Airbus UTM:
Defining Future Skies.

An Assessment of Public Perception of Urban Air Mobility (UAM)

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Executive Summary

The goal of this research is to understand the factors, across a wide range of demographics, that affect public perception of the deployment of Urban Air Mobility (UAM), a vertical takeoff-aerial transportation paradigm. This work is significant as we consider the impacts of new mobility technology to our communities. The benefits of UAM are compelling, but technologists must also consider the public's expectations and concerns.

Public perception is the aggregate view of a group of people. Our approach to measuring it involved several steps. First, we carried out a literature review and conducted expert interviews with city officials, aircraft manufacturers, academics, and policymakers. Then, we created a survey to analyze the initial perception variables, potential ridership, community support, convenience, cost, and general understanding of the service. Finally, we analyzed the data in order to uncover the most significant patterns.

Through the literature review and the expert interviews, we determined the broad factors most important to analyze: safety, noise, inequity, visual pollution, and privacy. Our survey results show that communities are most concerned about safety (55.6%), followed by the type of sound generated from the aircraft (49.3%), and then the volume of sound from the aircraft (48.8%). Other concerns include the time of day at which aircraft are flown (47.8%) and the altitude at which aircraft fly (47.8%). The aspect that is least concerning to respondents is the landing spot of the aircraft (41.2%).

Importantly, 44.5% of all respondents' initial reactions to UAM is in support or strong support while 41.4% of all respondents believe UAM is either safe or very safe. Economic theory argues that if uncertainty exists about the benefits of a new technology, there is an option value to wait before the adoption costs become sunken.[1] This suggests that the initial perception and perception of safety of UAM is quite positive.

Introduction

Rapid urbanization and reliance on automobiles causes gridlock and inefficiency in many cities across the world. There are a number of adverse consequences of recurring congestion, including delays, vehicular emissions based on stop-and-go driving, increased stress levels, noise, and vibration. In addition, intracity and intercity travel times can be unpredictable and disjointed. Our urban skies remain a relatively untapped resource for local transport.

Historically, innovations to battle congestion revolved around increasing transportation supply for the automobile, specifically by building more roads and/or increasing the number of lanes on

[1] B. H. Hall and B. Khan, "Adoption of New Technology," p. 4, 2002.

highways. However, these efforts have shown not only to be futile, but also often counterproductive, frequently leading to even greater congestion, worse equity outcomes, and wasted resources. Planners, engineers, and politicians are now looking for alternatives, and broad types of initiatives exist. These include providing incentives for behavioral changes in mobility, replacing trips (e.g., telecommuting), and perhaps most pressing, enhancing modal substitution by offering a wide variety of accessible transportation alternatives. Many ideas and technologies exist as possible modal alternatives, and one gaining traction is UAM. While UAM also encompasses the transport of goods in cities, this paper will focus specifically on the transport of people.

One prevailing architecture for UAM envisioned by governmental agencies, academics, and industry leaders is a shared service in which consumers request an on-demand aerial taxi, similar to the experience of ridesharing services today. Surface-level congestion suggests there is a demand not met by the current transport modes, and thus UAM can fill the mid-to-long distance gap that the car isn't efficiently addressing. By supplementing intercity and intracity transportation demand with UAM, travel times may be greatly reduced, and long-run positive downstream effects may include lesser environmental degradation, decreased energy costs, and fewer resources spent on infrastructure by leveraging free space rather than ground track or road that must be constructed.

Many stakeholders will play major roles in the successful design and deployment of UAM. The aircraft will be manufactured by leaders in private industries, similar to commercial aircraft today, and are envisioned to hold two to six passengers with a likely range of up to 200 miles.[2,3] Operations will be managed by private entities, such as Voom and Uber, providing mobility service expertise. Logistics and infrastructure will be developed and maintained by public agencies and businesses, but subsidized by private entities that rent out space, similar to present-day airports.[4] Operation and optimization will be regulated by aviation regulatory bodies, such as the FAA and EASA.[5] The stops, known as vertiports in the UAM community, will be dispersed thoughtfully across metropolitan regions, initially leveraging existing helipad locations, and eventually being placed at highly-connected areas where travel demand is dense, similar to the subway and commuter rails.[6] Initial designs aim for intrametropolitan travel and travel within large megalopolis clusters, such as the Northeast corridor in the United States.[7]

Before scalable UAM can become a reality, there are several challenges, both social and technical, to be addressed. This study is designed to help the industry understand the social considerations to the deployment of UAM.

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[2] P. Pradeep and P. Wei, "Energy Efficient Arrival with RTA Constraint for Urban eVTOL Operations," 2018.
[3] D. G. Drozeski, "Vertical Take-off and Landing (VTOL): Emerging and Transformational Capabilities," p. 8.
[4] M. J. Duffy, S. R. Wakayama, and R. Hupp, "A Study in Reducing the Cost of Vertical Flight with Electric Propulsion," 2017.
[5] M. G. Song and G. T. Yeo, "Analysis of the Air Transport Network Characteristics of Major Airports," *The Asian Journal of Shipping and Logistics*, vol. 33, no. 3, pp. 117–125, 2017.
[6] M. Balac, A. R. Vetrella, and K. W. Axhausen, "Towards the integration of aerial transportation in urban settings," 2017.
[7] J. Smart, "Our Amazing Aerial Future — How, When, and Why Air Taxis and Air Deliveries Will Change Our World," *Medium*, 20-Feb-2018.

Survey Design

The findings and results from the literature review and expert interviews, highlighted in the appendix, informed the specific design of the survey questions and provided specific parameters to be tested: safety, noise, inequity, visual pollution, and privacy. When designing the survey instrument, we actively randomized these parameters with the goal of understanding the ones that most affect people across the world in their future acceptance of UAM in their communities. The survey contains four types of questions: psychographic, scenario-based, general, and demographic.

We disseminated the survey in four geographies: Los Angeles, Mexico City, New Zealand, and Switzerland. We chose Los Angeles due to its notorious congestion and pollution, which has propelled the city's willingness to explore new transportation alternatives. The plethora of helipads in the metropolitan area makes it a unique geography for investigation and early deployment. Mexico City suffers from similar congestion and pollution as Los Angeles, and it has a unique history of adopting new mobility technologies, as on-demand helicopter services already exist in the area. The forward-thinking Ministry of Transport in New Zealand, aware of increases in tourism and new personal aircraft designs from local companies, expressed interest in UAM as a potential intercity option to promote tourism while still preserving the natural landscape. Given its small size and high density, the government of Switzerland, similar to New Zealand, cited increases in tourism and intercity travel, in addition to a more open regulatory framework compared to the United States'. These four locations gave us a sample of urban and rural, high and low income, developed and developing regions, as well as insight into how existing helicopter operations might influence perception for new urban electric vertical takeoff and landing (eVTOL) aircraft. Figure 4 (on Page 13) illustrates these geographies.

The psychographic questions are structured in such a way to test the following attributes: tech dependence, savviness, and trust; professional and personal aspirations; preferences about lifestyle, ranging from residence location to most conducive environment for focusing; privacy and openness; understanding of others; desire for efficiency; and general life satisfaction. By delving into these behavioral questions, we can understand what types of lifestyles have strong views about UAM.

The scenario-based questions provide five different scenarios about an aerial taxi, each of which has randomized values for the time of day the aircraft is flown; number of passengers; frequency of the aircraft sound; duration of each sound; type of sound emanated from the aircraft; visibility of the aircraft; the types of riders in the aircraft; landing location; and flight altitude. Then, we broke down each scenario's questions into two buckets: immediate reactions to the scenario and specific concerns about each of the above variables. These questions provide the basis of respondents' understanding of UAM in practice.

A sample scenario is shown in Figure 1. Specifically, in the sample, low altitude suggests that it is flying around 800 to 1000 feet. Morning implies between 7 AM and 12 PM. Visible means that a person on the ground can see the aircraft. The sound of a bee buzzing nearby lasts for five consecutive seconds. Each aircraft holds six students and flies above the respondent once every hour, landing at the helipad nearest the respondent.

Scenario 1:

- Low altitude
- In the morning
- Visible
- Sound from aircraft is like a bee buzzing
- The sound lasts for 5 seconds
- Aircraft holds six students
- Vehicles fly above you every hour
- Lands at the helipad nearest you

1. What is your initial reaction to this scenario?
2. How safe or unsafe do you perceive this scenario?

Figure 1. Sample Scenario

The general questions, presented as Likert scales from strongly disagree to strongly agree (shown in Figure 2), provide insight into the respondents' overall views of UAM in their communities, particularly emphasizing their potential ridership, political support, convenience, cost, and understanding of the service. By asking these general questions, we hoped to find potential collinearities among the variables to more accurately assess patterns.

