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Urban air mobility (UAM) in the metropolitan region of São Paulo: Potential and threats

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Abstract

Purpose: The increase in congestion and pollution in large cities combined with the innovation of air transport technology (drones and vertical takeoff and electric propulsion vehicles – eVTOL) and with the advances in autonomous technology have stimulated this research on the potential of Urban Air Mobility – UAM as an alternative to improve mobility conditions in urban centers. In this research, the evaluation of public acceptance of UAM was carried out with a focus on the metropolitan region of São Paulo (RMSP), the largest metropolitan region in Brazil, with about 22 million inhabitants, and one of the ten most populous metropolitan regions in the world.

Design/methodology: To fulfill the proposed purpose, an assessment of public acceptance of UAM (based on a survey) was developed. The survey identified the perceptions of potential customers regarding the gains of the air mobility alternative, as well as the restrictions and fears in relation to the UAM. The opinion poll was carried out along the same lines as the work carried out in Europe, allowing the comparison of results between the two markets.

Findings: The main results indicated the biggest problems for the implementation of UAM services in the metropolitan region of São Paulo, as well as the expectations and restrictions of customers, which will be important subsidies for the development of public policies to improve conditions mobility in the region.

Originality/value: UAM is a new, disruptive mobility technology that can improve travel conditions in highly congested urban centers, such as the RMSP. The success of this new

technology depends on understanding the challenges and opportunities, but mainly on the perception and expectations of potential customers.

Keywords: Urban mobility, urban air mobility, vertiports, eVTOL, mobility infrastructure

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1. Introduction

Urban air transport is not a new concept. The use of flying vehicles in urban areas dates back to the 40s (more precisely after WW II), through helicopters and rotary wing aircraft with vertical take-off and landing operations – VTOL. The services offered were on-demand transport (a form of air taxi, but with helicopters) and spread to several cities and metropolitan regions until the mid-1970s. Problems with operational safety, air pollution, noise, and costs ended up paralyzing taxi services (Helicopterinvestor, 2020). What he has observed since then is that urban passenger transport with helicopters exists as a niche market on a charter basis in cities such as São Paulo and Mexico City, where ground movement conditions are far from acceptable.

The recent technological revolution, with drones and the evolution of helicopters, in a scenario of constant worsening of circulation in the world's large cities, created conditions to redefine the use of air modes in urban displacements, using silent piloted and unmanned vehicles to carry out on-demand and scheduled operations – Urban Air Mobility (UAM).

Thus, Urban Air Mobility (UAM) has become an emerging topic that gained much attention and interest from academia and industry. The name itself refers to a field of research and technological innovation that has been central to contemporary urbanism – urban mobility. As the development of new mobility technologies is being spurred by the increasing pressure of traffic congestion in large cities, start-ups and established companies in the aviation and automotive sectors have moved into the UAM, with the aim of providing competitive solutions for a "new market" (Straubinger et al, 2020).

The common understanding found in technical and commercial literature on the subject is that urban air mobility is a safe and efficient air transport system that will use highly automated aircraft that will operate and transport passengers or cargo at lower altitudes in urban and suburban areas. UAM will be composed of an ecosystem that considers the evolution and safety of the aircraft, the operating structure, access to airspace, infrastructure development and community involvement (United States, 2020).

One of the keys to consolidating the UAM, as with any other mode of transport, is the vehicle: drones, flying taxis and autonomous vehicles, all electric-powered and capable of vertical take-off and landing (VTOL). There are several projects in progress, all pointing to the readiness for commercial use in the first half of the 20s (Panetta, 2019).

In addition to the vehicle, other aspects have to be worked on to enable the operation of new transport technology. In the case of the UAM, several studies, such as Straubinger et al. (2020) list other operational aspects:

- a) Flight crew licensing and training: requirements for pilots and other professionals involved in the operation, training, licensing, and performance of operators' tasks
- b) Landing areas: establishment and operation of UAM platforms as well as the use of infrastructure at existing airfields close to cities and which are not necessarily configured or licensed for commercial flight operations. Infrastructure will be dealt with in the next paragraphs
- c) Maintenance regulations both for the vehicle and for the technical personnel associated with the service

- d) Requirements for service providers, including their certification most likely based on existing regulations for commercial rotary-wing services
- e) ATM and ANS rules especially for low altitudes, provided for the UAM, need to be established. Additional ATM solutions allowing a high level of autonomy have to be found (keyword UTM UAM traffic management)
- f) High-resolution obstacle and topography databases are a must, including temporary obstacle update mechanisms (e.g.: a construction crane)
- g) Safety regulations for passengers and ground support personnel.

