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Understanding Advanced Air Mobility from a Human Experience Design Perspective: Utilizing a User-Centric Approach to eVTOL Development

Research Study Conducted by: The Gilmore Group, LLC located in New York, USA.

Abstract:

The recent development of Electric Vertical Take-Off and Landing (eVTOL) aircraft has brought forth a new sector of air travel known as Advanced Air Mobility (AAM). This study aims to elucidate significant user perceptions, expectations, and concerns regarding safety, comfort, experience, and tolerance of points-of-friction, as they relate to this new technology. The purpose of understanding AAM through the user-centric lens of both potential passengers and pilots is to bring a holistic developmental approach to all aspects of the AAM ecosystem which we term “Human Experience Design” (HED). Through conducting surveys and illustrating granular pain points and raising awareness of the general state of eVTOL acceptance, industry stakeholders can activate the Human Experience Design approach both in tactical design decision making and strategically in their operational and customer journey approaches; As it is still relatively early in the development process, HED will help assure AAM sector success by saving business’ time and resources. Furthermore, individual businesses, such as Original Equipment Manufacturers (OEMs), will gain a distinct advantage over competitors if they optimize cabin- and flight-deck experience as well as seamlessly integrate their product into a complete customer journey.

Introduction:

The advancement of battery technology, worsening city traffic congestion, community calls for less noise-pollution, and government commitment to clean energy, have catalyzed the development of Electric Vertical Take-Off and Landing (eVTOL) aircraft in recent years. The aircraft technology has garnered interest from governments, corporations, aircraft operators, private and commercial flyers, however, consensus among experts is that Advanced Air Mobility (AAM) still faces technological and regulatory hurdles as well as the challenge of complete airspace integration with current Air Traffic Control (ATC). These hurdles must be overcome, as stakeholders’ financial success and the economic viability of the AAM transportation system is contingent on theoretical benefits being delivered in real-world scenarios. This will require alignment between battery technology performance (e.g., energy density), infrastructure (e.g., energy grid, vertiport network), OEM product affordances (i.e., mission capabilities), operators (e.g., commercial airlines), and federal regulators (e.g., FAA, EASA, TCCA, etc.). Moreover, the AAM sector's success will be contingent upon user acceptance and the optimization of end-user experience. To that end, it will be critical to ensure awareness of user-centric perspectives on acceptance, safety, comfort, and their subsequent integration into operations and eVTOL design decision making. Drawing upon a multi-disciplinary background, encompassing industrial design, human-factors engineering, ergonomics, and branding, this study aims to further the body of research concerning psychological perception of safety, tolerance of points of friction, and human-factors engineering considerations in the emerging field of eVTOL. Thus, this study is comprised of three mass market surveys "Tolerance of Points of Friction & Expectations in eVTOL," "Public Acceptance of Flight Standards & Aviation Customer Experience," and "Public Perception & Acceptance of eVTOL" aimed to garner insights on the population of flying Americans. Additionally, one qualitative focus-group study was conducted with Pilots, "Helicopter & Fixed Wing Pilot's Concerns Regarding eVTOL Aviation." Subsequent data analysis was conducted to assess key design and operation factors influencing human perception, acceptance, and adoption of eVTOL aircraft. The findings shed light on significant psychological and physical experience considerations associated with eVTOL aviation, providing valuable insights for industry stakeholders and policymakers. The results also contribute to the understanding of the human experience in this new frontier of air travel, ultimately facilitating the development of user-centered solutions and enhancing the overall safety and usability of eVTOL aircraft. By examining user expectations, user tolerance levels, and user/public acceptance, this research aims to help bridge the gap between OEM technology and operations with the human user. Through better understanding what designs and operations are considered critical, we can better implement solutions while in the earlier stages of eVTOL development, paving the way for successful integration of eVTOL aircraft into the future transportation landscape.

Literature Review:

The emerging field of eVTOL aircraft and Advanced Air Mobility (AAM) has attracted significant attention, with researchers exploring various aspects of passenger experience, acceptance, market potential, and risk perceptions. This literature review aims to synthesize key findings from recent studies related to eVTOL passenger experience, acceptance, and factors influencing adoption and use of AAM.

