Strategic planning for Urban Air Mobility: perceptions of citizens and potential users on autonomous flying vehicles

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Abstract. World's current mobility systems are often inefficient and unsustainable, therefore the need for new schemes to satisfy mobility needs appears. This quest has given the impetus to the industry to invest in new technologies such as autonomous systems enabling self-driving vehicles. In this context, the concept of Urban Air Mobility (UAM), a term used for short-distance, on-demand, highly automated, passenger or cargo-carrying air mobility services, has arisen. This paper presents the introduction phase of strategic planning for the era of urban air mobility focusing on user and citizen acceptance of the system required for its operation. A survey is designed to capture the perception of citizens and potential users on aspects such as safety, security, well-being of the society (including issues of aesthetics, quality of life, social impacts), driving behaviour, mobility behaviour, expected benefits and their impact on the acceptance and the intention to use these systems. The acceptance of citizens and potential users (considered as two different groups) is analysed in terms of its potential uses (e.g. health emergencies, leisure, connectivity to remote regions). The survey is applied to the Metropolitan area of Lisbon and 207 responses were gathered. The collected data was analysed through correlation analysis and non-parametric tests. Conclusions are made on perceptions of citizens over different adoption and embracement levels.

Keywords: Unmanned Aerial Vehicles, Urban Air Mobility, Adoption, Technology.

1 Introduction

Population growth is today one of the major concerns that societies need to deal with. Currently, the earth is populated by 7 Billion people and that figure is expected to increase [1]. According to the United Nations, the number of inhabitants will grow by 10% until 2030 (reaching 8,9 Billion) and 26% by 2050, making a total of 9,7 Billion people, more 2 Billion that our present record [2]. This growth will affect various aspects of human life, one of them being urban transport. Cities are becoming more and more crowded, aggravating the problem of urban mobility. The future is not looking bright either, as every year more than 77 million people move from rural to urban areas [3]. In this context, for many cities moving by Public Transport (PT) is not a viable option [4]. Most of PT systems face unstable demand during weekdays, peak hours with crowded vehicles creating discomfort among the passengers and on low ridership periods it becomes difficult for PT companies to cope with high costs. Also, PT systems have a high infrastructure maintenance cost making it harder to maintain the service level and keep up with the demand.

This inefficiency of PT in conjunction with other aspects leads passengers towards private transport choices, mainly private cars. However, neither cars have proven to be efficient as a mode. Increased volumes of cars at streets result to congestion and increasing commuting times. Studies have shown that the average American citizen spends a total of 26.9 minutes per day in commute [5], and in India, the average commuter spends over 2 hours of their day on the road commuting to work or home [6]. Overall transportation in urban areas is characterized by extreme traffic congestion, long commuting time, air pollution and inadequate public transportation [7].

World's current mobility systems are clearly insufficient and unsustainable, therefore the demand for new mobility services has arisen. Noticing this demand, multiple companies started to develop new mobility services such as car-sharing (e.g. ZipCar, Car2Go) and ride-hailing services (i.e. Uber, Lyft) that offer more personalized services. Companies' business based on Sharing Economy began to thrive, creating opportunities including new business models such as Mobility as a Service (MaaS).

MaaS combines services from different modes of transport to provide customised mobility services, all in one interface [8], giving the user more flexibility by providing all the transportation means needed to commute. Such platforms combine different transport modes and give the users the possibility of choosing the ones they prefer and the ticket option they wish to use as well (e.g. pay-as-you-go or mobility packages)

This quest for the next big step in mobility has made companies invest heavily in research and development (R&D) of new technologies. One technology that has seen great growth in the last years is the autonomous systems enabling self-driving vehicles. Multiple companies started to invest and later test this system in cars and began to study the application of such technologies on other modes of transport, such as the self-driving aircrafts. Uber is one of the companies focused on developing this technology. In 2019, the ride hailing service company invested $457 Million in R&D of autonomous vehicles [9] indicating their vision of future urban mobility.

