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A New Mobility Era: Stakeholders' Insights regarding Urban Air Mobility

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Abstract: Urban Air Mobility (UAM) constitutes a future aerial mobility alternative, which concerns the use of electric and autonomous aerial vehicles for transporting people throughout a planned network of vertiports. To materialize UAM, several actors of the air and urban transport ecosystem play a vital role. This paper describes the insights gathered from 32 key stakeholders around the world to present and frame the key aspects for the future implementation of UAM. The participants include representatives from the UAM industry such as airports, airlines, aviation consulting companies, academia, and authorities. The data collection encompasses various key research areas, covering topics such as UAM strengths, weaknesses, opportunities and risks, requirements for implementation, concept integration in the existing transport system, specific use cases, business models, and end-user segments. The research aims at setting up the stakeholder scene and expanding the current literature for UAM by engaging key decision makers and experts towards shaping the new mobility era. The results demonstrate that ensuring certification standards for UAM fleets and updating the current legal and regulatory framework are the main prerequisites for UAM's realization. In addition, the usage of UAM for transporting cargo or for air ambulance services are the most mature business models for the coming decade.

Keywords: urban air mobility; advanced air mobility; stakeholders; requirements; SWOT analysis; UAM use cases

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1. Introduction

Urban Air Mobility (UAM) constitutes a state-of-the-art concept which enables new services for intermodal and multimodal transport, on-demand air passenger mobility, cargo delivery, search and rescue operations, as well as emergency services within or around metropolitan areas [1]. The idea of UAM is to bring urban mobility from the road to airspace with the aim of relieving current transport systems from challenges such as congestion and air pollution. Later, the concept was extended by NASA using the broader term of Advanced Air Mobility (AAM) to further consider operations that are not limited to urban areas but also include rural and inter-urban trips [2,3] and can additionally address the issue of limited accessibility to remote areas. Although in their strict definition, the terms UAM and AAM might represent different concepts [4], this paper adopts the term of UAM for both urban and inter-urban areas to be consistent with the recent European literature [5].

UAM is based on the operation of electric and autonomous air vehicles that have the capacity to take off and land vertically. These aerial vehicles are referred to as electric vertical take-off and landing vehicles (eVToLs) and can serve flights of up to 240 km [3]. The essence of Urban Air Mobility is to supplement ground transport trips or civil aviation short-haul travel providing new means of mobility with reduced travel times. The way UAM is going to be introduced in the existing transport system has been discussed in the existing scientific and gray literature. The majority of works support that UAM will enter the market in the form of an on-demand service offered to one (e.g., air taxi) or multiple users (e.g., air pooling) [3,6,7], while a small part of the existing literature identifies UAM as a private mode [8] or a scheduled and semi-scheduled service [9]. As for the needed ground infrastructure for UAM, the basic idea is that eVToLs would need infrastructure with specific characteristics. One the one hand, it is argued that the so-called vertiports could use the existing airports and heliports [10], while new vertiports could also be built directly into the urban area to serve UAM operations [11]. Additionally, and apart from the technological advancements needed for the electrification and automation of air vehicles, a variety of other factors are required for UAM implementation. Energy and infrastructure management, information and communication technologies, new requirements for air traffic management, regulatory framework, end users' acceptance, as well as new business models are some of the open issues that need to be further explored for the safe integration of UAM in the current air and urban transport system [2].

This paper presents the critical aspects for the future implementation of UAM by collecting, analyzing, and synthesizing input provided by 32 key stakeholders around the world. It focuses on the concept of UAM for passengers by considering use cases that are not limited to urban environments but also involve inter-city or inter-island passenger trips [1]. The current research work is developed in two phases. The first phase involved stakeholders from the international community with a high level of familiarity and knowledge of UAM, while the second phase engaged representatives from the Greek community.

Through the above research, the paper extends the existing literature by providing insights from experts to the following research questions:

Q1. What are the requirements and challenges for introducing and implementing UAM?
Q2. How will eVTOLs be integrated into the current mobility landscape?
Q3. What are the main UAM strengths, weaknesses, opportunities, and threats?
Q4. What are the potential use cases for UAM and their level of maturity for implementation in the period of 2030–2040? Who are the customers and what are their required types of services?
Q5. How will UAM implementation evolve in the Greek market? What are the viewpoints of the related Greek stakeholders?

The rest of the paper is composed of four sections. Section 2 presents a review of the state of the art and practice on stakeholders' engagement regarding innovative mobility concepts including UAM. Section 3 describes the research methodology and presents relevant information about the engaged stakeholders. Sections 4 and 5 analyze the insights from the international and Greek panel of experts, respectively. Section 6 presents the conclusions of our work and suggestions for further research.

2. Background

It is widely acknowledged that stakeholders' involvement is an essential prerequisite for the successful deployment of emerging technologies and innovative concepts from the beginning of the development process [7]. In the stakeholder analysis, the researchers gather and analyze qualitative information to determine whose interests and viewpoints should be considered for the implementation of the concept under study [12,13]. In the transport sector, several methods have been applied to collect data from stakeholders [14]. Structured brainstorming workshops (e.g., organized in round-table discussions), focus groups, semi-structured interviews, and questionnaires are the most common methods, while Delphi methods have also been adopted by some researchers. Such engagement methods have been used to gather stakeholders' insights and requirements regarding new mobility services such as autonomous vehicles [15,16], shared mobility [17], mobility as a service [18,19], and air transportation [20–22], while similar approaches have been adopted for planning traditional transport services [23–25].

In accordance with the above, a fundamental step towards the successful design and implementation of UAM involves the engagement of multiple players/decision makers with diverse backgrounds and from different markets. In this way, their viewpoints on the key aspects of the concept, such as challenges, opportunities, risks, etc., can be acquired. However, until today few studies have explored UAM by bringing together stakeholders. Most of the related studies have focused on their technical characteristics including propulsion systems, battery technology, and autonomy [26–28]. Limited literature concerns the development of econometric models [29–31] to explore perceptions and attitudes [32–35] and estimate users' willingness-to-fly [36] and willingness-to-pay for air taxis [37,38]. A few papers have also explored the development of transport network simulation models [39] and sustainable business models for UAM [40]. As yet, few studies have been conducted to investigate the challenges of UAM in terms of the legal framework and relevant perspective [10,41], including passenger safety [42], required infrastructure for eVToLs [11], and environmental footprint [14].