Given the above scenario, how much do you agree or disagree with the following statements?

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
I am concerned about the duration of the noise generated by the aircraft					
I am concerned about the volume of noise generated by the aircraft					
I am concerned about the type of noise generated by the aircraft					
I am concerned that the number of aircraft traveling in the sky every hour will cause too much noise					
I am concerned about the time of day the aircraft are flying					
	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
I am concerned about the altitude at which the aircraft is flying					
I am concerned if I cannot see the aircraft					
I am concerned about the safety of the individuals onboard the aircraft					
I am concerned about the safety of individuals on the ground who are being flown over					
I am concerned that two aircraft might collide					
	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
I am concerned that these aircraft may encroach on my personal privacy					
I am concerned that the size of the aircraft will "litter" the sky					
I am concerned that the number of aircraft will "litter" the sky					
I am concerned that the aircraft might land near my home					

Figure 2. Survey for Sample 1

The demographic questions are derived from a standard set of questions from the American Community Survey regarding age, ethnicity, income, gender, and education, among others. We asked these questions to gain a basic understanding of the respondents.[8]

Results

With 385 respondents from each geography, a total of 1,540 responses were collected from four geographies. In the sampling process, invites to the participants are sent out in a representative distribution. However, given that perfectly representative samples are extremely difficult to obtain, the samples are heavily distributed across all demographic and psychographic variables to reflect the nature of the population in that particular geography, as shown in Figures 3 and 4. Oversampling of certain groups may exist since it cannot be guaranteed who will be the first to respond, and thus some demographics will be more likely to respond than others.

Given the sample size, the margin of error (MOE) of results is approximately 2%, and thus all differences that exceed 2% show statistical significance. All findings shown subsequently have an MOE of 2%. Please note that a statistically significant difference describes a difference that actually exists, but does not necessarily indicate that the absolute magnitudes are high.

It must also be noted that these results reflect correlation and not causation. In addition, while there may be generalizable power to the results, many social, cultural, and political factors play into public perception, and thus extrapolating the findings accurately still remains an open area of study.

[8] https://www.census.gov/programs-surveys/acs/methodology/design-and-methodology.html

Key Demographics

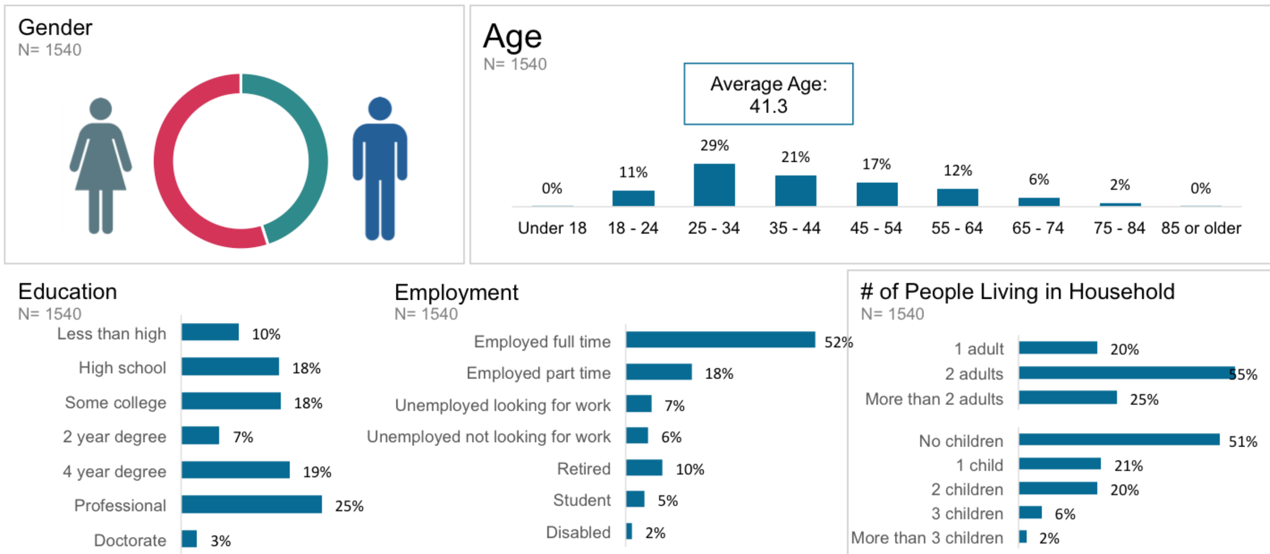


Figure 3. Key Demographics

Much of the analysis displays direct Likert score percentages, such as “strongly agree,” for each choice, or weighted averages of top-two box (TTB) scores. The TTB score represents the total percentage of respondents who “strongly disagree” or “disagree” with the parameters. Figure 4 shows the levers that were varied in randomized scenarios across sublevers.

Number of Responses: 1540

Levers & Sub-levers

Altitude
- Low, Medium, High, Very High

Frequency of Sound Every Hour
- 1, 2, 5, 10, 100

Landing Spot
- Far Away, Near

Number of Passengers
- 2, 4, 6, 12, 20

Type of Passenger
- Diverse, Students, Family, Executive, Missing

Time of Day
- Morning, Afternoon, Night, Middle of the Night

Type of Sounds
- Car Passing, Bee Buzzing, Truck Passing, Heli Above

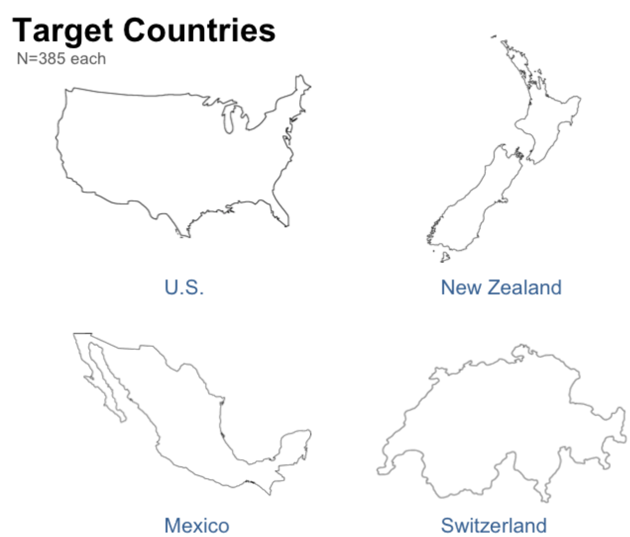


Figure 4. Levers in Each Category

Highest Positive Perception Factors

We found the combination of sublevers that produced the highest positive perception; in other words, which *combination* of values of the above sublevers produced the result to which most people positively responded. The best case scenario is:

- The aircraft has a sound like that of a bee buzzing
- It flies at a very high altitude
- It flies only once every hour
- It flies in the early morning
- It contains four passengers
- The passengers themselves are diverse
- The aircraft lands far away from home

Note that the levels of altitude and the definition of “diverse” were left to the respondent’s discretion. The *individual* parameters that produce the lowest average concern across all combinations are the aircraft having a sound like that of a bee buzzing at 44%, the aircraft flying at very high altitude at 44%, and the aircraft flying once per hour at 45%.

Lowest Positive Perception Factors

Similarly, the *combination* of values of sublevers that produced the lowest positive perception is the following:

- The aircraft has a sound like that of a helicopter
- It flies at a low altitude
- It flies 100 times every hour
- It flies in the middle of the night
- It contains two passengers
- The passengers are a family
- The aircraft lands near home

The *individual* parameters that produce the highest average concern across all combinations are the aircraft having a sound like that of a helicopter at 51%, the aircraft flying at a low altitude at 51%, and the aircraft flying 100 times per hour at 51%. Note that the spread between the lowest and highest levels of concern is approximately 7%, indicating clear statistical significance.

Overall Concern

Across all parameters gathered and tested, as shown in Figure 5 below, 56% of respondents are concerned about the safety of the individuals on the ground. The next grouping of concerns, at 49%, 49%, 48%, and 48%, respectively, are the type of noise generated, the volume of noise, time of day, and the altitude at which the aircraft are flying. Because these four parameters are within 2% of one another, that implies that their differences are not statistically significant.

The next grouping of parameters creating less concern and are statistically significantly lower than the above bucket are the duration of noise (46%) and whether one can see the aircraft (45%).

Finally, the parameter that generated the least concern at a statistically significant level is the landing spot of the aircraft (41%), which was four percentage points lower than its above bucket.

