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Urban Air Mobility for Sustainable and Smart Portuguese Cities: A Living Lab in Lisbon

Mobilidade Aérea Urbana para Cidades Portuguesas Sustentáveis e Inteligentes: Um Living Lab em Lisboa

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Abstract

This article focuses on urban mobility three-dimensional, aiming to provide conditions and practical tools to improve lives and reverse climate change through the innovation of urban mobility by implementing a living lab in Lisbon, Portugal. As urban mobility is about people, like climate change issue is a human issue, urban air mobility's technology humanization is the key to obtaining success in the long run. As a result of the ongoing engagement of Portuguese citizens alongside interaction with stakeholders, guidelines are provided to bring urban air mobility to the city of Lisbon. These guidelines could backbone future advanced discussions and narrow the gap between the science community, public authorities, professional actors (i.e., the industry), and consumers (i.e., people).

Keywords: Urban Air Mobility; Urban Mobility; Accessibility; Sustainable Mobility; Smart Cities.

JEL codes: L93, O18, Q01, Q55, Q56, R4.

Resumo

Este artigo foca-se na mobilidade urbana tridimensional, com o objectivo de fornecer condições e ferramentas práticas para melhorar a qualidade de vidas e reverter as alterações climáticas através da inovação da mobilidade urbana implementando um living lab em Lisboa, Portugal. Como a mobilidade urbana diz respeito às pessoas, assim como a questão das alterações climáticas é uma questão humana, a humanização da tecnologia da mobilidade aérea urbana é a chave para obter sucesso a longo prazo. Como resultado do envolvimento contínuo dos cidadãos portugueses a par da interacção com stakeholders, são providenciadas directrizes de modo a trazer a mobilidade aérea urbana para a cidade de Lisboa. Estas directrizes poderão apoiar futuras discussões avançadas e reduzir a lacuna entre a comunidade científica, autoridades públicas, atores profissionais (ou seja, a indústria) e os consumidores (ou seja, as pessoas).

Palavras-chave: Mobilidade Aérea Urbana; Mobilidade Urbana; Acessibilidade; Mobilidade Sustentável; Cidades inteligentes.

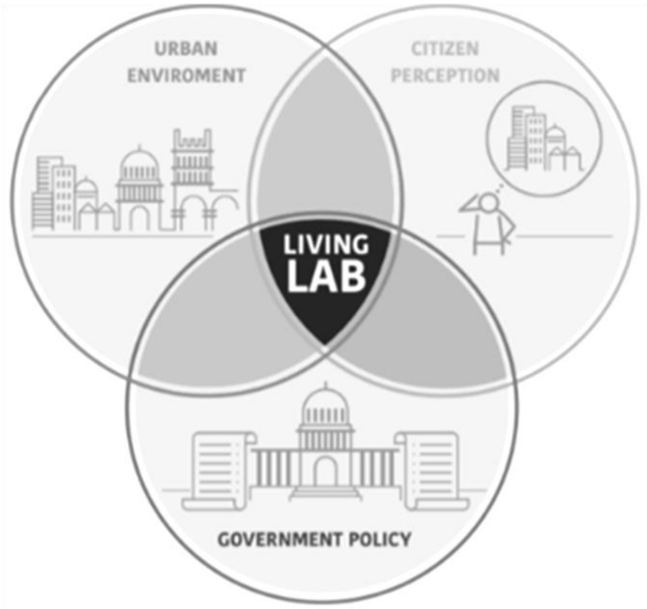
Código JEL: L93, O18, Q01, Q55, Q56 R4.

1. INTRODUCTION

The object selected for this paper is urban mobility three-dimensional (3D).

The increase in urbanistic movements leads to high resource consumption and environmental degradation, among other problems that need to be eased. Therefore, this research envisions providing conditions and practical tools to enhance lives and contribute to reversing the global issue of climate change through innovation in urban mobility. For that, this article uses a conceptual approach of analysing the logistics and feasibility of urban air mobility (UAM) in Portuguese cities using a user-centric approach by implementing a living lab in the capital of Portugal. Specifically, the living lab implemented is broken down into the urban environment, the citizen perception, and the government policy (see figure 1).

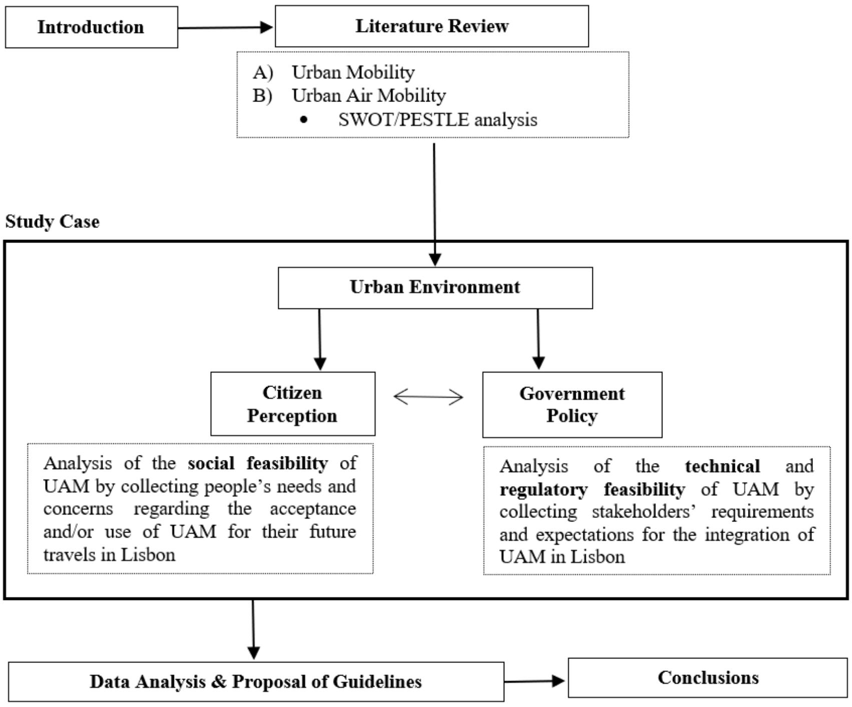
Figure 1. Three key areas of a living lab in urban areas