A recent focus-group study on the challenges for implementing UAM in real-life engaged ten experts of the aviation industry [43]. The aim was to assess several key performance indicators related to the future implementation of UAM in the area of Upper Bavaria in Germany based on the level of UAM relevance and feasibility. Among several parameters, energy consumption, air and noise emissions, total travel time saved, congestion (ground), inconvenience (access, egress, and waiting time), the total number of passenger trips, and safety (number of accidents) were found to affect UAM implementation. Additionally, Cohen et al. [16] explored the UAM ecosystem's viewpoints through interviews and workshops aiming to provide the milestones made so far, as well as understanding what is anticipated for the future of UAM. They classified the point-to-point services of a "flying car" into a six-phase framework representing the on-demand and vertical-take-off-landing characteristics.

Desai et al. [1] developed a roadmap to explore potential hazards, challenges, as well as benefits and opportunities and identify valuable uses cases of UAM. A Delphi method was applied engaging around 50 stakeholders and academic representatives. The results show that medical and defense use cases as well as airport shuttles are the most promising cases for implementation, while lack of community engagement is likely to have the most hazardous effect on the viability of UAM.

The above review indicates that few studies have focused on understanding stakeholders' points of view regarding UAM. This paper aims to expand the existing literature with insights from international experts regarding the requirements of introducing and implementing UAM; it explores the strengths, weaknesses, opportunities, and threats for UAM implementation, and identifies specific UAM use cases, business models, and end-users' segments. In addition, the acquired knowledge is used as a basis for investigating the application of the UAM concept in Greece and its market potential.

3. Methodological Approach

The purpose of this research is to capture stakeholders' viewpoints and insights on different topics regarding UAM implementation. Data collection was conducted through semi-structured surveys, which are regarded as a flexible means for acquiring a mix of qualitative and quantitative data [44]. The surveys were conducted in two phases, collecting data from experts at different geographical regions. At first, our study engaged international stakeholders who are actively involved with and have expertise in UAM, with the aim to investigate their views on the key aspects that will structure the new concept of UAM. At a second stage, our study focused on gathering data from Greek experts to further explore the potential implementation of UAM in Greece.

The questionnaires included closed and open-ended questions, thus allowing the experts to freely express their opinion [44,45]. Considering the different goals of the two study phases, the interview questions were slightly different, as presented in Figure 1. In the first phase, the survey questions addressed to the international community covered 4 sections: strengths, weaknesses, opportunities, and threats; requirements for UAM implementation; integration of UAM into the existing transport system; use cases and business models for the future time horizon of 2030–2040. In the second phase, specific questions addressed to Greek stakeholders involved the potential market size of UAM, potential geographical markets, business models, requirements, as well challenges and opportunities for UAM implementation in Greece. The surveys in both phases were carried out online due to the pandemic situation.

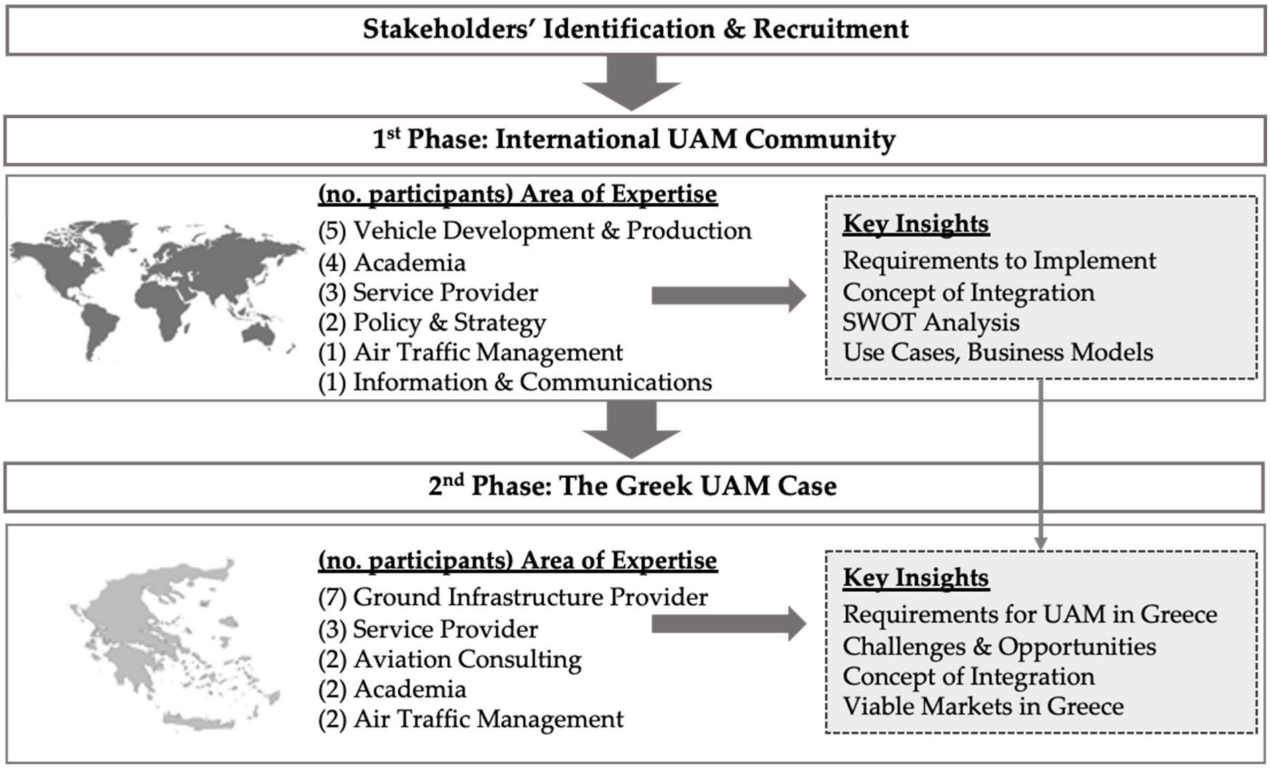

Figure 1. Methodological Approach.