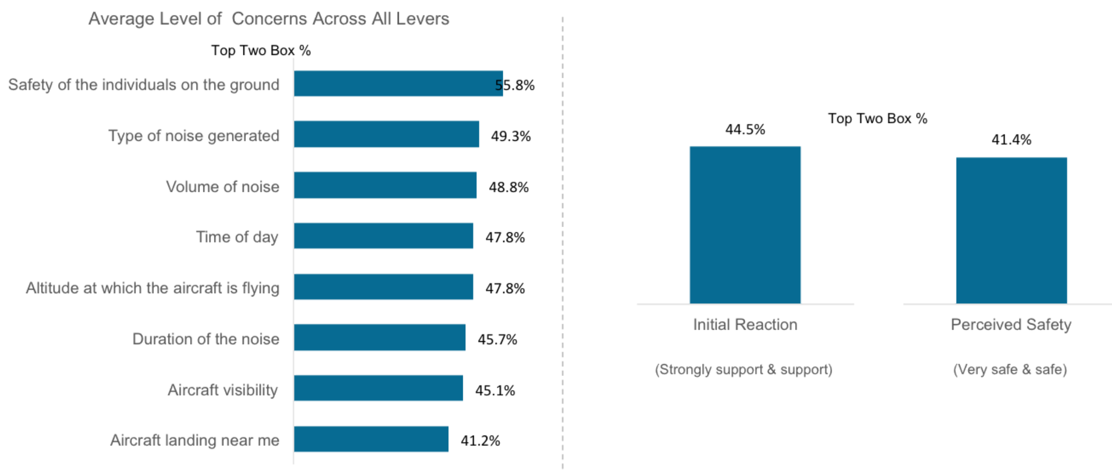


Figure 5. Average Level of Concern Across all Levers, Initial Reaction, Perceived Safety

Initial Reaction and Perceived Safety

Importantly, 44.5% of all respondents' initial reactions to UAM is in support or strong support. 41.4% of all respondents believe UAM is either safe or very safe.

In addition, as Figure 6 indicates, the initial reactions are more positive as altitude increases, as the frequency of sound decreases, and as the time of day is earlier. The initial reaction to the sound being that of a car passing or bee buzzing, all other parameters being equal, was also higher, at 44% and 43%, respectively, than if the sound was that of a helicopter or a truck, at 42% and 41%, respectively. This shows that there is a statistically significant difference between the initial reaction of a car passing compared to that of a helicopter or a truck, but the difference of initial reaction between the sound of a bee buzzing and a helicopter may be due to random chance.

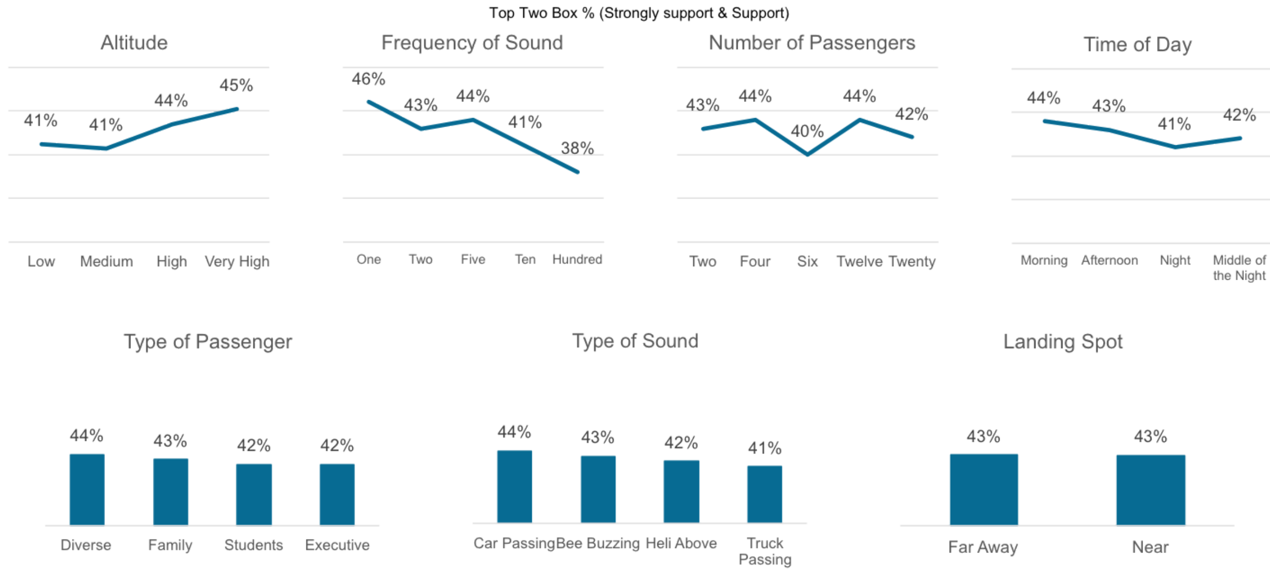


Figure 6. Initial Reactions

Given that the safety of the people on the ground is most concerning to respondents, a deeper dive, shown in Figure 7, details the parameters that contribute to perceived safety. The higher the altitude, the greater the perception of safety, as 43% of respondents find very high altitudes to be safe. 42% find low frequency of flight, at one per hour, to be safe. These tight score ranges often occur, particularly when the concepts are "big" (new, different, significant) and the perceived differences are relatively "small" (inputs that change the concept only on the margins).

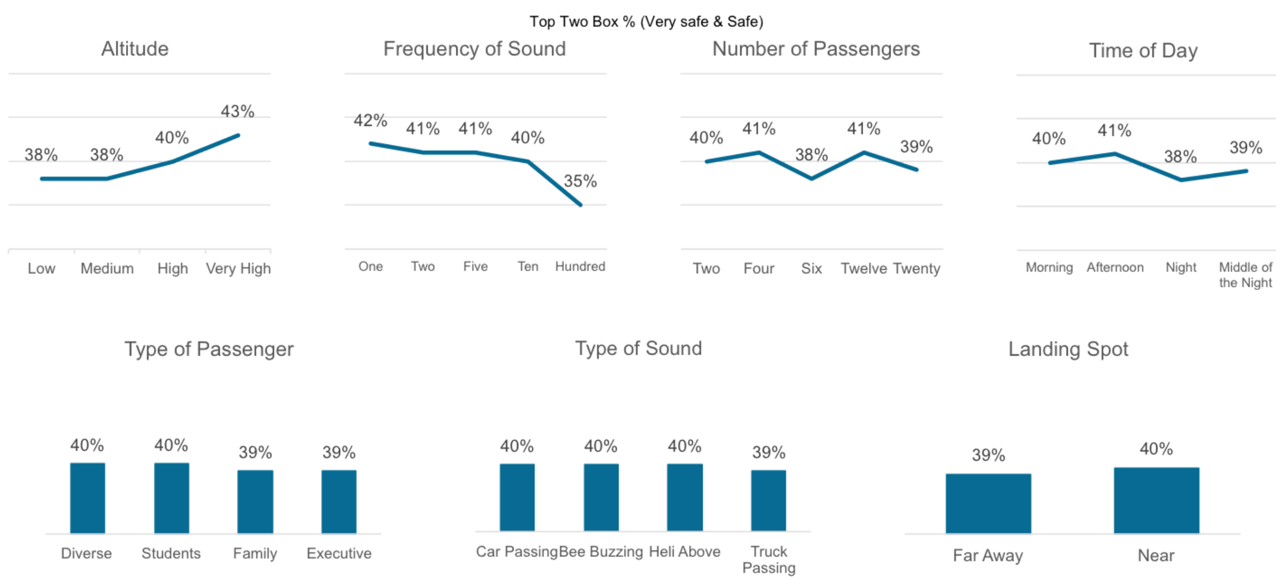


Figure 7. Perceived Safety

The elasticity of each of the levers is also important in understanding the variation of responses. In other words, the higher the elasticity, the larger the discrepancies are between the maximum and minimum sublever percentages. As shown in Figure 8, the type of sound generates the most difference at 7.2%, with the frequency of sound and altitude high as well, at 6.5% and 6.1%, respectively. Note that the difference among these variables is less than 2%, and thus the ranking among these values can change. This indicates that considering policy or deployment strategies that cater to the sublevers that produce the most positive reactions would be extremely beneficial. The time of day flown, number of passengers, types of passengers, and landing spots all have variation across their respective sublevers below 3.5%, which are statistically significantly below the above bucket of type of sound, frequency of sound every hour, and altitude.

