

The Aerial Transport in Urban Areas: Towards the Era of Manned VTOL-AV

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Abstract. The use of manned drones as an urban transport mean is related with many parameters. Those parameters must create a functional multilevel system in order to a such "manned drone use" to be considered as a key factor for the urban air mobility. Such parameters could be (but not limited to): technological, infrastructure for landing and take-off in cities, legal framework, safety issues, personal data, navigation methods, privacy problems, etc. This article analyzes those key factors, after a short "historical" presentation of "the manned drones" idea. A literature review of the models created until now is also included. In addition, an innovative and original idea for the realization of a such vehicle is also presented in our work together with a short analysis of possible impacts of the manned drones on the urban transport in a smart city.

Keywords: Urban Aerial Transport · Manned VTOL (drones) · MVTOL-AV · Urban Verti-Port

1 Introduction

Drones, named also with the acronym UAV (Unmanned Aerial Vehicles) are in use our days in many scientific and professional areas having multiple roles and applications. Agriculture, cartography, research and rescue missions, environmental protection, infrastructure inspection is just a few of the thematic areas in which are used. Last years a new aerial vehicle (AV) category appeared, the so-called Manned Vertical Take off and Landing Aerial Vehicle (MVTOL-AV). Several other names also exist for this category of AV. The MVTOL-AV make possible the transportation of passengers like a helicopter or a small plane. A few proposals of such models exist already as prototypes while a few are in commercial production. MVTOL-AV could be a solution of the aerial mobility for the traffic problems in mega cities. The research goals are presenting in the following paragraphs.

In paragraph two we present the initial ideas in which are based such vehicles and an analytical list of the most important existed models of MVTOL-AV. Paragraph three

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summarizes the frame of the project SAV^2 (Socrates Aerial Vtol Vehicle) [1]. Paragraph four analyzes the parameters related with the MVTOL-AV and their fly in the cities, such as legal framework, privacy, necessary infrastructure, noise, safety matters etc. Paragraph five presents our conclusions.

2 Manned VTOL Aerial Vehicle (MVTOL-AV): Initial Ideas and Actual Efforts

European Commission claims that drones used for the transport of people and goods will be particularly oriented to the achievement of publicly accessible services, thus creating benefits for citizens and local communities [2]. Nevertheless, initial ideas for manned drones started in films and comics (Spirou and Fantasio, Metropolis, Oblivion, Elysium, Avatar, Edge of Tomorrow etc.) (see Fig. 1).

Our days different car/airplanes and other companies are creating and testing new prototypes MVTOL-AV. Taxi companies are installing drone stations (vertiports) or buy building rooftops for them. A number of construction companies are specialized on the Vertiport installation.

At its second annual summit in Los Angeles in 2018, Uber presented the six Uber Skyports prototypes and its latest aircraft designs while choosing Melbourne as the first non-U.S. location for its aerial ridesharing service and commercial operations in the next years [3]. Built near music halls and stadiums, the ports are near crowd-attracting city spots. Each port can handle over 4.000 passengers per hour in a three-acre footprint and meet noise, environmental, and eVTOL charging station regulations [4].



Fig. 1. A: Comic SPIROU AND FANTASIO (1935 Belgium) [5], B: Movie METROPOLIS 1927 Fritz Lang [6]

The European Commission (EC), in its smart and sustainable mobility strategy, which was adopted in December 2020, underlined its support for the deployment of drones.

The use of drones in urban areas was also highlighted in the Commission's new urban mobility framework, which was adopted in December 2021. Although the EC mobility strategy does not specifically refer to the MVTOL-AV, such aerial vehicles could be integrated in the same strategically frame. On 29 November 2022, the European Commission has subsequently adopted its Drone Strategy 2.0 for a smart and sustainable unmanned aircraft eco-system in Europe.

The MVTOL-AV for passengers and cargo transportation may be soon a central fundamental urban transport mean. In the near future the rapid development of megapolis (megacities) will make the MVTOL-AV the key factor of the urban air mobility, as it will be the only sustainable alternative solution in the traffic conjunction problem and the urban transport problem in general.

Concerning the infrastructures for UAV and MVTOL-AV in March 2022 EASA presents the Prototype Technical Design Specifications for Vertiports (places for take-off and landing of UAV). The Prototype Technical Design Specifications for Vertiports offers guidance to urban planners and local decision-makers as well as industry to enable the safe design of vertiports that will serve these new types of vertical take-off and landing (VTOL) aircraft/and MVTOL, which are already at an advanced stage of development [7] (see Fig. 2A, 2B).

