Citizens´ attitudes towards technological innovations: the case of Urban Air Mobility

Abstract

Technological innovations and their enabled services support business growth and promise benefits for societies. In the mobility sector, technology adoption and its sustainable integration into current transport systems strongly depend on citizens' perspectives both as users and non-users. Following a bottom-up approach originating from the societal views, this study analyses the attitude of citizens towards Urban Air Mobility (UAM) and brings insights into the citizens´ expectations of the role that UAM can play in inhabited environments. The views of 485 residents of Lisbon in Portugal were collected to address aspects of UAM receptiveness. Six clusters of citizens were obtained expressing different attitudes towards UAM: open-minded, pollution sensitive, first movers, emergency supporters, skepticals and deniers. The designated clusters require different policies and practices from the side of policymakers and transport operators. The results indicate that positive attitudes towards UAM are characterized by higher intention to use such services suggesting that actions need to be taken to better comprehend each cluster´s expectations. The study sheds light on societal aspects of technology deployment and provides insights to UAM stakeholders for the sustainable inclusion of UAM in societies catering for all citizen-related topics and contributing to the development and diffusion of the UAM ecosystem.

Keywords: Urban Air Mobility (UAM); citizens attitude; technology foresight; societal aspects of technologies; receptiveness; UAM impact assessment

1. Introduction

Current mobility conditions in metropolitan areas and evolving citizens´ needs are demanding to reshape the offer of transport systems, forcing transport and mobility planners to provide innovative, integrated, and sustainable mobility solutions. New mobility services and their enabling technologies upon their integration into the urban and mobility systems are expected to respond to sustainability goals (UN, 2015) and increase citizens´ quality of urban life (Macke et al., 2018) promoting human and ecological well-being approaches (Barr et al., 2021). Apart from the ground and underground transport services, however, revolutionary technology developments from diverse industrial sectors are envisioning the inclusion and integration of airborne mobility, or mobility in the third (vertical) dimension, in current urban and metropolitan mobility systems.

Recent technological advances in distributed electric propulsion, digitalized air traffic management, and advanced automation flight operations are examples of how technological convergence enables what once was a futuristic concept, a fast-approaching reality in the near future. In the metropolitan context (encompassing urban, suburban and rural areas) a new transport mode is becoming potentially available to complement the transportation of goods and passengers through current transport infrastructure. The prospects of urban air mobility (UAM) featuring electrical aerial vehicles (e-AVs) are advancing through commercial offerings and prototypes of drones, or UAS (unmanned aerial systems), and emerging prototypes of electrical aircraft for passenger and freight transportation that are able to vertically take-off and land (e-VTOLs) (Rothfeld, 2019). The reported work deals with UAM services associated with eVTOL-based passenger(pax) transportation; here forth referred to as UAM(pax). At this point it should be clarified that drones are 'unmanned' meaning neither a pilot nor other humans are onboard, whereas in the case eVTOLs for passenger transportation, current advances and regulations indicate that these aircraft will have onboard, in a first phase (estimated minimum until 2035-40), a pilot. Advances in automated systems and artificial intelligence it is anticipated to lead towards unpiloted eVTOLs in the very long term. Several companies target this new type of electrical aircraft to be on the market until 2027 while considering timelines and implementation of relevant regulatory airworthiness frameworks. The developed eVTOL prototypes may have full or semi-automated systems for their flight operations (i.e. take-off, cruising, and landing operations), their capacity ranges typically from 2 to 5 passengers (e.g. Volocopter, 2020, Airbus 2021, Joby 2021, Lilium 2021) and the trip length they are foreseen to cover includes a variety of ranges, typically from to 30 km (Volocopter, 2020) to 80 km (Boeing, 2020, Vertical Aerospace 2022) or even further (Joby 2022, Lilium 2022).

The deployment of the cross-sectoral technological advances, and their convergence, are making UAM(pax) a reality and they have been embraced by regulators and policymakers worldwide (e.g. EASA 2021, 2022, Eltis SUMP-UAM 2021, NASA, 2017). UAM(pax) services are elaborated to contribute to the provision of complementary urban mobility services that will be safe, secure, sustainable, and inclusive (Eltis SUMP-UAM 2021). Up to date, some studies have focused on the demand estimation for UAM(pax) services (Rothfeld et al., 2018; Balac et al., 2019; Syed, 2017; Pukhova et al. 2021) while some others on the planning process. For example, Straunbinger (2020) reviewed the requirements for UAM(pax) implementation, ranging from regulations to vehicle standards; Nakamura and Kajikawa (2018) focused on regulatory aspects and Rajandran and Srinivas (2020) discussed the arising issues from UAM services in the three decision-making levels (strategic, tactical, operational). In addition to the aforementioned technical and operational challenges, there are, furthermore, the citizen and user aspects to be addressed. For example, drawing lessons learnt from the introduction of vehicle automation on the ground, several issues remain to be resolved on the side of user acceptance and technology adoption of automated vehicles which is always a challenging task in technology diffusion (Gkartzonikas and Gkriza, 2019). Similar challenges should also be identified early in UAM(pax) planning and implementation activities. In an era of co-creation among policymakers, transport planners, operators, local authorities, and citizens, the participation of the latter is necessary at an early stage of the design and integration of any new mobility service in existing transport systems. This need is also highlighted in studies analyzing impediments in the implementation of new mobility measures in the context of Sustainable Urban Mobility Plans (SUMPs) (Agouridas et al., 2021, Bezzera et al., 2020; May et al, 2017; Gil et al., 2011).

To plan responsible and viable UAM(pax) services, it is vital to consider cross-sectoral actors, the socio-technical dimensions of the emerging UAM business system, and the conditions that will ensure successful implementation. In this context, the EU's UAM Initiative, Urban-Air-Mobility Initiative Cities Community (UIC2, 2021) is supported by the European Commission and highlights the need of developing UAM through the lens of a "social business ecosystem". This UIC2 perspective is founded on three domain pillars: (1) Regulatory and financing frameworks for public-private initiatives, (2) Integrated urban mobility and planning, and (3) Co-creation with public actors (e.g. local authorities and citizens). These pillars are the cornerstones to reaching "sustainable and socially-embraced integration of urban air mobility" (UIC2, 2019). The current study focuses on the third pillar and the planning of future UAM services for passengers with eVTOLs by identifying and analyzing aspects of citizens' attitudes with the objective to designate important insights to mobility planners, local authorities, and regulators and hence, support the other first two pillars. The development and deployment of a mobility system that makes use of the urban airspace and relies on the operations of new advanced automated air vehicles in urban transport systems, requires the early involvement of urban planners and regional and local authorities (e.g. prefectures, municipalities) that are typically involved in the planning and management of transportation systems. In this context, UAM(pax) has to be seen as a complementary element of transportation systems with a clear purpose and public benefit (Agouridas et al., 2021). To this end, the actual use cases of UAM(pax) will be established not only by the offered technological capabilities but also by the willingness of local authorities, and their citizens, to integrate and adopt such services in their territories. Anecdotal evidence from the use of drones worldwide indicates that certain municipalities, or local communities, have prohibited their use in the absence of clear regulatory frameworks or public consultations prior to the deployment of drone services. In Europe, the role of local authorities has been captured in the recent regulatory framework (EU) 2021/664 for the airspace management for drones at low altitudes (U-space) [ref], and specifically its Article 18(f) that requires competent authorities to establish a coordination mechanism among diverse stakeholders included at local level. To this end, the perceptions and opinions of citizens, in a given local community, will become a key determinant to the deployment of UAM services whether through drones or eVTOLs. To this end, it is imperative to understand the citizens´ opinion and overall stance on the offer of UAM(pax) services enabled by a variety of new technologies, airborne mobility operations, and the required infrastructure. There are many aspects to consider, ranging from technical system-oriented factors to societal and human factors. Citizens´ opinions matter not only for the adoption of UAM(pax) services as a mode to use but also as a mode to welcome complementing existing ground mobility systems. At this point, research activities are called upon to research the needs, principles, and expectations in societies and ensure that new mobility solutions to be implemented need to be "ethically and socially acceptable" to identify (European Commission, 2018). The term receptiveness will be used henceforth for the expression of the citizen´s welcoming attitude towards UAM(pax) and distinguishing the opinion of a citizen, who is a receiver of UAM(pax)´s system impact, from the opinion of a potential user, who is an adopter of the UAM(pax) system services.

Following a bottom-up approach in transport systems and operations planning, this study focuses on the analysis of the perspectives of citizens on the introduction of UAM(pax) services in populated environments and the identification of citizen profiles regarding UAM(pax) receptiveness that express varying expectations over this new mobility means that is being developed. To achieve this objective, a survey is designed and data collection in the Metropolitan Area of Lisbon in Portugal resulted to the collection of 485 responses. A clustering approach is followed to segment and better understand citizen receptiveness towards UAM(pax) and then a per segment characterization was taken to address the issues. Six citizen clusters are obtained expressing different attitudes towards UAM(pax) services and requiring different policies and practices from the side of policymakers, local authorities and their mobility planners, and transport operators. Factors such as the respondents´ intention to use, adoption of new technologies, socio-demographics (age, gender, income, residence area, car ownership), basic mode of mobility were found to vary across the clusters. At this point, it is noted that this study aims to capture public opinions on a technology that is not yet available and hence, public expectations may evolve through time and change according to the new knowledge and information that will be becoming available on UAM(pax) services. The adopted approach and the results of the study shed light on societal aspects of technology deployment and provide evidence that could be employed in both transport planning and technology diffusion future studies. Overall, the study aims to provide insights to UAM stakeholders for the sustainable inclusion of UAM(pax) in societies catering for all citizen-related topics and contributing to the development of the UAM ecosystem.

The rest of this work is organized as follows. After this introductory section, Section 2 reviews basic concepts and research performed in the context of urban air mobility. In Section 3, the methodology is described, and the collected data of the conducted survey are presented. The next section, Section 4, deals with the process of citizen clustering while in Section 5 the discussion of the results and some planning and managerial implications for future urban air mobility operations. Finally, section 6 concludes the key remarks of the study and suggests steps for future work stemming from the presented analysis.

2. Literature

Urban air mobility (UAM) is a concept coined by industrial and institutional actors (e.g. Airbus, NASA) in mid-2010 with the ambition to leverage the possibilities offered by distributed electric propulsion systems towards the introduction of a new vehicle utilizing the very low altitude airspace over metropolitan areas. The long-term target is that drones and the newly designed electric air vehicles of vertical take-off and landing (eVTOLs) will be of advanced automation, and they may or, in the case of eVTOLs, may not require a pilot. Various applications can be envisioned for the deployment of these vehicles with great potential as currently seen in the agricultural (Mahroof et al., 2021) and medical (Ayamga et al., 2021) sectors.