Edwards and Price [1], in collaboration with NASA provides a critical starting point for user-acceptance-centric eVTOL research. The report explores eVTOL passenger acceptance through the recapitulation of historical insights developed since the 1970s. The paper categorically establishes the factors influencing eVTOL acceptance, including trust in autonomous systems, perceived safety, and the role of public perception in shaping attitudes towards eVTOL aviation. The study "eVTOL Passenger Experience" by Crown Consulting Inc. [2] offers valuable insights into aspects such as comfort, safety, and usability, providing a comprehensive understanding of the factors that contribute to a positive passenger experience in eVTOL operations.

Cohen, Shaheen, and Farrar [3] provide a further comprehensive overview of the history, ecosystem, market potential, and challenges associated with urban air mobility. The paper analyzes the current state of urban air mobility, highlighting key technological, regulatory, and social factors that impact its adoption and integration into existing transportation systems.

Yoo, Choe, and Soo-i-Rim [4] examine risk perceptions associated with urban and advanced air mobility (UAM/AAM) in their study. By applying a mixed-method approach, the researchers identified factors influencing risk perceptions and highlighted the importance of addressing safety concerns and building public trust to foster the successful implementation of UAM/AAM systems.

Haddad, Chniotakis, Straubinger, Ploetner, and Antoniou [5] focus on factors affecting the adoption and use of urban air mobility. Their research identifies critical factors such as infrastructure availability, regulatory frameworks, public acceptance, and environmental sustainability, shedding light on the complex interplay of factors that influence the successful implementation of urban air mobility solutions.

These studies collectively contribute to the understanding of eVTOL passenger experience, acceptance, and factors influencing the adoption and use of urban air mobility and AAM as a whole. By examining various dimensions of human perception, safety, market potential, and socio-technical factors, these studies provide a foundation for addressing the challenges and harnessing the opportunities presented by eVTOL and AAM in the transportation landscape.

Regarding this paper, as a market study, the research looked at opinions and thoughts of potential ticket-buyers (members of the American public both involved in aviation occupations and non-aviation occupations) who are non-experts. They study also included professional subject matter experts in the form of airline and helicopter pilots.

Building off well-established categories of concern regarding acceptance, this study is focused on granular scenarios and aspects to develop a more detailed and comparative understanding of what specific hypothetical situations and aspects of flying on eVTOL, as they may arise in the real world, are considered more salient than others. Whereas Edwards and Price [1] write, their "low fidelity" study was intended to develop an initial mapping of passenger acceptance; our study aims to build on this foundational understanding. As eVTOL designs have progressed over the years from 2020 to 2023, we have developed scenarios to elicit user response based on understandings of some of the most current eVTOL design and operational developments.

Methodology:

This research employed a mixed-methods approach, combining quantitative and qualitative data collection techniques. The primary data collection method involved the administration of three online surveys and focus-group to gather insights into the human perception, concerns, tolerance, and acceptance of eVTOL aviation in the context of the Advanced Air Mobility sector.

Study Design: Four studies were conducted using an online platform. Three quantitative surveys were designed to be generalizable to the United States' population of citizens that fly commercial or private aircraft (termed "Flying Americans"), while one focus-group for licensed pilots incorporated qualitative data through a combination of long/essay form response and Likert scale responses. Background of eVTOL and AAM was given to provide context of the new air transportation method. The studies were structured to capture relevant responses to specific eVTOL technology (e.g., Pictures of eVTOL aircraft) and experiential scenarios (e.g., experiencing bad weather). We collected data on demographics (e.g., age, gender), participants' level of flying experience (e.g., frequency of flying, cabin class preference), employment history in the aviation industry, and early adopter tendencies.

To analyze participants' responses, we utilized appropriate Likert scales in the surveys to enable quantitative analysis. The Likert scales allowed participants to rate their agreement or disagreement on specific statements and scenarios, rate their level of tolerance to points of friction scenarios from *extremely unlikely to fly again with eVTOL* to *extremely likely to fly again with eVTOL*, rate the importance of physical factors (e.g., leg room) and psychological factors (e.g., being familiar with the airline brand) from *not at all important* to *extremely important*, rate concerns of experiential aspect scenarios from *not at all concerned* to *extremely concerned*.

Sampling and Sample Size: The target population for the bulk of this research was the flying American population or "Flying Americans". We sourced the population percentage of flying Americans from the "Air Travelers in America Annual Survey" published by the Airlines for America association, which indicated a percentage of 44% among the US population. The approximate US population of 332 million according to the US Census Bureau.

Sample Size Determination: To ensure statistically significant generalization to the population of flying Americans, we conducted three separate studies with the goal of sample size of n>500 for each survey. With a sample size greater than 424, we would ascertain a Confidence Level of 90% and a margin of error of +/- 10%.