Gradually other companies, institutions and policymakers are analysing the possibilities of the urban mobility in the vertical dimension forming the concept of Urban Air Mobility (UAM) that expresses on-demand, highly automated (pilotless), passenger or cargo-carrying air transportation services [10]. This concept relies on short distance vertical take-off and landing aircraft (VTOL), therefore giving the flexibility needed to operate this aircraft. There are three main uses of UAM: last-mile delivery, air metro and air taxi. Last mile deliveries aim to transport goods from the distribution hub to the final delivery transportation. The Air Metro is an autonomously operated aircraft, that can accommodate 2 to 5 passengers at a time; it resembles public transport (PT) services since it has fixed routes, schedules and stops. Air Taxi, much like the Air Metro aircraft, is autonomous and can carry multiple passengers, the difference relies on the fact that this transportation mode has no fixed route, no schedule and no predetermined stops, it works only on-demand and requires multiple possible stops so that the service can truly become door-to-door [11]. Vertical take-off and landing aircrafts (VTOL) can be the solution to mobility problems, providing a fast, clean and ubiquitous alternative.

The current work analyses the aspects that can affect user adoption in the future and the embracement of this new mode from the societies. The next section presents background work that provides insights in the development of the current work. Then the design of the survey that reveals the attitude and perspectives of the public towards passenger aerial vehicles is presented and the preliminary results of the collected data are illustrated and discussed. The last section includes the conclusion and future work.

2 Literature Review

The Urban Air Mobility (UAM) concept aims to enable a world where people or goods can be transported in the urban environment in minutes rather than hours, always on demand. UAM can be realised in the form of air taxis and shared or owned vehicles, creating an on-demand flying service network. Currently, manufacturers are already on the prototype flying-test phase and are getting ready to reach market availability in 2023 [12]. These unmanned aerial vehicles (UAV) will be VTOLs, an all-electric aircraft that has the capability to vertically take-off and land, therefore does not require any runways [13]. According to Holden et al., UAM will add the third dimension, which increases the accessibility between suburbs and cities and, ultimately within urban areas [12]. In resemblance to the automated vehicles (AV), VTOLs will be fuelled by electricity and produce zero emissions whilst producing a much lower noise than a traditional helicopter [13]. The major manufacturers at the moment are Airbus with their model Vahana and CityAirbus; Boeing with Aurora (partnership made with Aurora flight sciences); and Volocopter with the Volocopter. These VTOLs are expected to have a range of 50Km and a top speed of 120Km/h.

The availability of the technology generates opportunities for the study of the future of mobility especially in urban and suburban areas with the respective requirements in infrastructure and service operation. Al Haddad et al. performed a study to observe which factors affect the adoption and use of UAVs and found that safety plays a crucial role in early and late adoption. Other factors such as affinity with automation, data and ethical concerns were also found to have an impact on adoption [14]. These findings were coherent with a NASA study, where respondents reported that safety, costs and environmental aspects were determinants of adoption and the majority of respondents (over 70%) stated they would be comfortable with other people using air taxis services regardless of them using it or not [11].

Eker et al. found that women are more concerned with safety than men (e.g. safe interactions between UAVs) meaning that this safety concerns may prevent women from being early adopters [15]. This finding corroborates with conclusions of Al Haddad et al. in which women expressed a lower interest in UAM, lower trust in automation, greater security and safety concerns. Moreover, women had a higher desire of having extra safety measures such as an operator on the ground and in-vehicle safety cameras [14]. Income and education background can also be indicators of the likelihood of adopting this service. Castle found that having a higher income and a greater degree of education would translate into a higher willingness to use UAM [16]. Furthermore, there is evidence that young respondents are more likely early adopters which might be explained due to the largely unknown capabilities of UAVs (Eker et al.). Additionally, it was suggested that informational campaigns should be designed and implemented to increase awareness [15].

Much like in Autonomous Vehicles, data privacy and ethical concerns can also have influential negative impacts on the early adoption of UAVs. Regulations should be created to establish standards for liability, security and data privacy [14]. Furthermore, environmental concerns were also observed as crucial points in the adoption of UAM service. NASA observed that the environmental impact was the third highest concern on their study with over 2,500 responses [11]. Al Haddad stated that there is the need of policymaking regarding in the area of noise and visual impact. Regulating these areas could lead to a higher public acceptance [14].

NASA also studied what key actions that policymakers and constructors could undertake that would increase the public comfort with air taxis. The actions were related with safety, environmental concerns, legal issues and with noise impact. The respondents showed a higher desire for actions such as proven lower accident rates than cars, successful human demonstrations of their safety and successful trials in other cities. The fourth most highlighted action was related with the environment, where respondents stated that they would feel more comfortable with air taxis if they are less harmful to the environment than regular cars. The least picked action was related with noise showing that respondents have a lack of concern with UAM noise [11].