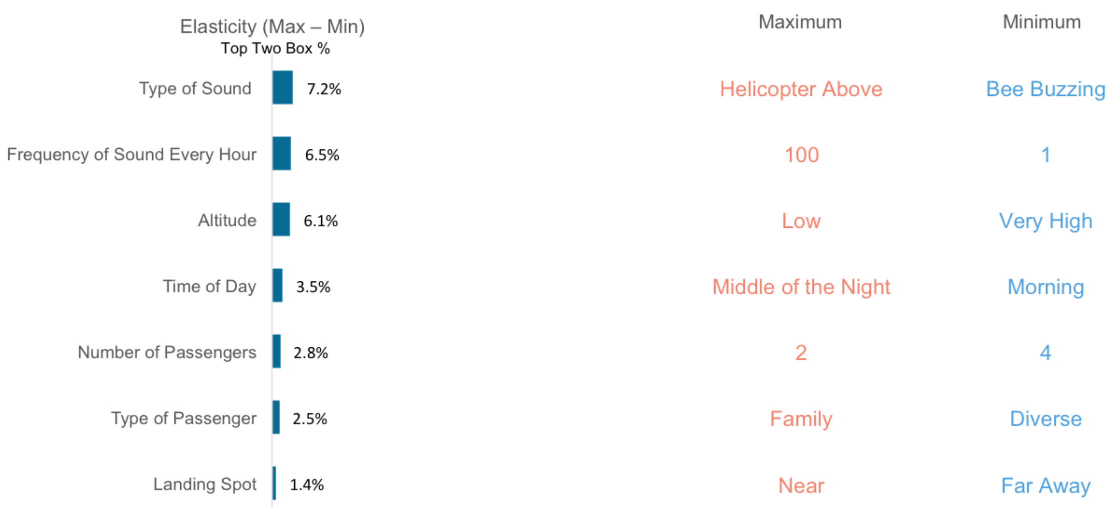


Figure 8. Elasticity of Responses

Key Results by Income and Age

In Los Angeles, the initial reaction is also strongly dependent on income and age, as shown in Figure 9. Out of LA-based respondents who make fewer than $60K annually, 39% have positive reactions to UAM. Further, of those who make greater than $150K annually, 50% or more have positive reactions to UAM. This may be due to the perception of UAM as an expensive transport option, which will be discussed later in the document. Perceived safety is not as clear across income.

Across age in all geographies, the 25-34 range have the highest initial reactions, as 55% view UAM positively, while only 15% of 75-84 year olds view UAM positively. Perceived safety also follows this trajectory, with younger respondents believing UAM to be safe while older respondents find it less safe. Please note two sampling details: (1) respondents who are 16 and older were eligible for the survey, and (2) the 85+ age segment contains fewer than 50 respondents, and thus the data may be highly directional in nature and should be taken with suspicion.

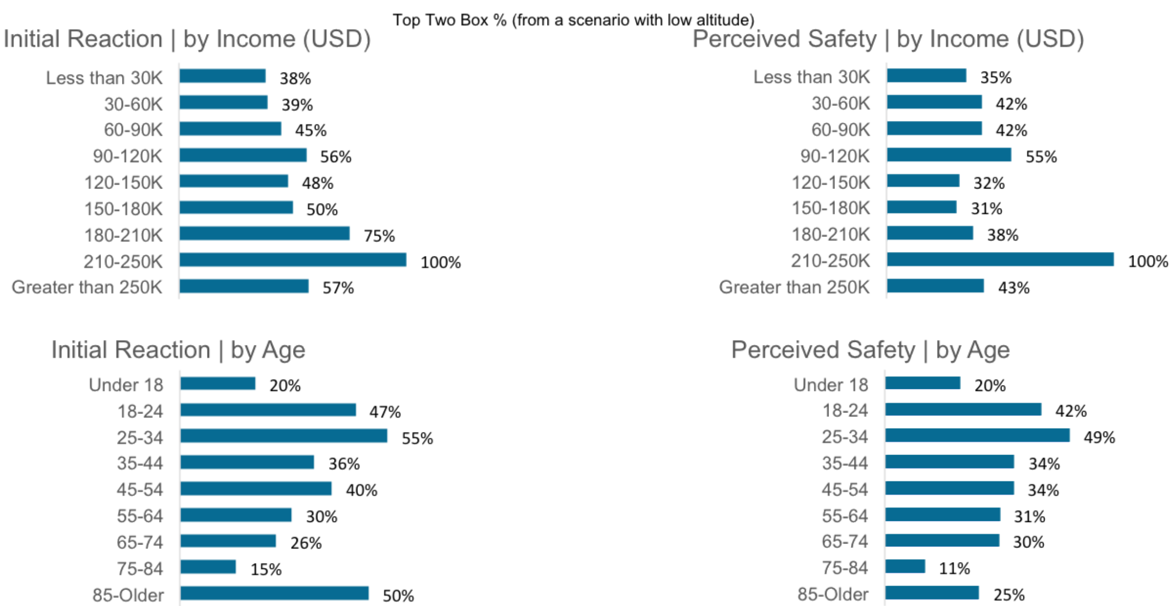


Figure 9. Key Results by Income and Age

Likelihood to Use

The likelihood to use UAM also varies across sociodemographic boundaries, as shown in Figure 10. 33% of respondents in Mexico City note that they are very likely to use UAM, 23% in Los Angeles, 15% in Switzerland, and 12% in New Zealand.

The TTB, reflecting being likely or very likely to use UAM, also shows excitement in Mexico City, with 67% likely or very likely to use UAM and only 16% being neutral. In Los Angeles, excitement for UAM use also exists, as 46% of respondents are likely or very likely to use UAM and 19% being neutral. Respondents in Switzerland and New Zealand appear less inclined to use UAM at the moment. In Switzerland, 32% of respondents are likely or very likely to use UAM, with 24% being neutral, while in New Zealand, 27% of respondents are likely or very likely to use UAM, with 25% being neutral.

Similarly, only 8% of respondents in Mexico City are very unlikely to use UAM, versus 21% in Los Angeles, 28% in New Zealand, and 29% in Switzerland. While many factors exist for this difference, including cultural, social, and political factors, it is interesting to note that on-demand helicopter services already exist in Mexico City, which may be generating more familiarity with the concept of UAM. Note that the difference between New Zealand and Switzerland may be due to random chance since it is below 2%.

Additionally, 25% of all male respondents are very likely to use UAM, while 17% of all female respondents are very likely to use it. On the other hand, 17% of all males are very unlikely to use it, while 25% of all females are very unlikely to use it. This suggests that males are more inclined to use UAM at the moment.

The type of area in which a person lives is also a telling factor of likelihood of use. 25% of all urban residents are very likely to use UAM, while 16% of all rural residents are very likely to use it. On the other hand, 15% of all urban residents are very unlikely to use UAM, while 32% of all rural residents are very unlikely to use it. This indicates that rural residents are more skeptical of using UAM.

Education also plays a noticeable role in likelihood to use UAM. Greater than 23% of all respondents with college or postgraduate degrees are very likely to use UAM, compared to less than 19% for those who have two-year degrees, high school degrees, or less than high school degrees. Meanwhile, 16% or fewer of those with college or postgraduate degrees are very unlikely to use UAM, while greater than 25% of all respondents with only a high school degree or less than high school degree are very unlikely to use it. These results demonstrate that education is a telling factor. It is important to note that many confounders exist to education and these results are correlative and not causal.

Demographic Profile	Very likely	Very unlikely
Country: (US / NZ / MX / CH)	23% / 12% / 33% / 15%	21% / 28% / 8% / 29%
Household Income: Average $ (USD)	89.7K	74.2K
Age: Average Age	38.4	48.1
Gender: (Male / Female)	26% / 17%	17% / 25%
Number of Children: Average	1.1	0.7
Type of Area: (Urban / Suburban / Rural)	25% / 15% / 16%	16% / 27% / 32%
Psychographic Statement: (Tech invades privacy / Dislike new / Active neighborhood / Early adopter)	20% / 22% / 25% / 31%	22% / 26% / 19% / 12%
Education: (Less than HS/ HS graduate / Some college / 2-yr degree / 4-yr degree / Professional degree / Doctorate)	11% / 14% / 19% / 18% / 23% / 27% / 48%	35% / 24% / 26% / 25% / 16% / 16% / 5%
Commonly Used Transportation: (Ridesharing / Public transit / Driving / Walking / Biking)	33% / 22% / 21% / 23% / 10%	19% / 16% / 22% / 26% / 27%
Length of Commute: Average (in minutes)	25 mins	19 mins

Figure 10. Likelihood to Use (Part One)

In terms of likelihood to use across those with or without children, with neutral to very likely representing values 3, 4, and 5, the average value across those with children is higher at 3.3, while those without children are more unlikely to use UAM, with an average of 2.8, as shown in Figure 11.

In addition, the current length of commute is negatively correlated with likelihood to use, with those who have commutes shorter than 20 minutes either neutral to UAM or unlikely to use it, while those with commute lengths greater than 20 minutes more likely to use it, with the longest commutes above 40 minutes giving an average likelihood of greater than 3.4.

