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FUTURE AIR TRANSPORTATION RAMIFICATION: URBAN AIR MOBILITY (UAM) CONCEPT

Mehmet Necati CIZRELIOĞULLARI [1*]

Pınar BARUT [2]

Tapdig İMANOV [3]

1 *Cyprus Science University, Faculty of Tourism, Department of Tourism and Hotel Management, mehmetcizreliogullar@csu.edu.tr*

**Correspondent Author.*

2 *Cyprus Science University, Vocational School of Applied Sciences, Department of Tourist Guidance, pinarbarut@csu.edu.tr*

3 *Cyprus Science University, Vocational School of Aviation, Department of Civil Aviation Cabin Services, tveyranimanov@csu.edu.tr*

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Abstract

Urban Air Mobility (UAM) is a new concept offered for solving urban transportation system problems, contributing to reducing traffic congestion, atmospheric pollution and mobility around metropolitan areas which is progressively an evolved aviation market. Facing the evolved dynamics in the airspace and on the ground, developed new technologies are able to withstand against destroy transportation infrastructures of the big cities, making it necessary to develop UAM services in the megapolises and regional transportation sector. Based on new technologies and modern business approaches, applying the next generation aviation infrastructure makes it capable of setting up a novel air traffic within the urban environment. This case study aims to explore the urban air transport advantages, particularly adoption of UAM, which might be an alternative next generation air transportation system. Referring to the collected operational data and design performances of the UAM, in this paper, we will try to describe a multi approach studying differences between traditional aviation transportation and UAM operation. The first step of the study consists of defining an airspace classification for UAM mission and use of applicable requirements for air navigation service providers and second part of the study describes performing UAM infrastructure and design of vertiports necessary for vertical take-off and landing (VTOL) vehicles. Detailed design specification is not included in this study but limited characteristics are indicated according to the VTOL manufacturer that are obtained from the test results. As far as VTOL vehicles have not started their mission yet, the UAM operators are at the stage of development to set up their future operation. The expected trend provides justifiable assumptions of the necessity of establishing the new transportation ramification within the aviation industry, upon transforming existing business activities and regulations.

1. Introduction

The concept of Urban Air Mobility (UAM) is a collaborative idea proposed by Aviation (FAA) and Space Administration (NASA) of the USA that enables transportation of passengers and cargo by the air with new electric air vehicles in various geographies within the urban environment to set up brand-new air transportation nodes (Bradford, 2022). The high density of the urban population and intensive increase of privately used ground transportation vehicles has become traffic congestion in metropolitan cities (Koźlak and Wach, 2018; Rajendran and Srinivas, 2020). Nowadays, large-scale transportation systems with their complexity and high maintenance costs need a comprehensive approach for proper planning and optimization of traffic operation and control, the whole transportation system, to solve the congestion problem while securing the environment and reducing greenhouse emissions (Teodorović and Janić, 2017). Particularly, engineering for air transportation includes new concepts of terminal design for passenger and freight services, construction of runways and landing surfaces, and installation of innovative navigation aids to provide safety for flights and route planning challenges (Barmpounakis et al., 2016). The demand for light and fuel-efficient aircraft with electronic controls increases the necessity for a widened conventional structure of the air transportation system adding the UAM operation in the near future in order to remove the traffic congestion problems in large cities. Urban air transportation is not the first disruptive technology in air transportation, therefore in case of successful application of UAM operation, the urban transportation system will be totally changed (Garrow et al., 2021). The concept of urban air transportation has entered into the service using helicopters by Los Angeles and New York Airways since 1947 during over 20 years of operations, carrying passengers and mail around the Los Angeles region as well as between Manhattan connecting 3 major airports in New York City. In recent years, there has been significant design progress in the urban air vehicles (UAV) by carrying out scientific analysis of the feasibility of using electric Vertical Take-Off and Landing (eVTOL) aircraft for air transportation purposes, and defining the future operation and ground infrastructure (Thipphavong et al., 2018).

