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INTEGRATION OF UNMANNED AERIAL VEHICLES INTO URBAN TRANSPORT SYSTEMS

Miloš MARINA[1]
Tanja ŽIVOJINOVIĆ[2]
Marijana PETROVIĆ[2]
Petar MIROSAVLJEVIĆ[1]

[1] Department of Air Transport and Traffic University of Belgrade-Faculty of Transport and Traffic Engineering
[2] Departments for organization, management and economics in traffic and transport, University of Belgrade - Faculty of Transport and Traffic Engineering

Abstract

The emergence of unmanned aerial vehicles (UAVs) created the basis for the development of new form of urban mobility, labelled as UAM - Urban Air Mobility. One of the associated question is how this new option can complement the existing mobility solutions in the urban areas. In this paper the possibilities of integrating passenger unmanned aerial vehicles (UAVs) into urban transport system are analysed. Previous examples of the integration of aircraft in passenger transport are presented. Finally, an approach for estimating the integration of unmanned aerial vehicles using the Analytic Hierarchy Process (AHP) method is presented.

***Keywords**: UAM, Integration, Advanced air mobility , UAV*

1 INTRODUCTION - TERMINOLOGY AND HISTORY

At the beginning, it is necessary to define unmanned aircraft. Different definitions of unmanned aerial vehicles can be found in the literature. ICAO's (International Civil Aviation Organization) definition from the 35th session of the 2004 Assembly reads: "Unmanned aerial vehicle - UAV is an unmanned aircraft, within the meaning of Article 8 of the Convention on International Aviation, which flies without a pilot on a given route and whose control is performed from a remote location or is programmed and completely autonomous. "Unmanned aerial vehicle system - UAS is an unmanned aerial vehicle with all its associated elements. Remotely piloted aircraft - RPA is an unmanned aircraft that is operated from a place that is not in the aircraft itself. Remotely piloted aircraft system - RPAS consists of the drone itself, the control station and the communication, command and control system [1].

A special group of unmanned aircraft consists of VTOL - Vertical Take-off and landing aircraft. VTOL aircraft belong to the category of hybrid unmanned aircraft, which uses specific possibilities of combining the fixed and rotating wing concept. VTOL aircraft are especially interesting for use in urban areas primarily because it takes good characteristics of the basic two concepts. For example, hybrid unmanned aerial vehicles have long range, with the ability to quickly switch from flight to landing mode and vice versa or to hover. After the conceptual definition, we continue with the aim of presenting a short history of UAVs. With the advent of aircraft, there was a tendency to create unmanned aircraft. The very concept of unmanned aerial vehicles was based to cover operations known as 3D - Dull, Dirty and Dangerous. UAV have existed for centuries and have been used exclusively for military purposes. Civilian applications tend to follow the development of military technologies after development and testing in the military field.

The earliest recorded use of *UAV* was for military purposes in 1849, when the Austrians attacked the Italian city of Venice. Aircraft were balloons of simple construction at the time. If we consider that a *UAV* is a body that is created by a buoyancy force by aerodynamic force and has the ability to control, a dragon would fit the given definition. In 1883, Douglas Archibald used a dragon to measure wind speed at 1,200 ft. The Kettering Bug was developed during the First World War, and is basically an air torpedo.

The basis of UAV as we know them today was laid by the scientist Nikola Tesla. With its patent Method of and Apparatus for Controlling Mechanism of Moving Vessels or Vehicles, i.e. remote control of radio waves of ships, vehicles or devices. The word drone was first used in 1935, when the British created remotely controlled aircraft. The word drone was designed based on one of the targets used, namely de Havilland DH82B Queen Bee. Reconnaissance drones were used for the first time in the Vietnam War. The Vietnam War is followed by a new chapter in the development of unmanned aerial vehicles. The new models were becoming more sophisticated, with better durability and higher heights to maintain height. This chapter marked the use of solar energy to power unmanned aircraft. In addition to military use, civilian usage can be found to a large extent today. The main task of UAVs for civilian purposes is to record and monitor. However, there are a large number of operations in which we can use them in modern life. In the continuation of the paper, the application of UAV under the auspices of the UAM concept is presented