In parallel, in the urban and wider metropolitan context, the population is increasingly growing in inhabited environments while transport geographical inequalities remain and the quality of life is being challenged. Under the prospect of the promising UAM(pax) technologies, there is the opportunity to explore the potential contribution of UAM(pax) to cities´ life. There is also the chance for a change in planning processes as, with the advent of drones and eVTOLs, insights can be given by citizens to identify the potential of these vehicles in mobility. In this section, new approaches in citizen-centred transport planning are discussed followed up by the current knowledge on UAM(pax), from the mobility viewpoint with the objective to explore in the current study how citizen perspectives on UAM(pax) can feed the emerging citizen-centered transport planning approaches.

2.1. Transitioning to citizen-centered city and mobility planning

The term smart cities has arisen to describe the transition to cities that are driven by technological developments which can serve people and their well-being (Zhu et al, 2022). New technologies in energy, mobility, digitalization, and advanced communications are expected to pave the way towards this type of future cities while some applications have already demonstrated their potential (ex. Dubai (Mohammed et al., 2014), Belgrade (Ilic et al., 2022)). Within the urban environment, several applications of drones have been envisioned that could enhance the functioning of smart cities from several perspectives (e.g. health, traffic management, logistics) and for several stakeholders such as citizens, industrial actors, civil protection agencies, and tourists (Mohamed et al., 2020). Furthermore, to achieve better and targeted mobility solutions, the collaboration of all stakeholders and integration of systems (e.g. information, infrastructure) are vital (Richer et al. 2020). Citizen consideration and participation has emerged as planning principle of sustainable environments (Lanzini and Stoccetti, 2020). Taking this into account, commercial interests and prospects on leveraging cross-sectoral technological advances enabling UAM(pax) services (e.g. Uber 2019) will be subject to integrated and sustainable mobility policies and practices (Agouridas et al., 2021). In this context, cross-sectoral stakeholder collaboration and alignment should be sought after in a way to manage the multiple layers of governance engaged in mobility. In the case of UAM(pax) additional layers of governance are originating from the aviation sector. In other words, the development of commercially, profit-driven UAM(pax) services representing the economic viability of such endeavors, will have to be balanced with other aspects of the triple bottom line (Elkington, 1997; Dhiman, 2008), namely the environmental and social aspects (Agouridas, 2022). The trade offs required among the positive and negative externalities from the deployment of UAM(pax) services require participative governance practices (Blanco, 2015; Gabriel, 2016; Guillard and McGillivray, 2022) in which the cities and their citizens are the prime actors. This is a cornerstone in mitigating and avoiding criticisms associated with the neoliberal governance of cities (Blanco, 2015; Gabriel, 2016; Guillard and McGillivray, 2022). For example, in Europe, the evolving policy making and regulatory frameworks related to UAM(pax) take continuous, bottom-up inputs, both by directly engaging with citizens (EASA, 2021) and local authorities in works of pertinent task forces through networks such as the UIC2 (UIC2, 2022). The aforementioned reflection aligns with other works found in the literature that highlight the importance of bringing in the citizen perspective to pave the way towards the development and establishment of demand-pulled governance models that can contribute to “avoid technological lock-ins and dependence of city governments on technologically produced knowledge” (Jiang, 2021). Further previous work has designated action transparency, citizen-authority collaboration, participation and partnership, and communication as key pillars of citizens´ quality of life in smart cities (de Guimaraes et al., 2020).

Citizen views and forthcoming engagement is imperative in future cities and, in this context, the terms “co-creation” and “urban living labs” are commonly used in current literature (eg. Alexandrakis, 2021, UIC2, 2022) to express the active collaboration of stakeholders with citizens in the introduction of new mobility and transport solutions abandoning the well-established top-down transport planning approach that positions the citizen as a passive receiver (Van Bueren and Steen, 2017). Barr et al. (2021) argue that up to date, the planning of mobility solutions, in the context of smart cities, has been encouraging behavioral shifts of citizens who have been merely passive receivers of solutions and choice makers. In this context, currently, there is a shift of research to the direction of exploring more actively citizens´ mobility needs and co-creating solutions with them. Through such studies, for example, analyzed through focus groups the characteristics of MaaS (Mobility as a Service) technologies that travelers desire in Madrid have been designated (Lopez-Carreiro et al., 2021); this study identified new types of information that were previously unexplored and passengers would like to have access to, such as real-time travel conditions on passenger-crowding, urban pollution levels, route facilities, vehicle condition, and urban security. Such activities that could provide more insights into citizen needs and views should be incentivized by Public Authorities as citizens seem to trust them more than the industrial sector. Evidence of this preference has been given by an international study in fourteen cities worldwide regarding the introduction of driverless mobility services. The study indicated that citizens attribute higher trust levels to governments than industrial agents possibly because they believe that in this way their interests are heard and safeguarded (Chng et al., 2021).

2.2. Elements of urban air mobility and citizens´ perceptions

The inclusion of new technologies in city´s life is usually a long-lasting process that involves understanding their preferences and opinions about the applications of these technologies. Public interests and customer needs should be ensured before technology deployment (Federal Aviation Authority (FAA), 2020). Advanced automation or automated vehicles are prime examples wherein issues on safety, security and ethics influence the level of trust of the potential users. This can be a determining factor in acceptance and can dictate the intention of using automated vehicles (Winter et al., 2020). There will be innovator adopters, who will want to make use of the technology with little or no resistance, and later some "early adopters" will also adopt, thus boosting the adoption by the other groups (Pettigrew et al., 2019). Positive perceptions such as the consideration of drones and eVTOLs as beneficial for the society (Keller et al., 2018), the envisioned travel time saving (Rothfeld et al., 2018), and their contribution to improve transport accessibility, especially in suburban areas (Holder and Goel, 2016) can be favorable aspects for the diffusion of eVTOLs to the market. By increasing people's awareness of the improvements that these technologies can bring to their daily lives, it will be easier to move from the acceptance phase to the adoption phase of making use of automated, or automated, air vehicles, and their subsequent scaled implementation in mobility solutions in the metropolitan airspace (Eker et al., 2020).

Emotional factors also affect people’s perceptions. To this end, it is important to understand, in a holistic way, the aspects that can influence the decision-making process of prospective users (Winter et al., 2020). Decision-making is a complex process, especially if people have little information available, such as in the case of eVTOLs or “air taxis”. Many potential users are unaware of or unfamiliar with high levels of automation, and certain emotions may be predictors in the acceptance of “air taxis” and urban air mobility systems. It is anticipated that during their first years of operation, safety aspects could appear as the main barriers in drones and eVTOLs services adoption (NASA, 2017; Al Haddad et al., 2020; Eker et al., 2020, Rice et al., 2022). Concerns over the potential arising risks to the public need to be assessed (Keller et al., 2018). For this reason, high levels of safety for these vehicles are being set up, and the means to achieve them are developed, as a top priority by manufacturers and regulators worldwide. To this end, significant research and development are undergoing to ensure the safety of unmanned aerial vehicles through the implementation, for example of advanced digital and automated systems for pilot aids, sense and avoid communication, and navigation systems (Holden and Goal, 2016; Mattei et al., 2021) and to identify possible safety risks (Ghasri and Maghrebi., 2021).

Apart from safety concerns, another common, less favorable aspect that concerns prospective UAM services is noise. The noise generated by UAM technologies has been identified as a critical factor in their fast and successful deployment (Eissfeldt, 2020). There are noise goals that must be met and restrict the level of decibels emitted by these air vehicles’ propulsion units (electric motors and propellers). Regulations for managing the noise footprint of aircraft and helicopters around airports and metropolitan areas are well in place. However, the premise of scaled UAM operations implies that new regulatory approaches need to be developed to take into consideration the blending of the noise generated by drones and eVTOLs with the existing background urban noise.

In addition to airspace access, operations safety, and noise impacts, additional regulation related to urban life, such as standards for liability, security, and data privacy should be established as discussed by Al Haddad et al. (2020) and more recently by Andritsos and Agouridas (2022). In fact, recent studies carried out by NASA in the USA (NASA, 2019) and EASA in Europe (EASA, 2021) indicate the need to consider additional factors such as privacy, cybersecurity of user data, visual pollution, wildlife protection, integration with other modes of transport, among others, apart from the typical factors of noise and environmental pollution attributed to aviation. For example, Al Haddad et al (2020) identified that both noise and visual pollution considerations of people are determinants for the smooth inclusion in mobility systems. Other recent works have highlighted the necessity to manage environmental impact through life cycle assessment approaches (e.g. Agouridas, 2022 and Zhao et al., 2022) and interface airspace management practices (e.g. designating restricted geozones for flights over heritage districts) with urban planning principles and local specificities (Agouridas et al., 2021; Guillard, 2022).

To complete the insights of technological, environmental, and societal factors related to the use of drones and eVTOLs as outlined above, socioeconomic and demographic aspects that affect citizens' perceptions should be addressed as well. For example, women demonstrate lower willingness to be early adopters due to their higher safety concerns and lower trust in automation. On the contrary, the impact of higher income and young age seem to positively influence adoption (Eker et al., 2020).

2.3. Remarks from the state of the art

The concept of smart cities is underlined by the provision of technological means to improve the quality of life, or livability, of citizens. Mobility is a central pillar of urban life and smart mobility aims to leverage technological advancements in serving citizens' needs. One challenge is the alignment of the technological pervasiveness of emerging mobility technologies (e.g. drones) with the citizens' expectations of such technologies' use and diffusion. This is core to the strategic planning and implementation monitoring of effective and efficient urban mobility services that are citizen centered. This perspective should be applied to all city-related aspects, including transport and mobility, to put the citizens in the center of the planning process and thus promptly position the role of social change in technological foresight activities. Local authorities (e.g. municipalities, prefectures) need to be able to make decisions based on evidence of what kind of mobility services they want to provide to their citizens, and to define how each mode will contribute to covering the mobility needs as well as mitigating consequences of any negative externalities.