In the EASA site is noted that *"…One of EASA's innovation is the concept of a funnel-shaped area above the vertiport, designated as an "obstacle free volume". This concept is tailored to the operational capabilities of the new VTOL aircraft, which can perform landing and take-off with a significant vertical segment. Depending on the urban environment and on the performance of certain VTOL-capable aircraft, omnidi-rectional trajectories to vertiports will be also possible. [Author's note: new proposals for private vertiports in urban buildings is presented in paragraph 4]. Such approaches can more easily take account of environmental and noise restrictions and are more suitable for an urban environment than conventional heliport operations, which are constrained in the approaches that can be safely applied"*. [7] All this kind of regula-tions can be used for the MVTOL-AV legislation framework. Such frameworks are under preparation in several countries.



Fig. 2. A: Vertiports EASA Prototype Technical Specifications March 2022 [7], B: Photo from Skyports company Vertipot depot [8]

Unlike conventional helicopters, MVTOL-AV are electrically powered and use multiple rotors to lift off the ground and maintain flight. They can operate autonomously

or be remotely piloted, and their small size and the user friendly and safe flight process make them ideal for use in urban environments.

Recent studies underlined the economic and environmental gains of the use of MVTOL-AV [9, 10]. Other MVTOL-AV parameters under investigation concern: secure take-off and landing in urban environment, collision danger, cabin environment (it should alleviate vertigo and claustrophobia), aviation system (it should minimize human flight control and allow autonomous operation, since the MVTOL-AV should also fly autonomously). Last but not least, MVTOL-AV designers must create a cost-effective and commercially viable product concerning its cost. [11, 12].

Volocopter, EHang, Joby Aviation, and Airbus are developing manned passenger drones. These firms manufacture safe, reliable, and efficient aircraft that meet flight's standards of international aviation services (see Table 1). German company Volocopter has completed many successful manned test flights of different MVTOL-AV prototypes. The last VoloCity prototype (see Fig. 3A), can carry two people, into a maximum 35 km distance range. It has 18 vertical lift rotors and a 110 km/h top speed. Public flying demos of this MVTOL-AV have been realised in Singapore and Dubai [13, 14]. Chinese startup EHang has also present MVTOL-AV prototypes: one with two and another with four passengers EHang 216 and 216L respectively versions. EHang has also passed test flights and received regulatory certification in China and Norway [13] (see Fig. 3C). California-based Joby Aviation created the five-seater Joby S4 (see Fig. 3D) with a 240 km range. Six rotors provide vertical lift and 320 km/h cruising speed. Joby Aviation has attracted investment from Toyota and JetBlue, demonstrating significant interest for the MVTOL-AV technology from car manufactures. With Vahana, Airbus has joined the manned passenger drone market, demonstrating the same interest from airplanes manufactures. Vahana Alpha One is a single-passenger aircraft for short urban transport. Eight rotors of this MVTOL-AV provide vertical lift and a 120 km/h peak speed. The four-passenger CityAirbus is one of the latest MVTOL-AV Airbus's project (see Fig. 3B) [15].



Fig. 3. A: Volocity [16], B: City Airbus Passenger Drone [17], C: Ehang 216 [18], D: Joby S4 [19]

Table 1. General Characteristics of MVTOL-AV Prototypes

Model	Volocity	City Airbus Passenger Drone Nextgen	EHang 216	Joby S4
Weight	900 kg MTOM (maximum take-off mass)	2.200 kg	599 kg Max take-off	907 kg
Passengers Number (pilots included)	2	4 passenger / 1pilot (optional)	2	5
Dimensions	-	-	18′ 4″ wingspan, 5′ 9″ length	35 ft wingspan, 24 ft length
Width	-	8 m Wingspan	-	-
Flight time	-	15 min	25 min	77 min
Propeller (Nb)	18	8 vertical electric ducted fans	8 dual rotors	6 propellers
Battery	9 battery packs Li-Ion (exchangable)	-	-	-
Powerplant	-	8 × vertical electric ducted fan, 100 kW (130 hp) each specially designed Siemens SP200D direct-drive, 4 × 140 kW (190 hp) battery output	All-Electric	-
Speed	110 km/h	120 km/h	128 km/h	321 km/h
Range	35 km	-	70 km	241 km