Sample size Calculation:

$$n = (Z^2 * p * (1 - p)) / (E^2 * N)$$

Where: n = required sample size Z = Z-score corresponding to the desired confidence level (e.g., for 90% confidence level, Z ≈ 1.645) p = estimated proportion of the population who fly commercial aircraft (0.44) E = desired margin of error (as a proportion, 0.10) N = population size (330 million).

Plugging in the values, we have:

$$n = (1.645^2 * 0.44 * (1 - 0.44)) / (0.10^2 * 330{,}000{,}000) \quad n \approx 423.84$$

Rounding up to the nearest whole number, the minimum required sample size for making generalizable statements about the population of Americans, with a population size of 330 million, a proportion of 44% who fly commercial aircraft, a confidence level of 90%, and a margin of error of ±10%, is approximately 424.

Quantitative data obtained from the surveys were analyzed using statistical methods, including descriptive statistics, correlation analysis, and inferential statistics. Qualitative data from the open-ended responses were subjected to thematic analysis to identify recurring themes and patterns.

This research adhered to ethical guidelines for data collection and participant anonymity. All participants were provided with informed consent regarding the purpose of the study, voluntary participation, and data confidentiality.

The utilization of mixed-methods research and a robust sample size aimed to capture a comprehensive understanding of the human perspective on eVTOL aviation. By combining quantitative analysis of Likert scale responses and qualitative analysis of open-ended responses, this methodology allowed for a deeper exploration of the psychological perception, tolerance, and acceptance of eVTOL in the Advanced Air Mobility sector among the target population of flying Americans and licensed Pilots.

Results:

Survey Response Rate: The mass market survey response and completion rate exceeded ranged from 97-99%. Overall, the high response rate and completion rate indicated a high level of accessibility and low participant fatigue. The high response rate enhances the reliability and representativeness of the collected data. The Pilot Focus Group follow up questionnaire had a lower completion rate of 77%, largely due to the long form/essay response.

Sample Sizes (using 100% completion rate individual responses only):
Public Perception & Acceptance of eVTOL; n=505
Tolerance of Points of Friction & Expectations in eVTOL; n=511
Customer Experience Index – Aviation; n=504
Helicopter & Fixed Wing Pilot's Concerns Regarding eVTOL Aviation; n=10

Sex: Following are sex demographic percentages figures.
Public Perception & Acceptance of eVTOL; 57% Female / 41% Male / 1% Other
Tolerance of Points of Friction & Expectations in eVTOL; 48% Female / 52% Male
Customer Experience Index – Aviation; 49% Female / 51% Male
Helicopter & Fixed Wing Pilot's Concerns Regarding eVTOL Aviation; 100% Male

Age: The age breakdown was very similar across all “Flying American” surveys but the Pilot Focus Group participants had larger percentage contingents of age brackets higher than 35 years old.