Previous research on technology adoption has shown that people living in the urban environment support earlier the use of automated vehicles (Saeed et al., 2020) and drones UAVs (Al Haddad et al., 2020) but from a planning perspective, high benefits are envisioned for the use of urban air mobility in the rural environment. These areas are characterized by the sparse distribution of population and, as a consequence of social and business benefit trade-off, they usually face poorer public transport solutions and the choice of private car is attractive (Alonso et al., 2018; Li et al., 2018; Wolny, 2019) if not forced (Carroll et al., 2021). Smart mobility could enable the provision of more inclusive and efficient transport experiences (Porru et al., 2020). UAM(pax) could contribute with its features of speed and air connectivity with low infrastructure requirements to the better coverage of needs in remote areas.

In addition, recent research presented the results of acceptance aspects indicating safety, security, and pollution as the main concerns. Attitudes towards both adoption and acceptance of new mobility services may vary across citizens. However, new sustainable solutions require to cater for the needs of both users and non-users so that they are both chosen for the individual mobility of citizens and overall, socially accepted as part of the transport system. Hence, the level at which citizens as users or non-users' welcome new mobility technologies in their transport system and services reflects how engaged they are. It is concluded from the literature review that while extensive work has been conducted on the acceptance and the possible adoption of UAM(pax) as a new mobility service, there is a gap in the research of citizen receptiveness in the transport planning process and UAM(pax) analysis.

To contribute to this direction, this study by designating clusters of a survey respondents' attitudes towards the UAM(pax) receptiveness, characteristics and perceptions will be analyzed with the aim to gain insights into the expectations of citizens. The designation of clusters paves the way for next generation studies on acceptance by focusing on specific characteristics of use cases and expected benefits. To the best of the authors´ knowledge, the different views of citizens as both future users and non-users have not been previously analyzed in the literature. This study is a first attempt to address the perspective of the citizens as a whole (users and non-users) and the service aspects that need to be addressed by policy makers active in this field to ensure the provision of responsible services that employ innovative technologies. The reported research is contributing to the establishment of an analytical framework to support evidence-based policy and decision-making by shedding light on the citizens' expectations and attitudes.

3. Methodology

3.1. Survey design and collected sample

A survey was structured in seven topics to collect information on the respondents´ UAM(pax) receptiveness, intention of use, their attitudes towards prospective UAM(pax) services, their mobility behaviour, their environmental concerns and their sociodemographic characteristics. The methodology reflects a clear distinction between "citizen-as-a-user' and 'citizens-as-a-non-user" perspectives. Citizens as users are usually interested in functionality and convenience while citizens as non-users are interested in disturbance and wider impacts (positive or negative). The topics were measured as follows and were introduced after asking whether respondents knew what Automated Air Vehicles are:

- ***UAM(pax) Public Receptiveness***: To understand the participant's receptiveness, the respondents were asked about their level of acceptance and the expected utility of UAM(pax) by trip purpose. All sentences were answered using the same 7-point Likert scale from 1 - Strongly Disagree to 7 - Strongly Agree and were adapted from several studies (Holder and Goel (2016), Keller et al. (2018), Al Haddad et al. (2020), Eissfeldt (2020) and Eker et al. (2020)).
- ***Public intention to use UAM(pax):*** The respondents were asked to state whether they are likely to use UAM(pax) services in the future, using sentences based on the previous topics to see if they could be barriers to using such automated air vehicles. They were also asked what they would them for (e.g. trips to work or college, leisure activities, social activities and healthcare services). The 7-point Likert scale of agreement was used as before.
- ***Intention to use of new technology****:* respondents were asked to place themselves in the adopter category that best represents them, ranging from 1 – Laggards (very skeptical of change) to 5 – Innovator (very venturesome and interested in new ideas) as proposed by Rogers (2003).
- ***Expected Benefits***: in this section, respondents were asked about how they did feel towards possible benefits of introducing Urban Air Mobility services in our society. A 7-point Likert scale from 1 - Strongly Disagree to 7 - Strongly Agree was used. The sentences were adapted from Holder and Goel (2016), Rothfeld et al. (2018) and Eker et al. (2020).

- ***Safety*:** Regarding safety, respondents were asked how safe they would be in a society that uses Air Vehicles, using different sentences and scenarios to obtain more trustworthy information. The same Likert scale of agreement was used and the sentences adapted from: Al Haddad et al. (2020), Eker et al. (2020) and Rice et al. (2022).
- ***Mobility Behaviour***: The respondents were asked how long they spent on their daily trips from/to work or college, and which means of transportation they use. They also were invited to rank their satisfaction level regarding their trips, encompassing work, leisure, and social activities. A 7-point Likert scale of satisfaction was used, where 1 – Totally Dissatisfied and 7 – Totally Satisfied.
- ***Socio-economic and demographics:*** Finally, the respondents were asked about some personal characteristics (age, gender), their income status, and the type of area they live.

A filter question was introduced at the beginning of the questionnaire in order to select only the inhabitants of the Lisbon Metropolitan Area. Along with the questionnaire, there was also a small text giving an introductory explanation about Urban Air Mobility enabled by drones and eVTOLs, trying to catch the attention of the participants and motivate them to want to know more about the subject, and consequently complete the questionnaire.

The research sample was obtained through the distribution of an online survey on social media. The target population was Lisbon Metropolitan Area Inhabitants with a focus on youth (age above 18 years old) and younger adults' respondents because these are the most aware of the emerging technologies. This focus is based on current knowledge on future potential users in the deployment of such services in the horizon of 2030-2035 onwards (e.g. roadmap of SESAR,2020). However as the topic of analysis concerns a technology not ready to be in place and the UAM(pax) system's development is dynamic, an age group distribution across all ages would be more relevant in the years to come as the deployment of UAM(pax) services will be evolving and will become more familiar. Therefore, a younger population was targeted but in order to have an inclusive approach, older population was also included in the analysis to have early insights on their views even though some of them may not benefit directly when the technology will be available to the market.

The online survey was designed with an average duration of 15 minutes and was conducted between July and November 2020. As the survey was conducted on social media, strategies to reduce possible sampling bias were implemented such as distributing the survey to various online channels to improve its visibility among respondents, adding personal contacts previously the link distribution in private groups of social media, and extending the collecting period of the survey to catch more infrequent users. In total 485 full and valid replies were collected from respondents residing in the Lisbon Metropolitan Area.

3.2. Sample characterization

Table 1 presents the sociodemographic characteristics of the sample. Respondents are not equally distributed regarding gender, as there are more male respondents (57.3%). The sample consists of many respondents under 35 years old (53.2%) and has few replies in the oldest age group. About 58% of respondents have a higher degree of education, and 38.6% have a master's degree. A quarter lives in a household with net income between 2000€ and 3000€ per month, and almost 50% of respondents have a household monthly net income between 1000€ and 3000€. In terms of mobility habits, almost 95% of the respondents have a driving license and 83.0% have a vehicle for their own use, that is, most respondents have the possibility of freely circulating on the public roads without resorting to public transportation, and almost 63% take advantage of it. Only 30.9% of the total sample have a monthly public transport pass.

Table 1. Distribution of respondents' sociodemographic characteristics

		N	Valid %
Gender			
	Male	278	57.3
	Female	207	42.7
Age Group			
	18 to 24	128	26.4
	25 to 34	130	26.8
	35 to 44	76	15.7
	45 to 54	75	15.5
	55 to 64	64	13.1
	65 + years	12	2.5
Have Children			
	Yes	194	40
	No	291	60
Educational level			
	High School	41	8%
	Apprenticeship with graduation	20	4%
	Bachelors' Degree	220	45%
	Masters' Degree	189	39%
	PhD	15	3%
Household monthly Net Income			
	Less than 1000€	70	14%
	1000€ to less than 2000€	122	25%
	2000€ to less than 3000€	132	27%
	3000€ to less than 4000€	77	16%
	More than 4000€	84	17%
Current Employment Situation			
	Employed	351	72%
	Student/Intern	90	19%
	Unemployed	28	6%
	Retired	16	3%
Driving License			
	Yes	459	94.6%
	No	26	5.4%
Own a Car			
	Yes	381	83.0%
	No	78	17.0%
Drive a Vehicle			
	Everyday	288	62.7%
	Couple of times a week	121	26.4%
	Once every two weeks	12	2.6%
	Once a month	10	2.2%
	Every couple of months	9	2.0%
	I don't drive	19	4.1%
Have a Public Transport Monthly Pass			
	Yes	150	30.9%
	No	335	69.1%

3.3. Segmentation approach

The Cluster analysis was employed to segment the sample based on the respondents' similarities, meaning that the respondents that fit the same group or cluster, are expected to have similar characteristics that differentiate them from the rest of the clusters. The cluster method aggregates the individuals according to a set of variables which constitutes the segmentation base variables.

Before conducting the cluster analysis, a Principal Component Analysis (PCA) was applied to reduce the number of items of public receptiveness that were used as base variables for the segmentation analysis. To perform the cluster analysis two different methods were sequentially employed to increase the legitimacy of the chosen solution, the hierarchical Ward and non-hierarchical K-means methods. Firstly, the hierarchical Ward method with Squared Euclidean distance measure was applied for the purpose of deciding the number of clusters to use in the K-means method. The latter method was employed to improve the accuracy of allocating each individual within the clusters. Finally, clusters of the chosen clustering solution were labelled using their characterization in terms of the segmentation base variables. The distribution of the levels of new technology adopters was also considered in order to help labelling clusters. Subsequently, they are also characterized using other variables, such as the perceived safety, expected benefits, and socio-demographics.

4. Segmentation results

4.1. Public receptiveness components

The PCA was conducted in order to reduce the 16 variables of UAM(pax) receptiveness into a smaller set of variables (principal components (PC)) as presented in Table 2. It is noted that for the facilitation of the respondents the term "UAM" has been used in the survey sentences after making it clear in the introduction that it concerns passenger transport. The chosen PCA solution was obtained with varimax rotation and is composed of five components which explain 73.4% of the total variance (KMO=0.819; Bartlett's test significance < 0.01). Two variables were excluded from the analysis. The first one was the "UAM is an acceptable means of transport" which had almost no correlation with the other chosen variables and had a very low commonality value very. The second one stated that "I am concerned that UAM will become a service only for the rich" and was excluded because it generated a one-variable principal component. indicating that this concept may not be multiphasic and multiple parts of the belief have not been measured in this study but could be included in future research. The five components were named: "Service Use Purpose", "Expected Societal Benefits", "Urgent Social Needs", "Environmental Aspects" and "Citizens´ Concerns". Table 2 presents the items per PC and their respective loadings.