All these items have been the subject of numerous works, in industry and academia – an accurate view of the state of the art can be found in GARROW et al (2021). The most recent and significant advances were the publications of parameters for the planning and design of vertiports by the United States (2022) and EASA (2022). Thus, the bases for the exploration of a market with enormous potential are being consolidated. To get an idea of this expectation, EASA (2020) projects for 2030 a European market for UAM services in the order of 4.3 billion euros (31% of the global market). Other reference such as Research and Markets (2022), suggest that the urban air mobility market is projected to grow to USD 17,269.71 million by 2035, registering a CAGR of 17.28% during the forecast period (2022 - 2035).

2. Literature review

But being a new and disruptive form of urban commuting, with impacts on the demand and supply of transport services, it is essential to assess the acceptance of this new technology by potential customers.

Research on the potential societal barriers of emerging technology is important to understanding the potential viability of the technology from a societal perspective, opportunities, and challenges associated with markets, use cases, business models, and partnerships. Research on societal barriers can also provide insight into the potential impacts of deployment. Additionally, research on societal barriers can help identify early technological, market, or consumer challenges to address, such as how UAM can be used to improve airport access or reduce commute times (Shaheen, 2018). Furthermore, it constitutes an important input in the formulation of public policies to help maximize the potential benefits and minimize the potential adverse effects of technology.

As of 2018, several studies have addressed the social acceptance of UAM services, with different geographic focuses or evaluation techniques, such as: Haddad et al (2020) used a stated preference survey to assess the perception of users in terms of adoption time horizon in the Munich region; in WINTER et al (2020) a quantitative methodology and non-experimental design were accomplished using 510 participants from the USA to develop a regression equation and assess model fit. Six significant predictors of consumer willingness to fly in autonomous air taxis were found: familiarity, value, fun factor, wariness of new technology, fear and happiness; WARD et al (2021) conducted a quantitative survey experiment in two studies of willingness to fly in autonomous air taxis among people from the United States and India (people from India were more willing to fly than people from the United States).

A broad and accurate overview of UAM public acceptance assessments can be found in Çetin et al (2022), where various surveys of social acceptance of the UAM are analyzed. The surveys reviewed are from various organizations (air traffic service providers, industry, research, universities, airspace security agencies) and countries (Australia, Germany, Brazil, USA, China, Korea, etc.), and were conducted between 2015 and 2021.

Among all the works analyzed, the "Study on the societal acceptance of Urban Air Mobility in Europe" (EASA, 2021) deserves special attention, for its scope and methodological consistency.

As part of the preparation of a regulatory framework regarding drone services in an urban environment, EASA conducted a study on the societal acceptance of UAM operations across the European Union. Based on research, literature review, local market analysis, surveys and interviews, the study examined the attitudes, expectations, and concerns of EU citizens with respect to UAM. According to EASA, the scope of the study was intentionally limited to the transportation systems that move people or cargo by air in and around urban environments for commercial or emergency service operations. Other use cases, such as infrastructure

assessment, surveillance, 5G emissions or state operations (e.g. military, and police surveillance) were excluded (EASA, 2021)

