Urban Air Mobility (UAM); Implementation & Feasibility

Michael Hakim[1]
Georgia Institute of Technology, Atlanta, Georgia, 30332, United States of America

Various factors are involved in the integration of UAM into current modes of transportation, including technical, safety, infrastructure, regulatory, and demand/acceptance aspects. The adjustment of each aspect is of the utmost importance to the successful implementation of UAM. Through thorough analyses of several research papers and literature on the many components of this matter, a comprehensive temporary verdict has been reached. Beginning with on-land infrastructure, the creation of vertiports requiring significant land area provides a more realistic boarding arrangement compared to the previously identified rooftops and helipads. Further into the technical aspect of UAM, creating vehicles that satisfy safety and noise regulations, provide comfort for passengers, and reduce travel time has resulted in the development of various propulsion arrangements and designs. These include a lift-fan design, a tilt-wing design, and a lift-and-cruise design, among a few others. The benefits and drawbacks of each layout are discussed. The operation of these aircraft will need to begin with a pilot before transitioning to full autonomy, which raises the question of how pilots will be trained. Not only this, the necessity of having an airspace capable of managing this air traffic has resulted in the development of U-space. Research on the arrangement of traffic within the U-space has concurred that having a layer organization results in the greatest efficiency and safety. These advancements led to the mandatory creation of simulation methods capable of replicating real-life situations as accurately as possible. An important aspect that is not widely considered is acceptance by the public. This involves the efficiency mentioned above along with safety for those on land and noise levels. Additionally, ease of access, waiting times, and cost impact the demand of the public. Together, the analyses of the numerous facets of UAM show that this mode of transportation may not replace current modes in the next decade or two and may take longer to become the main method used. Applications that are more achievable in the short term are the use of UAM in law enforcement, medical purposes, package delivery, etc. It may also take on a similar role to helicopters for news channels and for commercial purposes.

I. Introduction

With recent trends in sustainability and environmental preservation, the world has turned its eyes towards the main sources of pollution. One of those sources includes the transportation sector and everything involved, from the production of vehicles to the fueling of these vehicles. Along with this trend is the increasing demand for efficiency in all aspects of life. Together, these two have caused the field of aeronautics to develop the idea of urban air mobility. Urban air mobility (UAM) is airborne transportation through the use of VTOLs and eVTOLs. VTOLS and eVTOLs are vertical take-off and landing vehicles. The electric version of these is what is being studied as an option for a sustainable form of transportation. The timeline for when these vehicles can be integrated into the current transportation infrastructure has not been determined or discussed by anyone due to the various other factors involved in the implementation of these vehicles.

In regard to the factors involved, a pattern begins to arise as more factors are considered, and that pattern is that optimizing for one aspect involved leads to issues in almost every other aspect, as will be discussed. The first factor in need of attention is the design of the aircraft. This faces the same issue previously mentioned. The aircraft must be able to accommodate a certain number of people while also having a minimum range. To make sure the aircraft is efficient and sustainable, it must have a minimum speed and only rely on clean energy. Optimizing these two becomes a harder thing to accomplish when batteries are involved due to the sheer amount of mass needed for large enough batteries to be used. Not only this, adjusting design aspects such as the size of the rotor system or the

[1] Undergraduate Student, Aerospace Engineering, Student Member.

number of rotor systems makes way for the issue of sound pollution. On top of all of this come operating costs. Whether the public can afford this mode of transportation heavily impacts its application purposes in the future.

With these factors in mind, the infrastructure and regulations supporting these aircraft must be adjusted. Land infrastructure would be a good starting point. Part of the efficiency mission is ease of access. For passengers or cargo to be able to board these vehicles, vertiports must be created. However, the location, size, and methods of operation of these vertiports are dependent on the airspace regulations, rules, and locations decided upon.

While it may seem like the airspace integration is a trivial aspect of the process, this is, in fact, one of the most complicated parts. Current airspaces are not designed to accommodate these vehicles or the way they operate. Not only this, but the vehicles also require different certifications and safety regulations in order to even be able to fly in these airspaces. This all requires extra consideration if urban airspace is the route decided on for UAM

Finally, social acceptance in aspects such as noise pollution, privacy, and safety play an important part in the assimilation of UAM into the urban transportation landscape. Most current studies have managed to make developments in different areas of the field but have failed to address the remaining areas.

II. Designs

Design, as in any engineering feat, is a limiting factor. The many constraints and requirements imposed make it essential that every aspect of the design be optimized in great depth. In UAM, there are multiple configurations taken into consideration by the many different companies involved. These can be broken down into two categories: rotary-wing-cruise and fixed-wing-cruise [6]. Within the first are the rotary wing and the lift fan [6]. Within the latter are lift and cruise, tilt wing/prop, and tail sitter [6]. What is common among all of these configurations is their use of multiple forms of electric propulsion.

The first category, rotary-wing-cruise, involves aircraft that rely solely on rotating wings or fans to produce lift. This design choice gives these types of vehicles great performance when it comes to vertical lift and hovering. However, these setups suffer aerodynamically, speed-wise, and in regard to sound production. The lift-fan setup allows for a smaller aircraft but increases the sound issue.