Before conducting the surveys, a major step of the research included the identification and recruitment of the participating stakeholders. The main identification criteria were professional experience in UAM and good representation of key players of the UAM ecosystem and aviation, as acknowledged by the related literature [10,16]. As for their recruitment, direct messages (e.g., via emails or the LinkedIn message service) were sent to the targeted experts to participate in our research. As presented in Table 1, 32 stakeholders were engaged overall. The experts represent vehicle development and production (incl. eVToL companies and organizations), service providers (incl. airlines and handling operators), information and communication technology companies, air traffic management organizations (both for unmanned and conventional aerial vehicles), policy and strategy analysts, ground infrastructure providers (airports), aviation consulting companies, and academia. Especially for the international community (Phase 1), the participants consisted of 16 distinguished experts with different expertise representing the UAM ecosystem. This sample included 4 females and 12 males, with more than 11 years of professional employment and expertise on UAM. In Greece, where the UAM exploration is still scarce, the engaged stakeholders mainly represented the wider area of aviation and air transportation, although some of the stakeholders had strong expertise on UAM. The pool of experts consisted of 2 females and 14 males with more than 22 years of expertise on average.

Table 1. Stakeholders' characteristics.

	No.	Gender	Years of Expertise	Area of Expertise
1st Phase	1	Male	8	Vehicle Development and Production Providers
	2	Female	10	
	3	Male	3	
	4	Male	15	
	5	Male	26	
	6	Male	30	Service Providers
	7	Male	1	
	8	Male	7	
	9	Male	5	Air Traffic Management Organizations
	10	Male	25	Information and Communications Companies
	11	Female	12	Policy and Strategy Analysts
	12	Male	5	
	13	Male	15	Academia
	14	Female	8	
	15	Male	5	
	16	Female	8	
2nd Phase	17	Male	30	Service Providers
	18	Male	28	
	19	Male	10	
	20	Female	15	Ground Infrastructure Providers
	21	Male	-	
	22	Male	-	
	23	Male	25	
	24	Male	38	
	25	Male	31	
	26	Male	20	
	27	Male	20	Air Traffic Management Organizations
	28	Male	20	
	29	Male	14	Aviation Consulting Companies
	30	Male	4	
	31	Female	40	Academia
	32	Male	15	

4. Insights from the International UAM Community

The insights elicited by the international stakeholders are categorized in four sections that are elaborated below. It should be noted that all participants were encouraged to respond to the questions they were comfortable with and knowledgeable of and to omit the rest. Thus, the total responses of the stakeholders in the following subsections might differ.

4.1. Requirements for Introducing and Implementing UAM

The first section of our survey focused on the key UAM areas that are prerequisites for its successful establishment. As depicted in Figure 2, the participating stakeholders evaluated the importance of various requirements on a scale from 1 to 5, where 1 is "not important at all" and 5 is "extremely important". Our results indicate that, at its initial stage of implementation, the UAM realization requires addressing several aspects such as infrastructure, community integration, vehicle design, air traffic control, as well as regulatory and legal compliance [10].

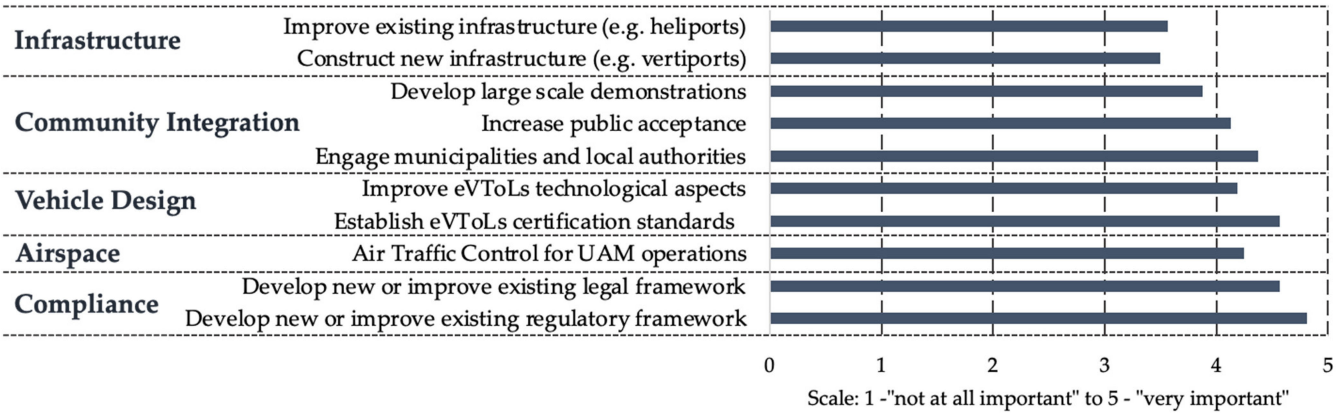

Figure 2. Requirements for UAM implementation.

Based on the participants' responses, the development of new or improved regulatory and legal framework is of utmost importance in order to make UAM a reality (with an average scale of 4.7). This finding is in line with the existing literature [16,41], as regulatory interventions are expected in every emerging technology. The UAM concept might face several externalities, not only before but also after the service launch. Even though UAM is at a very early stage, several regulatory measures have been imposed to ensure eVToLs' safe production and operation [1]. Yet, market-related policies should be eventually defined to allow services to be deployed at a large scale. The regulatory framework acceleration requires a holistic approach by incorporating market aspects such as pricing [10].

The second most critical requirement group concerns vehicle design. Participants perceived as highly important the production and operation certification standards for the eVToL (with an average scale of 4.6), followed by its technical improvement (rated as 4.2). The eVToL prototype constitutes the foundation of the innovation in this new aerial mobility concept. Its continuing technical improvement could maximize awareness and accelerate market penetration. On these grounds, the recent report of EASA [1] shows that certified aerial vehicles are highly dependent on societal acceptance, which is clearly needed for a successful future implementation of UAM. Currently, certification timelines and concept reports show that there are already technologically prepared companies for both cargo and passenger operations [46].