Table 2. Distribution of UAM(pax) receptiveness items and PCA results

PC and Items	Loading	Mean	Standard Deviation
Service Use Purpose (Cronbach's α=0.840, Var. expl.=36.3%)			
UAM should be used to transfer people for leisure	0.885	4.81	1.503
UAM should be used to transfer people for social activities	0.884	4.83	1.471
UAM should be used to transfer people from/to work or school	0.698	4.44	1.655

UAM should be used to transfer goods to people	0.648	5.32	1.467
Expected Societal Benefits (Cronbach's α=0.774, Var. expl.=13.3%)			
UAM will improve transport accessibility	0.818	4.84	1.512
UAM will increase the quality of life	0.733	5.31	1.249
UAM will be as safe as with airplane transport	0.637	4.28	1.466
UAM will be beneficial for the society	0.597	5.01	1.113
Urgent Societal Needs (Cronbach's α=0.812, Var. expl.=10.4%)			
UAM vehicles should be used to respond to emergency cases	0.881	6.25	1.033
UAM vehicles should be used to transfer people from/to healthcare services	0.873	6.02	1.080
Environmental Aspects (Cronbach's α=0.796, Var. expl.=7.5%)			
I am concerned that UAM will increase noise pollution	0.904	4.94	1.555
I am concerned that UAM will increase visual pollution	0.86	4.82	1.575
Citizens´ Concerns (Cronbach's α=0.703, Var. expl.=5.9%)			
I would not feel comfortable living in a city that offers UAM	0.818	3.19	1.556
UAM will be risky to the public	0.806	3.90	1.353

4.2. Cluster Profile Analysis

4.2.1 The emerging UAM-receptiveness clusters

The above-described dimensions were then used as a basis to perform the cluster analysis, and more than one solution was found. From the hierarchical Ward method, five to seven cluster solutions were obtained and analyzed. Sufficient differences between clusters were identified to favor and opt for the six clusters solution, which was used as the initial solution for the non-hierarchical K-means analysis. The K-means method allows for a more precise distribution of the respondents in the cluster division.

Hence, the cluster analysis resulted in a final solution of six clusters with different levels of UAM(pax) receptiveness regarding the application of UAM(pax), each distinctive in size and other characteristics. Figure 1 shows the distribution of standardized mean scores of the UAM(pax) receptiveness principal components per cluster and Figure 2 presents the distribution of levels of new technology adopters per cluster.

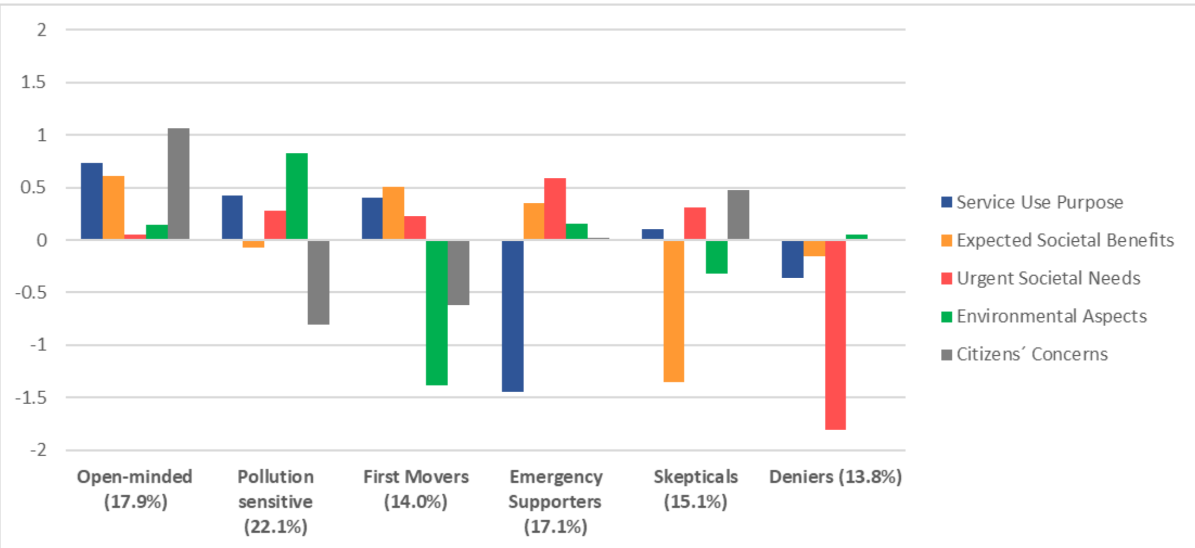

Figure 1. Mean scores of Receptiveness Principal Components per cluster (citizen-aggregate perspective)

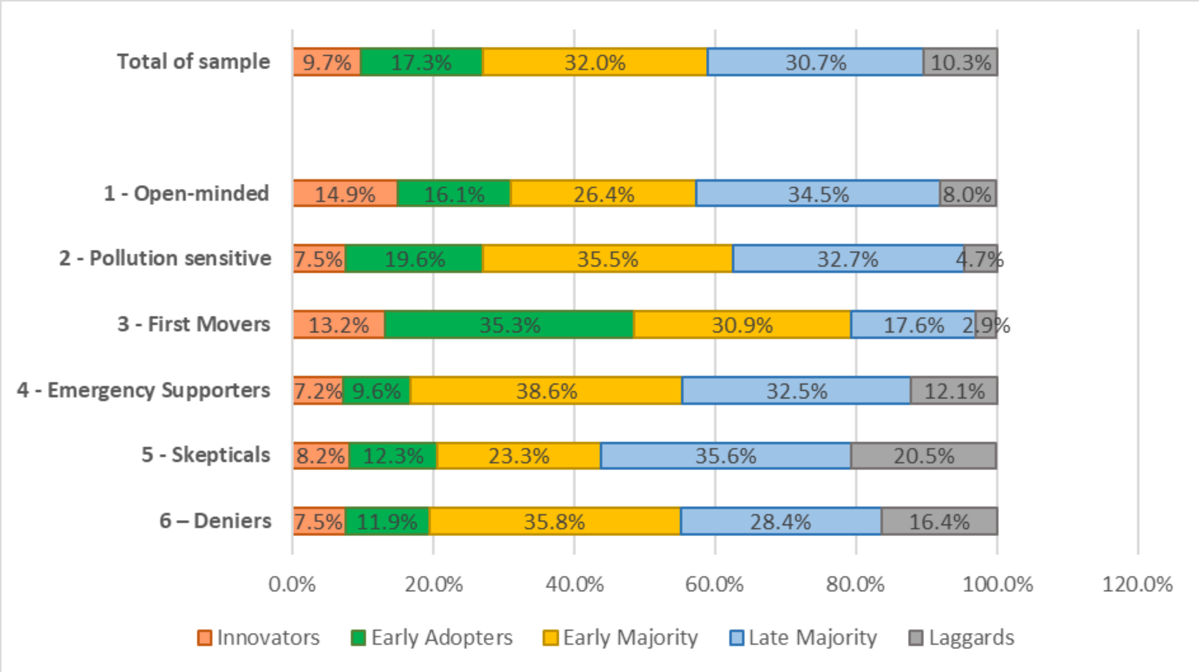

Figure 2. Distribution of adoption category per cluster (citizen-user perspective)

Cluster 1 counts for 17.9% of the sample and has an average positive mean in every component, meaning the participants of Cluster 1 are very open to UAM services. They understand the possibilities of using this mobility service and the associated benefits, but they are also aware of the risks they might present to people. Overall, they have a welcoming attitude. Therefore, the participants of Cluster1 were named "***Open-minded***". This group entails the highest percentage of expressed innovators (14.9%) but also has a moderate percentage of expressed laggards (8%).

Cluster 2 comprises 22.1% of respondents. Unlike the rest of the clusters, the members of Cluster 2 indicate a significantly higher consideration for the environment and seem worried about the potential visual and noise pollution caused by UAM(pax). For this reason, this cluster was named "***Pollution sensitive***". They also express high concerns about the deployment of UAM(pax), but they recognize the utility on individuals´ mobility and the expected benefits.

Cluster 3 entails 14.0% of the total sample and its members have a higher appreciation of the benefits that UAM(pax) services could bring to the society for commuting, emergency, and health situations. However, they are not worried about the noise and visual pollution. All the factors point out a group with high levels of technological acceptance, as more than 45% of the cluster members consider themselves to be early adopters or innovators of prospective UAM(pax) services; therefore, they earn the title of the "***First Movers***".

Cluster 4 contains 17.1% of the respondents. Its members expressed that they would only accept the use of UAM(pax) for emergency or health cases, without demonstrating trust in the usefulness of this technology for more purposes. Therefore, they are named the "***Emergency Supporters***" citizens. The members of cluster 4 do not demonstrate strong intention to use UAM(pax) services early with the percentage of laggards surpassing the innovators by 4.9 percentual points.

Cluster 5 represents 15.1% of the sample. Besides seeing some use in emergency and healthcare for eVTOLs, these cluster members do not think the benefits for general use will overcome the risks for the society, meaning they are not convinced about the benefits of implementing this technology in the transportation sector. Thus, the participants in this cluster were named the "***Skepticals***". This cluster has the highest percentage of laggards (20%) and late majority adopters (35%).

Members of cluster 6 express a group of "***Deniers***" because they have demonstrated a negative average value across almost all component variables. They do not even find UAM(PAX) useful for emergency and health situations. Most of the representatives of cluster 6 regard themselves as a late majority or laggards (41.0%) when it comes to adopting UAM(PAX).

4.2.2 Cluster characterization

To detail the cluster characterization, the average values for Expected Benefits (Figure 3), Safety (Figure 4) and Intention to Use (Figure 5) items were used. Clusters are also characterized in terms of socio-demographics and their mobility characteristics (Table 3).

The participants from Cluster 1, the **"Open Minded",** value safety and consider it an important factor in UAM(PAX) services. Despite being open to the deployment of UAM(PAX) services, it is interesting that they have the highest average in the analyzed concerns. Specifically, besides having the possibility for a person on ground to take control of the vehicle at any moment, they also emphasize the importance of the performance of the vehicle under poor weather conditions. The "Open Minded" members welcome the use of UAM(PAX) for any purpose, demonstrating in general high levels of receptiveness and intention to use in all the stated purposes, but in comparison to the other clusters they have the highest receptiveness level for the use of UAM(PAX) services to execute leisure trips. They also expect the deployment of UAM(PAX) services to enhance the reduction of the travel times and facilitate trips that serve the activities of police and ambulances. This cluster entails people of all age groups with a higher percentage of the people between 55 and 64 who represent 25% of its members. In terms of the other socioeconomic characteristics, this cluster has a balanced composition (income, education) compared to the others. When analyzing the residence environment, it is observed that a very high percentage, almost half of the members live away from the urban environment. Specifically, 49% of the members of this cluster stated that they live in rural areas.