Thanks to these development successes, worldwide logistics, and aviation companies are vying to take potentially more market share with the use of Urban Air Mobility for delivery cargo, goods, and passengers which are expected to launch in the near future. The famous aircraft manufacturer Airbus (EU), Boeing, Sikorsky and Kitty Hawk (USA), Lilium (Germany), and E-Hang (China) started actively building up electric UAV design and development, years later followed by Bell, Joby Aviation, and Uber (USA) Embraer (Brazilian), Rolls-Royce (UK), and Toyota (Japan) have joined eVTOL production of the urban air transport market, and currently on the way to conduct flight tests process in countries across the world. Thanks to the operation of offered full-electric vertical take-off and landing aircraft, urban air service is able to introduce safe, quicker, and trustworthy arms of the air transportation system (Hawkins, 2020; Rajendran and Srinivas, 2020). Collectively, there are striving different design concepts of eVTOL aircraft with different technical specifications and characteristics that have been invested in more than 2 Billion USD. In 2020, there would be produced a total of 260 aircraft with different types of eVTOL across large variations in the seat numbers, distance and speed (see Figure 1) (Sherman, 2020; Garrow et al., 2021).

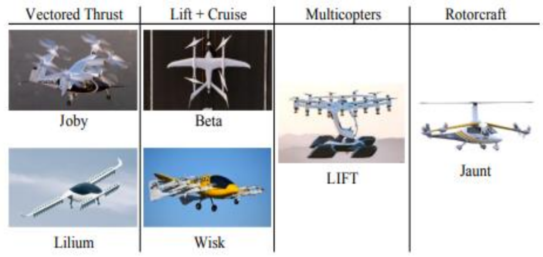

Figure 1. Different UAM aircraft design type. (Garrow et al, 2021)

Taking into attention the multiple design models and the different sizes of the eVTOL aircraft, international aviation organizations and government agencies are necessary to issue appropriate regulations, standards, and procedures for coordination of urban air mobility transportation systems (Preis and Hormung, 2022). Here at this point, it is taken into account of take-off and landing weight, speed, maneuverability, automation, navigation, surveillance, and communication. To provide safe and efficient use, the airspace capabilities require a standardized set of procedures and rules that ensure flight safety (Prevot et al., 2016). There is currently the elaboration of a modern style of air transportation ramification, so-called urban air mobility, driven by real market demand in the future. Most of the preceding studies with regard to the UAM operation have considered using traditional air transportation system (Niklaß et al., 2020; Straubinger et al., 2020; Tuchen, 2020). In this study, it has been tried to establish a completely separate system serving urban air mobility which classifies the relevant details of air traffic control management and creates the appropriate infrastructure for UAM vehicles. However, operational concepts and procedures are not yet approved by the legal authorities while traditional air transportation systems already use existing NextGen and Single European Sky's ATM Research (SESAR) harmonization concepts. Within the context of this research, it is important to identify and evaluate various key performances and main principles of city air operation and to analyse its overall technical and operational data for feasibility as an additional arm of the air transportation system.

Within the milieu of this study, the following questions will stand as the research questions:

- What is the environmental impact of using UAM air transport?
- What are the applicable methods for UAM operation?

2. Literature Review

2.1. UAV Characteristics

Urban Air Mobility (UAM) is considered as the use of unmanned air vehicles (UAV) in big metropolitan areas commonly perceived as inner-city air taxis, destined for various purposes and special operations including passenger and cargo transportation in urban environments piloted or remotely piloted functions. Besides, UAVs also include the associated infrastructure with air and ground services ensuring flight safety (Gollnick et al., 2020). UAM vehicle take-off weights are varied in a range of between 350-900 kg with maximum indications of 2500 kg, while payload range is estimated between 200-400 kg which rises up to 1000 kg depending on aircraft size in Figure 2 (Lin and Hung, 2011; Yinka-Banjo and Ajayi, 2019; Gollnick et al., 2020).

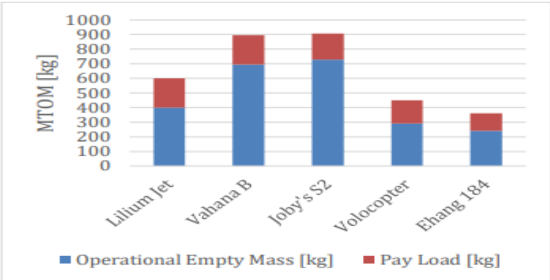

Figure 2. Average take-off weights of UAVs. (Yinka-Banjo and Ajayi, 2019)

Referring to the analysis of 6 methods conducted by Reis (2020) for conventional propulsion twin-engine UAV carrying 4 passengers and freight with a payload up to 200-600 kg consisting of average maximum take-off weight (MTOW) is 1434 kg. Given the variety of UAM aircraft and the design concept, determining specific dimensions (width, length, height) is time-consuming and ambiguous due to the lack of a wing, a keel of these aircraft. But, the operational characteristics of each of them are determined by the manufacturers indicating the take-off weight, passenger capacity, speed, and flight range. Numerous authors' publications have provided various UAM aircraft data sheets and features related to different types of eVTOLs. Most popular vectored thrust aircraft such as a Lilium Jet, Airbus A3 Vahana, Bell Nexus 4EX, and Joby S4 can use their powers either for lifting or cruise operation. As stated by Sherman (2020), vectored thrust design is expected to become an effective eVTOL vehicle but the disadvantage consists of complexity because of airframe design which is unsafe during the transitional stage from vertical flight position to horizontal attitude.