Lisbon is chosen as the study case due to its road congestion and noise and atmospheric pollution concerns (intensified by the Humberto Delgado Airport located in the middle of the city where aircraft noise and microparticles emitted by aircraft are highly harmful to citizen's health). After analysing the urban environment of Lisbon, this research investigates the citizen perception, giving guidance to the government policy key area. Because urban mobility is about people, like climate change issue is a human issue, humanizing the technology of UAM is the key to success in the long run. In other words, the fundamental element to foster an innovative mobility solution for cities is placing people at the centre of the solution design of UAM (ENoL, 2021).

In this way, a living lab is implemented, fostering ongoing engagement of people in the decision-making process alongside a parallel interaction with stakeholders as this project unfolds. The stakeholders contacted are the airport authority of Portugal (*ANA* Airports of Portugal), the Portuguese air navigation service provider (ANSP) (*NAV Portugal*), the Portuguese Civil Aviation Authority (*ANAC Portugal*), Lisbon City Council, and the Government of Portugal. The results obtained from the living lab will illuminate the path to integrate UAM successfully, consistently considering people's needs and concerns and the stakeholders' expectations and requirements for this integration, by exploring ways to mitigate concerns and maximize opportunities. Simply put, the methodology followed along this research is displayed in figure 2.

Figure 2. Methodology



This paper contains five parts: an introduction, a literature review about urban mobility and urban air mobility, a study case, the study case data analysis, and conclusions.

Ultimately, guidelines based on real data and feedback are provided to narrow the gap between the science community, public authorities, professional actors (i.e., the industry), and consumers within the UAM market. Also, these guidelines serve as a tipping point for future advanced discussions to bring on-demand UAM to Portuguese cities.

2. LITERATURE REVIEW

2.1 Urban mobility

Urban mobility refers to all the movements in urban areas, i.e., all the daily trips by the inhabitants and freight in a city, and the logistics associated with such trips (Shang, Doulet and Keane, 2009). These urban areas are considered key actors to achieve the United Nations (UN) Sustainable Development Goals (SDGs) (BMZ, 2016). Dominating the employment and economic output, urban areas, also called metropolitan areas or "greater" (e.g., Greater London), comprise the city itself as well as the surrounding areas, and it can refer to cities, towns, and suburbs (National Geographic, 2021). On the other hand, mobility contributes to the quality of life since it expresses the ability to move or be moved in a free and easy way.

Sustainable urban mobility allows to improve accessibility and quality of life and create urban areas more attractive. Being a goal of the UN by the year 2030, urban areas of the future will have a vast majority of citizens making their daily urban trips sustainably (BMZ, 2016). But there is an emerging concern to achieve a shift towards sustainable urban mobility. Urban mobility has to meet a dynamic equilibrium between all actors and stakeholders involved and develops better solutions.

Still, as the world gets crowded, the increase in urban road traffic has intensified pollution and noise in cities, deterioration the quality of life of all human beings. Notably, an innovative and swift change in urban mobility needs to occur now.

Yet, the urban airspace could be a potential alternative for urban movement (Bulusu, 2019). Being under the spotlight recently, UAM might be the solution to tackle this rise in urbanistic movements, revolutionizing the current urban mobility.

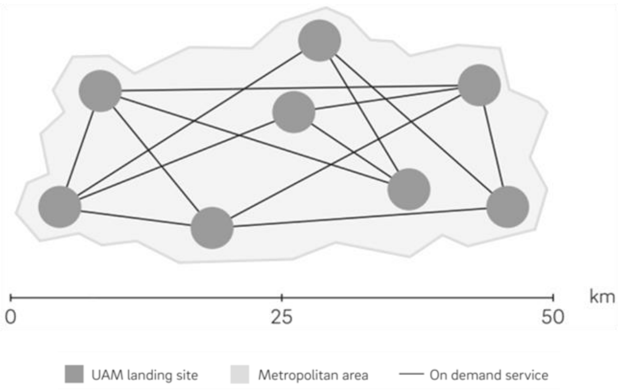
2.2 Urban air mobility

As a booster for future urban mobility, UAM can increase accessibility into cities and the urban airspace while simultaneously contributing to decreasing emissions, the noise level of decibels, and commuting times in a much safer way than by road transport. Overall, the UAM market is on fast-paced growth, and the following years will unfold an exciting new chapter in urban mobility.

Imagine taking off and landing anywhere and anytime in where you reside. UAM enables urban point-to-point connections, air taxi networks, and on-demand mobility (ODM) service (see figure 3) using hybrid and electric vertical take-off and landing (eVTOL) vehicles. These intracity connections offer a new travel solution to complement existing modes of urban public transport for the transportation of passengers, freight, and services providers (e.g., emergency responses, mobility service for disabled citizens, rescue operations, humanitarian missions, sustainable tourism, sightseeing, and so on) at lower altitudes within urban areas (EmbraerX, Atech and Harris Corporation, 2020). Also, if UAM's research and development (R&D) embraces a user-centric approach, i.e., connecting directly to humanity and reflecting its values, we might push the world forward by changing how we all travel in cities in the future, leading to a new global mobility revolution. Meanwhile, UAM has the power to point the way toward a new world of accessibility by adding to other travelling options. This increase in accessibility reflects the concept of the radius of life (Blue Zones, 2021) which seeks to optimize the environment where people spend 90 per cent of their lives to, therefore, promote community transformation. The radius of life will get people moving faster even living further away from the city centres, i.e., in rural areas, resulting in more control of urbanization, reduce in cost of living, and leading to longer lives.