The "**Pollution Sensitive**" are the participants who are more concerned with the noise and visual pollution that may occur due to the implementation of this new mode of transport. They do not firmly believe that UAM(PAX) will make transportation easier to move for the population in general but think their use for healthcare services or leisure and social activities is appropriate. This cluster gives much more importance, compared to others, to having an operator available to give control to the aircraft in case of emergency. The reduction of road congestion and travel times seem to be the benefits expected from the implementation of UAM(PAX) services, besides helping the police and healthcare agents. This is the cluster of balanced gender that involves many young people, as 58.9% of the members are between 18 and 34 years old. More than 85% have either a bachelor's or a master's degree. In this cluster the highest percentage of respondents who walk on their daily mobility either as the main mode (about 70%) or complementary to public transport (48.6%). It is also noteworthy that in this group the highest percentage of people who have had major injuries in past accidents is met (8%).

The members of the "**First Movers**" cluster although they are not too concerned with the safety of the vehicles and potential collisions, they are concerned with some safety aspects as they feel it would be important to be able to people on air to be able to communicate and give manual control to operators on the ground in case of emergency. Aside from using UAM(PAX) service for healthcare, these participants also see themselves using this mode of transport for social activities, not so much for commuting. They expect UAM(pax) services to highly reduce road congestion and travel times and, in general, they appreciate most of the expected benefits that UAM(pax) services could provide to society. This group mostly entails male participants (72.1%) and has the lowest percentage of people younger than 34 years old (35%). Regarding the financial possessions, the members of the “First Movers” have in general a higher household monthly net income when compared to most other clusters as 45.9% of the respondents stated they have an income higher than 3000€. Almost all the cluster members have a car (97%) and it is also noticed that almost two thirds of the members have been involved in a car accident (67%) which is the highest percentage among the clusters. Finally, the mobility behaviour of this cluster is different from the others, as 64% of the member clusters stated that they do not consider walking part of their everyday mobility but 90% of the members are metro users on a daily basis. The fact that most participants are men and the age group is generally older might be an important factor in making the cluster the most prone to welcome UAM(pax) as men are more likely to engage earlier in new technologies and adjust easier to technological changes.

The “**Emergency Supporters**” individuals, as described above, are participants of the fourth cluster as they tend to welcome UAM(pax) only when used for healthcare services and emergencies. Despite the strict attitude towards the deployment of UAM(pax), these members do not demonstrate negative behaviour on the appreciation of the expected benefits of UAM(pax) services. Compared to the other clusters, they are the most concerned with the operation of vehicles under bad weather conditions and they strongly expect to have the chance to contact an operator to take control of the vehicle in case of an emergency. Most of the members of this cluster are young participants, 36% belong to the 18-21 age group and 65% are between 18 and 34 years old while 26% of them are students. In this cluster, approximately 50% of the members have had an accident, which is also the average value of all the sample, but 34% of them had minor injuries, a fact that may have affected their strong support for the use of UAM(pax) options in emergency cases. The daily mobility experience of 70% of the members of this cluster includes the use of bus, a percentage that is high compared to the other clusters. Finally, in this cluster there are citizens who use shared bikes for their daily mobility, but the share is relatively low (4%).

Members of the fifth cluster, the “**Skepticals**”, are not convinced that UAM(pax) will bring many benefits to society, except for the case of emergency or police-related situations, because they could act faster. This group is the most skeptical on the expected benefits of UAM(pax) services for the society, and they have a moderate attitude towards the risky aspects that would concern society. It can be noted that performance under poor weather conditions and the safety upon their introduction to mobility are two aspects that concern this cluster more than the others. Approximately one third of the members (30%) are very young (18-24); this is the highest percentage seen among the clusters and almost equal to the equivalent age share of the pollution sensitive. Also, there is a strong presence of women (63%). It is noteworthy to mention that approximately 26% of the Skepticals did not own or lease a car at the time they participated in the survey and that they hold the lowest percentage of people who have experienced a car accident (46% compared to percentages above 50% seen in the other clusters). Daily bike users compose 18% of the cluster members which is a high percentage considering that these are all the bike users who own the bikes participating in the sample. Also, bike sharing systems are also used daily by 6% of the cluster members which results in a total of 24% daily bike users in the sample, indicating that this micro mobility mode is strongly present in this cluster compared to the others.

The sixth and last cluster, the **"Deniers",** is among the groups with the least intention to use UAM(pax) services, even in emergency and healthcare situations. As for expected benefits, they think UAM(pax) might facilitate the job of police and ambulances. However, they do not regard that UAM(pax) services will provide safer and faster trips than other existing means of transport. This group has the highest percentage of participants earning less than 2000€/month (50%). A clear mode use is observed in this cluster as all the members are daily bus users (100%) while only 11% of them use the car in their daily mobility. The mobility behaviour of this cluster is what mainly differentiates it from the other clusters characteristics.