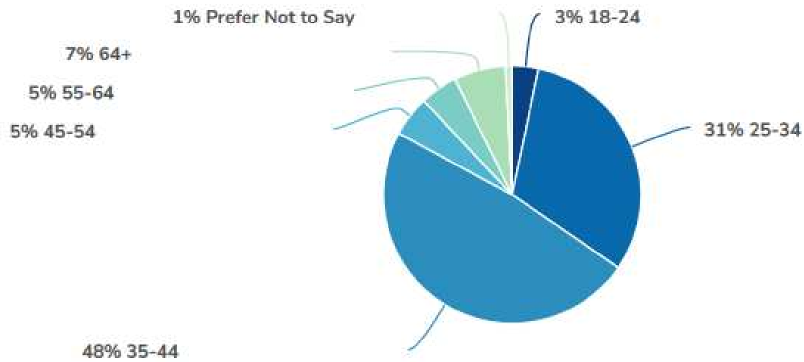


Fig.1 Approximate Average Breakdown of Age for Three Quantitative Surveys

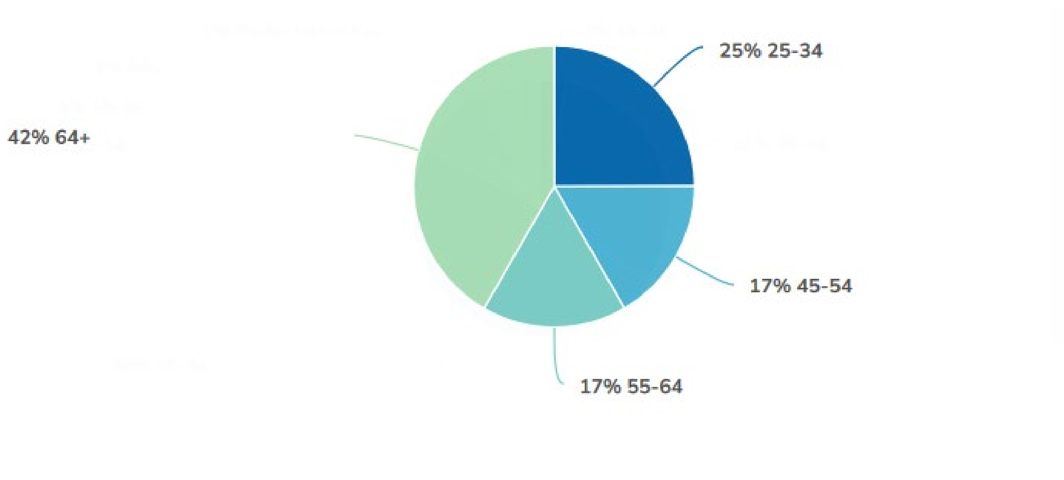


Fig.2 Breakdown of Age for Pilot Focus Group

Early Adopter: We asked participants how likely they were to describe themselves as early adopters. The graph below shows similar response distribution across all three quantitative surveys.

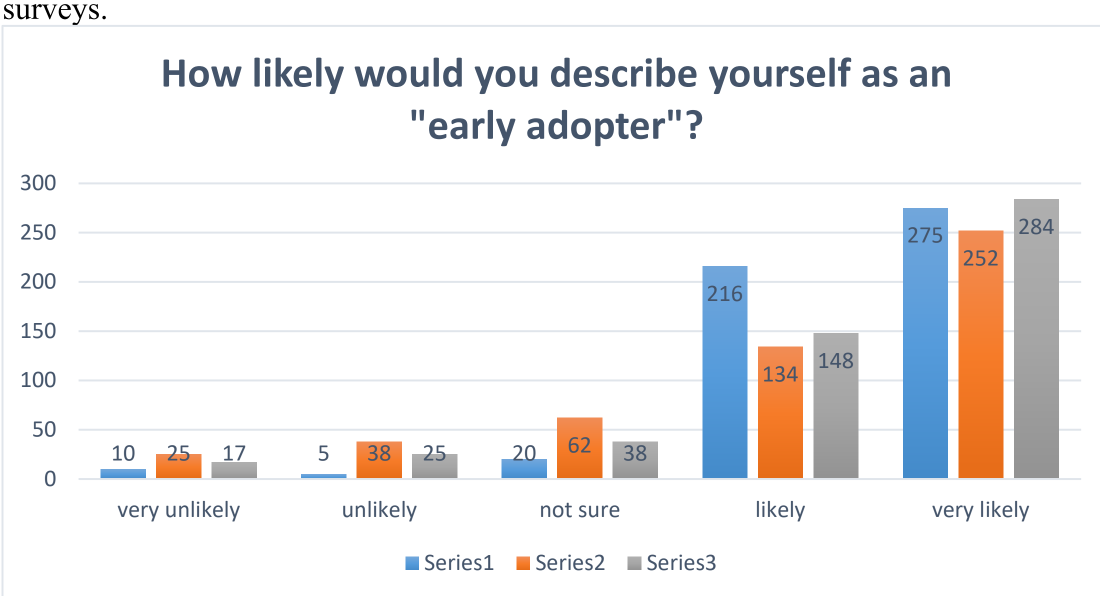


Fig.3 "Early Adopter" "American Flyer" Survey Responses (1-3)

A somewhat different distribution was recorded for the Pilot Focus Group. Where they were less likely to describe themselves as an early adopter.