Although AVs and UAVs are not the same to the user's eyes, they share strong commonalities not only on the constituents' technology [12] but also on the challenges they face as a new way of transportation and the expected benefits. It is expected that automation in mobility will potentially improve the societies´ quality of life by contributing against the traffic and the environmental crisis, improving users' productivity, reducing car crashes and hence increase safety [17]. Social benefits will arise as well, as AVs would be the possibility to solve the mobility problems of the elderly, people with disabilities or even children [18] and could enable higher independent mobility for the non-drivers whilst increasing road capacity and reducing traffic congestion [19]. AVs can offer last-mile solutions and fill the transportation needs in places with less frequently used routes. When compared to Public Transportation (PT), AVs offer more privacy, comfort and intimacy, seating availability would be guaranteed and walking time would be significantly reduced [20].

3 Methodology

As technology is rapidly evolving, the industry is developing prototypes of passenger aerial vehicles and some of them have already performed thousands of test flights (e.g. Airbus Vahana). With this rapid growth the need of research that assesses people's perception towards UAVs and their intention to use them for mobility needs arises. In this study it is proposed that the integration of UAVs in the future transport systems is decomposed to two dimensions, the intention of citizens to use them and the embracement of this vehicle type from the society which indicates the voluntary inclusion of the mode in the transport system. UAM has various benefits for the cities that adopt this transport mode. However, it is important to ensure that the UAM does not decrease the quality of life by congesting the sky and increasing the noise pollution. Therefore, having the public involved and co-creating becomes crucial for the adoption of UAM [21]. The rate of adoption is suggested that depends on the trust people have on technology and the tendency towards new technologies´ adoption, the perception of the people over the expected benefits and safety of UAVs, concerns over cybersecurity, people´s travel well-being, mobility and driving behaviour, their environmental concerns and their sociodemographic characteristics. Hence, a conceptual model is developed to research the impact of these aspects on the people´s embracement and intention to use UAVs (Figure 1).

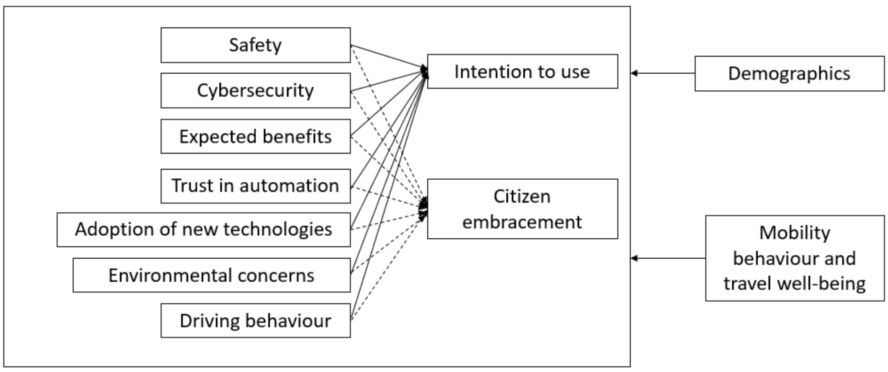

Fig. 1. Conceptual model of UAVs adoption

3.1 Presentation of hypothesis to test

In order to access the citizens embracement and intention to use UAVs, the following hypothesis will be tested according with the table below.

Table 1. Hypothesis over adoption and embracement levels

#	Hypothesis
H1	Men intend to use UAVs earlier than women
H2	Safety is perceived in a different way among the public embracement levels
H3	Young people are willing to adopt UAVs earlier than older
H4	Familiarity with shared mobility services has an impact on adoption and embracement
H5	Public embracement levels vary across adoption levels
H6	Income levels don´t vary across adoption levels.
H7	The expected benefits are differently perceived among the public embracement levels
H8	Accident history vary across adoption levels
H9	Cybersecurity is perceived in a different way across public embracement groups

H10	People satisfied with ride hailing services are willing to embrace this mode early

3.2 Survey design

To collect the data that will assess the conceptual model, a survey was designed consisting of four parts, with a total of 49 questions. The collected data had the form of categorical (in a 7-point Likert scale), continuous and ordinal variables. The first part of the survey is composed by questions that reflect the trust of the respondents in automation and their attitude towards the adoption of new technologies. Statements were presented to the respondents and they were asked to express the level of agreement as well as the level of adopting a new technology or mobility innovation. Respondents were also asked their view on shared mobility services and other mobility innovations.