The survey results were very homogeneous among all those surveyed across the EU and in all socio-economic categories. They can be clustered into 10 key takeaways: 1. EU citizens initially and spontaneously express a positive attitude toward and interest in UAM; 2. The notion of general/public interest is a determining factor for acceptance: use cases for the benefit of the community are better supported than use cases satisfying individual/private needs; 3. The main benefits expected from UAM are faster, cleaner, and extended connectivity; 4. When encouraged to reflect upon the concrete consequences of potential UAM operations in their city, EU citizens want to limit their own exposure to risks, in particular when related to safety, noise, security, and environmental impact; 5. Safety concerns come first, but the study also shows that citizens seem to trust the current aviation safety levels and would be reassured if these levels were applied to UAM; 6. Noise is the second main concern expressed; 7. UAM is seen as a good option to improve the local environmental footprint, through reduced urban traffic congestion and better local air quality; but at the same time citizens express major concerns about UAM's impact on wildlife; 8. The results also demonstrate a limited trust in the security and cyber security of UAM; 9. The integration of UAM must respect residents' quality of life and the cultural heritage of old European cities; and 10. Local residents and authorities feel directly affected by the deployment of UAM and want to engage and play an active role in its implementation (EASA, 2021).

Virtually all available studies of social acceptance of UAM are focused on urban centers in the northern hemisphere. This fact leads to an immediate question: what happens when assessing the social acceptance of the UAM in a city in the southern hemisphere, where general urban mobility conditions are much lower than in the northern hemisphere? To answer, we have proposed to evaluate a practical case: the Metropolitan Region of São Paulo – Brazil.

3. Case study: The metropolitan region of São Paulo

Established by a Federal Law of 1971, the Metropolitan Region of São Paulo (RMSP), also known as Greater São Paulo, is the largest metropolitan region in Brazil, with around 22 million inhabitants, and one of the ten most populous metropolitan regions in the world. It comprises the city of São Paulo (the capital of the state with the same name and the largest city in the country) and another 38 municipalities (Figure 1).

Its area – 7,946 square kilometers – corresponds to less than one-thousandth of the Brazilian surface and just over 3% of the territory of São Paulo (Figure 2). The urbanized area comprises 2,200 square kilometers (around 221,000 blocks). Between 1962 and 2002, the urban area increased from 874 km² to 2,209 km², in a continuous process of the conurbation, which made cities lose their physical limits (due to the growth of the urban area of São Paulo towards neighboring cities) giving rise to a continuous urban spot.



Figure 1. Metropolitan Region of São Paulo: RMSP (emplasa.sp.gov.br)



Figure 2. RMSP, São Paulo State and Brazil (pt.wikipedia.org)

One of the hardest problems in the metropolis, along with safety, is mobility, whose general conditions are far from the desired minimum. There was no integrated planning between circulation and land use. As a result, the RMSP presents a monocentric pattern on the metropolitan scale, with strong commuting movements from the periphery to the expanded center of the city of São Paulo (Harris, 2015).

The most recent Origin-Destination survey in the RMSP, carried out in 2017 by the Companhia do Metropolitano de SP (since 1967, in every final year 7 this survey is applied), pointed out that in that year 41.4 million trips were carried out per day in the RMSP. Metropolitan Region of São Paulo, of which 28.2 million are motorized (15.3 million are public transport and 12.9 million are private vehicles) and 13.2 million are non-motorized (12.9 million travel by foot and 0.4 million bicycle trips).

To meet this demand for urban displacement, the RMSP road network has 40 thousand km, and a complex public transport system, not fully integrated, basically operated by conventional bus; each municipality has its own bus system. The largest of these systems is in the city of São Paulo, with an operating fleet of more than 14,500 registered buses that transport 10 million passengers per working day (Sptrans, 2020). There is also a metropolitan bus service operated by the State of São Paulo, which offers intercity services throughout the RMSP.

The metropolitan rail transport network in the RMSP is small, with a total length of 372 km (230 km inside the city of São Paulo). It transports around 8 million passengers per working day (Metro SP, 2020; CPTM, 2020) and comprises metro and monorail services (6 lines) and metropolitan trains (7 lines). This system is operated by four companies, two state public companies and two private concessionaires (one subway line each).

In the last decade, the provision of infrastructure to support commuting in the RMSP started to rely on a network of cycle paths, currently with more than 1,000 km (650 km in the city of São Paulo) in practically all municipalities in the metropolitan region.

Three airports (Guarulhos International, the main airport in the country, located in the municipality of the same name and 25 km from the center of the capital; Congonhas, the second busiest airport in Brazil and only 8 km from the center of São Paulo, and Campo de Marte, in the north of the city of São Paulo and focused on general aviation) and a great helipad network make up the airport infrastructure that completes the services and infrastructure to support travel in the RMSP.