Shortly, the relevant UAM research fields are composed of social, technical, political, regulatory/legal, environmental, and economic considerations (e.g., public acceptance and potential users), vehicles, infrastructures (i.e., ground infrastructure and urban air traffic management (UATM)), market actors; operations; integration; regulation; and modelling (Straubinger et al., 2020).

Figure 3. Uam ecosystem (baur, schickram, homulenko, martinez and dyskin, 2018)



2.2.1. Swot/pestle analysis

Both SWOT and PESTLE analyses are strategic analysis tools widely used for business goals planning. SWOT analysis allows to capitalize the business' strengths, minimize weaknesses effects, make the most of opportunities, and reduce threats impact. Complementary to SWOT analysis, PESTLE analysis considers the environmental context that affects the business and the possible changes in this context (Gray, 2016). For complex systems and a need for extensive analysis of external parameters, a SWOT/PESTLE analysis turns out to be the most popular tool (Hill and Westbrook, 1997).

Given the fact that UAM operations may be quite complex, a SWOT/PESTLE analysis is applied. This analysis highlights the positive effects (i.e., strengths and opportunities) and negative effects (i.e., weaknesses or threats) related to the UAM

market. Table 1 clusters a wide range brimming of these factors that may impact and influence future UAM operations.

Table 1. Swot/pestle analysis of uam market

SWOT/PESTLE analysis	Internal factors		External factors	
	Strengths	Weaknesses	Opportunities	Threats
Political	- Innovative mode of urban mobility, and hence innovative city hub; and - Higher public acknowledgement.	- Existence of few or no policies for UAM.	- Government initiatives to raise the adherence to friendly environmental transportation; - Positive effect on the overall urban mobility; «and - Funding from higher governments (e.g., European Commission (EC)) due to innovative initiatives.	- Low resilience from the government to support long-time decisions.
Economic	- Traffic flow optimization; - Multimodal integration.	- Higher electrification; and - High investment in initial acquisition.	- Higher employment opportunities; and - Innovative opportunities for businesses.	- Increased demands on local gip capacity; and - City's economic situation degradation.
Social	- People flow optimization; - Higher swiftness and adaptability to emergency response, mobility service for disabled citizens, rescue operations, humanitarian missions, and deliveries distribution; - Lower commuting times; and - Easier access to airspace for the people.	- Lower privacy; and - Higher difficulty of people's willingness and acceptance.	- Increase of tourists and visitors; and - New trend launching that could facilitate public willingness and acceptance.	- Risk of incidents and accidents; - Passenger interference with UAM operations and passenger illness during flight; - Cyber and physical security-related threats as sabotage and terrorism; - Higher inequality; - Unsafe proximity to people and structures; - Potential privacy violation.
Technological	- Higher safe and secure system compared to helicopter operations.	- Higher airspace congestion; and - Advanced technologies are still under development for cybersecurity, sense-and-avoid, fight control, contingency management procedures, cooperative route planning, weather consideration, localization with high-precision, and automated flight.	- Higher automation for on-demand businesses.	- System failure or loss of control; - Aircraft's collisions and bird strikes; - Cybersecurity-related risks; and - Potential UAM route conflicts with existing ATM and increase of ATM workload.
Legal	N/A	- Existence of prohibited or restricted airspace areas for UATM; - Existence of few or no regulations at all UAM fields; and - Existence of prohibited or restricted urban areas for vertiport placement.	- Overview opportunity for optimizing airspace.	- Need for people and passenger protection laws; and - Regulation could never allow UAM implementation.
Environmental	- Environmentally friendly (vehicles are electric-powered); and - Small footprint for ground infrastructures.	- Higher visual pollution.	- Competitive advantage due to green practices.	- New environmental laws; - Vulnerability to weather conditions; and - Potential interference with birdlife.

3. STUDY CASE

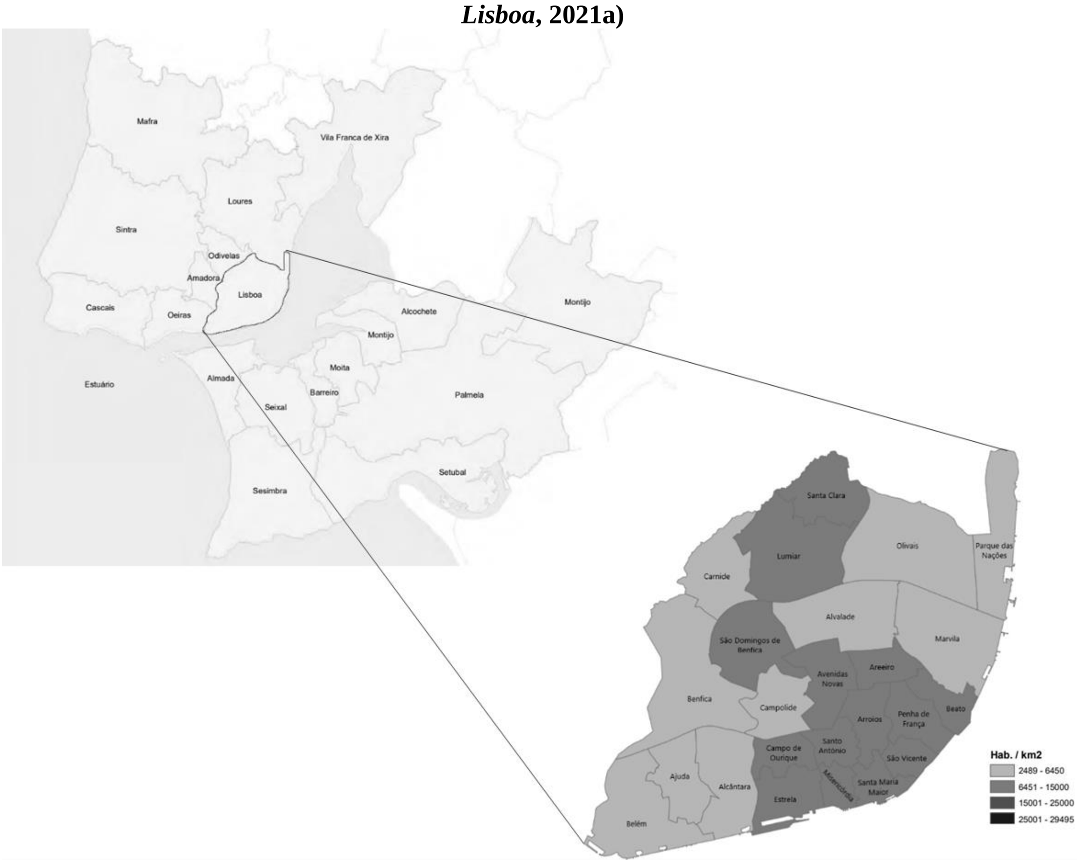
Lisbon is chosen to be the study case. Being the most populated city in Portugal, more pressure is placed on its road network. Additionally, this city already envisions to leverage itself as a smart city that places its citizens and their needs at its core, which meets this article's proactive user-centric approach.