Similarly, community integration constitutes a set of requirements crucial for UAM's future implementation (with an average scale of 4.2). Among them, the participants seem to consider the engagement of municipalities and local authorities as the most important requirement. Expectedly, these public bodies are essential UAM players as they could provide guidance and support at diverse levels, including regulatory framework, large-scale operations, and community awareness. Additionally, participants highly rated the requirement of public acceptance for future UAM implementation. As it is widely explored in the current literature, social acceptance plays a key role in building the market and accelerating its penetration. Developing large-scale demonstrations could also help towards this direction according to the stakeholders' viewpoints, along with the current lessons learnt by the numerous UAM demonstrations that have already taken place.

Additionally, adaptations of air traffic control have been mentioned as an important requirement (score 4.3) for UAM operations.

Finally, infrastructural aspects such as the construction of new infrastructure or technical improvements of existing facilities (e.g., airports and heliports) were also examined in our survey. Although the participants supported that ground infrastructure (e.g., vertiports) are crucial for the materialization of the UAM concept, the level of their rating (3.5) indicates that all the other requirements should be placed in priority in order to make UAM a reality.

4.2. Integration with the Current Transport System

The inclusion of innovative aerial mobility services is expected to affect both the supply and the demand of the current transport modes. On these grounds, one of the survey questions aimed to identify how the UAM is anticipated to interact with the current transport landscape. The stakeholders were asked to share their viewpoints on whether they regard UAM as a complementary or a competitive alternative service to the current mobility choices. The current transport services were categorized as follows: air, water, and land transport, while the integration of UAM was separately assessed for urban and inter-urban trips. As Figure 3 depicts, UAM might be regarded as either complementary or competing with the existing mobility services depending on the type of trips under consideration.

Type		Interurban trips		Urban trips		No Relevance
		Complementary	Competing	Complementary	Competing	
Air	Airplane for leisure purposes	◑ 9	◔ 4	◔ 6	-	○ 2
	Airplane for business purposes	◑ 10	◔ 5	◑ 10	-	○ 1
	Helicopters	◔ 8	◑ 10	◔ 5	◑ 11	○ 0
Water	Seaplanes	◔ 7	◔ 5	◔ 6	-	○ 2
	Coastal Shipping	◔ 7	○ 3	◔ 5	-	◔ 4
	Cruise	◔ 6	○ 0	◔ 4	-	◑ 9
Land	Intercity trains	◑ 9	◑ 9	◑ 9	○ 2	○ 1
	Intercity buses	◑ 10	◔ 6	◑ 9	○ 2	○ 0
	Urban Public Transport	◑ 9	-	◑ 11	◔ 8	○ 0
	Taxi/ Ride-hailing services	◔ 8	-	◔ 8	◕ 12	○ 0
	Car (inc. private, car-sharing)	◔ 8	◔ 5	◔ 8	◑ 11	○ 0

% of Participants	
< 20%	○
≥ 20%	◔
≥ 40%	◑
≥ 60%	◕
≥ 80%	●

Figure 3. UAM integration with the existing transport system.

Regarding the air transport system, UAM is mainly considered as complementary to airplanes both for inter-urban (≥60% of the stakeholders) and urban trips. This is not the case for helicopters, where most of the stakeholders view them as competing modes. This can be explained by the fact that eVToLs could be seen as similar transport modes to helicopters [47], yet more sustainable and environmentally friendly.

As for water transport, our results indicate that seaplanes and coastal shipping are less likely (≥60% of respondents) to compete with UAM, while cruises are regarded as having no relevance with UAM services.

Finally, most of the stakeholders (≥80%) consider many land transport modes as complementary to UAM both for urban and inter-urban trips. Focusing on urban trips, cars and taxis are expected to operate in competition with UAM. This finding is in line with the existing literature which supports that UAM might be a competitive mode to transit and commute with an increased level of trust and comfort [48], while another study [49] found that a range of 50 min car rides would compete with UAM. However, overall, the participants supported that intercity trains and buses, as well as urban public transport and sharing services, will interact complementarily. However, UAM might achieve its growth by gaining market share from such land transport alternatives; even though UAM could still provide solutions to mitigate externalities such as ground congestion [3]. Additionally, as expected, inter-city trains and buses might both compete and supplement UAM for inter-urban trips, while many stakeholders indicated that urban public transport, taxis, and cars could be complementary to UAM. The viewpoints of our stakeholders are also in accordance with the study published by Sun et al. [6], who provided an in-depth analysis of air taxis' on-demand competitiveness regarding door-to-door travel time estimation in 29 European countries. Their results show that ranges between 80–130 km and 220–340 km trips with air taxis constitute a competitive option to car and aircraft, respectively, while railways would compete with air taxis for routes between two cities. They also indicated that competitiveness depends on the characteristics of the region and its network rather than the distances to the destination. Figure 3 summarizes the number of stakeholders' responses, while the pie charts to the right provide an illustration of the total participants.

4.3. SWOT Analysis

This section presents the results from a SWOT analysis conducted based on the stakeholders' responses. As Figure 4 shows, the participants were asked to characterize a list of UAM elements as strengths, weaknesses, opportunities, and threats (the option of choosing more than one category was available). The presented UAM elements are grouped into the categories of environmental aspects, socio-economic aspects, vehicle characteristics, and transport issues. In the table, the dots illustrate the number of the participants' responses: the wider the dot, the more responses. In addition, the number of responses is indicated in brackets next to the dot.