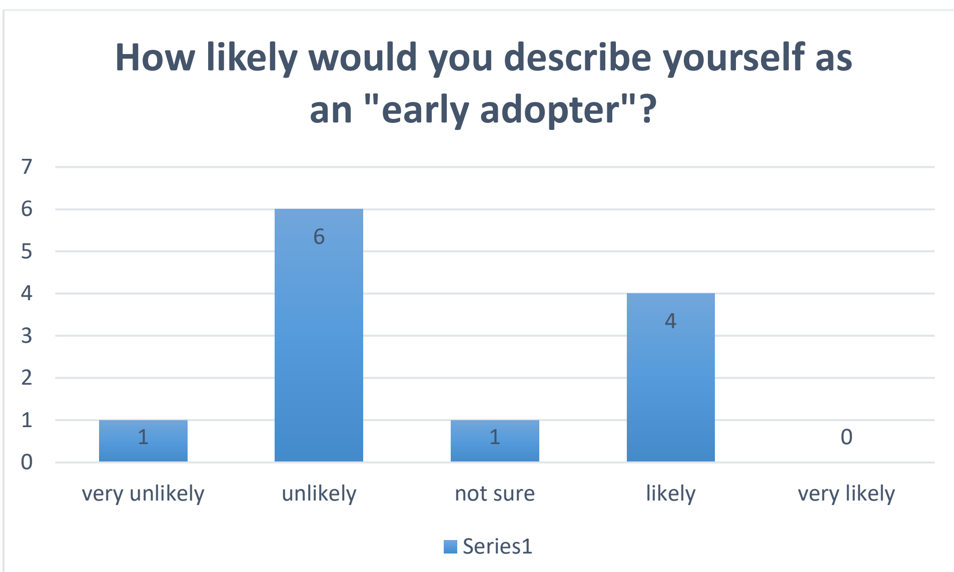


Fig.4 "Early Adopter" Pilot Focus Group Responses

Profession in Aviation: For the American Flyer surveys, we asked whether respondents had ever been a pilot, aircraft mechanic, flight attendant, or worked in the aviation sector. The approximate average breakdown for all three quantitative surveys is represented by the graph below.

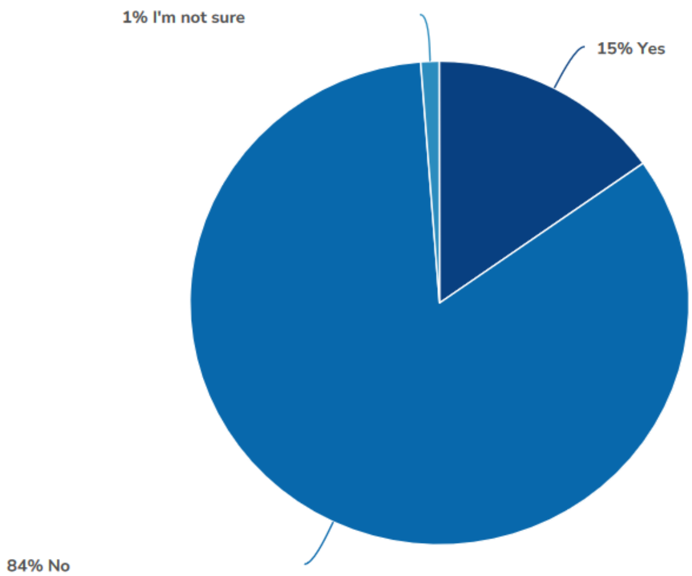


Fig.5 Profession in Aviation

Commercial Airline Experience: We asked all respondents about their level of experience regarding flying on commercial aircraft. We asked about whether they have ever used this travel method before. The graph below shows approximate average responses for the three quantitative surveys.

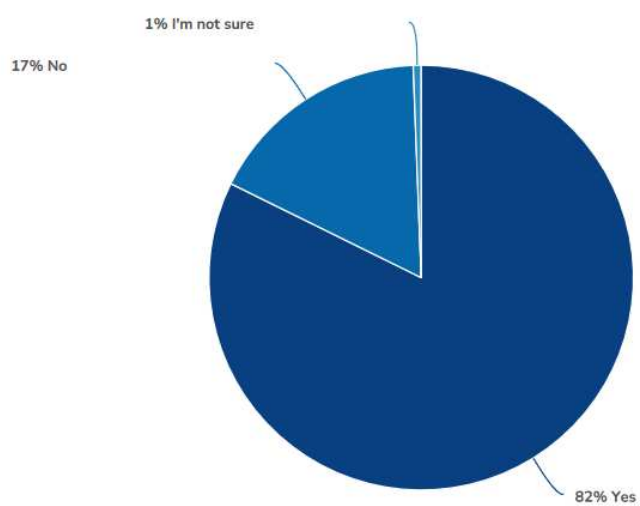


Fig.6 Percentage of flying Commercial

Using conditional logic, respondents that had flown commercial were also asked what frequency and what cabin class preference they had.