The focus of the paper is on the possibility of integrating UAM into urban transport systems. One of the associated question is how this new option can complement the existing mobility solutions in the urban areas. In this paper the possibilities of integrating passenger UAV into urban transport system are analysed. Previous examples of the integration of aircraft in passenger transport are presented. Finally, an approach for estimating the integration of unmanned aerial vehicles using the AHP method is presented.

2 UAM CONCEPT

The Urban Air Mobility-UAM concept includes urban and intercity transport services for passengers and goods by air. Urban air mobility is a new, safe and sustainable system of passengers and cargo air transport in urban areas.

This concept is made possible by new technologies as well as integration into multimodal transport systems. The aircraft used to realise this concept are VTOL - aircraft that take off and land vertically and RPAS - remote controlled aircraft. EASA (European Union Aviation Safety Agency) expects commercial implementation in EU cities around 2025. It is estimated that by 2030, about 340 million people living in the EU will experience UAM [2].

The advantages of this concept are safer mobility, faster mobility, cleaner mobility and the development of new jobs. Introducing the UAM concept, contributes to reducing the risk of participating in fatal accidents in air taxis in relation to road transport. It is estimated to save 15 to 40 minutes compared to a standard city road and more than 70% of the time spent on emergency / medical delivery. In addition, the use of electric and hybrid aircraft reduces local CO_2 emissions.

3 EXAMPLES OF AIRCRAFT INTEGRATION INTO CITY TRANSPORT SYSTEMS

The practice has shown that aircraft can be integrated into urban transport systems. The main advantage of UAM system is the avoidance of congestion in large cities. The most common application is based on the transport of passengers by helicopter from the city centre to the airport. Below are some successful projects.

3.1. Voom

An Airbus-owned company that connected helicopter operators with customers. The concept was based on the ability to provide services on demand. The company has operated in the US, Mexico and Brazil. A total of 15,000 passengers were transported. Voom has contributed to the introduction of a new approach to using the concept of air traffic. In a way, it contributes to shaping the development of future UAM models. The basic idea of this concept is to provide a practical, convenient and inexpensive service.

The company's business in Brazil has come up with several important facts regarding the requirements of UAM users. During the week, the busiest days were Tuesday and Thursday. During the day, the greatest demand occurred during rush hour, i.e. in the early morning and late afternoon. The busiest routes were from and to local airports. The average flight duration is 11 minutes, which is estimated to be twice less time than looking for a parking space.

The platform allows booking and realising a flight within 60 minutes or planning up to 7 days in advance. At the very beginning of business in Mexico, there were three very important ones: a large traffic jam, the existence of good helicopter infrastructure and separate air traffic control for helicopter traffic [3].

3.2. Ubercopter

Uber offers its customers an integrated airport transportation service, which includes helicopter transportation. The system allows booking on weekdays from 14:00 to 18:00. It operates in New York on the route Manhattan and JFK Airport. The application enables you to provide transportation to the heliport. There is a restriction of the zone from which the transport can be done, i.e. the area is shaped in relation to the heliport. The application on smart mobile devices enables fast access and reservation of the system. The application allows the client to view the time of transportation as well as the price of ride, depending on the required route. The company emphasizes the following advantages: safety - flights are performed by a certified helicopter carrier with a responsible management system, saving time - the system allows travel to the airport door to door with minimal exposure to city crowds, simplicity - quick and easy booking. The helicopter flight itself takes 8 minutes. The price of a one-way ticket is between $ 200 and $ 223, which depends on the demand, i.e. the driving time. The price includes transport to the heliport, transport by helicopter to the JFK heliport and transport from the heliport to the terminal or destination at the airport [4].