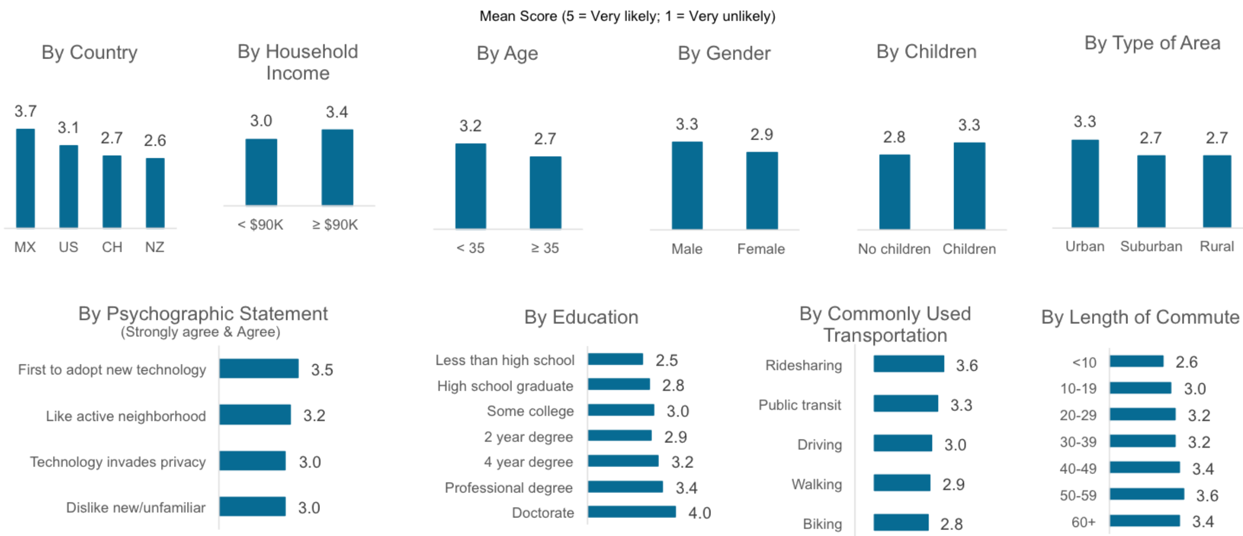


Figure 11. Likelihood to Use (Part Two)

Likelihood to Support

The likelihood to support UAM as a mode of transit is highest in Mexico City, at 35% very likely to support. Elsewhere, 18% are very likely to support UAM in Los Angeles, 14% in New Zealand, and 13% in Switzerland. In fact, in Switzerland, 31% are very unlikely to support UAM, shown in Figure 12.

Demographic Profile	Very likely	Very unlikely
Country: (US / NZ / MX / CH)	18% / 14% / 35% / 13%	16% / 23% / 8% / 31%
Household Income: Average $ (USD)	87.4K	78.8K
Age: Average Age	38.6	47.3
Gender: (Male / Female)	24% / 17%	15% / 23%
Number of Children: Average	1.0	0.7
Type of Area: (Urban / Suburban / Rural)	23% / 16% / 16%	13% / 24% / 33%
Psychographic Statement: (Tech invades privacy / Dislike new / Active neighborhood / Early adopter)	18% / 20% / 23% / 29%	21% / 23% / 17% / 12%
Education: (Less than HS/ HS graduate / Some college / 2-yr degree / 4-yr degree / Professional degree / Doctorate)	10% / 15% / 20% / 21% / 20% / 26% / 30%	36% / 21% /22% / 23% / 13% / 14% / 7%
Commonly Used Transportation: (Ridesharing / Public transit / Driving / Walking / Biking)	26% / 23% / 19% / 18% / 16%	19% / 14% / 21% / 20% / 24%
Length of Commute: Average (in minutes)	31 mins	20 mins

Figure 12. Likelihood to Support

Across all geographies, ridesharers and those who use public transit are most likely to support UAM, at 26% and 23%, respectively. 19%, 18%, and 16% of all drivers, pedestrians, and bikers, respectively, are very likely to support UAM. Meanwhile, 24% of bikers are very unlikely to support UAM. Ridesharers, drivers, and pedestrians are significantly more likely to support UAM compared to bikers, at 19%, 21%, and 20%, respectively. Only 14% of those who use public transit are very unlikely to support UAM, which is statistically significantly different from the other modes. This suggests that public transit riders are not as averse to UAM, perhaps due to the hope of improving mobility options.

Convenience and Cost

Perceived convenience of UAM is also an important concept for people. Perceived convenience is highest in Mexico City, then in Los Angeles, then in New Zealand, and lowest in Switzerland, at 36%, 27%, 23%, and 20%, respectively. This is displayed in Figure 13.

Perceived cost is highest in Mexico City, then New Zealand, then Switzerland, and finally those in Los Angeles are most likely to find UAM to not be particularly high in cost, as shown in Figure 14.

Demographic Profile	Very convenient	Very inconvenient
Country: (US / NZ / MX / CH)	27% / 23% / 36% / 20%	9% / 8% / 5% / 16%
Household Income: Average $ (USD)	87.4K	78.8K
Age: Average Age	38.6	47.3
Gender: (Male / Female)	24% / 17%	15% / 23%
Number of Children: Average	1.0	0.7
Type of Area: (Urban / Suburban / Rural)	23% / 16% / 16%	13% / 24% / 33%
Psychographic Statement: (Tech invades privacy / Dislike new / Active neighborhood / Early adopter)	27% / 26% / 31% / 34%	10% / 13% / 8% / 6%
Education: (Less than HS/ HS graduate / Some college / 2-yr degree / 4-yr degree / Professional degree / Doctorate)	10% / 15% / 20% / 21% / 20% / 26% / 30%	36% / 21% / 22% / 23% / 13% / 14% / 7%
Commonly Used Transportation: (Ridesharing / Public transit / Driving / Walking / Biking)	26% / 23% / 19% / 18% / 16%	19% / 14% / 21% / 20% / 24%
Length of Commute: Average (in minutes)	31 mins	20 mins

Figure 13. Convenience

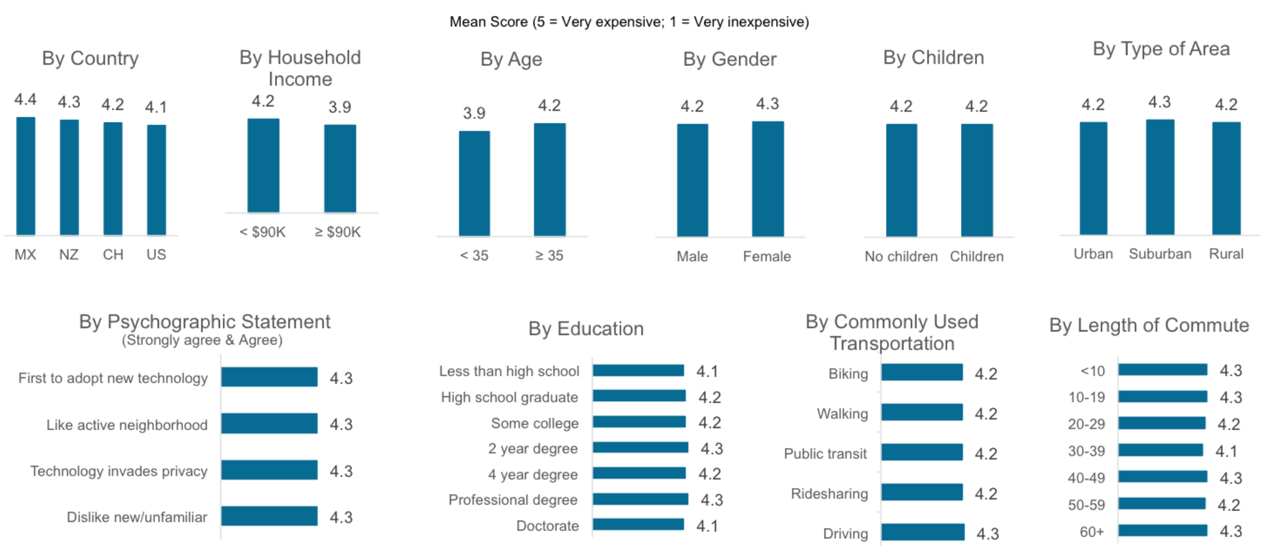


Figure 14. Perceived Cost

Key Results by Country

The level of concern is also split by country, with Mexico City and Los Angeles showing the highest, at 54% and 53%, respectively. This is a surprising result given the positive initial reactions and perceived safety. This may be due to the sheer density and volume of population in these two areas as well as respondents' believing their cities may be closest to adoption, which can trigger conservative thinking due to imminent change and possible threat.[9]

Residents of Mexico City also have the highest initial reaction to a low altitude scenario, with 62% of all respondents viewing UAM positively, which is a stark contrast to Switzerland and New Zealand, where 29% and 28%, respectively, have positive initial reactions to a low altitude scenario.

