeoff-and-landing (eVTOL) vehicles. Up to now, hundreds of eVTOL designs have been proposed. An eVTOL vehicle is an aircraft that uses electric power to hover, and it leverages designated helipads, called vertiports, to take off and land, exhibiting the following advantages compared with helicopters: less noise, a higher level of safety, more economical, and more environmentally friendly. These features suggest that eVTOLs shall become a key player in future urban mobility.

EVTOLs drive the era of urban aerial mobility (UAM), a more convenient, efficient, and sustainable urban commuting option, moving future mobility off the road and into the air. Although there are some uncertainties, UAM is moving much faster than most imagine. The FAA has developed the UAM Concept of Operations version 1. NASA has proposed several initiatives to help emerging UAM players. European Union Aviation Safety Agency (EASA) is also working on several pilot projects to make UAM a reality in Europe within 3–5 years. Joby Aviation is expecting to launch its commercial aerial ride-sharing service in the United States by 2024. Japan's government targeted 2023 as the starting date for commercial flying taxi services. EHang is close to eventual certification in China and will move to commercial operations in 2025. All these players endeavor to take the leading position in this emerging market.

For UAM, vehicle technologies are close to being mature, and all the deployment plans expect it in 3–5 years. Morgan Stanley predicted that UAM will ultimately grow to a $9 trillion market globally. For such a giant market, and a close timeline for the deployment, we should be well prepared. Below, we highlight some urgently needed developments or challenges for the early stage of UAM and finally point out the roadmap to the future path of UAM.

ENERGY AND POWER TECHNOLOGIES

Although eVTOL vehicle technologies are ready for deployment, energy and power technologies are still the main bottlenecks that significantly affect the efficiency of UAM systems. Based on the current technologies, most energy will be consumed during the climbing and descending processes, so flying distances are relatively short, and batteries will need to be frequently recharged, so the utilization of eVTOL fleets are relatively low. Thus, for eVTOLs, high-energy-density batteries are always the direction, and keeping the batteries small and light is also critical for flying. Meanwhile, the design of the power systems should follow the principle of creating as little noise as possible, since flying aircraft will create noise pollution in urban environments.

COMMUNICATION TECHNOLOGIES

Future urban mobility systems rely heavily on advanced wireless communications to enable high data rates and low latency transmissions for being "smart." For instance, the recent deployment of the fifth-generation (5G) mobile network led to a monumental application in connected and autonomous vehicles, so vehicles can efficiently communicate with control centers and nearby vehicles. Such a similar technology should also be in place for UAM. Traditional radar and radio communications, used for civil aviation, cannot be applied to low-altitude flying aircraft over dense urban space, and more importantly, they cannot fulfill the requirements of high data rates and low latency transmissions. The application of 5G to UAM is still an unverified and doubted solution considering that the main disadvantage of 5G is its limited coverage range, and the lack of encryption during the connection process makes 5G a vulnerable target for a cyberattack. Thus, UAM urgently calls for more developments in communication technologies, and a potential solution may be the combination of 5G and satellite communications, which is a recent conceptual mode for the next-generation mobile network, i.e., 6G.

URBAN AIR TRAFFIC SYSTEM

Civil aviation has complex air traffic control systems to ensure safe and efficient movements of aircraft in high-altitude space. A similar centralized system should also be built for the urban low-altitude space, but it comes with more challenges. The cruise altitude of civil aircraft is normally on the top of the troposphere or the bottom of the stratosphere, so the cruising is not affected by various weather conditions, except for the takeoff and landing phases. However, UAM, which happens in urban low-altitude spaces, is extremely vulnerable to complex urban weather conditions, e.g., heavy rain, snow, and wind, which inevitably bring the challenges of huge uncertainties to the systems. Meanwhile, the structure of the urban low-altitude space is very complex, since it is affected by buildings and terrain, and the volume of UAM traffic would be orders of magnitude larger than that of civil aviation. In addition, heavy UAM traffic flows will inevitably lead to noise pollution, so in addition to the improvements at the vehicle level, the corridors for urban air traffic should be away from residential areas. All these features should be considered while designing urban air traffic systems.

GROUND TRANSPORTATION COORDINATION

The success of the UAM relies on developments in the air and requires coordination on the ground. At the early stage of UAM, eVTOLs provide flying services between fixed vertiports, not for door-to-door commuting. We need ground vehicles to support the first-mile travels (from origins to departure vertiports) and the last-mile travels (from arrival vertiports to destinations). Thus, a seamless intermodal experience between ground travel and flying is very critical. Another major challenge, as shown in one of our studies, is that large-scale applications of UAM will attract much more ground travel demands near vertiports, which will inevitably make the areas of vertiports much more congested. All these concerns should be tackled beforehand to fully unlock the benefits or advantages of UAM, i.e., convenience, efficiency, and sustainability.