3.3. Helipass

The Helipass platform allows users to book a helicopter flight to over 300 destinations. Most flights are operated in France. The flights are for various purposes, from panoramic flights, transfer flights to flights on personal request. The content is offered through an application, through which a flight is booked in three steps. The initiator of this company is one of the largest aircraft manufacturers, Airbus. The following are examples of lines on which they operate with their basic characteristics.

Passenger transfers from Nice Airport to Sint Tropez are made daily every 15 minutes. The route starts at Nice Airport, followed by helicopter transport to the heliport in Sint Tropez. The service includes transportation of passengers to their place of stay. The total duration of the transfer is 20 minutes. The transfer price for the entire aircraft is 1,200 €, for the lease of the entire helicopter capacity of 6 seats. It can be concluded that the cost of an individual ticket is 200 €. The helicopter used for this transfer is the Airbus H130, a civilian helicopter with a maximum cruising speed of 220 km / h. Another interesting route is on the route Nice - Monaco.

The duration of this transfer is 7 minutes. The regular line runs every 15 minutes. There are more than 50 flights a day, coordinated by a plane from Nice Airport every flight. In addition to transport by helicopter from the airport to the heliport, the service includes coverage and transportation from the place of collection of luggage to the place of departure of the helicopter, as well as transportation by limousine to the destination address in Monaco. The service price allows passengers to carry 1 cabin luggage up to a weight of 23 kilograms. The price of the transfer for the entire aircraft is 750€, for the lease of the entire helicopter capacity of 5 seats. It can be concluded that the price of a single ticket is 150€. The helicopter used for this transfer is the Airbus H125, a civilian helicopter with a maximum cruising speed of 220 km / h. There is also an additional service package, which includes the transfer of passengers to the terminals themselves. The additional service package can be used only by passengers of the following airlines: British Airlines, Air France, KLM, Qatar Airways, Emirates, Corsica Airlines and Turkish Airlines [5].

3.4. CBD Helicopter

CBD offers passenger transfer services in the second largest city in Australia, Melbourne. The company offers transfer of passengers from or to the heliport located in the center of Melbourne to or from the surrounding airports and islands. Transfers can be made from the following locations: Melbourne Airport (Tullamarine), Moorabbin Airport, Lilydale Airport, Geelong, Mornington Peninsula and Phillip Island. Figure 1 shows destinations with transfer times [6].

Fig. 1 *CBD transfer lines in Melbourne [6]*

Table 1 shows the average flight times of transfers from the heliport located in the centre of Melbourne to the destinations with their distance. Prices are shown in two cases. In the first case, when more than 4 people are flying, an individual price per passenger is given. The second case concerns a flight in which only one passenger is transferred. It can be seen that the price for an individual transfer is some three times higher than when there are 4 or more passengers.

Table 1 CBD Melbourne Transfer - basic flight information [6]

CBD Melbourne Transfer	Flight time [min]	Air distant [km]	Price [AU$]	
			4+ pp	1
Melbourne Airport (Tullamarine)	8	20	545	1695
Moorabbin Airport	14	22	375	795
Lilydale Airport	18	35	495	1545
Geelong	25	63	545	1745
Mornington Peninsula	25	66	645	2045
Phillip Island	35	78	695	2245

Costs do not depend on the distance travelled, but on the attractiveness of the destination. The highest prices are for the transfer to the airport, due to the significant time savings. Reservations are made through the site and include transportation from the heliport to the specified points. The offer does not include combined door-to-door transport

3.5. RAYNA Dubai

There are various platforms through which helicopter flights can be booked in Dubai. The company offers flights to and from the airport, as well as panoramic city tour flights. It is possible to book a helicopter flight from Terminal 1 or 3 from Dubai Airports to two heliports in the city. One is located in the Deira area, while the other is in Bur Dubai. They are located at a similar distance from the airport, at some 8-10km. The price for the whole flight from the airport to the heliport is $ 40-45, depending on the number of passengers. The number of passengers in this offer can be between 1-5. The return is slightly cheaper and costs $ 30-37 per flight. The platform allows Slot time selection, and provides a connection with the minimum waiting time. The service does not include transport to the hotel, but the user must organize the transport himself [7].