3 SAV^2 Manned VTOL-AV Project

The "DOMINATE" school (DrOne MissIon desigN And daTa process)/ (https://dominate.uniwa.gr/) – University of West Attica – Center for Long-term Education (https://kedivim.uniwa.gr/en/), offers drone education programs for the European drone licenses A1/A3, A2 and specialization on drones applications in cartography, search and rescue, infrastructure inspection, and more. In conjunction with the National Service for Civil Aviation, we developed drone education programs in accordance with EASA Mobility requirements. The DOMINATE school immediately became a hub for new research and project development. The DOMINATE educators staff includes university academics from many areas: Computer Science, Geoinformatics, Civil Engineering etc. The SAV^2

project idea started six years ago. After testing many drone models, we opted to design and propose our MVTOL-AV based on the DJI Mavic Air 2 model (see Fig. 4A). The DJI Mavic Air 2 model's stability in heavy winds and user-friendly navigation functions were the main factors for this pick. The prototype's initial design was for carbon fiber bucket seats for passengers and pilots and aluminum for the remainder. Figure 4B is presented a 3D design of first SAV^2 prototype. Figure 4C and D present the model equipped with sensors to prevent collision (see Fig. 4C) and parachutes (see Fig. 4D) in case of total failure of all rotors [1].

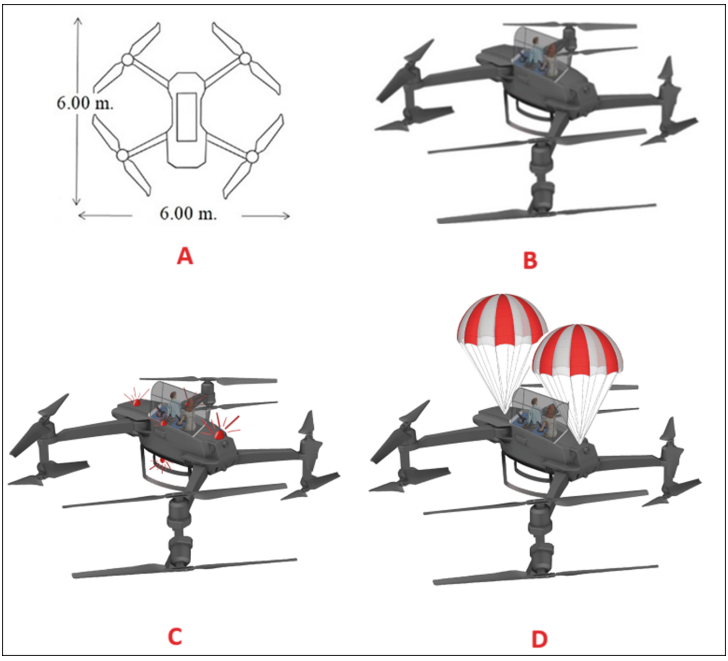


Fig. 4. A. SAV^2 dimensions. B. First basic model mainframe. C. First basic model mainframe with sensors. D. First basic model mainframe with parachutes

Our manned SAV^2 prototype is easy to fly, pilot training is similar to a car training license. Additionally, automated and pre-scheduled flights simplify things for the passengers. On this is based the idea of aerial autonomous taxi. Such MVTOL-AV, along with low-cost infrastructure and an appropriate legal framework, will be an important part of the solution of the city and megacity urban transport problems in the near future. Previous successful attempts confirm project feasibility (see Table 1). All aspects of the proposed SAV^2 design and construction use existing know-how. The cost is exceptionally low. The implementation of our theoretical design will follow a sequential order of flying tests using: 80 kg human dummy model, 80 kg passenger/pilot, two passengers with baggage (300 kg), four passengers with 320 kg maximum weight, ten passengers weighing up to 1000 kg.

4 Urban Air Mobility with MVTOL-AV: A Future that is Already Here?

4.1 Infrastructure for Urban Air Mobility

Today's major smart city projects give grate importance at Sustainable Urban Mobility (SUM) and consider it as a top-ranked topic. Apart of the new mobility services, electric cars and cars/bus without drivers, SUM includes initiatives for Urban Air Mobility (UAM) [20]. A Smart City and its basic component, the smart home, will be significantly transformed by the emerging Urban Air Mobility (UAM) and its associated technologies. New structural components, architectural designs, specialized infrastructure and new IT infrastructure, will emerge and will be installed or required in buildings that are planned to support UAM.