The most recent register of aerodromes by the regulatory agency (ANAC, 2023) indicates that Brazil has 1327 helipads (this number does not include helidecks - offshore helipads). Of this total, 292 helipads (22%) are in the RMSP.

In this complex infrastructure, the number of helipads in the metropolitan region stands out, some of which are equipped with the entire structure for maintenance and helicopter hangar. Most of these infrastructures (191 helipads) are in the city of São Paulo. According to a survey carried out by the Brazilian Association of Helicopter Pilots – Abraphe (2021), the metropolitan region hosts the largest fleet of helicopters in operation in the world, with 411 registered aircraft and about 2,200 daily take-offs and landings.

The basic reason is the difficulty of moving on the ground. As the supply of road infrastructure and services to support urban travel has not followed the evolution of demand, what is observed is daily traffic jams. The City's Traffic Engineering Company monitors 868 km of public roads in the expanded center of the capital. Daily traffic jams in the monitored area are on the order of 100 km, often exceeding 200 km on Fridays or eve of holidays. In this way, air travel is no longer an alternative and becomes a priority for users with a high value of time and traveling for business reasons.

This scenario proves to be attractive for the installation of UAM services. Potential customers already have some kind of familiarity with urban air travel, which can help, but not solve, the issue of "swapping" the helicopter for a vehicle (probably unmanned) that operates closer to the ground.

4. Data and methods

The evaluation of UAM services perspective in the Metropolitan Region of São Paulo was carried out through a measure of the acceptability and possible social barriers of this new technology.

The evaluation of the acceptability and barriers of UAM in the Metropolitan Region of São Paulo was carried out based on a survey with a substrate of potential customers, who were invited to answer a structured questionnaire based on the one applied by EASA (2021), the closest to the objectives of this study.

4.1. The questionnaire

The questionnaire had 16 questions, which can be grouped into four parts: (1) demographic characterization of the respondent, (2) degree of familiarity with air transport and urban air mobility; (3) identification of concerns and benefits; and (4) willingness to use UAM services.

The demographic characterization followed the pattern: gender - age group - income group - education. Familiarization included issues related to the use of air transport in general and helicopter services in the metropolitan region of São Paulo. Regarding UAM, a conceptual text was presented on the technology and asked about knowledge prior to reading. Concerns and benefits were exposed in two specific questions, listing aspects such as safety, security, noise, privacy, and time savings and improvements in rescue operations and emergency care. The use of UAM services was asked for the respondent being a passenger and being a pedestrian circulating under a vehicle providing UAM services.

4.2. Collecting the answers

The questionnaire was implemented using Google Forms in the period September - October 2021 for preselected groups: infrastructure council of FIESP (Federation of Industries of the State of São Paulo); subscribers to the Connected Smart Cities and Agência Infra websites, infrastructure and transport groups of engineers and urban planners. This pre-selection, which generated 192 responses, aimed to optimize the possibility of identifying benefits and challenges for the implementation of UAM services in the metropolitan region of SP. Based on the pre-selection established, it can be said that it is a prospection with opinion makers in mobility and infrastructure.

4.3. Results

The demographic characterization of the sample was as follows:

a) 77% male;

- b) 60% between 35 and 64 years old
- c) Undergraduated or graduated = 85 %
- d) Monthly income: 43 % between R\$ 10 mil and R\$ 30 mil

This is a profile compatible with the pre-selected extract for prospecting. This compatibility is reflected in the use of air mode for travel. Asked about the frequency of use in the year before the pandemic, for work or leisure, they answered:

- a) 32% used air transport once or twice
- b) 22 % used 3 5 times
- c) 15 % used 6 10 times
- d) 17 % used every month of the year

Specifically, in relation to the use of helicopters to travel in the city of São Paulo or its Metropolitan Region, only 12% responded that they had already used them. These results point to respondents who are familiar with the use of air mode in general, with less intensity in the case of metropolitan helicopter services.