4 UAV IN UAM

The previous chapter presented the use of aircraft in passenger transport in urban areas. There are several potential applications of the UAM concept as part of new mobility models. The possibility of applying UAV for point-to-point passenger transport, i.e. air taxi, is indisputable. An air taxi would operate on the principle of today's road taxi vehicles. UAVs can form part of a multimodal journey as part of a broader mobility system as a service, or part of the MaaS concept. They can potentially be used to transfer passengers to and from the airport, as well as for medium-range long-haul flights to urbanism or intercity environments.
The continuation of the paper shows the challenges that need to be overcome for the integration of the UAM concept. Integration must be based on 4 basic levels: 1) Physical integration, 2) Operational integration, 3) Information integration and 4) Billing integration. The physical integration of the UAV requires the strategic deployment of vertiports (take-off and landing zones), battery charging stations, and maintenance facilities. A large network of vertiports would require either the construction of new infrastructure or the modification of existing infrastructure. To create a unified traffic management system, it is possible to install additional infrastructure along pre-defined corridors, for faster communication and geolocation. The costs of planning and implementing the policy and infrastructure for the safe functioning of the UAVS are high. Costs are high due to the need for integration with the energy system and other modes of transport. Based on the priorities of each country, in terms of safety, cost, travel time, reliability and comfort, the level that must be met to enable the operation of the UAV will be defined. In cities with passenger-oriented infrastructure, UAV would generally be deployed as an additional transport solution. The basis for the autonomy of UAV operations is the development of advanced

technologies in terms of artificial intelligence and cognitive systems. It is necessary to install sensors equipped to work outside the GPS environment. Today's technology from autonomous cars needs to be improved, so that it can be applied in UAV systems. Energy management is one of the key issues when considering increasing the capacity and range of passenger UAVs. Current technological solutions for batteries need to be improved or an alternative will have to be found. [8]

EASA estimates that the acceptance of citizenship and the trust of future UAM users EASA has conducted a comprehensive study on the social acceptance of UAM operations across the European Union. The study was conducted by McKinsey & Company and the Arup Sound Lab between November 2020 and April 2021. With this research, the EU revealed interesting insights that will help EASA to prepare future regulatory frameworks. [9] Ten key research findings are listed below [10]:

- Positive attitude towards the UAM concept throughout the EU: 83% of respondents have a very positive attitude towards UAM, 64% of respondents are ready to try drones, while 49% air tax, the answers were homogeneous and without major differences by cities and groups of respondents.
- Strong support for cases of use of public importance: cases of emergency and / or medical transport arouse the greatest public interest, according to the research, the three best cases of use are: 41% transport of the injured to hospital, 41% delivery of medical equipment and materials to hospitals and 36% transport of emergency medical personnel
- Three expected benefits - faster, cleaner and extended connectivity: 71% of respondents believe that emergency time will be reduced, 51% believe that congestion will be reduced, 48% reduction of local emissions and 41% development of remote areas
- The three biggest concerns are: safety, the environment and security. The following percentage of respondents were concerned about the concept of drone use in terms of: safety 44%, safety 39%, environmental pollution 35% and 28% due to noise. The following percentage of respondents were concerned about the concept of using air taxis in terms of: safety 37%, safety 29%, environmental pollution 38% and 38% due to noise.
- Safety: existing levels of aviation safety are the main benchmark for comparison. The respondent expects the safety of UAM operations at the level of today's aircraft operations. It is recognized that as the age of the respondents increases, the concern of the respondents regarding safety also grows.
- Environment: the protection of wildlife is a priority. The research showed that the respondents were similarly worried about the impact of drones and air taxis on the environment. About 60% of respondents are concerned about their negative impact on animals, 52% of respondents are concerned about the creation of additional noise, while 42% are concerned about the negative environmental impact of the production of such vehicles, including batteries.
- Noise: acceptable at the level of familiar city sounds. The level of anxiety varies depending on the unrecognized sound. Familiar city sounds at the same decibel levels are better accepted.
- It is necessary to build trust among citizens. The level of confidence in the security and cyber security of UAM technology is just over 50%. However, half of the respondents who do not trust UAV technology would change their opinion if clear regulatory frameworks on this issue formed at the EU level.
- Existing land infrastructure: citizens expect good integration. UAM services should be integrated into existing city service systems. Integration needs to be done so as not to disrupt the city's infrastructure and landscape. As many as 68% of respondents stated that it is desirable to deliver the package or to the address of the recipient.
- Regulatory framework: must be made at all levels together. A similar level of government confidence in local, regional, national and European authorities in meeting the expectations of the regulatory framework for UAM. It is necessary for local authorities to work on the integration of UAM, in order to gain acceptance by society. Respondents agree that it is essential to involve local authorities in constructing UAM systems in their cities.