The second category, on the other hand, provides a slightly more intuitive solution that, if implemented correctly, could address the aerodynamic, speed, and range issues while also keeping the sound level relatively low. The lift cruise aircraft make use of a rotary system for take-off and landing. This gives the vehicle the ability to take off from a wide variety of places. When airborne, the aircraft can make use of the fixed-wing part of the aircraft for the remainder of the flight until descent is required. At that point, the aircraft would use its rotary system to land. The tilt-wing/prop type of aircraft uses a rotary system for takeoff, and once it reaches altitude, the rotary system changes its axis alignment so that it can propel the aircraft forward. This configuration causes extra complexity that may be subject to more maintenance issues. Lastly, the tail-sitter configuration performs as its name implies. This setup causes issues with passengers, as being in this orientation may not be suitable for everyone. This is an aspect that conflicts with social acceptance, as will be discussed later on in the paper.

The layouts discussed, while innovative, need to take into account battery sizes and efficiency figures in order to accomplish the sustainability goals. Additionally, maneuverability needs to be considered. The different capabilities and sizes of the aircraft, along with the way they interact and communicate with each other, impact the design of the airspace(s) they will occupy. For example, the different sensor systems on board each aircraft, such as those required for object avoidance or radar, need to be considered, as these also affect the airspace layouts. The range of accuracy of these tools in each aircraft is also important. Furthermore, the aircraft need to be versatile in regard to what is contained in their payloads. Whether it be people, packages, medical services, or anything else, the aircraft needs to have easy adjustments, as do most other forms of transportation.

III. Regulations and Infrastructure

A. On-Land Infrastructure

In order to make these UAM vehicles accessible to the public and to anyone who requires their services, on-land infrastructure must be built. Some speculate that 'vertiports' can just be rooftops, helipads, or other existing infrastructure. Others speculate that this may not be feasible and that the vertiports may need their own decently sized landmasses to accommodate their traffic. When planning on-land infrastructure, aircraft size must be taken into consideration, along with ways to refuel/charge the vehicles, ease of access by people, and ease of exit. The location of these vertiports must also be decided based on where the most vertiport traffic would be and where the highest demand for these aircraft would be. Not much land infrastructure is necessary, but the task of managing the aircraft in these vertiports may result in the aircraft joining airports. This will then impact the airspace and other regulations necessary for the aircraft to operate.

B. Airspace

Airspace is the factor that is impacted by almost every other choice made in the UAM field. Many see that UAM should take place within cities and at altitudes that do not exceed the heights of the tallest buildings. This poses quite a few problems. Primarily, the ability of aircraft to avoid crashing into anything. A secondary issue that will be reviewed later is privacy. When determining how the airspace should be divided, object avoidance is of the utmost importance. This calls for a way to separate the vehicles. The proposed methods are fixed separation, dynamic separation, or no standard separation [2].

What is meant by fixed separation is pre-determined separation distances between all aircraft, regardless of size, speed, and capability (maneuverability). Dynamic separation is similar, but instead of being the same for all, it is dependent on the capabilities of each aircraft. For example, more capable aircraft may require small separation distances. Finally, having no standard separation implies that each aircraft is at the mercy of instruments and must make sure it avoids other aircraft and buildings. While this may seem more efficient, it does pose more safety concerns than the other alternatives.

Avoiding collisions can be done in other ways than just sensing an obstacle and moving. Having pre-determined plans or relying on data collected by other aircraft can also work. When operating in an urban environment, these aircraft need to be able to cope with the wind generated between buildings and the different weather conditions. These can affect the efficiency, performance, and safety level of these aircraft.

The decision-making methods for object avoidance can either be human-operated, autonomous, or a mix of both. Whichever option is decided upon will also be the option used for navigation. If autonomy is the option chosen, connectivity between each vehicle is required. This communication must be fast and accurate due to the speeds and circumstances the aircraft find themselves in. Researchers believe that in order for this to be feasible, connectivity capabilities need to improve massively. These researchers believe that maybe with the development of 6G, the desired level of connectivity will be achieved [1]. Not only this, the AI decision-making algorithms will need great improvements to reach a satisfactory level.

On the other hand, having human control requires that these individuals be trained in the operation of these vehicles. This then alters the design of the aircraft and, as will be discussed later, the regulations and certification.

With these factors in mind, different ideas of where and how the airspace(s) will operate have been proposed. For example, NASA has proposed an airspace where the airspace is broken up into three sections [2]. The sections vary from having many restrictions to having very few restrictions [2]. Other ideas include having a corridor in the sky that makes it easier for aircraft to operate in busy areas. Some believe that by providing better routes for more advanced aircraft, less capable aircraft will have the motivation to improve their aircraft, thus improving the airspace. The idea of a U-space has also been mentioned. In this U-space, each aircraft must have identification. The airspace is then split up into 3 categories that have different levels of identification and training required [2]. Having layers is another option, where each layer serves different types of aircraft. Lastly, the idea of allowing free flight has been talked about. While this option may reduce costs due to shorter routes, it also decreases safety levels and thus will rely more heavily on technology to avoid obstacles or other aircraft. These are just a few of the many different ideas researchers have come up with. However, a common trend among these is not addressing a few or many of the other factors discussed above.