Overall, the results indicate that stakeholders consider UAM elements related to transport disruptions and transport characteristics as opportunities. The UAM environmental aspects are considered as strengths by the stakeholders, while a unique conclusion cannot be derived for the socio-economic aspects, where the stakeholders' responses are split among threats, opportunities, or weaknesses. It is also interesting that stakeholders' opinions vary with regards to the UAM vehicle-related elements, some of those considering them as opportunities and some as weaknesses. It is also interesting that stakeholders' opinions vary with regards to the UAM vehicle-related elements, some of those considering them as opportunities, some as weaknesses, and fewer as strengths. Starting from the environmental aspect of UAM, the stakeholders mainly view UAM emissions either as a strength (6 out of 16) or an opportunity (6 out of 16) for its implementation. This viewpoint is in line with the findings of previous studies which focus on the analysis of the greenhouse gas emissions of eVTOLs [14]. UAM is regarded as being more environmentally friendly in comparison with both ground-based cars with internal combustion engine and battery electric vehicles in terms of GHG emissions per passenger-kilometer. On the other hand, visual pollution is regarded by the stakeholders as another environmental concern, characterized as a threat (6 out of 16) to UAM implementation, while noise pollution presents equally divided views among strengths (5 out of 16), weaknesses (5 out of 16), and threats (5 out of 16).

Socio-economic characteristics draw almost equal attention among the categories. Most of the participants consider the urbanization trends (9 out of 16) and the perceived fun of traveling with eVToL (8 out of 16) as opportunities for UAM implementation. On the other hand, people's awareness towards UAM (9 out of 16) might perform as a weakness, while people's perception towards automated transportation (7 out of 16), and poor digitalization in the population (7 out of 16) might constitute potential threats for UAM deployment. Other socio-economic elements, such as car ownership attitudes and passengers' physical and cognitive limitations, gather few observations in each classification.

The UAM realization is also linked with a variety of elements related to aerial vehicles. On these grounds, the majority of the stakeholders regarded the distance range (12 out of 16) and the eVToL capacity (9 out of 16) as weaknesses for UAM implementation. Moreover, other weaknesses include the flying altitude (9 out of 16) and travel speed (9 out of 16). The general trends of automation and electrification in the transportation sector were considered either as strengths or opportunities from most of the participants.

		Strengths	Weaknesses	Opportunities	Threats
Environmental Aspects	Impact on emissions	(6)		(6)	
	Visual pollution	(3)	(5)		(6)
	Noise pollution	(5)	(5)		(5)
Socio-economic Aspects	Urbanization trends	(5)		(9)	(1)
	Car ownership attitudes	(2)	(3)	(4)	(3)
	People's perception towards automation	(3)	(2)	(3)	(7)
	Poor digitalization in the population	(1)	(4)		(7)
	People's awareness towards UAM	(2)	(9)	(1)	(3)
	Passengers' physical & cognitive limitations	(2)	(5)	(2)	(3)
	Perceived fun of traveling with eVToL	(5)		(8)	
Vehicle Characteristics	Distance range	(2)	(12)	(1)	
	Flying altitude	(4)	(6)	(3)	(1)
	Travel speed	(4)	(6)	(4)	(1)
	Capacity		(9)	(5)	(1)
	Reliance on eVToL's technology	(2)	(4)	(3)	(5)
	Automation in transportation	(6)	(1)	(7)	
	Electrification in transportation	(8)		(7)	
Transport Issues	Potential integration of UAM in MaaS	(5)		(10)	
	Covid19 and other emergency situations	(5)		(9)	(1)
	Trip cost	(1)	(6)	(4)	(4)
	Safety issues	(1)	(4)	(2)	(6)
	Cybersecurity issues	(1)	(2)		(9)
	Investment costs for operators	(2)	(8)	(1)	(2)
	Urban traffic congestion	(5)		(9)	
	Poor air connectivity	(3)		(7)	(3)
	Poor coastal connectivity	(4)		(7)	
	Prevailing weather conditions	(1)	(9)		(5)

Note: This table provides a graphical illustration of the SWOT analysis. Dots are used to illustate stakeholders responses, the wider the dot, the more the responses. For a more clear visualisation: Blue color indicate strength; Yellow color indicate weakness; Green color indicate opportunitty; Red color indicate threate. Also, the number of the responses is included in the parenteses.

Figure 4. SWOT Analysis.

Concerning transport-related characteristics, most of the participants expect that COVID-19 and other emergency situations (e.g., natural disasters) (10 out of 16), as well as the potential integration of UAM in MaaS (9 out of 16), would act as opportunities for UAM. Moreover, safety (6 out of 16) and cybersecurity (9 out of 16) issues related to eVToL were considered as potential threats for UAM, while the literature is limited regarding safety and security issues [42,50]. The cost of the trip did not draw much attention on any specific classification, which requires more investigation. Additionally, participants mostly came to an agreement that urban congestion (9 out of 16), poor air (7 out of 16), and coastal connectivity (7 out of 16) could benefit the UAM concept, which we classified as opportunities in the SWOT analysis. On the contrary, prevailing weather conditions could be either weaknesses (9 out of 16) or threats (5 out of 16) and could challenge UAM implementation, as also concluded in the literature [51,52].

4.4. Use Cases, Business Models, and End-User Segments

NASA [46] has defined six stages of UAM maturity levels to classify the implementation of future operations based on the density of aircraft volumes, the complexity of operating conditions, and the reliance on automation. These six stages assess the UAM future implementation and are briefly described as follows:

- Initial state, ML-1: late-stage certification testing and operational demonstrations in limited environments.
- Initial state, ML-2: low-density and low-complexity commercial operations with assistive automation.
- Intermediate state, ML-3: low-density and medium-complexity operations with comprehensive safety assurance automation.
- Intermediate state, ML-4: medium-density and medium-complexity operations with collaborative and responsible automated systems.
- Mature state, ML-5: high-density and high-complexity operations in highly integrated automated networks.
- Mature state, ML-6: ubiquitous UAM operations with system-wide automated optimization.

Based on the above classifications, the participating stakeholders were asked to evaluate specific use cases and business models in terms of their maturity level. Since the UAM implementation will be materialized in future time horizons depending on location, participants were asked to specify any location (e.g., continent, country, city, or origin–destination pair) that they considered as potential eVToL markets in the 2030–2040 period. Singapore, the Middle East, USA, UAE, Japan, China, East Asian countries, and North America, and inter-island passenger and cargo transportation in the Caribbean are some of the proposed locations. After aggregating the responses, our results indicate that all use cases are expected to exceed ML-2 by 2040. The fact that the participants predict an ML-3 (score 3.2) for inter-island connections and suburban mobility (score 3.0), followed by urban mobility with ML-3 (score 2.8), is interesting. Overall, the participants seem to expect low-density and medium-complexity operations with comprehensive safety assurance automation for all use cases. UAM provides a transport alternative with minimized ground infrastructure space and travel time saving. On these grounds, inter-island and suburban connections, which are usually characterized by the lack of connectivity and accessibility, might be useful use cases [1]. In the case of urban mobility, UAM may generally trigger changes in land use, communities' choices, and have an impact on the emergence of de-urbanization, as connectivity and accessibility may be improved, and hence, people would choose less dense areas to live in [3].