At the second part, the participants were introduced to the UAVs and were presented some of the aircraft and service characteristics. This introduction helped the respondents to get more familiarized with the subject before expressing perceptions on it. Then the level of agreement to statements related to expected benefits, safety and cybersecurity of UAVs were measured. To assess the respondent´s view on expected benefits, their perception regarding UAVs impact on road traffic, mobility behaviour, safety and independence on mobility (e.g. disabled people mobility) was captured. Safety concerns were reflected through the measurement of the respondent´s agreement with situations that may occur such as flying under poor weather conditions or their fear of having a mid-air collision. The respondents were also asked to state if they would feel safer if the UAV service had some characteristics such as a pilot on ground ready to take over the aircraft if needed, the possibility to speak with an operator at any time or security cameras inside the VTOL cabin. The participants´ view on cybersecurity was assessed through the measurement of the degree of concern they had towards critical points of cybersecurity such as data privacy, user tracking, loss of privacy and loss of control. The intention to use UAVs was measured using the Technology Adoption Life Cycle (from innovators to laggards) and the purpose of use was also reported. The embracement of the new mode as a citizen (not necessarily as a user) was also included; statements towards the level of comfort if UAVs are available in their city, the availability of UAVs to everyone, and the possible purposes of use of UAVs were evaluated.

The next part of this survey consisted of questions about the respondents' mobility (mode of transport, travel time, transfers) and driving behaviour (e.g. enjoying driving, driving after drinking, involvement in accidents) and environmental concerns. To finish the survey participants provided some socio-demographic information (e.g. age, gender, income, residence).

4 Results

A total of 207 random replies to the online survey were collected. The survey was created on Lime Survey and shared through WhatsApp, Facebook and E-mail. It was found that there is reliable relationship between the measured dimensions and the measured aspects of intention and embracement (alpha Cronbach). Among the respondents, 55% are male and 45% female, 28% are younger than 25, 34% belong to the age interval 25-34, 6% to 35-44, 11% to 45-54, 20% to 55-65 and 1% the rest. Regarding the type of residence area, 38% live in a big city (1 million - 10 million inhabitants), 45% in a city with less than 1 million inhabitants, 11% in a town and 5% at a village. The composition of the sample´s employment state is the following: 47% are employed full-time, 7% part-time, 10% self-employed, 3% currently unemployed, 20% students at the university and the rest are retired and volunteers. When analysing the statistics of the trip purposes UAVs should be used for, it is found that the replies of the respondents vary significantly in the "strongly agree" level of the replies where it is seen that 20% believe they should be used for healthcare service, 7% for social activities, 6% for leisure and 3% for work. More than 50% of the respondents disagree (at any level) with the use of UAVs for work trips, 23% for leisure and 32% for social activities.

The embracement of the new vehicle type was analysed in its relationship to safety aspects, cybersecurity, expected benefits, trust in automation and adoption of new technologies through the Pearson correlation indicator; when appropriate the Spearman correlation indicator was applied. It was found that there is a statistically significant (up to 0.05 level) correlation among the perception of some aspects and embracement. Specifically, the concern of respondents about possible collisions of the first vehicles appears to affect the embracement aspect with the highest correlation to be among the possible collisions and the generated to the public (0.452). The respondents indicated that whether they would feel comfortable living in a city that adopts this mode is related to the risks of terrorism, possible collisions and technology readiness the first years. The expected benefits to mobility independence and better conditions of traffic were positively related to the aspects of embracement. Familiarity with new mobility services was also positively related to embracement. Contrary to what was expected, the availability of connection to ground operations did not affect significantly all the embracement aspects apart from the perception of UAVs being beneficial for the society that had a low (0.263) and positive relationship with this service option. Weather conditions were not found to influence embracement. Finally, noise and visual pollution had a negative impact on the adoption of UAVs and their perception as acceptance means of transport in a city.

Regarding the relationship of intention to use to safety and cybersecurity, the fear to fly, lack of communication with on-ground services and fear of possible collisions had an impact on the prevention of people from using the new mode. On the other hand, the adoption of new existing mobility solutions, the perception of gains in road congestion and travel time had a positive correlation to the adoption of UAVs.

In order to analyse variations of perceptions among different adoption and embracement levels, a Shapiro test was performed to assess the applicability of ANOVA analysis. It was shown that the data doesn´t follow a normal distribution and hence, non-parametric tests were applied. The results are presented below separately for the intention to use and the perception of UAVs as an acceptable transport mode. No differences were found among the adoption and embracement levels when analysing Affinity to Automation, Mobility Technologies, perceptions on Cybersecurity and Environmental issues while Safety perceptions varies only among different embracement levels.