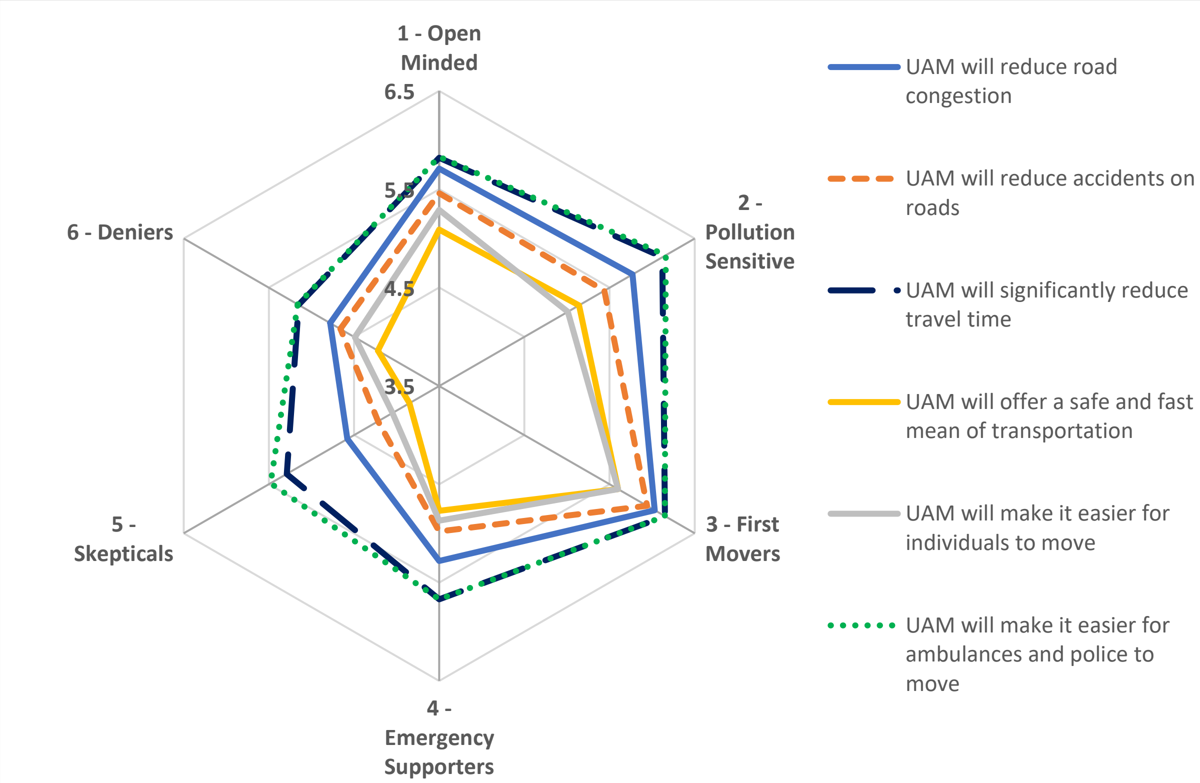

Figure 3. Distribution of Expected Benefits items (average values) per Cluster

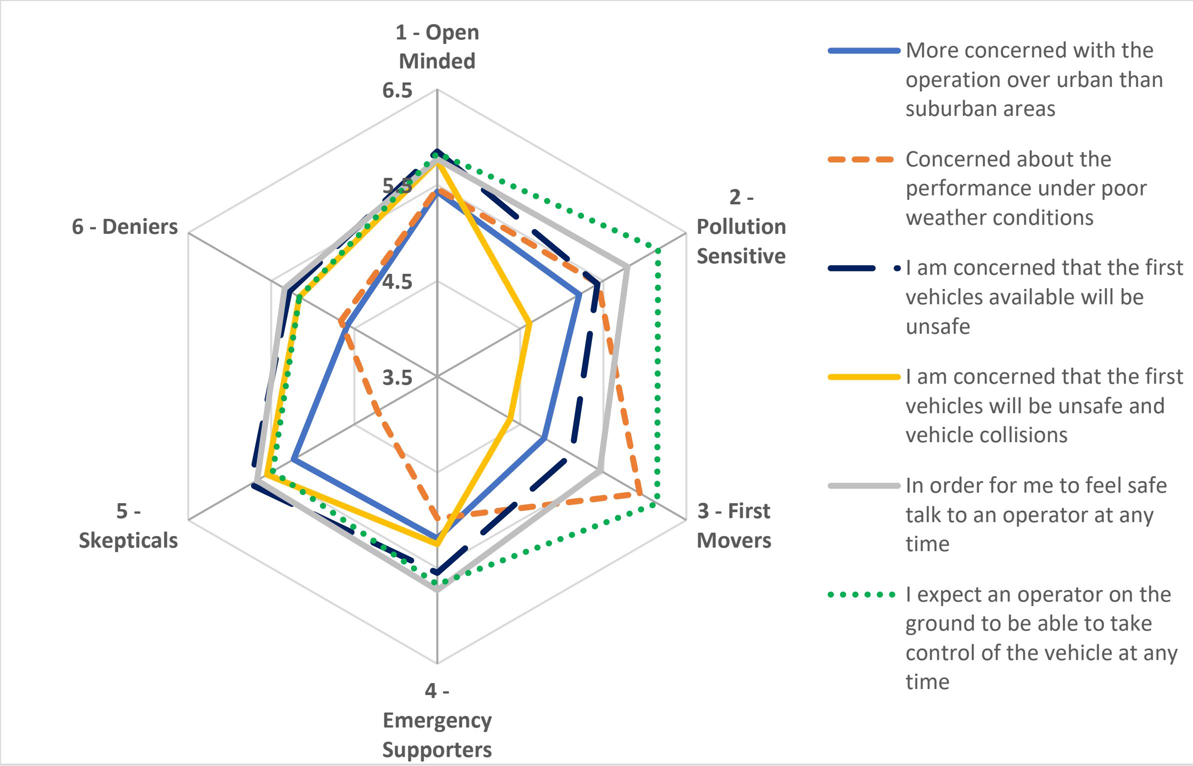

Figure 4. Distribution of Safety variables (average values) per cluster

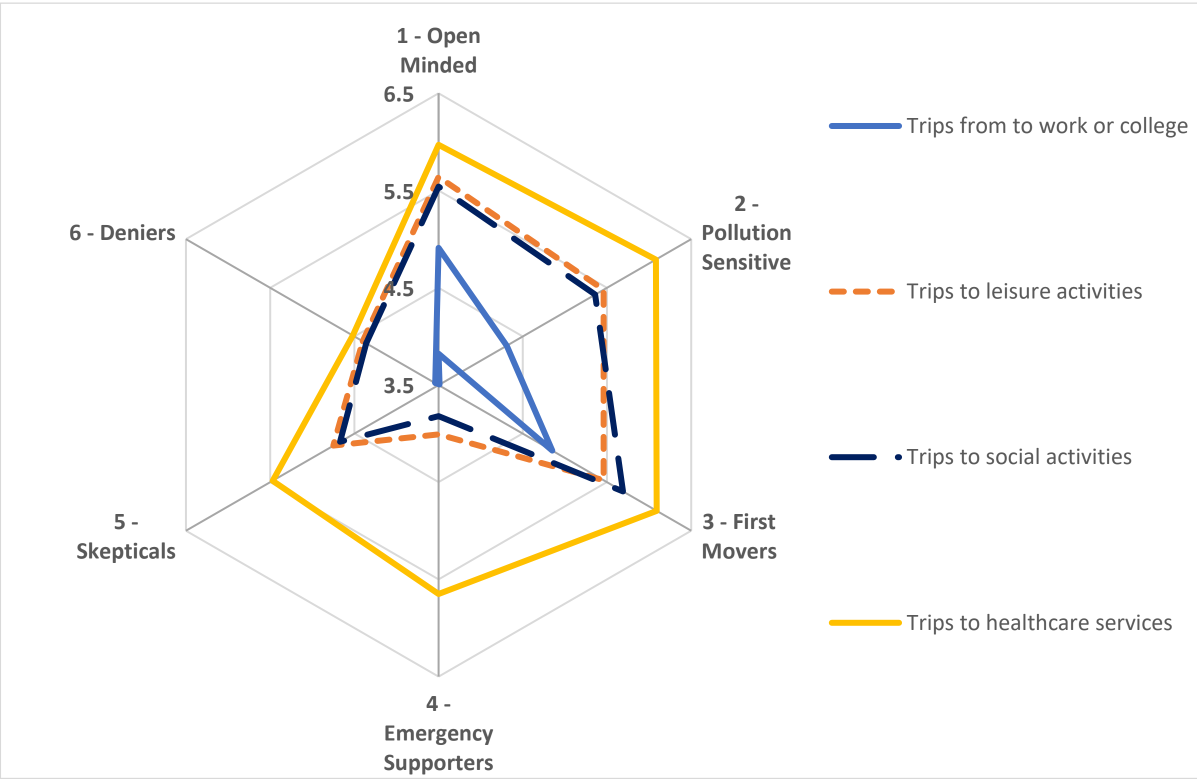

Figure 5. Average values of Intention to use variables per cluster and trip purpose

Table 3. Clusters´ sociodemographic and mobility characteristics

Personal and mobility Characteristics	Citizen´s Clusters					
	1 - Open Minded	**2 - Pollution Sensitive**	**3 - First Movers**	**4 - Emergency Supporters**	**5 - Skepticals**	**6 - Deniers**
Gender						
Female	46.0%	50.5%	27.90%	45.80%	37.00%	43.30%
Male	54.00%	49.5%	72.10%	54.20%	63.00%	56.70%
Age						
18 to 24	19.5%	29.9%	19.1%	36.1%	30.1%	20.9%
25 to 34	25.3%	29.9%	16.2%	28.9%	24.7%	34.3%
35 to 44	14.9%	14.0%	19.1%	10.8%	16.4%	20.9%
45 to 54	12.6%	18.7%	19.1%	9.6%	19.2%	13.4%
55 to 64	25.3%	7.5%	25.0%	12.0%	8.2%	10.4%
65 or older	2.3%	0.0%	1.5%	2.4%	1.4%	0.0%
Children						
Yes	44.8%	37.4%	54.4%	27.7%	37.0%	41.8%
No	55.2%	62.6%	45.6%	72.3%	63.0%	58.2%
Education level						
High school	13.6%	7.5%	10.3%	6.0%	6.8%	7.5%
Apprenticeship with graduation	6.9%	2.8%	2.9%	1.2%	8.2%	3.0%
Bachelors' degree	42.5%	43.0%	47.1%	57.8%	42.5%	40.3%
Masters' degree	34.5%	43.0%	36.8%	33.7%	37.0%	46.3%
PhD	2.3%	3.7%	2.9%	1.2%	5.5%	3.0%
Household net monthly income						
Less than 1000€	17.2%	16.8%	11.2%	16.3%	12.9%	9.6%
1000€ to less than 2000€	21.8%	20.6%	25.9%	24.8%	22.4%	39.4%
2000€ to less than 3000€	29.9%	30.8%	17.1%	22.4%	27.9%	32.0%
3000€ to less than 4000€	18.4%	15.9%	21.5%	13.9%	12.9%	12.5%
More than 4000€	12.6%	15.8%	24.4%	22.4%	23.7%	6.6%
Employment						
Employed	75.80%	65.53%	79.40%	57.80%	71.98%	73.10%
Student/Intern	13.60%	26.33%	14.80%	32.50%	22.58%	22.40%
Unemployed	6.80%	6.73%	2.90%	6.00%	3.38%	4.50%
Retired	3.40%	1.13%	2.90%	3.60%	2.08%	0.00%
Residence environment						
Urban environment with mixed land use	17.20%	39.30%	32.40%	31.30%	28.80%	29.90%
Residential suburban environment	33.30%	25.20%	32.40%	34.90%	39.70%	37.30%
Rural environment	49.40%	35.50%	35.30%	33.70%	31.60%	32.90%
Previous experience with car accident						
Yes	50.00%	56.60%	66.70%	51.40%	46.40%	56.50%
No	50.00%	43.40%	33.30%	48.60%	53.60%	43.50%

Accident injury type						
No injuries	80.50%	83.30%	77.30%	65.80%	87.50%	82.90%
Minor injuries	14.60%	8.30%	15.90%	34.20%	6.30%	17.10%
Major injuries	4.90%	8.30%	6.80%	0.00%	6.30%	0.00%
Car ownership						
Yes	81.70%	84.90%	97.00%	81.10%	73.90%	79.00%
No	18.30%	15.10%	3.00%	18.90%	26.10%	21.00%
Driving license						
Yes	94.30%	99.10%	97.10%	89.20%	94.50%	92.50%
No	5.70%	0.90%	2.90%	10.80%	5.50%	7.50%
Owning a vehicle						
Yes	81.70%	84.90%	97.00%	81.10%	73.90%	79.00%
No	18.30%	15.10%	3.00%	18.90%	26.10%	21.00%
Driving or using a vehicle						
Everyday	64.60%	60.40%	75.80%	56.80%	62.30%	58.10%
Couple of times a week	25.60%	29.20%	19.70%	32.40%	21.70%	27.40%
Once every two weeks	1.20%	2.80%	1.50%	2.70%	4.30%	3.20%
Once a month	2.40%	0.00%	3.00%	0.00%	4.30%	4.80%
Every couple of months	0.00%	2.80%	0.00%	4.10%	2.90%	1.60%
Not drive	6.10%	4.70%	0.00%	4.10%	4.30%	4.80%
Walking in daily trips						
Walking exclusively	10.30%	10.30%	4.40%	9.60%	5.50%	10.40%
Along with other means of transportation	40.20%	48.60%	30.90%	48.20%	46.60%	37.30%
No	49.40%	41.10%	64.70%	42.20%	47.90%	52.20%
Mobility behaviour – daily use of:						
Car	66.70%	54.50%	60.00%	58.30%	37.50%	11.10%
Motorcycle	13.30%	0.00%	0.00%	0.00%	6.30%	0.00%
Bicycle	0.00%	3.00%	0.00%	0.00%	18.80%	0.00%
Bus	46.70%	51.50%	50.00%	70.80%	56.30%	100.00%
Ferry	6.70%	3.00%	0.00%	0.00%	0.00%	11.10%
Train	60.00%	33.30%	50.00%	12.50%	50.00%	11.10%
Tram	6.70%	3.00%	20.00%	4.20%	0.00%	11.10%
Metro	46.70%	81.80%	90.00%	79.20%	62.50%	77.80%
Taxi	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Shared Car	6.70%	0.00%	10.00%	8.30%	6.30%	0.00%
Shared motorcycle	0.00%	3.00%	0.00%	0.00%	0.00%	0.00%
Shared bicycle	0.00%	0.00%	0.00%	4.20%	6.30%	11.10%
Walking	46.70%	69.70%	60.00%	54.20%	62.50%	44.40%

4.2.3 UAM(pax) Receptiveness and Intention to Use

Figure 5 shows the actual UAM(pax) receptiveness level per cluster in accordance with the intention to use UAM(pax). It presents, on a scale from 1 (Strongly Disagree) to 7 (Strongly Agree), the average values for each cluster in the items of receptiveness (x axis) and Intention to Use (y axis). All average values are higher than 4, meaning that all the clusters have a global mean on receptiveness and Intention to use above the median point of the scale which is very positive in terms of how the groups see and feel about UAM(pax). The bubble size is proportional to the cluster size while the bubble colour is applied according to the level of new technology adoption. Thus, the darker the green is, the more innovative the cluster is; the darker the red is, the more the cluster is composed of laggards.