5 EVALUATION OF INTEGRATION OF UAM SYSTEMS BY AHP METHOD

The AHP (Analytic Hierarchy Process) method will be used to evaluate the integration of the UAM concept. AHP was developed by Thomas L. Saaty (1980), as a method of multicriteria analysis for the purpose of decision making in group or individual decision making.

The method was used primarily for the reason that it allows to show the influence of several variable factors when choosing an alternative. This method was used by K. Nosal and K. Solcka in the paper Application of AHP Method for Multi-criteria Evaluation of Variants of the Integration of Urban Public Transport [11]. The paper itself is a method of choosing the mode of transport based on certain criteria. Also, the method was applied in the work of S. Luca, with the topic combining the functional unit concept and the analytical hierarchy process method for performance assessment of public transport options [12]. This paper presents strategic management of transport planning based on AHP. The method must consist of objectives, criteria, sub-criteria and alternatives in order to adequately assess the choice of using UAM. As the method can be used for individual and group decision making, we consider it ideal for applying the evaluation of the UAM concept in megalopolises.

In the process of analysis, it is necessary to adhere to the axioms: reciprocity, homogeneity, dependence and expectations. The basic phases that need to be applied are: (1) Defining the goal of decision-making, (2) Making decision-making elements, (3) Determining the mutual importance of elements, (4) Calculating weight coefficients and degree of consistency, (5) Evaluation of alternatives and selection of the most favorable alternative.

Following the steps of the method at the beginning, we must define the goal of decision making. In this case, it is the choice of mode of transport in megalopolises. [13]

The next step is to define the criteria and sub-criteria. The criteria and sub-criteria were selected on the basis of previous research conducted on research on the choice of modes of transport in urban areas and the above presented research EASA 2020/2021.