About 44% of respondents answered that they had prior knowledge of the UAM concept. A result below expectations, since it is an extract close to mobility technologies and, during the period in which the questionnaire was available, EVE (Embraer's subsidiary dedicated to UAM) was the subject of several mentions in the national media due to agreements signed with customers abroad for the supply of eVTOL vehicles.

Given the degree of familiarity with UAM, respondents were urged to select among seven possible benefits of UAM (respondents could choose more than one) – 784 choices were made by the respondents, summarized in the following table, where the "%" column indicates the percentage of respondents who indicated the benefit.

With the total sample, the main benefit was the improvement in emergency response time, followed by time savings in cargo transport and time savings for passengers. The perception of the benefits of UAM (mainly emergency assistance, followed by cargo and passengers) is the same as the survey carried out by EASA (2021).

Contrary to the assessment of benefits, the assessment of concerns showed that these concerns are greatly influenced by the degree of prior knowledge of the UAM. Thus, the results of the assessment of concerns (next table) are presented differently from the results for the benefits.

Seven possible concerns were presented, and respondents could choose more than one. The 544 respondents' choices are consolidated in Table 2.

Benefits	% of respondents	
Time savings – cargo	75,0	
Time savings – passenger	70,8	
Improved emergency response	77,7	
Reduction of traffic jams	46,4	
Noise reduction	35,9	
Air pollution reduction	56,8	
Improved access	45,8	

Table 1. UAM Benefits

	Prior knowledge of UAM		Total sample
	Yes (%)	No (%)	
Noise	25,9	27,1	26,6
Visual pollution	21,2	32,7	27,6
Safety	81,2	75,7	78,1
Threats and security	57,6	49,5	53,1
Privacy	41,2	29,0	34,4
Unemployment	5,9	11,2	8,9
UAM is only for high income	43,5	63,6	54,7

Table 2. UAM concerns

As in the EASA survey (2021), the main concern with UAM services is safety. In the work of EASA (2021) security appears as a second concern, and aircraft noise comes right after security. When concerns about aircraft noise are added to noise from vertiports, item noise pollution appears to be the main concern.

After the issue of safety, the respondents indicated that the UAM presents itself as another alternative only for high-income groups, a very different result from the EASA (2021) work. The image of helicopters in São Paulo is reflected in this position and indicates the need for an effort to take off the new technology from helicopter services. It is emblematic that more than 60% of respondents who declare that they do not know the concept of UAM associates the technology with helicopters. This perception made the concern about security appears as a third concern considering the total sample and in second place for the sub-extract of those who claimed to have previously known the concept of UAM.

Publicizing a technology that is quieter than helicopters in the region with the largest fleet of these vehicles in the world, it is more than expected to have a low perception of noise pollution as a concern with UAM, contrary to what is found in studies from abroad (especially those developed in Europe).

Regarding the willingness to use an UAM air taxi service, the responses were as follows:

Total willingness to try a UAM air taxi:

- a) Manned (human pilot on board) = 47% (91 respondents)
- b) Unmanned = 21% (41 respondents)

No willingness to try a UAM air taxi:

- a) Manned (human pilot on board) = 11% (21 respondents)
- b) Unmanned = 28% (54 respondents)

Taking the willingness to try an air taxi service operated by eVTOL as a measure of the acceptance of UAM services, there is a similarity between what was obtained in the survey carried out in São Paulo and the results exposed by EASA (2021), as well as the aforementioned by Garrow et all (2021), always in the range of 45 – 50%. When services with unmanned vehicles are proposed, this acceptance is much lower.

Considering the concerns raised by the respondents, where the issue of safety is highlighted, the results of the willingness to try an eVTOL air taxi, with and without crew, are coherent and define a challenge for the industry - the awareness of potential customers about the safety of unmanned vehicles.

Asked about their perception of safety as a pedestrian with UAM services circling overhead, the answers were:

Full acceptance of "over my head" eVTOL circulation:

- a) Manned (human pilot on board) = 47% (90 respondents)
- b) Unmanned = 24% (46 respondents)

No acceptance of "over my head" eVTOL circulation:

- a) Manned (human pilot on board) = 6% (12 respondents)
- b) Unmanned = 23% (45 respondents)

These results are consistent with the safety concerns raised by the respondents and reaffirm the need for a special effort to make the use of unmanned vehicles feasible.