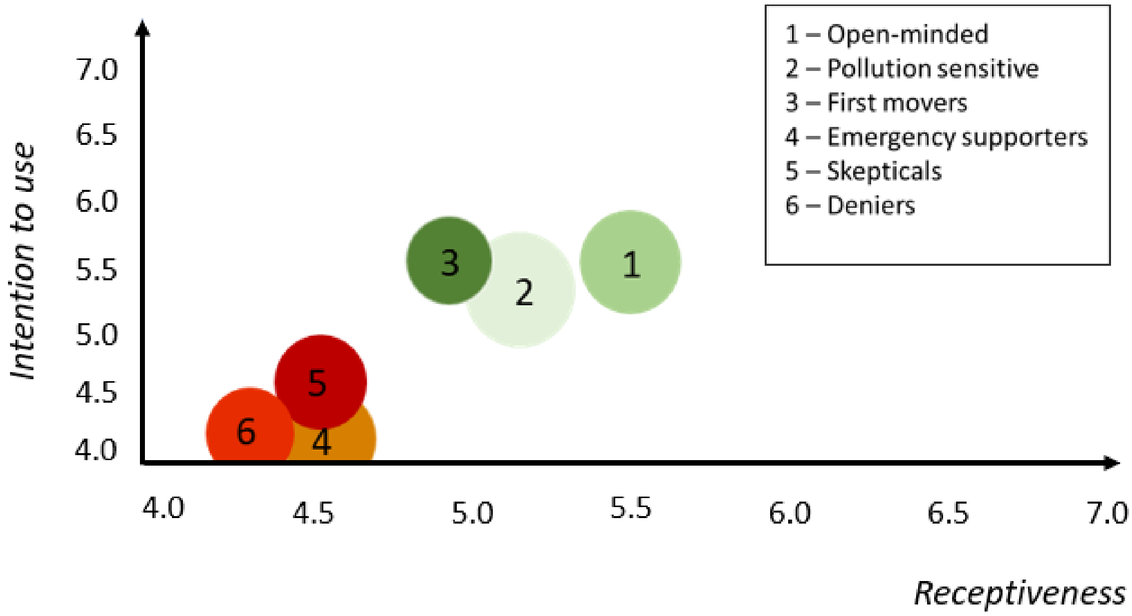

Figure 6. Clusters distribution (global mean scores) by Receptiveness and Intention to Use UAM(pax)

The "Open Minded" (Cluster 1) members have the highest average on Receptiveness (5.49) meaning they are those individuals that more easily welcome the implementation of UAM(pax) services in the transport system. On the other hand, the "First Movers" (Cluster 3) are most prone to use these vehicles (Intention to Use average is 5.52) although they also have a high average of receptiveness. These two cluster groups correspond to the population segments that will not pose barriers to the implementation of UAM(pax) services as a new and innovative mode of transport. "Open Minded" and "First Movers", jointly with the "Pollution Sensitive" (Cluster 2), state to be more innovative and therefore, they will not need many incentives to welcome UAM(pax). However, "Emergency Supporters" (Cluster 4), "Skepticals" (Cluster 5) and "Deniers" (Cluster 6) will be the citizen segments that require more engagement measures and incentives to better understand the reasons behind their levels of receptiveness and Intention to Use, as they have average below 5. Public entities such as governments, private companies that manufacture drones and eVTOLs, and others involved in the legal and other phases of the UAM(pax) service implementation process should focus on the citizen segments that pose barriers in welcoming UAM(pax) services, such as the "Skepticals" and the "Deniers". The citizen segments that will be the Innovators or First Adopters will most likely have a big role in turning the rest of the population onboard with UAM(pax) services, and their feedback and word-of-mouth communication will have an impact on the levels of receptiveness of the rest (Pettigrew at al., 2019).

To better understand the differences among the clusters that indicate a positive attitude towards UAM(pax) services and among those with a more negative attitude, the statistical differences in their replies in the statements of the expected benefits, safety aspects, the intention to use, and the social support items were analyzed. Table 4 presents the results of the multiple comparison tests conducted first for clusters 1, 2, and 3 (open-minded, pollution sensitive, and first movers) and then for clusters 4,5, and 6 (emergency supporters, skepticals and deniers). Differences with p-values lower than 0.05 are presented[1].

The results indicate that the emergency supporters appreciate the expected benefits of UAM(pax) services compared to the skepticals as the mean values of their replies are higher. For example, the average value of the replies of the emergency supporters to the statement "UAM will reduce accidents on roads" was 0.757 higher than the average of the replies of the skepticals. No differences were detected among the positively expressed clusters in the perceptions of the benefits. However, some safety aspects seem to concern more the open-minded individuals compared to the pollution sensitives and the first movers. Specifically, the open-minded are more concerned with the performance of the first air vehicles and the chance of collisions in the air. A highlight of the differences in the perceptions of the clusters is that among the clusters that have expressed less supportive opinions towards UAM(pax) services, the emergency supporters support much less the social usefulness of UAM(pax) to serve leisure, social, commuting, and good transfer trips compared to the other two clusters, but they appreciate significantly higher the contribution of UAM(pax) in emergency cases and healthcare services. A similar pattern is observed for the intention to use.

Table 4. Differences among clusters´ perceptions

	Open minded & Pollution sensitive	**Open minded & First movers**	**Pollution sensitive & First movers**	**Emergency supporters & Skepticals**	**Emergency supporters & Deniers**	**Skepticals & Deniers**
Expected Benefits Items	**1 & 2**	**1 & 3**	**2 & 3**	**4 & 5**	**4 & 6**	**5 & 6**
UAM will reduce road congestion					0.702	
UAM will reduce accidents on roads				0.757		
UAM will significantly reduce travel time						
UAM will offer a safe and fast mean of transportation				0.922		
UAM will make it easier for people to move				0.813		
UAM will make it easier for ambulances and police						
Safety Items						
More concerned with the operation over urban than suburban areas						
Concerned about the performance under poor weather conditions						
I am concerned that the first UAM services will be unsafe		0.733				
I am concerned that the first UAM services will be unsafe and vehicle collisions may occur	1.151	1.376				

[1] The p-values from these tests should be considered as approximations of the true p-values since the clusters are non-random groups.

In order for me to feel safe talk to an operator at any time				
I expect an operator on the ground to be able to take control of the vehicle at any time				
I expect an operator on the ground to be able to take control of the vehicle in case of emergency			0.694	
Intention to use in:				
Trips from to work or college				
Trips to leisure activities		-0.741		
Trips to social activities		-0.852		
Trips to healthcare activities			1.128	0.943
Social support per Trip Purpose				
UAM services should be used to transfer people for leisure		-1.545	-1.054	
UAM services should be used to transfer people for social activities		-1.560	-1.072	
UAM services should be used to transfer people from/to work or school	0.750		-0.937	
UAM services should be used to transfer goods to people		-0.933		0.969
Urgent Societal Needs Satisfaction				
UAM services should be used to respond to emergency cases		2.125		1.879
UAM services should be used to transfer people from/to healthcare services			2.174	1.858

The next step in the analysis is hence the comparison of trip purposes for users and non-users. While numerous studies exist on adoption that presumes the role of user, very few studies have focused and shed light on the opinion of "quitted" users that no longer choose a service or non-users (Matubatuba and de Meyer-Heydernrych, 2022) usually with the perspective of potential future users. This study follows the concept of citizens users and non-users of UAM(pax) without inferring about the probabilities of adoption and receptiveness from the side of non-users. Hence, a societal perspective of the deployment of the technology for the offer of transport services and, hence, public good and utility is adopted. In this case, when the appropriateness of use per trip purpose is analyzed, it is observed that the perceptions of clusters 1, 2, and 3 are very similar on UAM(pax) appropriateness as a UAM(pax) user and a non-UAM user while clusters 4, 5, and 6 differ slightly in this case. Figure 6 illustrates the average values of the replies in the intention to use UAM(pax) services for various purposes per cluster (x axis) and the perception of UAM(pax) use appropriateness for different trip purposes as perceived by each cluster. The skepticals appreciate more than the emergency supporters and the deniers the potential utility of UAM(pax) services, but they express similar levels of intention to use. Hence, although their intention to use is below the average of the replies, their attitude on what trip purposes UAM(pax) services can be employed for is above the average replies.

A dilemma appears in this figure between individual and societal costs and benefits because we see that the positive attitude continues the same while the negative differentiates the skepticals form the other two categories which seem to be more firmly oriented towards a disutility of UAM(pax) while the skeptical may express a more positive or neutral behaviour.

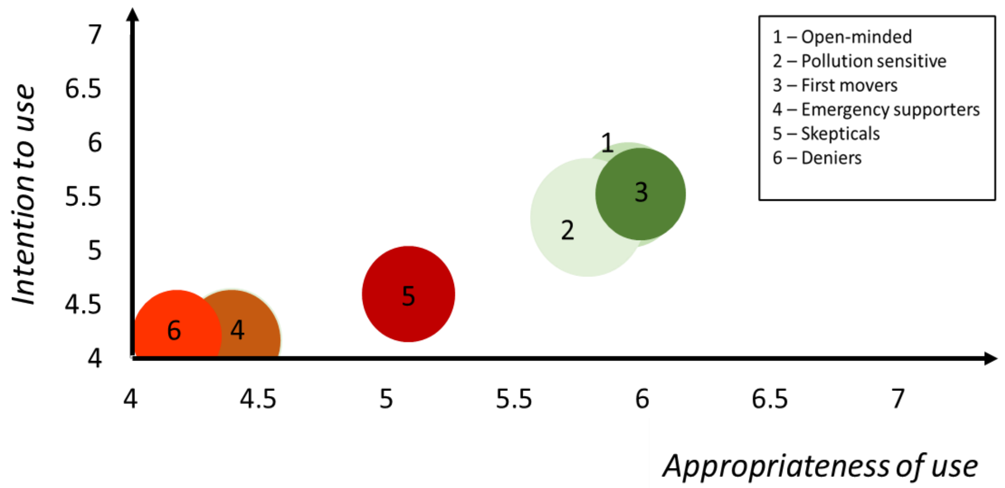

Figure 7. Clusters distribution (global mean scores) based on utility appropriateness per trip purpose for society (x) and the individual (y)

5. Discussion

5.1. Clusters´ comparison

Many interesting insights arose from the cluster analysis. Two opposite clusters were identified. The "First Movers" had high levels of receptiveness, and most participants regarded themselves as Early Adopters or Innovators in the adoption category classes. On the other hand, the "Deniers", a segment of the population that does not believe that UAM(pax) will bring any sort of benefits to society, mainly composed of people classified as either Laggards or Late Majority in the adoption category classes. The rest of the clusters lacked those highly defining characteristics; however, they can be distinguished and be put closer to the "First Movers" or "Deniers", in terms of their levels of UAM(pax) receptiveness.