Another popular aircraft category; Aurora Flight Sciences Pegasus, EmbraerX Eve, and Wisk Cora stand currently in the design process in two configurations of autonomous thrusters used for Lift+Cruise purposes which is the first set used for vertical take-off and a secondary kit is used for cruise only. Volocopter VC200, the eHang 216, and the ultralight Lift Aircraft Hexa are wingless multi-copter families, designed to use two functions as a vertical lift-take-off and cruise flight. Rotorcraft design types such as a Jaunt Air Mobility gyrocopter and the Pal-V Pioneer flying cars are another area being considered for the UAM concept that includes electric helicopters and novel autogyros. Overall, this eVTOL are designed in different configurations in passenger seat numbers, cruise velocity, and distance in Table 1 (Garrow et al., 2021).

Table 1. Characteristics of e VTOL

e-VTOL types	**Seat**	**Speed, km/h**	**Range, km**
Lilium Jet	2-5	300	300
Airbus A3 Vahana	1	190	50
Bell Nexus 4EX	5	240	240
Joby S4	5	322	240
Aurora-Pegasus	2	180	80
EmbraerX Eve	5	N/A	N/A
Wisk Cora	2	161	40
Volocopter VC200	2	80-100	30
EHang 216	1	130	35
Lift Aircraft Hexa	1	96	20-25
Jaunt Air Mobility	5	280	N/A
Pal-V Pioneer	2	160-180	400-482

The flight range on conventional aircraft is determined through depending on the take-off weight and the range of the desired flight on which the required amount of fuel consumption is calculated. While for eVTOL aircraft, the flight range is determined by based on the electrical storage capacity for particular air transport, and it is important to note that the performance of designed batteries plays the main role in the definition of specific flight range in urban environments (Preris, 2021).

2.2. UAM Airspace Classification

For Urban Air Transportation (UAT) operation in urban airspace, the current crucial task is still to set up Air Traffic Management problems. Airspace classification has been created by ICAO that identifies controlled (A, B, C, D, E) and uncontrolled (F, G) areas. Standardization of the airspace designated with seven class operations is defined according to flight rules and services rendered by air traffic control in Figure 3 (Bauranov and Rakas, 2021).

Figure 3. ICAO Airspace classification. (Rattanagraikanakorn et al., 2018)

Except for class G, all aircrafts operated in controlled airspace and within every airspace class managed by air traffic control management, providing separation support, trajectory definition, and upon transition level. Airspace-based flights in higher altitudes are not suitable for the VTOL aircraft because intracity flights are carried on below or equal to 1000 feet. For the integration of UAM operations in classes E, F, and G for existing ATC systems, it stays necessary to increase airspace capacity and separation policy to be able to control all operations within specified classes (Thipphavong et al., 2018; Bauranov and Rakas, 2021).

Today, the NextGen program proposed by the FAA is in progress to apply modern technologies to enhance the current performance and reliability of airspace management and to increase automation capabilities. Collaborative work between NASA and FAA aims to develop new methods for ATC management to improve air traffic capacity, enhance trajectory efficiency, mitigation of air congestion, and constraint management. The NextGen concept considers the development and implementation of Urban Air System (UAS) and Urban Traffic Management (UTM) which will provide more automated traffic management remotely piloted Urban Air Vehicles to follow air traffic separation minimum of the urban aircraft as well as to ensure safety requirements (Bharadwaj et al., 2019; Lundberg et al., 2018). The UAV automation system provides self-separation and collision avoidance safety by applying onboard surveillance and program processing algorithms for threat detection and resolution. The future system will allow users desired routes, use of the applicable speed and related altitude, and better integrated operational capabilities (Khan et al., 2017).

2.3. UAM Ground Support Structure

The Growth of the UAM industry is dependent on its technical development and commercial eligibility which contributes to the certification process and production ramp-up in the future. The commercial concept requires a building of ground service infrastructure for supporting UAM providers and operators in Figure 4.