In addition, 54% of those in Mexico City also believe UAM to be safe, while New Zealanders are the lowest, with only 24% of respondents perceiving UAM to be safe. Figure 15 gives the breakdown.

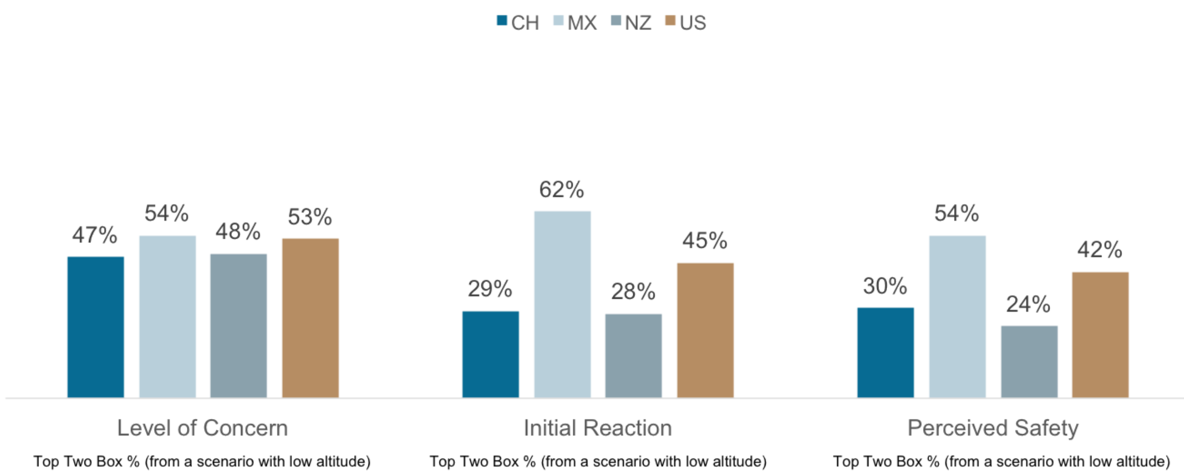


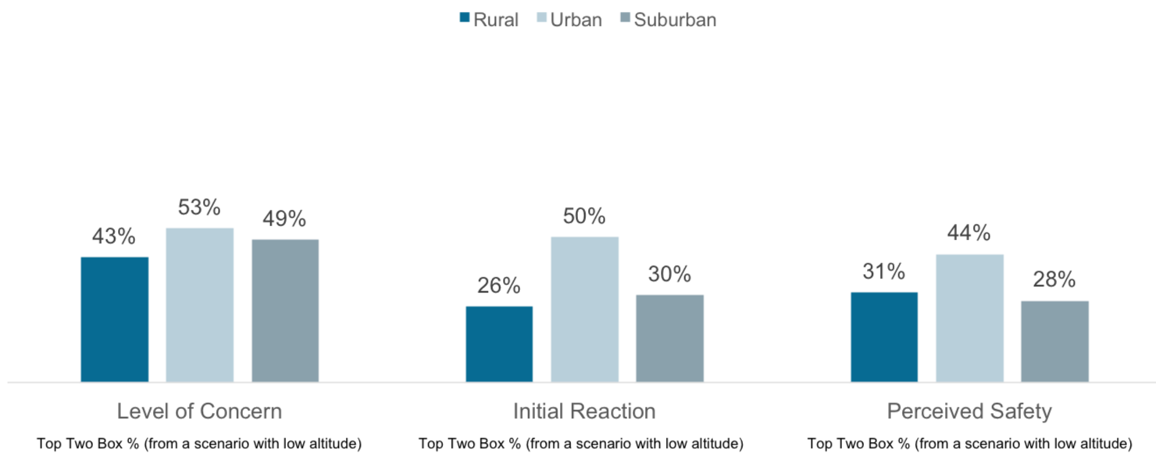
Figure 15. Key Results By Country

Key Results by Type of Residential Area

By residential area, those in all urban areas had the highest share of concern (53%), positive initial reactions to UAM (50%), and positive perceived safety (44%), given a low altitude circumstance, as shown in Figure 15. These differences are significant. Similar to concern in different geographies, it may be that urban residents are more concerned due to the density of population in the areas.

[9] P. R. Nail, I. McGregor, A. E. Drinkwater, G. M. Steele, and A. W. Thompson, "Threat causes liberals to think like conservatives," *Journal of Experimental Social Psychology*, vol. 45, no. 4, pp. 901–907, Jul. 2009.

Rural respondents have a lower level of concern (43%), but this does not align with their initial reactions (26%) and perception of safety (31%), which are also much lower, as shown in Figure 16. Contrary to urban populations, perhaps rural populations believe that there is open space and safety will not be an issue.



Top Two Box % (from a scenario with low altitude)

Figure 16. Key Results By Country

Key Results by Form of Transportation

Current mobility patterns and travel behavior give us insight into acceptance of UAM as well. Ridesharers (38%) are least concerned about UAM, and their initial reactions (61%) and perception of safety (50%) are highest. Those who ride public transit also have positive initial reactions of UAM, as shown in Figure 17. Those who walk have the least positive initial reactions and perceive UAM not to be safe. Drivers have mixed reactions to UAM, as 40% have positive initial reactions, 49% are concerned about it, and 37% find it to be safe.

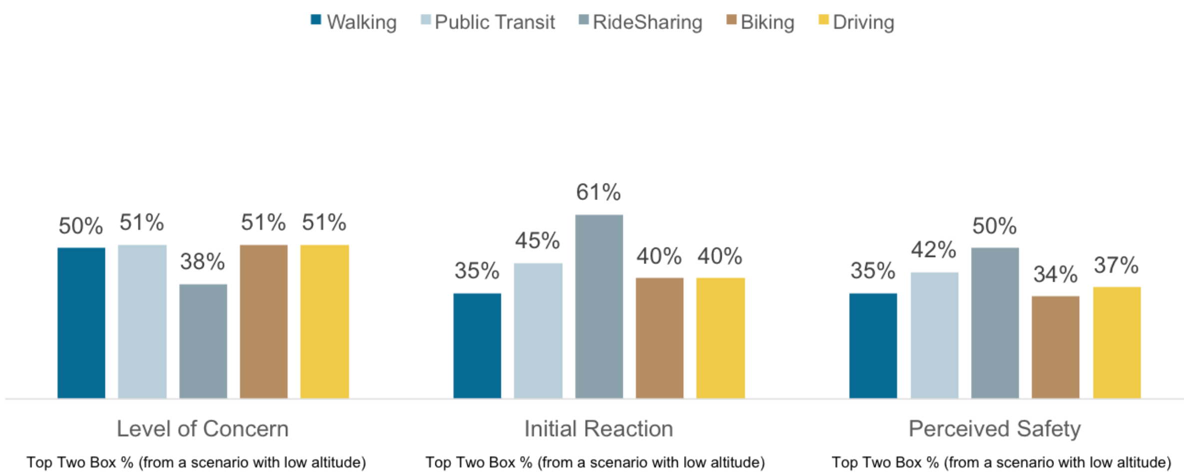


Figure 17. Key Results by Form of Transportation

Key Results by Length of Commute

Another important parameter of the perception of UAM is the current length of one's commute. There is a concave up pattern in the initial reactions, with 56% of those with short commutes fewer than 10 minutes viewing UAM positively, while 56% of those who have commutes longer than hour also viewing UAM positively. Those who have 10-19 minute commutes have the lowest initial reactions, at 39%, as shown in Figure 18.