Figure 5 summarizes the stakeholders' viewpoints on the maturity level of different use cases and business models for the coming decade (2030–2040). Participants consider that eVToLs are likely to be used for cargo deliveries with a maturity level close to ML-4. Considering the current situation, where many companies have already implemented drone operations for the last mile delivery, this finding is relatively reasonable. The next most likely business model to be implemented during this period, based on the participants' viewpoints, is air ambulance, with an expected maturity level of around ML-3 (score 3.3), as also stated in other studies [1]. For instance, considering the occurrence of injuries and the need for immediate treatment, UAM would play a key role, either by transporting the injured person to the hospital or the doctor to the scene of the accident.

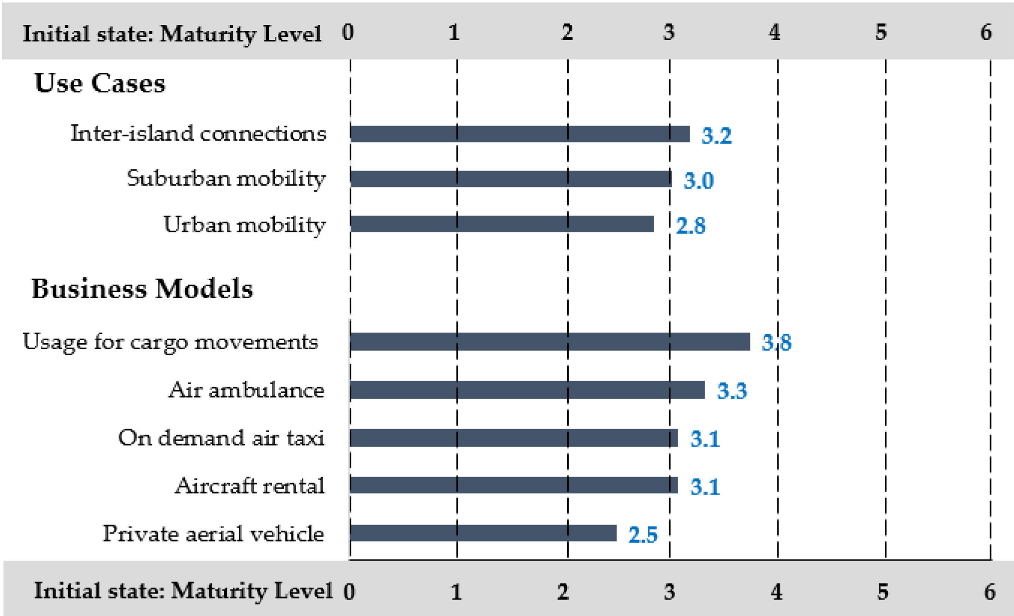

Figure 5. Use cases and business models, 2030–2040.

Moreover, according to our sample, aircraft rental and on-demand air taxis present almost equal readiness (ML-3, score 3.1). The air taxi market, and especially passengers' aerial mobility, is crucial for UAM market development. However, as our results indicate, its implementation will occur at a slower pace. Based on the current situation, there are numerous helicopter operations that constitute a mobility alternative, either for renting or ridesharing. Last but not least, the participants had more conservative opinions regarding the use case of private aerial vehicles for the period of 2030–2040, with maturity level ranging between ML-2 and ML-3. The above findings supplement the existing literature, which has indicated that three mature business models for the UAM concept might include airport shuttle services, company shuttle services, and regional public transport shuttles [40].

To successfully implement the UAM concept in an area, it is also important to identify the potential customers and their preferences. The analysis of the stakeholders' responses indicates that private firms as well as technology-savvy users might constitute two target groups for UAM. As presented in Figure 6, tourists and young people can also be a potential population segment to adopt UAM, based on the opinion of 16% and 15% of the participants, respectively. However, elderly people and families are less likely to adopt UAM based on the opinion of the surveyed stakeholders. Although our findings are generally in line with the existing literature [1,31], further research focusing on market segmentation and demand analysis is required in order to draw more detailed conclusions.

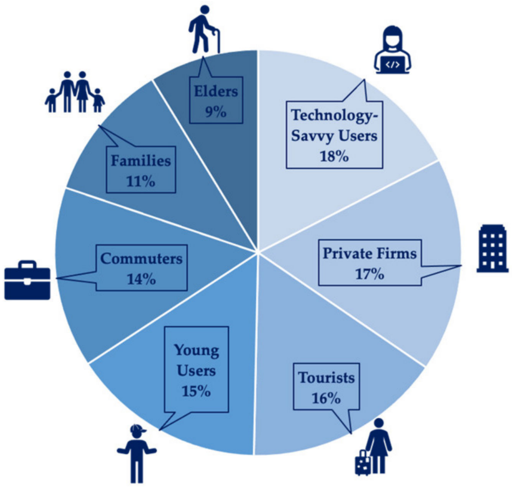

Figure 6. Potential early adopters of UAM.

5. Insights for the Greek UAM Case

The Greek case might be considered as a valuable case for UAM implementation in terms of several aspects. Regarding its geography, Greece has a plethora of islands which are spread around the Greek territory, while many of them are grouped in complexes (e.g., Cyclades, Dodecanese, and Ionian islands). This fact provides an advantage for the UAM implementation in Greece, since in many cases, the pairwise geographical distances between the islands are lower than 60 nautical miles (around 100 km), which fulfill eVToL's distance range requirements. Another aspect which could support UAM implementation in Greece is the fact that many islands lack adequate connectivity and accessibility via traditional modes. The provided transport modes to access islands are mainly ships and airplanes, while in some areas, seaplanes are under consideration to supplement the existing transport system and perform as an alternative mode. However, passengers in the majority of islands firstly have to connect with a hub, either the port of Piraeus or the airport of Athens, in order to go to another island. Moreover, islands with barren lines are characterized by their unique geomorphological surface, making access by sea or air impossible. In addition, considering the high touristic flows during summer, the market penetration could reach high levels in Greece. On these grounds, in the 2nd phase of our research, we engaged several stakeholders from the Greek community to express and elaborate their viewpoints on the Greek case.