Figure 4. UAM infrastructure requirement (Hader, 2022)

Increasing demand of UAM inner-city air transportation in the near future will become a reality among the population in metropolitan areas which would require development of ground infrastructure to serve the passenger and cargo particularly building of UAM terminals. As urban air transportation vehicles are fully or hybrid electric with vertical take-off and landing performances, the ground surface service point is commonly referred to vertiports which is shown as follows in Figure 5 (Preris and Hornung, 2022).

Figure 5. e-VTOL vertiports for UAM service (Crumley, 2022)

The essential ground structures, physical and facilities needed for UAM aircraft are landing pads in different metropolitan areas ensuring take-off and landing, a central passenger traffic hub, and the formation of digital infrastructure for booking platform and set of service networks (Rodriguez, 2021). According to Gollnick study's (2020) which stands based on methodology and results of the sustainable conception of urban air mobility (UAM), it is assumed that the use of airspace for urban flight operation to be completely separate from commercial aviation used airspace operation with Air Traffic Control, interfaces and terminal infrastructures.

3. Result and Discussion

A significant difference between urban air transport and commercial aviation is clearly expressed in the diversity of the philosophy of air transportation and the organization of ground infrastructure as well as according to the performance of aircrafts particularly relating to cruising speed, flight altitude, commercial payload, travel distance, and the most notable manned and unmanned concept in Table 2.

Table 2. Comparative characteristics Traditional Air Transportation System and UAM

	Range, KM	Altitude FT	Speed km/h	Power	Capacity	Noise	CO2
Traditional Air Transportation	Short: 1000 Medium: 3000 Long: 11000	Up to 40000	500-950	Turbo Fan Turbo Jet	50-550	80-100 dB	3%
UAM Air Transportation	Intracity: up to 100 Intercity: 100-400	500-1000 Up to 5000	100-300	Electricit y	1-5	Noiseless	0

At first perceiving air transportation always focuses on aircraft, while the new transportation mode UAM is complex of flying vehicles ultimately solving the urban traffic congestion problems. Compared to traditional airplanes powered by jet engines using fossil fuel, which are able to conduct long-distance flights, UAM is an electric vehicle adapted to battery powers and equipped with several rotors purposed for intercity and intracity flights at low altitudes.

The usage of UAM air transportation is considered to reduce the impact on the environment, such as the elimination of greenhouse gasses, air pollution and noise mitigation which is ecological sustainability that significantly overcomes traditional airplanes (Bian et al.,2021). Currently, when UAM is in the process of designing and testing stage, relevant procedures and standards are under development by legal institutions, aviation authorities as well as the certification and property rights of UAM operators are still a sensitive issue. As a novel mode of air transportation, UAM might be a brand-new aviation industry with distinctive features regarding procedures for regulations, approvals, operations, infrastructures, maintenance, and certification (Rizzi and Rizzi, 2022). Besides, as a new branch together with innovative applications and high technology design concepts, relevant aviation administration needs to ensure the quality and flight safety of UAM operation referring to issued regulations. The concept of flying within urban areas is based on the idea of VTOL which eliminates the necessity of the long runway and also makes it inevitable to design new infrastructure including vertiports and appropriate passenger terminals including energy/charging provision, storage, and maintenance.

Unlike the traditional logistic and freight forwarder distribution providers, UAM is a better choice for e-commerce since it can offer the usage of communication network infrastructure using 5G access for faster delivery and shipment. Regional and national airspace air navigation service is the main attribute of UAM operation in urban areas which requires both national and international rule frameworks for common development concepts. Taking into account the future increasing volume of air traffic used by UAM operations, it must completely be separated and controlled from traditional air traffic in Figure 6.