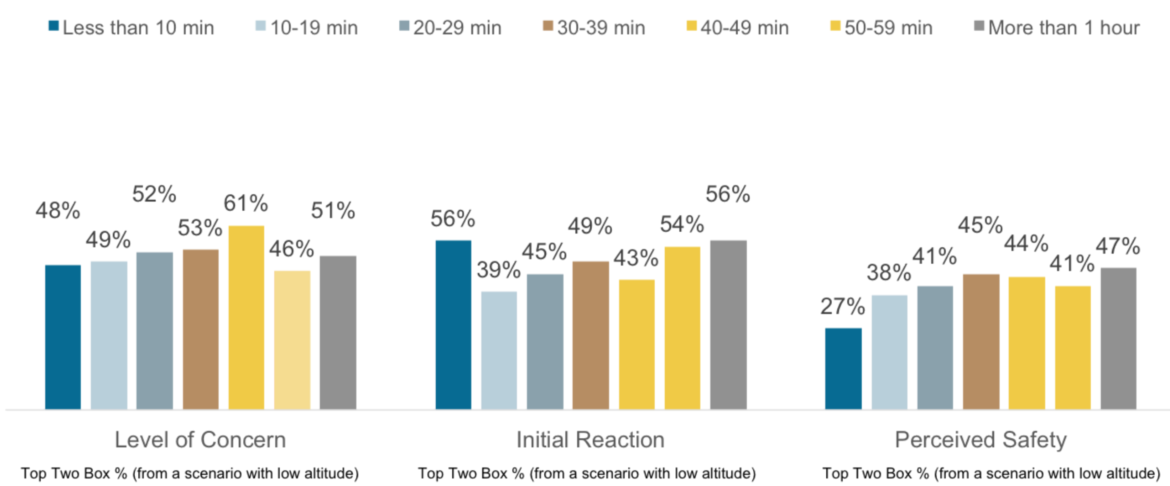


Figure 18. Key Results by Length of Commute

Conclusion and Next Steps

This initial study of public perception reveals several insights that can help propel the industry forward in urban planning, policymaking, and engineering.

Given the concern for the safety of individuals on the ground, the public may initially be more supportive of operations flown over the least populated areas, such as waterways or open fields. Also, established aircraft manufacturers with excellent safety records may be preferred to new market entrants.

Original equipment manufacturers (OEMs) and industry leaders must continue to move toward noise-mitigation, as both the type of noise and its volume strongly affect perception of UAM, as exhibited by the high elasticities. Respondents demonstrated they would not want an irritating noise, and that their preferred volume is near the level of a bee-buzzing or car passing rather than a truck or helicopter. Designs of noise attenuation filters is thus an ongoing growth area.

In addition, given that the frequency of flight presently causes concern, it will be important in early controlled field trials that greater frequency does not lead to a reduction in safety or a palpable increase in noise annoyance. As noted before, these guidelines are based on relative statistically significant differences compared to other parameters, rather than absolute percentages.

The per-geography metrics show that respondents from Mexico City are open to UAM for both use and as a typical mode of transport. Los Angeles, while not as positive as Mexico City, also has positive initial reactions to UAM. These results seem reasonable given that Mexico City and Los Angeles are notorious for their traffic congestion. Both also have considerable urban helicopter operations today. Switzerland and New Zealand, however, view UAM less positively, with concerns about safety, perhaps due to their mountainous geographies and relative lack of congestion.

In addition, it is clear that urban citizens are more interested in UAM than rural citizens, with suburban residents having mixed feelings. These data could be useful in determining flight trajectories and landing spots for UAM. For future mobility use, it is also important that those who use ridesharing and public transit view UAM most positively, which means that advertising to that urban base and developing infrastructure that complements existing ridesharing and mass transit may be beneficial. Short distance commuters and those taking trips that can be made walking or biking are not worth advertising to for UAM adoption.

Levers that were originally thought to be paramount, including the landing spot and time of day being flown, are still important, but are not as significant. It confirms that flights during the day, both in the morning and afternoon, are met with greater positivity, which is important for UAM as a commuting strategy. By showing the value of UAM for commutes, greater trust, and thus, usage, will occur, which will subsequently drive costs down and propel the industry.

We also find that the there is a fairly notable positive perception among higher income and younger individuals. This is important to note in future transportation planning and policy, as young, wealthy urbanites may be the initial target consumers for UAM, and thus their travel patterns may dictate vertiport locations.

This project generated a wealth of detailed data regarding public perception of UAM, and indeed not all of it has been explored in-depth. Several next steps lie ahead, including continuing to find patterns and regularities within these data, while also informing regulators, aircraft designers, local communities, and academics about the findings. These collaborations could help spur future research, strategy, and policy to make UAM a reality across the world. Further demonstrations and tests with communities, city officials, regulators, and other stakeholders are necessary to best design UAM operations.

We are looking for communities to work with for future studies. Please let us know if you are interested in participating! [jessie.mooberry@airbus-sv.com]

Appendix

Methodology

To assess public perception of UAM, we used a sequential mixed-methods approach. First, we conducted a literature review and expert interviews to determine which factors to consider in detail. We then extracted specific qualities of those factors; for instance, for the factor of noise, we studied the frequency, type, and time of day. We then used this information to design a survey to help us understand the significance of each of these qualities and factors. The goal was to determine the issues that are most significant for individuals when they envision a future with these aircraft in the sky.

Literature Review

We began with an extensive literature review of UAM deployment. We first read academic and industry papers about the state-of-the-art in UAM aircraft and network architectures. Then, we explored research that detailed the perception barriers for both riding in these aircraft and experiencing these aircraft as citizens of local communities. Finally, we comprehensively reviewed previous discrete choice models and perception surveys in the adoption of new vehicle technologies.

In the state-of-the-art of UAM, Brown and Harris developed hypothetical on-demand aircraft configurations and conducted sensitivity analyses to determine optimal conceptual designs, using cost, aircraft size, noise envelope, power limitations, and regulations as constraints.[10] Johnson, Silva, and Solis outlined that purchase cost of on-demand aircraft is roughly driven by empty aircraft weight, power considerations, and the cost of electronic systems.[11] Nneji et al. believes that increasing aircraft autonomy is fundamental to scalable UAM, which requires precision in determining separation from other vehicles, monitoring energy, maintaining ride quality, and preparing for emergencies.[12] They also detailed the different phases of a typical UAM trip. Vascik and Hansman explained that community acceptance issues resulting from aircraft noise, availability of Takeoff and Landing Areas (TOLAs), and the scalability of operations under Air Traffic Control (ATC) are the three key operating constraints that will affect UAM.[13]

Research conducted about unmanned aerial vehicles revolved primarily around drones rather than aerial taxis. Chang et al., Clothier et al. and Lidynia et al. conducted surveys and found that

[10] A. Brown and W. Harris, "A Vehicle Design and Optimization Model for On-Demand Aviation," 2018.
[11] Johnson, Silva, Solis. "Concept Vehicles for VTOL Air Taxi Operations," NASA Moffett Field, 2018.
[12] V. C. Nneji, M. L. Cummings, A. J. Stimpson, and K. H. Goodrich, "Functional Requirements for Remotely Managing Fleets of On-Demand Passenger Aircraft," 2018.
[13] P. D. Vascik and R. J. Hansman, "Evaluation of Key Operational Constraints Affecting On-Demand Mobility for Aviation in the Los Angeles Basin: Ground Infrastructure, Air Traffic Control and Noise," 2017.

perceptions of drones were primarily negative or neutral, with the broader issues of privacy, security, and safety as the main triggers.[14,15,16,17] Pytlik-Zillig et al. discovered that it would behoove the industry to distance itself from the word "drone," which respondents often likened to autonomous military attacks and spying.[18] Reddy and DeLaurentis explored factors that affect public and stakeholder opinions about unmanned aircraft using multinomial probit models, finding that income, age, political ideology, and frequency of flying in commercial aircraft were significant parameters.[19] Prior established different approaches to understand resident perception.[20]

As with most new technology innovations, primarily in transportation, understanding the extent to which the public will use a new mode is important. In the limited literature about flying with UAM, Garrow et al. designed a mode choice survey around high-income workers in Atlanta, Boston, Dallas-Fort Worth, the Bay Area, and Los Angeles.[21] Due to the limited scholarship for UAM, it is important to understand how surveys were designed and public opinion formed for other new mobility technologies, such as autonomous vehicles (AV). Bansal, Kockelman, and Singh analyzed mode choice for AV, while Howard and Dai analyzed public perception of AV, finding that the most attractive features were amenities, convenience, environmental friendliness, increased mobility, safety, and speed.[22,23]

Expert Interviews

After the literature review to understand the state-of-the-art and current best practices, the next component was to conduct interviews with field experts within UAM, across academia,