4.1 Variations in intention to use

A Mann-Whitney *U* Test indicated that the adoption levels of male respondents are higher that the adoption level of female respondents, indicating that men are willing to adopt this mode earlier than women. When considering the respondents' accident history, the Mann-Whitney *U* Test indicated that the adoption levels of respondents who had at least one accident as a driver exceeded those of the respondents who have never had a accident as a driver. Kruskal-Wallis tests were performed to explore differences in other socioeconomic aspects across adoption levels. Contrary to what expected, considering age, there were no differences in the distribution of the groups. Also, no differences were found when considering monthly income of respondents. Tests on mobility behaviour indicated that respondents with higher adoption levels had higher satisfaction levels with ride hailing services but the frequency of use did not vary.

Differences on the perception of expected benefits across Laggards and the other adoption levels were found when considering the perception of the aspects "The use of Air Vehicles will make my travel time more productive across intention to use", "Air vehicles will offer a less stressful mobility experience" and "Air vehicles will increase the trips people will make". The aspect "Air vehicles will offer a safe and fast mean of transportation" received lower rates by Laggards and Late Majority compared to the other adoption levels. In the driving behaviour of the respondents, their feeling of safety when driving the car on their own was higher in the cases of Early Adopters compared to Early and Late Majority. Differences were also tested among some aspects of public embracement. Considering the perception of the aspect "Air Vehicles will increase the quality of life in the cities that offers this transport mode" among the adoption categories, it is found that Laggards rated lower this statement compared to the other adoption categories. The same difference was found on the analysis of the improvement of transport accessibility for all citizens, the equality of plane´s and UAV´s safety, and the sense of safety and comfort that UAVs inspire. They also have a higher rate of perceived risk for the public, stress and fear they cause. Regarding the visual and noise pollution aspects, the Kruskal-Wallis test indicated that Early Adopters tend to have lower concerns over these aspects compared to the other categories.

4.2 Variations in embracement

The analysis of the socioeconomic aspects was similar to adoption´s, only gender differences were found on the perception of "Air Vehicles are an acceptable means of transport". Kruskal-Wallis tests were also performed with multiple groups. The tests revealed that when considering the aspects "The use of Air Vehicles will reduce road congestion" and "The use of Air Vehicles will reduce accident on roads", respondents that accept more UAVs as a means of transport tend to believe that UAVs will reduce road congestion. The analysis of differences in the aspects "The use of Air Vehicles will make my travel time more productive" and "AVs will significantly reduce travel time" across the public embracement, showed that people more open to UAVs tend to believe more on travel time and time productivity benefits generated by UAVs compared to those that are less receptive on UAVs as a mode in the city. In terms of urban planning and accessibility to transport networks, perceptions over the facilitation of connecting remote areas to bigger cities and multimodal nodes, the release of free space in the urban environment for other facilities (such as pedestrian zones), the mobility opportunities to people with reduced mobility independence and the seamless mobility of police and healthcare staff were higher at the groups that find UAVs an acceptable transport mode. The same conclusions were made for the reduction of CO2 emissions and the belief that UAVs will offer a safe and fast transport mode and a less stressful mobility experience. Differences among high and average levels of public embracement were observed among respondents that "Somewhat agree" with the statement "I'm concerned that the first Air Vehicles available will be unsafe due to possible vehicle collisions in the air above cities" on the public embracement tend to differ with the respondents "Strongly agree" and have a higher perception of the safety of UAVs. Low embracement levels also demonstrated higher propensity to drive after having drunk alcohol.

5 Conclusion and future work

There is a need for a new, safer, faster, and greener solution of transportation. UAVs can be a new opportunity in urban mobility. This study presented the dimensions to be studied in the process of the introduction of UAVs in mobility systems in a way that they can serve citizens and potential users. The intention to use and the embracement of UAVs are both important for the successful planning and implementation of the new service in the third dimension of urban space. A survey was conducted in Lisbon area to collect data on citizen´s perceptions over aspects related to the introduction of UAVs in the transport system of a city. Through the analysis of 207 random replies and the conduction of correlation and non-parametric tests, six out of ten proposed hypotheses were validated (H1, H2, H5, H7, H8 and H10) indicating differences among the perceptions of men and women, variations in the adoption and embracement levels according to the safety perceptions, expected benefits and satisfaction with shared mobility services. Further analysis will be conducted through the development of discrete choice models that will model the intention to use and public embracement levels.

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