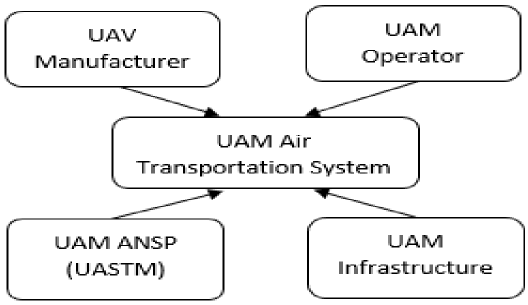

Figure 6. UAM Air Transportation System

The European Aviation Safety Agency (EASA) has already offered a community to discuss and suggest an acceptable regulatory-legal structure for enabling safe operation over cities at low altitudes for UAM aircraft with vertical take-off and landing (VTOL), which will help public acceptance of modern air transportation systems. Involved countries continue the collaborative communication via ICAO to provide the maximum applicable level of similarity of the regulations, standards, and procedures concerning urban air vehicles (UA) for easement and perfection air navigation services. ICAO closely works with Contracted Civil Aviation Authorities (CAA) in 193 countries, aviation industry stakeholders, and relevant organizations for the elaboration of Standards and Recommended Practices (SARPs) for unmanned aviation. The implemented Remotely Piloted Aircraft Systems Panel (RPASP) is intended for Instrument Flight Rules operations in controlled airspace and airports. The main attention of the RPASP is emphasized on the airworthiness of vehicles, UAM provider certification, ATC Management, 2-way Communication-Command and Control System (C2 Link), Detect and Avoid (DAD) policy, safe operation, and overall protection (Malaud, 2019). Initially, the UAM ecosystem can be used in similarity to the being helicopter operation rules by applying landing surface, routes, and air navigation services supported by ATC organizations. FAA is currently working on the projects to identify UAM infrastructure for air traffic management procedures at low altitude flights among urban environments and the development of future vertiport standards. Almost this year FAA has issued interim guidance for facility requirements VTOL, to support early operation (FAA, 2022). In order to ensure safety of air vehicles, maintenance is a key area which is necessary to explore and apply for safe operation. A windfall of materials concerning full UAM specification and detailed system description in the maintenance manual as well as the maintenance program is not yet accessible for the researchers to predict the maintenance concept of UAV. However, new generation aircrafts including UAV are designed using a variety of digital sensors and devices which generate huge amounts of data (Tsach et al., 2007). In order to leverage those data, new maintenance challenge demand is necessary to make it reliable, efficient and optimal to reduce maintenance cost. In this context, a new maintenance concept is foreseen via using Artificial Intelligence elements such as Digital Twin, Internet of Thing, Machine Learning etc (Alexopoulos et al., 2020).

Taking into account average accepted flight levels at 5000 ft, it is acknowledged that proposed UAM flight operation and current air traffic management do not reflect all metropolitan areas in an ideal manner. There are existing cities that are developed around unstable geographic locations with elevations, mountains and water bodies which constrains urban flight operations. Future developments and appropriate operation requirements besides regulations of the authorities are able to solve such restrictions.

4. Conclusions

UAM is the latest aerial transportation system of the 21st century in an urban environment ensuring passenger and cargo transportation. Thanks to its new design concept with propulsion system, automation, and vertical take-off and landing capabilities, it makes a huge contribution to zero-emission policy, noiseless and safe operation, as well as significantly cost-efficient infrastructure requirements. Essential weakness eVTOL vehicles is low energy density of the battery which is enough for hundreds of kilometers flight routes. In order to ensure long range operation, development of new energy technologies is still needed.

Safety for conventional aircrafts, designed and operated within current aviation transportation system is provided by existing rules and regulations issued by international aviation authorities. Principal aviation organization’s ICAO, EASA, FAA and State Civil Aviation Authorities working on amendments, for adaptation of these standards for eVTOL aircrafts and associated with pilot training, maintenance staff qualification, air traffic management and ground facility requirements. However, additional specific new relevant regulatory documents are considered for eVTOL functions to meet safety standards. Except safety issues that impact the development of urban air mobility is public acceptance of the new air transportation system in urban areas, intensive entry to service which is expected from 2025. Formation of the UAM infrastructure will be significantly easier then ground transportation and railways, which do not have need of road and track lay downs. High-pitched scale new technologies implemented within eVTOL transportation system contributes successfully to the growth of this industry and also the activities of the involved companies, service providers gain momentum in this sphere.

The study shows the urban air transport advantages particularly the adoption of UAM which might be an alternative next generation air transportation system. Referring to the collected operational data and design performances of the UAM, it has been described as multi approach studying differences traditional aviation transportation and UAM operation. The study consists of defining an airspace classification for UAM mission and use of applicable requirements for air navigation service providers as well as performing UAM infrastructure and design of vertiports necessary part of the VTOL vehicles. In spite of detailed design specification not included in this study, however limited characteristics are indicated according to the VTOL manufacturer obtained from the test results. To the degree that VTOL vehicles have not begun their mission so far, the UAM operators stand at the advancement stage to arrange their forthcoming operation. The outcome of the study offers reasonable expectations of the need of founding the fresh transportation implication within the aviation business upon converting prevailing corporate actions and rules.

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