As for the potential of services, three alternatives were proposed for respondents to choose, with the following results:

- 1. Air taxi service between two points in the city of São Paulo, at a cost 70% higher than the special taxi = 58% (111 respondents)
- 2. Air taxi service between the city of São Paulo and Guarulhos Airport = 49% (94 respondents)
- 3. Air taxi service between the city of São Paulo and Campinas Airport / Viracopos = 32% (62 respondents)

In all the studies where it was possible to select a specific service, access to the international airport was always prioritized. In the present study, the choice of internal service to the city is just a reflection of the general conditions of circulation in São Paulo and corroborates the general perception of mobility restrictions that are found in the city and its metropolitan region. It is worth remembering that the cost relationships were estimated based on the relative costs found in the work by EVE (2021), and that variations in this distribution may occur due to changes in the relative prices of transport modes.

5. Conclusions

Urban air mobility services (UAM), still in the study and experimentation phase, have been placed as a consistent alternative for improving mobility conditions in large centers.

A series of eVTOL vehicle projects, as well as studies of demand and acceptability, operation, infrastructure, and air traffic management of these vehicles are found in the literature, with simulated applications in large urban centers.

In this context, the São Paulo Metropolitan Region, a cluster of more than 22 million inhabitants, where daily congestion of hundreds of kilometers coexists with the largest urban fleet of helicopters in the world, is one of the richest places to experience the potential of this new technology to support urban displacements.

The prospection aimed at identifying the acceptability and challenges for the implementation of UAM services in the metropolitan region of São Paulo showed the following results:

- 1. Regarding the acceptability of UAM technology and services, there is a positive predisposition in the metropolitan region of São Paulo when it comes to services with manned vehicles (human pilot on board). In this scenario, 47% of respondents reported being totally willing to try the service, against 11% who were not willing to
- 2. This level of acceptance drops to 21% when it comes to unmanned vehicles, while the percentage of unmanned vehicles rises to 28%. This result shows the need for an effort to clarify the potential market for the

safety conditions of unmanned vehicles, a measure of extreme importance since much of the technology's viability depends on a migration to "driverless" vehicles

- 3. The acceptability of the respondents as pedestrians follows the same logic as the situation as passengers: total acceptance of the circulation of UAM vehicles "over my head" for 47% of respondents, a percentage that drops by half (24%) in the case of vehicles not manned, reinforcing the previous observation about safety issues in "driverless" operations
- 4. The survey showed that the respondents understand that the improvement of assistance and removal services in emergencies will be the main benefit of the technology, followed by the gain of time in the transport of loads and by the gain of time in the displacement of passengers
- 5. Although this order is the same as observed in other surveys, such as EASA (2021), the reasons for this are different: in the European case, the available mobility conditions do not encourage the exchange for a new technology, contrary to what happens in São Paul. But the perception that the UAM technology is only for high-income brackets induces the potential customer in São Paulo to prioritize the benefit for segments other than passengers
- 6. The previous conclusion is corroborated by the fact that all the surveys analyzed in the literature search point to the UAM services connecting the main international airport in the region as having the greatest potential, contrary to what was verified in São Paulo, where the services of air taxi connecting internal points of the city was pointed out as the one with the greatest UAM potential
- 7. Specifically in relation to restrictions with UAM, the survey pointed out that the main concern with UAM services is safety associated with accidents (safety). Contrary to what was observed in all the surveys analyzed, the second concern of the respondents was the elitist nature of the technology (UAM is only for high-income individuals), which was more significant in the sub-extract of the sample that had no prior knowledge of UAM concepts. The most likely reason for this is the confusion observed between UAM and helicopter services: São Paulo has the largest urban fleet in the world; EVE's pilot operation was a helicopter-operated liaison; there is an inevitable comparison between services, which limits the potential of the new technology.

The above conclusions allow us to establish a robust strategy for the deployment and expansion of UAM services in the metropolitan region of São Paulo in order to improve general conditions of mobility in the region.

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