C. Regulations and Certification

As mentioned above, if autonomous decision-making is not employed and instead human control is used, then training is required. This opens the door for the type of training these pilots will need and how to guarantee that they are certified.

Certification is not just limited to pilots. The aircraft will need to pass different tests to make sure they acquire the certification they need to operate. While all of the certifications needed for operation have not been decided yet, a few categories have been identified. The first is the safety category. To become certified in this aspect, an aircraft must be able to operate after one or more failures have occurred in its mechanisms. This also means that the aircraft must be able to travel a minimum distance after these failures have occurred to ensure a safe recovery. Another category that has been decided on is sound level. The types of propulsion systems used, while effective for their purpose, do not accommodate sound regulations or the comfort of people outside and sometimes inside the aircraft. In order for the UAM to successfully integrate into the urban landscape, each aircraft must be limited in its sound production levels. This poses another constraint on the overall design. Additionally, the instruments within the aircraft must perform with certain accuracies in order to be considered fit for flight. Lastly, the impact of the aircraft on the environment must be regulated; otherwise, the purpose of these aircraft would be lost. This entails monitoring electricity consumption for the range flown. This also involves the use of environmentally friendly materials in production. Overall, the levels of regulations and certification for all aspects of UAM are still up for debate and improvement.

IV. Social Acceptance

Finally, acceptance by the public is the remaining step in the assimilation of UAM into the modern world. Social acceptance involves privacy concerns, cost, accessibility, and belief in safety. Privacy concerns arise due to the possibility of the flight of these vehicles taking place between buildings and urban areas. While drones already intrude on people's privacy, having larger aircraft carrying people may cause presidents to feel more vulnerable. Not only this, as mentioned several times before, the public may not accept the noise pollution created by these aircraft unless it is at a level that may or may not be unattainable.

Costs raise another concern. If the intention for UAM is to serve as another form of public transportation, then the cost to board has to be low. However, if the intention is for travel, like with planes over short distances, then cost may not be as big of a concern. Similar to cost, accessibility to the public is a part of social acceptance. Being able to board the aircraft quickly and easily will make people more willing to use this form of transportation. Unlike regular aircraft, security clearance and all of the checks for people to board these aircraft will have to be quick to keep with the efficient theme. This causes a slight safety concern, along with the general safety concerns people have with such aircraft. Regulations and certifications aid in comforting the public and ensuring their safety.

V. Conclusion

Overall, the field of UAM is rapidly expanding and developing. As a result, there are a plethora of details in need of modification and optimization. There is added complexity in this process as each part, when changed, affects another part. Not only this, but lots of the technology that researchers believe will be necessary for UAM to function has not been developed yet or is too advanced for what is currently available. Altogether, the field of UAM may not be a feasible option for mass transportation in the near future. UAM may replace niche areas currently operated by on-land vehicles, but the replacement of public transportation or even addition to that is still something for the far future.

References

[1] Ansari, S., Taha, A., Dashtipour, K., Sambo, Y., Abbasi, Q. H., and Imran, M. A., "Urban Air Mobility – A 6G Use Case?" *Frontiers in Communications and Networks* [online journal], Vol. 2, 10.3389/frcmn.2021.729767 [retrieved 28 February 2024].

[2] Bauranov, A., and Rakas, J., "Designing Airspace for Urban Air Mobility: A Review of Concepts and Approaches," Progress in Aerosapce Sciences [online journal], Vol. 125, 10.1016/j.paerosci.2021.10072 [retrieved 22 February 2024].

[3] CİZRELİOĞULLARI, M. N., BARUT, P., and IMANOV, T., "FUTURE AIR TRANSPORTATION RAMIFICATION: URBAN AIR MOBILITY (UAM) CONCEPT: URBAN AIR MOBILITY," *Prizren Social Science Journal* [online journal], Vol. 6, No. 2, 10.32936/pssj.v6i2.335 [retrieved 27 February 2024].

[4] Schuchardt, B. I., Geister, D., Lüken, T., Knabe, F., Metz, I. C., Peinecke, N., and Schweiger, K., "Air Traffic Management as a Vital Part of Urban Air Mobility—A Review of DLR's Research Work from 1995 to 2022," *Aerospace* [online journal], Vol. 10, No. 1, 10.3390/aerospace10010081 [retrieved 23 February 2024].

[5] Song, K., "Optimal Vertiport Airspace and Approach Control Strategy for Urban Air Mobility (UAM)," *Sustainability* [online journal], Vol. 15, No. 1, 10.3390/su15010437 [retrieved 1 March 2024].

[6] Straubinger, A., Rothfeld, R., Shamiyeh, M., Büchter, K., Kaiser, J., and Plötner, K. O., "An Overview of Current Research and Developments in Urban Air Mobility – Setting the Scene for UAM Introduction," Journal of Air Transport Management [online journal], Vol. 87, 10.1016/j.jairtraman.2020.101852 [retrieved 26 February 2024].