In addition to the above-discussed technological developments or challenges, it is worthwhile to mention some social science problems of UAM. UAM will be a completely new urban travel experience. Public perceptions about UAM will be the major drivers for its development, where we should focus not only on the

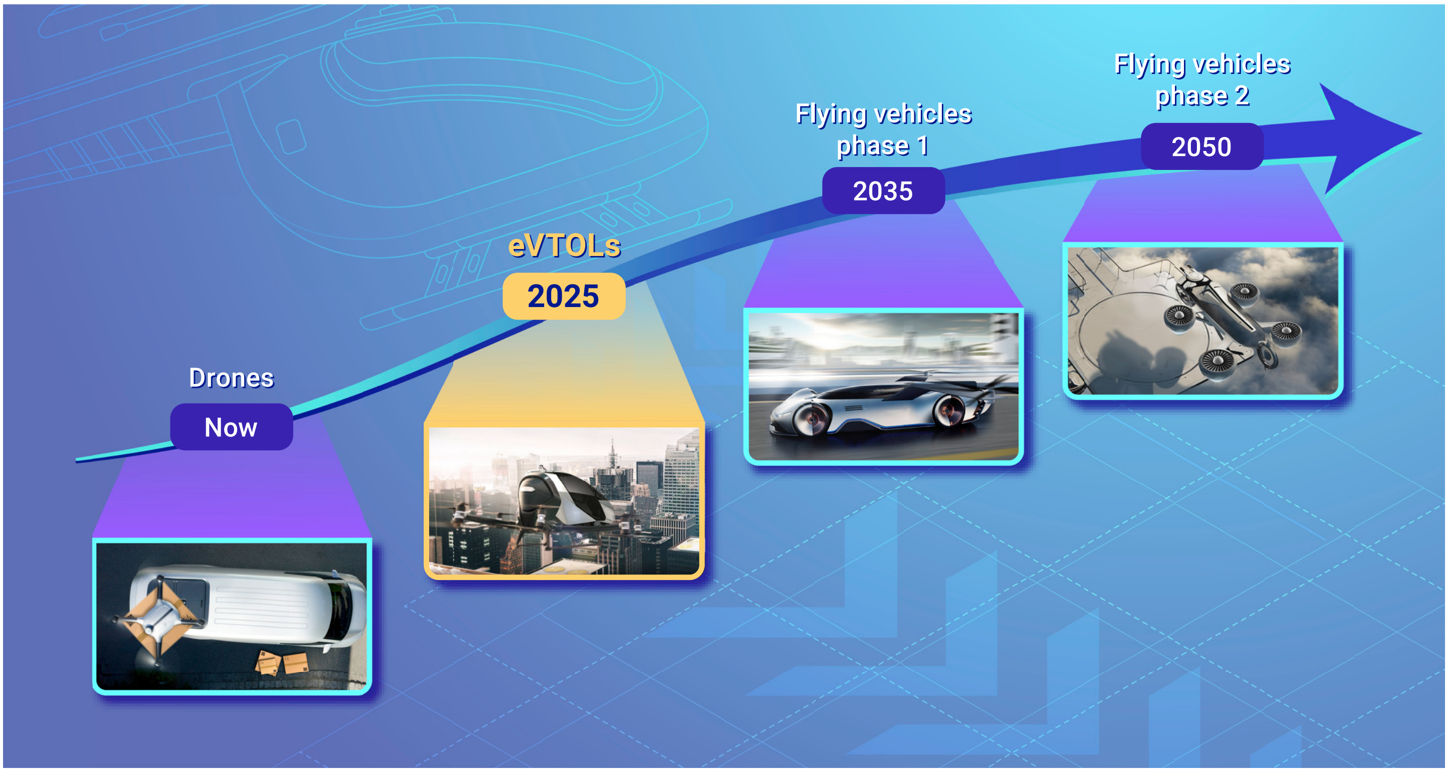

Figure 1. Roadmap to the future urban mobility

potential demand for UAM travel but also on the public concerns about UAM, especially on safety and privacy issues. Meanwhile, the social welfare of UAM and the impacts of UAM on cities are still unknown. All of these call for more research to fully understand UAM and more importantly to propose adaptation strategies.

ROADMAP TO THE FUTURE OF UAM

Traditional urban transportation relies heavily on road infrastructure, competing with other infrastructure in cities for limited land space, leading to the root cause of traffic congestion. Shifting from urban ground transportation to urban aerial transportation will free traffic capacity in the air. Drones have been recently used to deliver parcels, moving urban logistics to the air. In the years following, eVTOLs will be used to transport passengers, moving urban commuting to the air, albeit eVTOLs still leverage the infrastructure of vertiports for takeoff and landing, leading to first-mile and last-mile issues discussed above. Thus, we expect that the era of eVTOLs would still be a transition to future urban mobility, during which we can improve the capacity for commuting in rush hours in cities, but in this era, we cannot solve the problem of traffic congestion for good.

We are also expecting that the era of eVTOLs will ultimately evolve into the era of flying vehicles (Figure 1). At the beginning of that era, we may still need to leverage the existing road infrastructure for takeoff and landing, which would solve the problem incurred by eVTOLs in congested areas near vertiports. However, in this stage, we need to propose more advanced traffic engineering techniques to coordinate ground and flying vehicles, since they will interact during takeoff and landing. Eventually, we expect that flying vehicles will not need any infrastructure. In that case, we do not even need road infrastructure, which will free tremendous land space in cities and completely reshape cities.

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DECLARATION OF INTERESTS

The authors declare no competing interests.