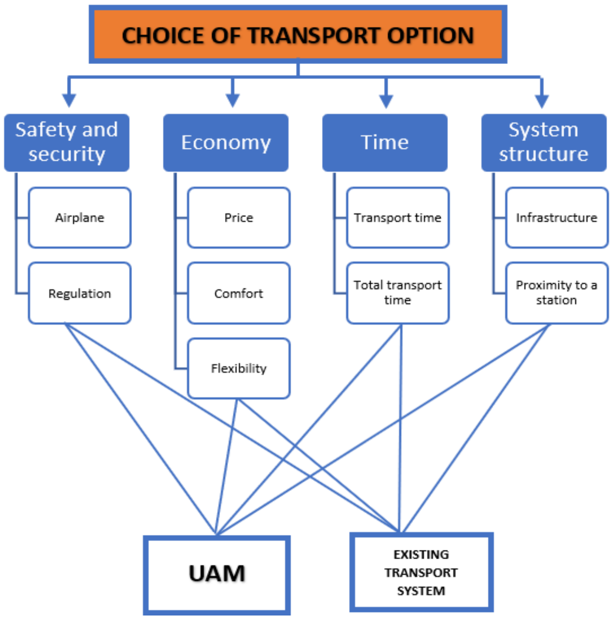

Fig. 2 *Structure model for the case of the choice of mode of transport*

Figure 2 shows the structure of the hierarchical model for the case of selecting the option of transport. The main criteria in this decision-making process are: security, economy, time and structure of the system. The sub-criteria for safety are: aircraft and the regulatory framework. The sub-criteria for economy are: ticket price, convenience and flexibility of the transport system.

During the time, two times were selected as a sub-criterion, that is, the total transport time and the transport time. After the structure of the System, we believe that it is necessary to take into account the infrastructure of the system and the proximity of the station. At the end of this section, it is necessary to define alternatives. In this case, we have the UAM concept and the existing city passenger transport system.

The next step is to determine the mutual significance by groups. The mutual significance by groups was done based on available statistical data and on the basis of the subjective feeling of experts. The target group of this research is people who are in congested parts of cities. It is assumed that the target group of users has a higher payment option. Based on all that, an individual division of influential factors was made, as well as their importance in choosing the goal. Figure three shows the weight coefficients of the model elements [14].

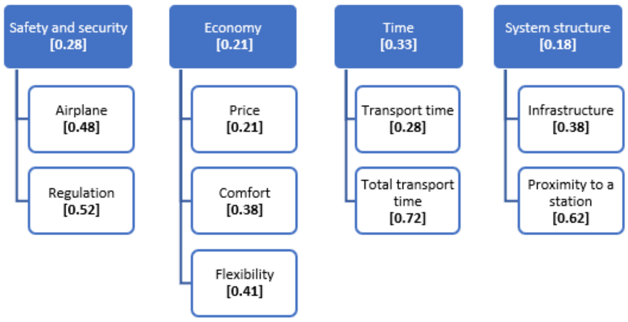

Fig. 3 *Calculated weighting coefficients*

At the very end, an assessment of the importance of all individual factors in the choice of alternatives was made. The choice of alternatives in the AHP method represents the phase where the connection between the decision goal and the alternative is left. By calculating the vector of the significance of the goal, the adequate influence of the alternatives on the goal was obtained.

Table 2 shows the importance when choosing modes of transport. It is recognized that about 17% of users of existing systems would have a justifiable reason to use the UAM Passenger Transport System.

Table 2 Coefficient of choice of alternatives

TRANSPORT OPTION	SELECTION [%]
EXISTING	83
UAM	17

6 CONCLUSION

Unmanned aerial vehicles are definitely the backbone of the future UAM passenger transport system. Dozens of unmanned aerial vehicles intended for air taxis are currently being developed. Nowadays, the development and testing of UAM is at a high technological level. There are currently a number of technological obstacles, but it is assumed that they will be overcome in the next 5 years. The main thing that can hinder the integration of UAM is the acceptance of this mode of transport by users. Research conducted on the territory of the EU shows that citizens are concerned about issues of safety, security and noise, which can be produced by unmanned aircraft in urban areas. It is essential to adopt clear standards and recommendations at all regulatory levels. In the coming period, it is necessary to focus most of the attention on changing the attitudes of future users. It can definitely be said that there is already a potential UAM market. Using the AHP method, it was estimated that some 17% of users of current systems would benefit from using a UAM system. Despite the existence and construction of new land passenger transport systems, large cities have problems with frequent traffic congestion. The most significant contribution of UAM would be noticeable in moments of traffic peaks. Therefore, the integration of UAM into urban passenger transport systems is an issue that needs more attention in the coming period

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Contact address:
Miloš MARINA
Department of Air Transport and Traffic
University of Belgrade-Faculty of Transport and Traffic Engineering
11000 Belgrade
Vojvode Stepe 305,
E-mail: Miloš MARINA