5.1. Requirements for UAM in Greece

First, the stakeholders were requested to assess the requirements that need to be ensured to implement UAM in Greece. In line with the 1st phase's results (see Section 4.1), the participants evaluated highly the need for a new legal framework and the development of a new network for UAM. In addition, the need to address the environmental potential barriers such as noise and visual, as well as the integration of eVToL in wider mobility schemes, were considered as crucial.

In addition, the survey focused on the required infrastructure for implementing UAM, where the respondents were asked to further express their viewpoints through an open-ended question. First, they were provided with indicative information on the configuration and requirements of future vertiports or skyports. Then, the participants were asked to express their opinion about whether the existing infrastructure of airports and heliports could provide an initial solution for materializing UAM in Greece. Some of the participants raised concerns related to the need of available space with specific technical characteristics and maintenance support, while one stated that "The eVTOLs will be dozens in each vertiport and will require a basic technical line maintenance on the spot, unlike the helicopter that for every technical problem has to go to an organized technical maintenance centre". On the contrary, another participant supported that the construction of new vertiports would be an unsustainable solution, while another highlighted that vertiports will require car parking of large capacity due to extensive demand.

Moreover, concerning the barriers that UAM will face, the majority of the participants mentioned the lack of legislative framework, in conjunction with appropriate air traffic management. In addition, a common opinion among the participants was that weather conditions would be a significant hurdle for the implementation of such a concept in Greek islands.

5.2. Opportunities and Challenges

In this part of the survey, the stakeholders were asked to characterize either as an opportunity or challenge several factors affecting UAM implementation in Greece, including environmental, transport, trip, and human-related parameters.

With regards to the environmental factors, there is a general agreement among the participants that visual pollution will pose a challenge, while noise pollution was seen as an opportunity for the Greek market. Additionally, there is ambiguity concerning weather conditions, which illustrates the controversial opinions of the surveyed stakeholders.

On the other hand, transport issues such as the poor connectivity of several areas though the existing air and sea modes, as well as the issue of traffic congestion, seem to act as opportunities for UAM implementation. However, the developed competition of boat sharing services, which are provided mainly in Greece for island hopping, was accounted as a challenge for the potential eVToL market in Greece.

Focusing on the technological aspects, eVToL features technological advancements in the battery and automotive technologies, while arising questions on trip-related matters. Trip cost, reliability, safety, and trip distance were categorized as challenges by the majority of stakeholders, in line with the existing literature [1] and the 1st phase's results that consider them as weaknesses. However, in this case, stakeholders' responses may lie in the fact that in Greece there are many inter-urban and inter-island destinations with poor or zero connections, and eVToL could be a viable opportunity. With respect to other operational issues, privacy and working hours caused controversy among participants' answers, with a slight dominance of the challenge formation.

Moreover, considering the human/passenger-related factors, the participants were found more likely to consider them as a challenge, consistent with the existing literature [1], with the major challenge being social awareness. In particular, the physical and cognitive limitations that some people face (e.g., elderly and people with disabilities and kids) were assessed as challenges for UAM penetration.

In a nutshell, the UAM concept is linked with various factors that affect its future implementation. For the Greek case, trip cost, reliability, and safety emerged as promising primary challenges. In addition, weather conditions may be a significant hurdle, as Greece is widely known for the meltemi winds (strong, dry, seasonal winds that appear over the Aegean Archipelago).

5.3. Integration with the Current Transport System

Our results also showe that helicopters and taxi services are expected to be a competitive mode to UAM in the Greek market, while full-service airlines (FSCs) and private cars seem to be considered as complementary services. Although the experts in the 1st phase considered seaplanes as complementary modes (see Section 4.2), the 2nd phase stakeholders expect that seaplanes will perform as competitors to UAM in the Greek transport system. This finding can be explained by the existing seaplane market that is built and is about to be operational in Greece. Due to its unique geomorphic surface, the Greek territory advances the establishment of water airports and seaports facilitating waterways for seaplanes to operate.

5.4. Viable Markets in Greece

Last but not least, stakeholders were asked to express their opinions on the potential origin–destination (O–D) markets in Greece for UAM. For this purpose, and in order to acquire a better and visual understanding, they were presented with the following map (see Figure 7). In it, we illustrated a circle of 100 km radius which corresponds to the maximum distance that can be flown by an eVToL (given the current technical limitations for battery charging). More than half of the stakeholders (9 out of 16) reported that inter-island connections would consist of a viable network. More specifically, the Cyclades, a complex of islands at the center of the Aegean Archipelago, was considered by the Greek experts a viable market for UAM in Greece (3 out of 10). The Cyclades include several islands, such as Naxos, Paros, Santorini, and Milos, constituting the most popular tourist destinations in Greece. An interesting opinion that was also expressed by a stakeholder was the development of a UAM network among various destinations within Crete. For instance, connections such as Rethymno–Heraklion–Chania–Sitia would be viable O–Ds. This is expected since Crete constitutes a top touristic choice in Greece.