There are several projects that, focus on the development of the required infrastructure for UAM [21]. These plans and ideas will impose a significant change in classic building design in the near future. Let's not forget how, through the centuries, urban mobility and its corresponding means of transportation, imposed the various designs, requirements, restrictions, or additions in the domain of building manufacturing [23]. When mobility used horses, the stable was a major part of the building and in coastal areas the dock became also an integral part of the building. Today, the car parking place or box is always included in a home or building plan. Tomorrow's Architects and Civil engineers will naturally include a kind of docking platform in every building they design to serve the UAM needs (see film "The fifth element").

The challenge for Smart-City/Smart-Building designers today, is to incorporate as early as possible in their projects, the future needs for UAM. The addition of Vertical Take-off/Landing infrastructure (Verti-Ports) to every new architectural design will soon become a necessity.

This design extensions will cause various changes in building infrastructure, the strength of roof/pavement, the allowed height in the area, the distance from other obstacles, buildings or electrical wires, etc. They must also be rapidly deployable, cost-effective, and "compatible", i.e., vehicle-agnostic, ensuring access for all vehicle operators (see also previous reference EASA Vertiports Specifications [7].

On the other hand, existing buildings will also need 'struggle' to find a place to install their Urban-Verti-Port by making roof upgrades, reinforcements, and required additions to accommodate UAV docking stations. Larger buildings with big flat roofs may easily use their infrastructure for Verti-Ports. Already in London, companies such as Skyports are investing in roofs of large buildings or into new constructions for Verti-Ports [22].

4.2 Characteristics and Requirements for a Versatile Verti-Box Docking Station

As presented in [23], Verti-Box is a smart Docking Station and it is proposed as an alternative to other more complex installations (Verti-ports, Drone-dromes, Skyports, etc.). Verti-Box also serves as the transportation container and housing box of the proposed SAV^2 (SOCRATES Aerial Vtol Vehicle). The basic characteristics of this Docking Station are described below:

Basic Verti-Box Properties: Easy Transportation, Easy Installation-Deployment, All Weather Protection, All required Instrumentation by the SAV^2.

Basic Functional Requirements: All-weather Functionality (–50… +50 °C), Automatic Open/Close for takeoff/landing and protection, Automatic Battery Recharging/Replacing, Unique Station Identification, Stable and Secure Network connections. Uninterruptible and Sufficient Power, Compatibility with all Networks, Weather and Proximity Sensors, as well as, advanced Scheduling capabilities for Arrival/Departure and recharging of multiple UAVs.

As also presented in [23] Verti-Box is an easy to transfer and deploy docking station, that will provide the necessary support for SAV^2's take-off and landing, recharging, servicing, as well as, housing, transfer and delivery. After installation, the upper half of the box opens automatically to double the landing area and allow the deployment of SAV^2.

It is based on existing models of Container Boxes, standardized for road, rail or ship transportation. Using a crane, Verti-Box can be placed everywhere, from a building roof or terrace, to any suitable open area. In order to install, there is a number of requirements that need to be fulfilled, depending on where the Verti-Box will be placed:

Installation requirements on a building Roof/Terrace:
When installed on a building, at least the following requirements should be met or provided:

Roof/Terrace dimensions should provide a rectangular free space of at least 50 m^2, in order to permit to a 20 ft/6 m Shipping Container to unfold and offer a landing diameter of about 7,00 m.

Roof/Terrace should have weight support capabilities of at least 4 t or 80 kg/m2 for the Container and Equipment (2500 kg) and the SAV2 (700 kg net + 300 kg payload). Typical capabilities of 1–1.5 t/m^2, found in contemporary buildings, will suffice but every case should be checked as there are significant differences between buildings depending on the design and the use of the top floor.

Wind/Weather Shields (folding transparent panels for SAV^2 protection) especially for tall buildings should be a requirement.

Electricity connections (a combination of Mains and Solar panels for uninterruptible supply) for Battery Charging and support of all Electric/Electronic equipment.

Network Connections (above 1GB) supporting all types of communication for all subsystems/components, and, using: Cable (UTP), Wi-Fi, 5G, and IoT technologies.

Storage Facilities for Auxiliary Batteries, Oil, Water and Consumables, Replacement Parts (motors, blades, wheels), fire protection, etc.

Roof/building Access Facilities should be provided such as: Elevator to the roof, Parking space, as well as connections to other transportation means.