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[14] V. Chang, P. Chundury, and M. Chetty, "Spiders in the Sky: User Perceptions of Drones, Privacy, and Security," 2017, pp. 6765–6776.
[15] R. A. Clothier, D. A. Greer, D. G. Greer, and A. M. Mehta, "Risk Perception and the Public Acceptance of Drones: Risk Perception and the Public Acceptance of Drones," *Risk Analysis*, vol. 35, no. 6, pp. 1167–1183, Jun. 2015.
[16] C. Lidynia, R. Philipsen, and M. Ziefle, "The Sky's (Not) the Limit - Influence of Expertise and Privacy Disposition on the Use of Multicopters," in *Advances in Human Factors in Robots and Unmanned Systems*, vol. 595, J. Chen, Ed. Cham: Springer International Publishing, 2018, pp. 270–281.
[17] C. Lidynia, R. Philipsen, and M. Ziefle, "Droning on About Drones—Acceptance of and Perceived Barriers to Drones in Civil Usage Contexts," in *Advances in Human Factors in Robots and Unmanned Systems*, vol. 499, P. Savage-Knepshield and J. Chen, Eds. Cham: Springer International Publishing, 2017, pp. 317–329.
[18] L. M. Pytlik-Zillig, B. Duncan, S. Elbaum, and C. Detweiler, "A Drone by Any Other Name: Purposes, End-User Trustworthiness, and Framing, but Not Terminology, Affect Public Support for Drones," *IEEE Technology and Society Magazine*, vol. 37, no. 1, pp. 80–91, Mar. 2018.
[19] L. Reddy and D. A. DeLaurentis, "Multivariate Probit Models and Qualitative Analysis of Survey on Public and Stakeholder Perception of Unmanned Aircraft," 2016.
[20] J. Prior, "Factors influencing residents' acceptance (support) of remediation technologies," *Science of The Total Environment*, vol. 624, pp. 1369–1386, May 2018.
[21] L. A. Garrow, B. German, P. Mokhtarian, M. Daskilewicz, T. H. Douthat, and R. Binder, "If You Fly It, Will Commuters Come? A Survey to Model Demand for eVTOL Urban Air Trips," in *2018 Aviation Technology, Integration, and Operations Conference*, Atlanta, Georgia, 2018.
[22] P. Bansal, K. M. Kockelman, and A. Singh, "Assessing public opinions of and interest in new vehicle technologies: An Austin perspective," *Transportation Research Part C: Emerging Technologies*, vol. 67, pp. 1–14, Jun. 2016.
[23] D. Howard and D. Dai, "Public Perceptions of Self-Driving Cars: The Case of Berkeley, California," presented at the Transportation Research Board 93rd Annual Meeting, Transportation Research Board, 2014.

government, and industry. We used the following basic questionnaire for each interviewee, with marginal changes depending on position and field:

1) What do you think the major social perception factors are right now for the adoption of flying cars?
2) How do you think the industry can inform the public of the tradeoffs of this new technology?
3) How do you think the industry can get the support of the public?
4) When you think about these aircraft flying in your community, what would you say are the most important challenges that need to be fixed before you would be okay with it?
5) How did you determine that these were major issues to be regulated? What exactly was the methodology? Surveys and polls? Have you spoken with cities and citizens?
6) How can we use autonomous car policy (or other technologies that were integrated into society) to our advantage to develop good UAM policy?
7) What would be needed to convince a city that this is a technology worthy of adopting?
8) How do we make the deployment best for cities? Do we cater toward equity, sustainability, and access? At what levels? What are the tradeoffs to consider?
9) What's the process for a city to approve the deployment of emerging technology?

Present-day pilots gave insight into the challenges associated with operating small aircraft. Engineers, vice presidents of strategy, and product managers for aircraft design firms, such as Vahana from A^3 by Airbus, provided background into the system-level characteristics, such as noise, that must be considered. Academics across the world in aerospace engineering, civil engineering, and urban planning provided intuition about the design of effective surveys and the state-of-the-art research challenges in UAM. Governmental agencies such as the FAA and NASA discussed the highest priority issues for UAM deployment. In addition, local and national governments across the world, including Los Angeles, New Zealand, and Singapore, gave insight about how they historically integrated new transportation technologies, and also how they plan to integrate UAM and develop new policies specific to these aircraft deployments.

The interviews helped organize the issues into three separate buckets: (1) Possible concerns, (2) UAM deployment strategy, and (3) Survey design and deployment.

Speaking with city and country officials from New York, Los Angeles, Mexico City, Singapore, and New Zealand, we found that public entities were generally concerned about five issues, the first three of which are of greater magnitude. The categories are organized by the number of times they were raised by each interviewee and by the import placed upon them in the literature review, though they are all approximate. Please note that the data for each of these bullets are personal opinions from interviewees and have been anonymized to protect our interviewees. They do not reflect the positions of Airbus.

- The first is *safety*.
    - Anytime an airplane crashes, it makes the news.

    - People believe that anything with a rotor is not as safe as a fixed wing.
    - The idea of having vehicles in the air makes people nervous. In Mexico City, people are scared that helicopters/eVTOLs will stop working. Tragic incidents have happened before.
    - Helicopters are not perceived to be safe.
    - People in Mexico City see pilots as if they are Uber drivers; thus, safety is compromised, and the public sees these safety blips as a reason to be afraid. It is similar to what happened with Uber and its autonomous car incident.
    - People do not trust machines fully yet, so having a pilot provides peace of mind.
    - If going fully autonomous, wording is important. The industry should say “self-piloted” as opposed to “autonomous.” The idea is that “self-piloted” still implies preemptive determination of what the aircraft should do and where to go, while “autonomous” implies that it is making decisions on its own.
    - The current discussion in the space revolves around the safety error levels being 10^{-9} or 10^{-7}.
- The second is *noise*.
    - Localities decide where you can take off and land, so if they don’t want you to operate in their city due to certain factors (mostly noise), they are able to restrict operations.
    - In a nation outside the U.S., one particular helicopter operator has received only one complaint about noise; it is also noted that this nation does not have as stringent regulatory and safety guidelines as the U.S. In the U.S., however, this same helicopter operator found that noise is the biggest complaint.
    - Various cities in California have already created legislation to shut down helicopter operations above them by limiting helipad construction and usage. This is largely because of the noise.
- The final big concern is *inequity*.
    - UAM needs to be a mobility option for all people. If the public sees it as a way for the rich to travel around, they will definitely not accept it. Places in California focus on equity issues, but places like Dallas are not as concerned about social equity.
    - In Mexico City, helicopters are considered ultra-VIP and for the wealthiest section of the population. Lower income people resent helicopters in certain geographies.
    - NIMBYism (not-in-my-backyard) is an issue - will having these in the air help me or hurt me? Can I afford to use this myself? If not, is this just another way that rich people get to avoid more challenges of the city?
    - Is it neutral to the poor? The externalities to the average or poor person need to be measured.
- The next (lesser) concern is *visual pollution*.
    - People are afraid that their beautiful skies will become inundated by these new vehicles.
    - If the industry present the gradual deployment as opposed to swarms of aircraft in the sky, then communities may be more receptive.
- The smallest concern is *privacy.*

- While there is more hoopla about privacy in this day and age, most people do not associate large vehicles with breaches of privacy.

It was accepted across the interviewees that greater public adoption is more feasible outside of the U.S., predominantly due to American cultural reasons regarding car ownership linked to ideological freedom and choice. In addition, some level of congestion has been deemed to be acceptable by the public (e.g. two hours one-way in traffic is still acceptable to the public across the globe.)

Deployment strategies also varied across the interviewees, but certain patterns emerged. The first widely accepted truth is that the key to deployment is “evolution, not revolution.” Leaders at NASA, Airbus, and from academia believe it to be best to initially operate on helicopter routes, managing the noise signature along loud areas like highways, and then slowly expanding outward. Flying in the outskirts of a city, rather than over communities, until it is deemed acceptable and safe is important in gaining trust. In this incremental approach, interviewees acknowledged that if UAM starts in confined and highly controlled places, then communities will be receptive to them once they see them safely transporting people.

From a regulatory perspective, interviewees, especially pilots, believe that modeling the chronology after helicopters is most reasonable, primarily because helicopters had also been deployed incrementally for various uses. This evolutionary approach is to prove the technology’s safety and reliability. To that end, most interviewees agreed that one of the major strategic directions that all players in the space ought to do is to align themselves with their aviation regulatory agency and try to use existing legislation (such as with helicopter and commercial fixed-wing) to craft new legislation. In practice, one helicopter operator is progressing under the assumption that if the public happily accepts helicopters above them, then they should be pleased with eVTOL, not only due to higher safety and noise standards, but also due to the versatility and potential scale of UAM.

Indeed, experts believe that the prototypes by Cora in New Zealand, eHang in China/Dubai, and Vahana in Oregon, among others, will help develop familiarity and acceptance.

Our expert interviewees also gave insight into survey development and design. Because there has been minimal literature about community acceptance of UAM, most academics found it to be a fascinating area of research. Scholarship is increasing in mode choice with UAM and noise studies, but to our knowledge, this is the first detailed exploration of public perception of UAM. As a result, suggestions to design a survey to imagine a futuristic technology that does not exist included likening UAM to helicopters, including graphics, testing with specific scenarios, and making the surveys geography-dependent.