Lisbon's zones with high population density (see figure 4), key points of interest (see figure 5), and traffic nodes, i.e., the major entrances into the city, where traffic is more concentrated (see figure 6), could serve as well as optimal locations.

According to the most recent census, the city of Lisbon has the following demography (*Câmara Municipal de Lisboa*, 2021a, and Statistics Portugal, 2021):

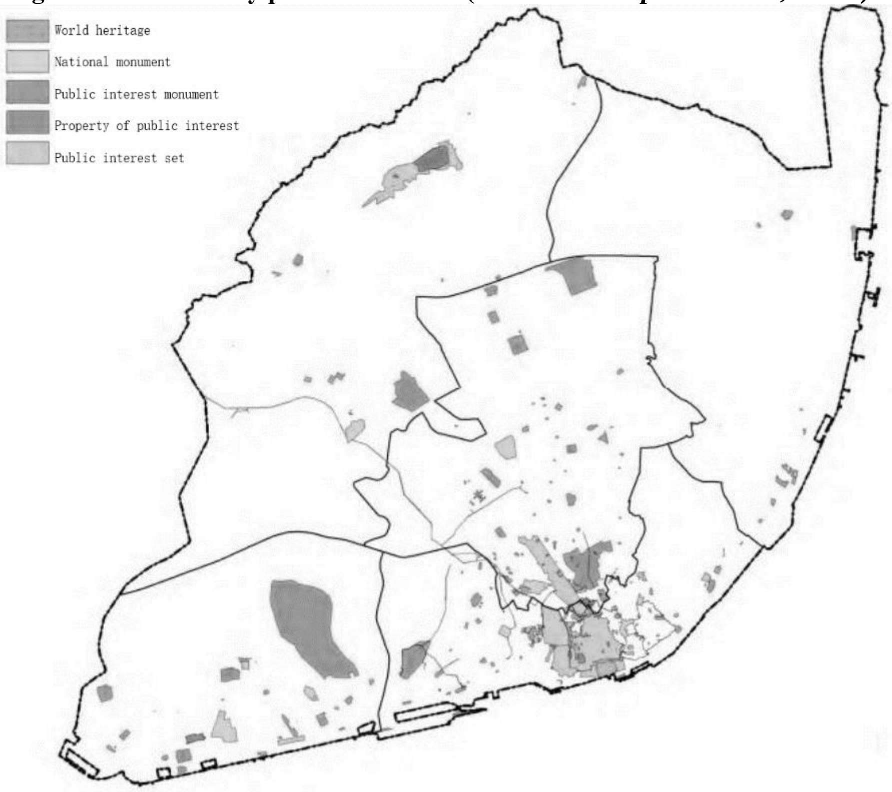
- Area: 100.1 square kilometres;
- Population: 552,700 habitants;
- Population density: 6,436 habitants/ square kilometres;
- Metropolitan area: 2,821,876 habitants

Figure 4. Lisbon metropolitan area and population density of the city of lisbon (*câmara municipal de Lisboa*, 2021a)



The historic nature of its buildings raises challenges to integrate UAM, compounding with several challenges ranging from the city's irregular topography to its aged population. The highest point with 745 feet (227 metres) MSL is in the Monsanto Forest Park, which will not leverage concerns, at first, since UAM is envisioned to have operations at altitudes above 1,500 feet (457 metres) AGL, as mentioned earlier. Besides that, the tallest buildings in Lisbon are the Saint Gabriel Tower and the Raphael Tower in *Parque das Nações* and with 361 feet (110 metres), followed by the Sheraton Lisboa Hotel & Spa in *Avenidas Novas* with 315 feet (96 metres), the Twin Towers in *Campolide* with 295 feet (90 metres), and the Corinthia Lisboa Hotel in *Campolide* with 272 feet (82.9 meters) (Council on Tall Buildings and Urban Habitat, 2021).

Figure 5. Lisbon's key points of interest (*câmara municipal de lisboa*, 2021a)



Also, the city has a vast area of the coast (represented as the Lisbon Port Administration (APL)) which could be a potential zone to place vertiports over. Plus, regarding air transport, the airport of the city in *Olivais* is known as the Humberto Delgado Airport (location indicator: LPPT (ICAO) or LIS (International Air Transport Association (IATA)) and it is 7 square kilometres northeast of the city centre (IVAO Portugal, 2021). Regarding the rail transport, the train stations are the Rossio Station, Cais do Sodré Station, *Santa Apolónia*, and *Gare do Oriente*.