Open Area HUB Deployment requirements:
Using a number of Verti-boxes and their supporting facilities (easily transferred also in container boxes), one can create a quickly deployed airfield/Hub for specific uses, especially when far from any existing Verti-port or DroneDrome, e.g., Special Points-Of-Interest, Emergency Cases, Auxiliary Connections to other Hubs, etc.

The supporting facilities for open area deployment include all required infrastructure (also coming in easily deployed container boxes) that aims to provide access to the required electrical power and network connectivity (see Fig. 5) [24]. They may also come in container box with:

An Electricity Part: for the Electricity Generators, Solar Panels, Power Converters, Cabling and Connectors.

A Networking Part: for Network Antennas, Satellite dish, Mobile and Wi-Fi connections, as well as, a small Tethered UAV/repeater for areas with reception difficulties.



Fig. 5. According to Deloitte analysis, Urban Air Mobility (UAM) would require a robust city infrastructure [19].

4.3 How the Manned and Unmanned Drones Will Fly in the Urban Environment?

If large numbers of drones are ever to provide delivery services in urban areas, MVTOL-AV traffic legal frame, rules and relative legislation need to be created to safely manage the flow. The American Institute of Aeronautics and Astronautics' 2017 (AIAA) SciTech Forum in Grapevine, Texas, (https://www.aiaa.org/) provides some of the concepts that NASA's Ames Research Center developed for UAS traffic management in urban areas.

Three basic concepts [25] had been proposed (see Fig. 6): Sky-lanes: Vehicles must follow the centerline of each lane, and fly in one direction. / Sky-tubes: Vehicles move inside each tube, and fly only in one direction. / Sky-corridors: Vehicles can fly in any direction, but the vehicles themselves must maintain safe separation (probably the implementation of a such concept will be at a higher altitude than the first two concepts).

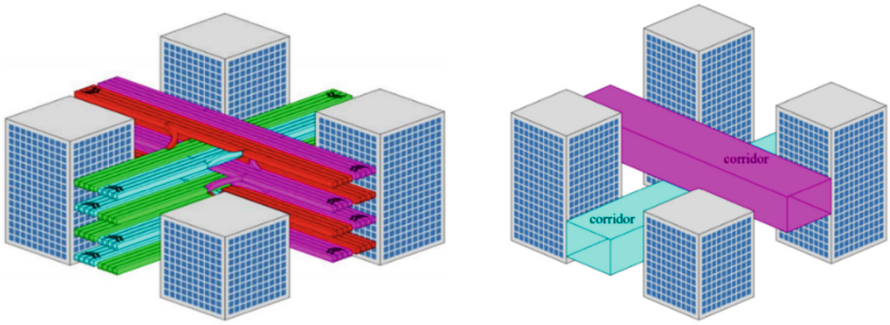


Fig. 6. UAS Traffic Management (UTM) concepts [26]

It is clear that in the near future the design development and implementation of an European Unmanned Traffic Management (UTM) System it is absolutely necessary in order to guarantee the integration of the remotely piloted aircraft systems (RPAS) - (including the MVTOL-AV) - into national and European airspace. The question that also arise is if such a system must be included in the general air traffic. [27].

5 Conclusions/Further Development

In our planet exist more than 34 mega cities. The first eight megacities are: Tokyo, Delhi, Shanghai, São Paulo, Mexico City, Dhaka, Cairo, Beijing. All confront big traffic problems making hard the life of their citizens. In addition, traffic problems don't concern only cities of such a size. Cities of a much smaller size also confront enormous traffic problems. The only solution seems to be the use of the third spatial dimension for mobility, the aerial mobility.

Although the technology of manned drones presents exciting opportunities in urban air mobility, a number of problems in their use have not found yet their solution. Overcoming these obstacles means: creation of legal regulations, solutions in different safety technical issues, infrastructure construction for take-off and landing, design of aerial corridors for safe navigation, aerial traffic MVTOL-AV flight rules ensuring safety in MVTOL-AV flights and many more.

As a consequence, a number of questions arise: How difficult is the construction of low-cost MVTOL-AV? Which are the difficulties of MVTOL-AV flights in an urban environment? Which are the necessary modifications in the existing legal frame? (e.g. in some countries the property of a house also extents above the house.) Where will be the places of take-off and landing? Exist urban planning studies concerning the urban air mobility and the impact to urban environment? Are ready the car manufacture companies to thing about a possible shift to the MVTOL-AV?

This paper gives a general frame of the aerial urban mobility based on the literature review, the SAV^2 project, and research efforts of Drones pilot School DOMINATE in UNIWA.

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