The first and third clusters, labelled as "Open-minded" and "First Movers" respectively, entail the most innovative people in the study, both have the most participants from the age groups of 25 to 34, which are young people with some financial possessions, and the age group of 54-65. These participants from the older age group probably no longer worry about their children´s financial care, therefore have more time and also money to spend on themselves since when they were young, they did not have a chance to take advantage of technological developments as currently the younger people do. The Portuguese population, especially older age groups, are very fond of air transport since it has always been a part of the country's history and culture. In addition to that, the Portuguese coastal area is very long, and has several aerodromes across it, thus it does not come as a surprise that older people are one of the population segments that are most likely to adopt and use Urban Air Mobility as an innovative and safe mode of transport. Regions with aeronautic activity might be more receptive to UAM(pax) and its residents might be more willing to use such services early after their introduction to the mobility systems.

Especially in the third cluster, the "First Movers", there is a big difference in gender distribution, with men counting for 72% of the participants in the cluster. This is a differentiator factor since men are known to better or at least more easily accept technological change (Al Haddad et al., 2020; Hohenberger et al., 2016). Also, the fact that there is a higher percentage of men may also result in the lower concern with the environment as previous literature indicates that women are more worried with the environment. On the other hand, the “Pollution Sensitive” cluster is the only one with a bigger percentage of female participants which is aligned with the literature.

“Emergency Supporters”, “Skepticals” and “Deniers” are the most adverse groups with regard to UAM(pax) services as a mean of transport and they all share a few similarities in their demographic distribution. For example, these clusters have a predominant percentage of younger respondents; the only exception is the respondents in the age group of 45 to 54 which represent 19.2% of the Skepticals. Most of the participants in these clusters regard themselves as either Late Majority or even Laggards when it comes to adopting UAM(pax), yet those in the “Open-Minded” and “First Movers” (higher adoption) regard themselves more as Early Adopters or Innovators.

There are some factors that will have an impact on how society will feel about prospective UAM(pax) vehicles and automated driving, namely safety which according to Panagiotopoulos and Dimitrakopoulos (2018) is the most important one. Al Haddad et al. (2020) also stated safety as the most important factor in adoption followed by cost in second and trip duration in third. Safety regards not only the safety of the rider itself but of the vehicle and the conditions in which it will operate. Across all clusters, most respondents either stated to Agree or Strongly Agree to be concerned with using an UAM(pax) in bad weather conditions. Having the possibility to transfer manual control or even talk to an operator on the ground could be one method to increase trust among possible users and thus increase the levels of receptiveness.

With the implementation of UAM(pax) the noise and visual pollution levels will probably rise due to the circulation of Air Vehicles. However, according to our study, the cluster with higher levels of receptiveness has the participants who are less concerned with visual and noise pollution with 36.8% of “First Movers” responding Disagree to both questions. Urban pollution, especially noise pollution, will be a big barrier to implementing UAM(pax). It is a problem that should be tackled early and get the population to participate in finding a solution to the problem.

5.2. Strategic planning for sustainable development of UAM(pax) services

The reported work, first, contributes an analytical typology for gaining insights into the citizens´ perspectives in a given city. Although the data collection can be enhanced to include more people of older ages and more metropolitan areas, it provides a solid basis for yielding insights in the context of evidence-based policy making. For example, during the early phases (Phase 1 and 2) of the SUMP process cycle (Rupprecht Consult, 2019; Agouridas et al., 2021) with regard to the selection of mobility networks and services to be complemented through UAM(pax), the involvement of citizens and the consideration of their views is fundamental. The approach of this study provides insights on citizens´ perceptions on potential uses of UAM(pax) sheds light on the potential barriers that could impede the growth of UAM(pax). At this stage mobility scenarios are envisioned and discussed with citizens during the strategic development of a mobility plan. Further, at this stage spatial implications at urban and interurban interfaces should be also addressed in the context of designated functional urban areas (FUAs) (Agouridas et al., 2022). In addition, the proposed framework could be used to provide data about the definition of pertinent key performance indicators and measures for monitoring and evaluating the deployment of UAM(pax) services as part of Phase 3 and 4 of the Sustainable Urban Mobility Plans (SUMP) process cycle (see also SUMP-UAM, Agouridas et al., 2021).

Second, the designated clusters and their description, although they represent a given sample from the Metropolitan area of Lisbon, and hence cannot be generalized to other cities and countries, they provide insights of the attitudes of this local society. To this end, informed decisions can be made that will be tailored to the specificity of this locality. Assuming a replication of similar studies in other targeted cities and countries, the results could then prove beneficial to institutions at national and supranational levels. Moreover, such results could be used by private stakeholders involved in the preparation of UAM(pax) services, such as urban air traffic management service providers, drone and eVTOLs manufacturers, to inform and enrich their user-driven design processes and strategic foresight analyses. Furthermore, when taking into consideration the continuous digitalization of smart mobility and smart cities governance practices, the proposed analytical framework can serve as a backbone support tool for data analysis and evidence generation for smart city authorities.

Specific recommendations could be given for some of the clusters. For those citizen groups that present a more reserved attitude towards UAM(pax) services, further engagement activities need to be initiated by Local Authorities and the Public Administration field in general. To this end, awareness and information diffusion campaigns as well as active measures for facilitating and encouraging co-creation practices with citizens are examples of actions that could be taken in the context of participative governance. Otherwise, there is a risk, for example, of providing mobility solutions to citizens who have already good mobility accessibility and have reached a certain level of satisfaction with their current mobility experiences while others suffer lower quality services. Similar conclusions have been deducted from the citizens´ views on automated driving (Marques dos Santos et al., 2022). For the group with more environmental concerns, Eissfeldt (2020) notices that one way to combat the noise pollution factor should be the active involvement of the population (e.g. real-time data capture on nuisance) in developing and agreeing on mitigation measures for this problem by understanding the level of tolerance in the different communities. Determining such a level of tolerance in communities' air corridors and routes could be developed according to the information given by the public.

Considering the above, the reported work contributes to balancing technological forecasting activities by taking into consideration not only the advancements and maturity of UAM(pax) technologies but also the societal expectations for the impact, usage, and adoption of such technologies and their enabling services. For example, the derivation and description of citizen clusters for UAM(pax) services contribute to establishing a more balanced approach to the evolution of the UAM(pax) socio-technical system and its transition towards more sustainable and responsible development and deployment of UAM(pax) services.

6. Conclusion

To ensure the responsible use of new technologies in the mobility sector, the public opinion should be heard and considered. Governments, Local Authorities and social entities can benefit and pave the way for the seamless integration of UAM(pax) technologies in mobility systems by delivering services that respond to the expectations of citizens and are positively perceived. This study focuses on the exploration of citizens´ attitudes towards UAM(pax) and analyzes the aspects related to the citizens´ receptiveness of prospective UAM(pax) services. A survey was designed to address the view of people on the topic of UAM(pax) and data was collected from 485 respondents who live in the Lisbon Metropolitan Area. Then the citizens were clustered into groups following a clustering process based on the receptiveness levels of the respondents on UAM(pax) services.

The data analysis indicates that citizens´ receptiveness towards UAM(pax) is expressed by the perceived societal benefits, the expected cover of urgent societal needs, the appropriateness of UAM(pax) per trip purpose, environmental aspects and concerns. The clustering process designated six citizen clusters that presented different views on the receptiveness components; some of the clusters seem to focus more on the positive aspects of UAM(pax) while others express overall doubts on the contribution of UAM(pax) services on the society. Although the clusters´ views may differ on the appropriateness of UAM(pax) on several trip purposes, it is observed that there is a common understanding on the potential benefits on healthcare issues. Another key finding that also stimulates future research is the fact that higher levels of receptiveness seem to be assigned to citizens who expressed higher intention to use such services soon after they are available at the market. Future studies could focus on expanding the data collection process to more cities and citizen segments and address the sociodemographic characteristics and mobility behaviour may influence the views of citizens.

Overall, the results found in this study point out the importance of analyzing the characteristics and the citizens´ perception of UAM(pax) to understand how to act towards a successful implementation of UAM(pax) services in the sense that citizens are expected to both welcome the use of UAM(pax) in the transport system and use them for their mobility needs. The information gathered can support Governments, Policymakers, and industrial manufactures to shed light on how to approach the market structuring in the early stages of developing and implementing UAM(pax) in this case study. In this way a contribution towards the planning of sustainable urban air mobility plans is achieved.

This study also presents some limitations. The sample was conducted on social media, hence the study was restricted to the availability of the most active respondents on these platforms. However, many controls were implemented to diversify the respondents in order to have a sample as representative as possible of the population. In future research, the sampling method chosen should be carried out to avoid sampling bias e.g. a door-to-door collection approach. Also, the study is limited to one geographical area in Portugal, but the approach could be employed to analyze the citizens´ view in other metropolitan areas as well. Finally in terms of the collected content, the second statement that was excluded from the receptiveness principal component analysis was one stating that "I am concerned that UAM will become a service only for the rich". It was excluded because it generated a one-variable principal component indicating that this concept may not be multiphasic and multiple parts of the belief have not been measured in this study but could be included in future research. Research to this direction would be of great importance as it would reveal indications on whether UAM(pax) would actually contribute towards mobility equity or lead to mobility inequalities and how much it would contribute to the SDGs.

Future research could repeat the data collection and capture the evolution of public opinion along time and age as this is an evolving topic and opinions evolve as more information becomes available to the public. Also, it is suggested that that future samples include the geographical zone of the respondents and map the replies to identify spatial correlations among geographical areas and receptiveness levels. Furthermore, it should be acknowledged that while this study is focused on UAM(pax) use cases and citizen perspectives to cover societal perspectives such as noise and visual pollution, a wider environmental impact analysis should be covering aspects through a whole life cycle assessment approach (e.g. incl. resuse and recyclability) approach should be dealt in future research to explore the industrial and biodiversity perspectives and impacts of UAM(pax) (eg. Agouridas, 2022).

Furthermore, a wider societal impact assessment including employment, health, inclusion and responsible consumption should be further analyzed in future research.

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