In addition, the industrial and logistical market areas in Lisbon have been vanishing over the years, where many of the spaces with industrial characteristics have given rise to new residential developments, commerce, or offices (Cushman and Wakefield, 2010).

Lastly, Lisbon possesses lots of hospitals (private and public) scattered around the city. The *Hospital Santa Maria* in *Alvalade* and the *Hospital São Francisco de Xavier* in *Belém* are the only ones that include heliports, turning both hospitals a potential location for vertiports placement for emergency responses.

All said about Lisbon's demography and land use/zoning, the weather conditions and birdlife are explored next. Briefly, two external factors, i.e., factors that cannot be controlled, are considered for the UAM operations: the weather conditions where the eVTOL vehicles will operate and the birdlife that UAM will be very likely to interfere with.

The mensal variation of the weather conditions for the city of Lisbon can be seen in the Portuguese Institute of the Sea and the Atmosphere (IPMA) website (IPM, 2021). According to the Koppen classification, Lisbon has a temperate climate with a rainy winter and a dry and hot summer (i.e., Hot-summer Mediterranean climate (Csa)). Throughout the year, wind ranges from roughly 50 square kilometres per hour to 80 square kilometres per hour utmost, and temperature generally varies from nearly 7 degrees Celsius to just above 29 degrees Celsius, precipitation suffers sudden changes between zero mm and slightly below 107 millimetres.

Regarding birdlife, it is important to note that bird strikes happen mostly below altitudes of 3 square kilometres where UAM operations will occur. Lessons can be learned from the proposed new airport in Montijo to expand the Lisbon airport. This new airport was projected to be located at the Tejo River Estuary, negatively impacting its sensitive fauna. This estuary is currently a haven for migratory birds between the beginning of October until the end of February. Overflying these areas during that period is prohibited up to 1,000 feet (304.8 meters). For prevention, UAM must not operate in these areas of sensitive fauna. Otherwise, it would be hazardous, impacting nature and passenger safety (SPEA, 2021).

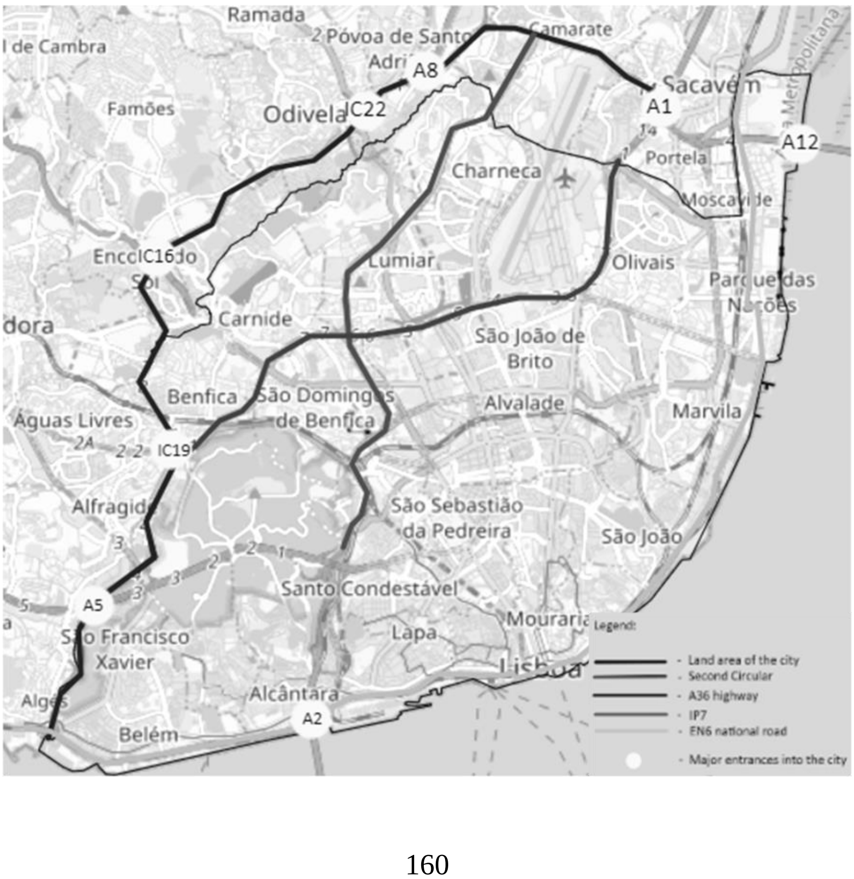
The weather yearly and birdlife is already analysed. Yet, it is still missing to look at the existing transportation and accessibility of Lisbon.

To better understand the optimal locations for vertiports implementation in Lisbon, we must overlook the existing transportation and the access to the city (by road, rail, maritime or fluvial, and air transport). According to EASA, vertiports must be integrated within the local mobility network (EASA, 2021). Besides closeness to other transport modes, connection times to them must be guaranteed as well.

The access to the city of Lisbon is quite extensive, with several highways and national roads. The interval between 7 am and 10:30 am is quite congested, as well as the interval between 5 pm and 8 pm (sometimes even worse compared to the morning period). Ordered in a descending way regarding traffic density, the major entrances into the city of Lisbon are the A2 highway (also known as the 25th of April Bridge (height of 624.9 feet, 191 metres) which connects *Alcântara* (within the city) to *Almada* (outside the city)); A5 highway; A1 highway; IC19; A12 highway (also known as Ponte Vasco da Gama Bridge (height of 486 feet (148 metres)) which connects *Parque das Nações* (within the city) to *Alcochete* (outside the city)); A8 highway; IC22; IC16 highway. One of the highest traffic densities at rush hour is the Second Circular, an urban road that connects the eastern part of the city (A1 highway) to the western part (IC19). The city's airport generates more than 15 percent of the traffic of this urban road (*Câmara Municipal de Lisboa*, 2019).