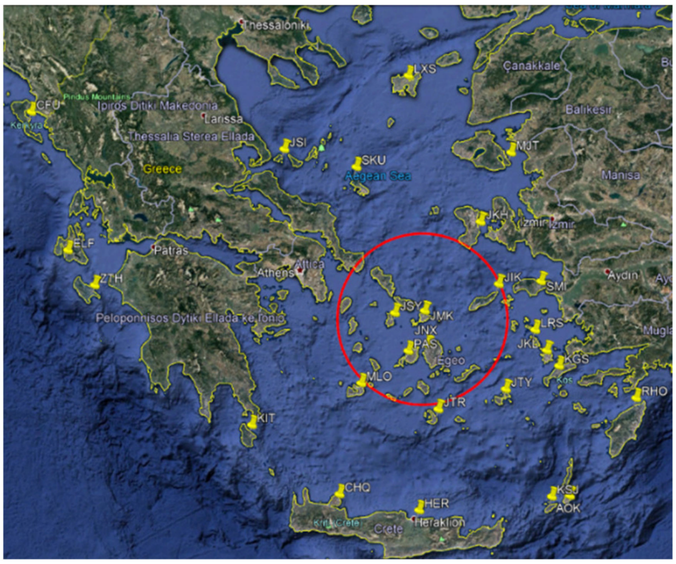

Figure 7. Aegean area pinpointing airports in yellow.

6. Conclusions

The aim of the paper is to provide useful insights collected from industry and academic representatives regarding UAM implementation. For this purpose, quantitative and qualitative data were collected through online surveys in two phases engaging two different expert pools consisting of 32 stakeholders in total.

The introduction and further implementation of UAM is at its early stages, with the regulatory and legal compliance of various UAM aspects being the most important steps towards UAM realization. Certification standards and community integration are some of the challenges that need to be overcome for the establishment of the UAM market and its penetration. These findings might be useful for policymakers, responsible authorities, and organizations to demonstrate progress and follow fast-pace technological advancements, while it is also important for municipalities and public bodies who should focus on raising public awareness and maximizing social acceptance.

Considering the current mobility landscape for both urban and interurban trips, it is characterized by high complexity and diversity. UAM integration is expected to affect the existing transport system. Transport and urban planners, as well as the responsible authorities, should take into consideration that eVToLs might supplement several existing mobility services for air, water, and land transport in order to provide an integrated transportation system for passengers. Exceptions are intercity trains for the interurban trips, while taxi, private car, and ride hailing services are regarded as competing with UAM in urban trips. In addition, helicopters are regarded by stakeholders as competitor for UAM.

Findings from the SWOT analysis indicate that elements related to transport characteristics are considered as opportunities, while some socio-economic aspects are characterized either as threats, opportunities, or weaknesses. More specifically, major strengths of UAM include its potential impact on emissions and the automation and electrification in transportation, while major weaknesses are people's awareness of UAM, eVToLs' distance range, as well as prevailing weather conditions. UAM appears to have many strong opportunities to grow, including the existing urbanization trends, the people's perception of fun when traveling with eVToL, and the current urban traffic congestion, while the strongest opportunity for UAM is its integration with other mobility services in MaaS schemes. Last but not least, cybersecurity is one of the most important threats for the development of UAM.

As for the potential use cases of UAM, for the future period of 2030–2040, inter-island connections appear to be a viable use case, followed by suburban and urban mobility. This finding might be useful for both service providers and market strategists. The establishment of a comprehensive and sustainable UAM network is highly affected by the use cases. Besides, as for the business models, cargo movements are expected to be the highest maturity level towards production and operation by far. Compared with the existing situation, in which UAM is still scarce, business models are now at the lowest maturity level (ML0-1), meaning late-stage certification testing and operational demonstrations in limited environments. Overall, UAM is expected to supplement the existing transportation system, however, it is not likely to become a regular transport mode. According to the findings, it is expected that UAM will be utilized as an on-demand service for special use cases.

Focusing on the customers, technology-savvy tourists and private firms are considered to be the early adopters of UAM. Although this finding is very important for academia and service providers, it requires further research and market analysis to extract more detailed conclusions.

This paper established uniqueness by providing findings for the Greek case. Interesting conclusions include viable markets. The results show that eVToL would be implemented in the Greek market for island destinations, exploiting the infrastructure provided by the Greek regional airports. Although, the current relatively poor air and coastal connectivity in the Greek network is regarded as a significant opportunity for UAM, there are several challenges that need to be overcome in Greece.

Although this study provides useful findings for the UAM ecosystem, we acknowledge that it has some limitations. The sample size (32 participants) might be rather limited, raising concerns regarding its representativeness. However, it should be noted that engaging a large number of stakeholders is a common challenge, as the sample sizes of existing studies indicate [19,43,53]. In addition, it is emphasized that the participating stakeholders of our research in both phases hold senior positions in the aviation and UAM industry and cover the fundamental areas of UAM interest (e.g., airspace access, community engagement, and operational strategies), as well as focus on a variety of use cases (e.g., drone operations, supply chain, and passenger mobility), drawing meaningful conclusions. Another restriction that the study faced was related to the COVID-19 outbreak. More specifically, the Greek survey was initially intended to be conducted through face-to-face meetings, in order to have the opportunity for a more fruitful discussion. Due to the pandemic situation and the restrictions imposed in Greece, they were finally carried out online. Finally, the stakeholders' group in Greece mainly includes aviation experts with lower levels of expertise in UAM (in comparison with the international group). This is reasonable given the limited development of UAM in this geographical area.

Future research should focus on addressing many other essential aspects affecting the UAM implementation in the context of the future mobility era, such as weather disruptions, demand/supply business assessments, and policy analysis. Specifically, in order to quantify the demand of UAM, follow-up research, including stated preferences data collection and mode choice modeling addressed to travelers may assess the factors affecting their choices as well as key obstacles such as time losses due to modal changes for door-to-door travel. Such an analysis can shed light on the effect of different time components and number of transfers on the overall demand of UAM and its level of usage. Another key issue is that in most cases the public transport system is characterized by "loss making", thus needing to be subsidized. Hence, a detailed exploration of a viable business model of UAM with the possibility of subsidization is needed, differentiating among passenger and freight as their requirements strongly differ. Furthermore, a detailed investigation of the technical and operational principles of UAMs is critical for its successful implementation. Finally, while the current study aims to contribute to the stakeholder scene and introduce the Greek case, stakeholder analysis in different areas would be beneficial for the realization of UAM in alternate contexts. Overall, Greece constitutes a useful case considering its island-hopping characteristic. Similarly, the UAM market could be developed in other island nations such as Japan, Indonesia, and the Philippines. Future research could focus on those cases to investigate the business model of island connections.

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