The IP7, also called North-South Axis, is a highway that runs through the city from north to south, and it connects the A2 highway to the Circular Regional Interior of Lisbon (CRIL). This latter is also called the A36 highway or IC17, being the road along the periphery of the city in its interior. The circular that goes along the periphery of the city in its exterior is called the A9 highway (also known as the *Circular Regional Exterior de Lisboa* (CREL)), but it is not represented in the figure below. Contrary, the road that goes along the coast of the city (the marginal zone) is the EN6 national road, also called the Avenue Marginal, that connects Parque das Nações (close to the A12 highway) to *Cascais* (outside the city). Together with the marginal zone, two zones within the city are equally difficult regarding traffic density: the Campo Grande in *Alvalade* and the Marquis of Pombal Square in *Santo António*.

Figure 6. Lisbon's traffic nodes



As referred above, the accessibility into and within the city is quite extensive. Unfortunately, the irregular topography of the city makes it harder for disabled citizens to move around, especially in the old and high zones of the city, e.g., *Alfama* in *Santa Maria Maior*, *Chiado* in both *Santa Maria Maior* and *Misericórdia*, and *Bairro Alto* in *Misericórdia*. Lisbon has a satisfactory mobility service with a wide range of modes of transport like bus, metro, tram, taxi/uber, train, tourist bus, car, bicycle, motorcycle, vessel (ferry, catamaran, and cacilheiro), and cable cart. Besides that, the city has elevators to allow reaching its seven hills. Through the *Zona de Emissões Reduzidas* project, significant changes in the existing transportation are being made by the *Câmara Municipal de Lisboa*. This revolutionary project prioritizes the improvement of quality of life and reduction of pollution and congestion in Lisbon. It limits the circulation of light and heavy vehicles on working days where residents, public transport, and rescue vehicles are the only ones authorized to circulate in this new reduced emissions zone of Avenida-Baixa-Chiado (*Câmara Municipal de Lisboa*, 2021b).

Up to now, we look to the demography, land use/zoning, weather conditions, birdlife, existing transportation, accessibility of Lisbon. Next, we explore spots for initial vertiports placement.

Vertiports can be constructed in the city centre, whereas their placement must possess additional space for Maintenance, Repair and Overhaul (MRO) operations with a minimum area of 1,000 m^2. Existing landing pads (e.g., helipads) and taxiways (e.g., airports and aerodromes) could be used for initial vertiports placement besides rooftops, parking lots, floating barges, highways cloverleaves, and turnabouts. The aerodromes and heliports in the Lisbon Metropolitan Area are listed on the Aeronautical Information Services (AIS) website (AIS, 2015). Current helicopters' air routes could be used for initial UAM operations. Only then, the operations could extend to more complex and ODM operations like air taxis and private/executive transportation, for which routes are missing. It is also indispensable to take into account no-fly zones. Within Lisbon, a fly zone to pay more attention to (once it covers the boundary defined by the coast of the city) is the non-airspace management cell. This one is a restricted area named LPR26A MONTIJO, it is used for air exercises, and its airspace classification is Class D (AIS, 2015).

Table 2 shows the modes of transport available and roads close to each optimal location for vertiports placement. Vertiport no. 5 could be in the airport or near it to alleviate the Second Circular road. To decrease the time of emergency responses, vertiport no. 7 could be in the heliport of Hospital Santa Maria and vertiport no. 1 in the heliport of H*ospital São Francisco de Xavier*. Being close to Gare do Oriente train station, vertiport no. 4 could be on the rooftop of Saint Gabriel Tower or Raphael Tower or over water as a floating barge vertiport. Vertiport 6 could be near the *Estádio José Alvalade*. The vertiports no. 3 and no. 6 cover locations of high population density. Finally, vertiports no. 2, 3, and 8 could be initially placed in parking lots, the top level of parking garages, floating barges, or highway cloverleaves and turnabouts, considering additional space.

Table 2. Closeness between other modes of transport and roads to optimal locations for vertiports placement

<table>
<tr><th rowspan="3">Vertiport no.
Location</th><th colspan="7">Modes of transport</th><th rowspan="3">Roads</th></tr>
<tr><th>Road transport</th><th colspan="3">Rail transport</th><th>Maritime or fluvial transport</th><th colspan="2">Air transport</th></tr>
<tr><th>Bus</th><th>Tram</th><th>Metro</th><th>Train</th><th>Vessel</th><th>Helicopter</th><th>Airplane</th></tr>
<tr><td>1
Belém</td><td>✓</td><td>✓</td><td></td><td>✓</td><td>✓</td><td>✓</td><td></td><td>• A5
• EN6</td></tr>
<tr><td>2
Alcântara</td><td>✓</td><td>✓</td><td></td><td>✓</td><td></td><td></td><td></td><td>• A2
• EN6
• IP7</td></tr>
<tr><td>3
Misericórdia | Santa Maria Maior</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td><td></td><td></td><td>• EN6</td></tr>
<tr><td>4
Parque das Nações</td><td>✓</td><td></td><td>✓</td><td>✓</td><td></td><td></td><td></td><td>• A12
• EN6</td></tr>
<tr><td>5
Olivais</td><td>✓</td><td></td><td>✓</td><td></td><td></td><td></td><td>✓</td><td>• A1
• Second Circular</td></tr>
<tr><td>6
Lumiar</td><td>✓</td><td></td><td>✓</td><td></td><td></td><td></td><td></td><td>• IC22
• Second Circular
• IP7</td></tr>
<tr><td>7
Alvalade</td><td>✓</td><td></td><td>✓</td><td></td><td></td><td>✓</td><td></td><td>• Second Circular</td></tr>
<tr><td>8
Benfica</td><td>✓</td><td></td><td></td><td>✓</td><td></td><td></td><td></td><td>• A5
• IC19
• IC16
• Second Circular
• IP7</td></tr>
</table>

4. DATA ANALYSIS

4.1 Citizen perception

Phase 1 fosters understanding the people's concerns and needs regarding the acceptance and/or use of UAM for their future travels. Likewise, we seek to gather people's preferred locations for vertiports placement. Consulted using internet-based communications, we disseminate phase 1 survey to the population that lives, works, and studies within the capital of Portugal. This dissemination comprises getting in touch with the city of Lisbon's parish councils, non-governmental organizations, educational establishments, companies, and the like. We have collected 89 responses. The key results from the citizen perception's survey are detailed below:

- More than half of all responders are satisfied with the current urban mobility in Lisbon, whereas approximately 32.6 percent of people is unpleased with it and under 10 percent shown to be indifferent to this matter;
- 60 percent of them are slightly familiar with the UAM concept and purpose. Controversy, barely 18 percent of responders scarce of knowledge about it;
- The more people know about this emergent technology, the more likely they are to experience eVTOL flights across Lisbon. Even though less than 25 percent affirmed not to be willing to use UAM in their future commutations, a significant percentage of about 74.1 percent expressed some and abundant interest in using it;
- The top three people's needs relative to UAM include time savings, contribution to less air pollution, and pleasure which scored 74, 43, and 32 responses, respectively. Additionally, the interest of nearly 30 responses is on sending and purchasing merchandise, expressing a sizeable tendency to the appearance of new future business and work opportunities;
- The top three people's consist in the travel costs with 51 responses, safety concerns with 43 responses, and noise pollution and environment concerns that both amount to the identical level of concern (with precisely 30 responses each). In addition, security concerns represent just about 30 responses and hence should be taken also as a priority; and

- The top three places for vertiports placement include parking lots with the highest rank of 60 responses, followed by existing helipads or heliports which total for 52 responses, and airports in third place with 46 responses. From these results, we confirm the potential of the vertiports no. 1 (*Belém*), 5 (*Olivais*), and 7 (*Alvalade*), described in table 2, because they contain either a heliport or airport.

4.2 Government policy

Now, we explore the logistics and feasibility for UAM integration in the urban area of Lisbon. Thus, this phase's strategy gears towards three steps:

1. Define stakeholders involved in the decision-making process;
2. Identify the reason for their resistance through their expectations and requirements; and
3. Explore and discover ways to minimize their concerns and maximize opportunities.

For that, the stakeholders involved in the decision-making process of urban mobility in Lisbon are consulted with electronic surveys. For each stakeholder is created an electronic survey which dissemination comprises sending requests for participation via phone and electronic mail (email). Table 3 lists the key results obtained from the government policy's surveys and opportunities for UAM integration in the city. Overall, stakeholders assume a positive initial attitude and a firm willingness to actively contribute to the integration of UAM in Lisbon.

Table 3. Expectations and requirements from stakeholders and opportunities of uam integration

Expectations and requirements	Opportunities
• Need for adaptation of the airspace and ground integration and capacity. This concern englobes the development of new laws and regulations for urban airspace reconfiguration and phased integration with the existing aviation and the advanced training with a "reskilling" process for service providers, operators, and pilots deal with the different roles, processes, systems	• Opportunity to overview the airspace architecture and optimize current airspace operations. By doing it, the complexity of managing a three-dimensional space with high-density air transportation might be decreased and all operational safety requirements guaranteed
• Need for enabling technology. So, biotechnology, blockchain technology, and artificial intelligence should go through further progress	• Need for real-time update and share of data. The data network must be high resiliency and low latency to allow managing automated air traffic in real-time. For that, information technology has to be heftily advanced
• Need for real-time update and share of data. The data network must be high resiliency and low latency to allow managing automated air traffic in real-time. For that, information technology and 5G network communication has to be heftily advanced	• Higher employment opportunities. The switch from manned aircraft to unmanned aircraft will forever vanish some of today's jobs, whereas other work opportunities will appear in maintenance, remote control, data analysis, and cybersecurity. The goal here is to protect people, not jobs. Still, these new jobs will require an advanced individual specialization, so there is an urge to invest in people to equip them with new technical and interpersonal skills beforehand

2.3 Citizen perception & government policy connection

Narrowing the gap between the science community, public authorities, professional actors (i.e., the industry), and consumers are crucial to UAM's success. UAM integration must cultivate and nurture global and national cooperation without neglecting people to be part of the decision-making process.

So, afterwards connecting the insights provided by people and stakeholders, we conclude that they share two similar worries about the UAM integration: safety and sustainability.

On the one hand, safety concerns represent internal and external safety concerns. External concerns represent the actual problem (e.g., collisions), while internal ones refer to how the external problem makes them feel (e.g., for stakeholders is the responsibility to provide safe and secure operations, and for the people is the feeling unsafe without a pilot onboard). Since problems should be solved starting from the root, the primary focus should be to find solutions for internal concerns.

On the other hand, focusing now on sustainability concerns, about one billion tons of CO_2 and its equivalents represent the carbon footprint of air transportation. Notably, the aviation industry must assume its responsibility to the world and emit more carbon-free emissions while working economically. UAM is propelled by electricity to reduce carbon footprint, and there is nothing wrong with using more energy as long as it is carbon-free (e.g., zero-carbon energy). Unfortunately, today's environmental laws and regulations are outdated. We need changes in policy by coming up with policies that make a big difference in the environment. Local and national governments should create policies and incentives to help reduce emissions without wrinkling the economy while making that adaptation an attractive investment in everyone's lives. However, to be truly sustainable, people must first want to fly electric, and so, elected officials should support best practices without imposing them. On the other way, the impact that UAM would have on the environment will displace the birdlife and wildlife and require the adequacy factor of the energy networks. In the perspective of birdlife and wildlife, there will be a need for the latest data on the risks for those animal species and projections from computer models that predict the impact of UAM on them. For example, an adaptation of UAM on birdlife and wildlife must go through three stages: first, reduce risks posed by UAM; second, get ready for and respond to emergencies (e.g., bird strikes that might cause fatalities to both humans and animals); third, after the disaster, plan for services for animals and people who have been displaced or affected in some way.

2.4 Proposal of guidelines

Bearing in mind the UAM's will of changing lives for the better through innovation in urban mobility towards sustainable urban mobility and smart cities implementing urban air mobility in cities worldwide, we propose a three-step roadmap with lean practices for UAM integration in Lisbon:

1. People: Create a marketing plan (Miller, 2017) based on citizen perception
   - 1.1. People's needs:
     - Time savings
     - Contribute to less air pollution
     - Enjoyment, sightseeing, and tourism
     - Sending and buying merchandise
   - 1.2. People's concerns:
     - Travel costs
     - Safety and security concerns
     - Noise pollution
     - Environment concerns
   - 1.3. Express empathy and authority by resonating UAM's will with people and sharing real data with them (e.g., UAM testimonials and statistics), respectively
   - 1.4. Give them a plan of action (ICAO, 2017):
     - Inform: provision of information from stakeholders to people;
     - Involve: exchange of information between both parties;
     - Collaborate: exchange of information and consider it over the decision-making process.
   - 1.5. Call them for action
   - 1.6. Test this marketing plan and reflect on its successful and tragic results
   - 1.7. Identify, record, and share people's transformation (i.e., before and after visual illustrations to make daily and continuous improvements)
2. Process: Adapt and reinforce this marketing plan by interconnecting the three key areas of the living lab (e.g., urban environment, citizen perception, and government policy)
3. Product: Deploy and expand a vertiport network in Lisbon. Potential vertiports are no. 1 (*Belém*), 5 (*Olivais*), and 7 (*Alvalade*)

UAM ecosystem depends on people, followed by the process, and finally by the product. This roadmap orientates the understanding of how to manage these three key elements efficiently and effectively.

These guidelines include a three-step plan of action for people engagement in the decision-making process, consisting in informing, involving, and collaborating directly with the people. Of course, it is not enough to give people a plan, so, by then, we must inspire them by calling them to act on it for them to contribute and be part of a larger cause than themselves.

To clarify, the market of UAM reveals a gap in engaging this technology with the people, which is the key enabler to success in the long run. So, narrowing the gap between the science community, public authorities, professional actors (i.e., the industry), and consumers are crucial to UAM's success. This research has thrived to humanize UAM through these guidelines.

Ultimately, these guidelines could serve future advanced discussions to introduce on-demand UAM nationwide and its Portuguese community.

5. CONCLUSIONS

Current urban mobility has a long way to lie ahead until it meets a dynamic equilibrium between all actors and stakeholders involved and integrates a safe, secure, and reliable UAM in cities. The implementation of UAM must meet a wide array of urban environments and their needs. Plus, although being under the spotlight recently, without the right vision and hard work on UAM, citizens might not fully engage in the long term with UAM. Hence, citizens need to believe in UAM's will liberally change people's current habits today to save us and build together an eco-friendly and innovative future.

Therefore, this investigation aims to provide conditions and practical tools to change lives for the better and protect the world environment through the innovation in urban mobility towards sustainable urban mobility and smart cities using a user-centric approach by implementing a living lab in a particular city.

In summary, by tackling people and stakeholders' concerns related to vertiport networks (e.g., safety, security, environmental, travel costs, and noise pollution concerns), the needs of people (e.g., time savings, contribution to less air pollution, pleasure, and sending and purchasing merchandise) and the requirements of stakeholders (e.g., adaptation related to airspace and ground integration and capacity, enabling technology, and real-time update and share of data) might be addressed, as by-products. Also, we could minimize concerns by maximizing opportunities related to UAM, like performing an overview for optimizing the airspace architecture and enhancing current airspace operations, a chance for businesses to develop on-demand, innovative, and green technologies, and higher employment opportunities.

Further research would reinforce this paper. Studying and performing the following suggested tasks might be a useful way to strengthen this article and contribute to meaningful positive changes in UAM: facilities location problems (i.e., find optimal locations of vertiports to diminish travel costs); the Free Zones for Technology (ZLT) - Framework for Regulatory Sandboxes (*Agência Nacional de Inovação*, 2021); vertiports and Humberto Delgado Airport integration; vertiport network's passenger flow and traffic prediction; vertiport network impact and integration with Lisbon's transport network; vertiport network worthiness analysis (i.e., make parallelism of the ins and pos regarding eVTOL travel over car travel); anthropology and digital anthropology; data visualization tools (i.e., modelling, simulation, and visualization technologies); environmental laws and regulations updating; cost-benefit analysis (i.e., analyse the economic feasibility); risk management cycle assessment; life cycle assessment; extend the living lab implemented throughout this research; physical infrastructure suitability assessment (i.e., the study of types of city infrastructures that need to be repurposed, renovated, or redeveloped to incorporate vertiports); and fuel capacities assessment (e.g., electricity generation, transmission, distribution, and storage).

Whilst is all told, we all together must take action now. Earlier, we have alerted that an innovative and rapid change in urban transportation needs to occur. For example, by having all its operations propelled with zero-carbon energy just as cheap, reliable, and safe as what we get from fossil fuels, UAM might revolutionize transportation worldwide and prevent a climate crisis. However, what each of us could do? As the climate change issue is a human issue, the most important solution consists in changing behaviours, and UAM technology can strikingly help with that.

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