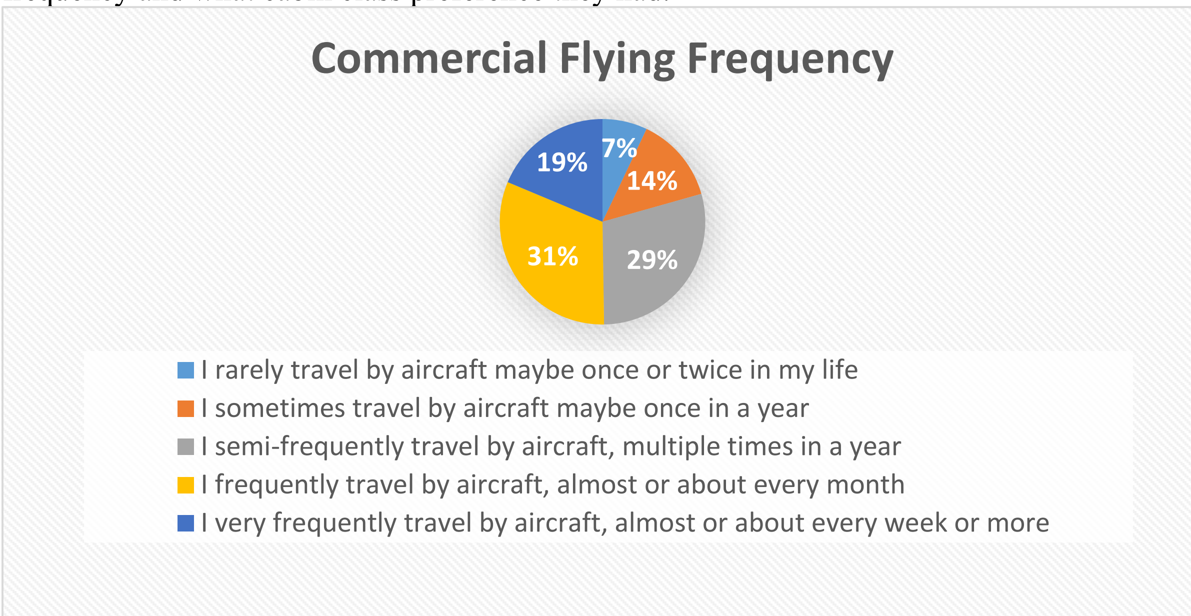


Fig.7 Commercial Flying Frequency: Average Percentage

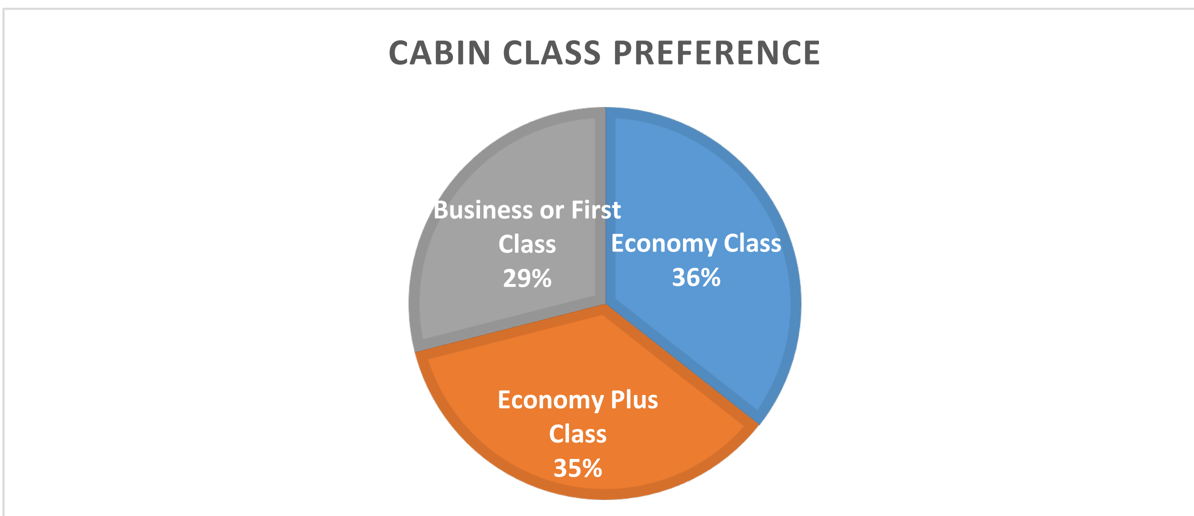


Fig.8 Cabin Class Preference: Average Percentage

The following represents responses to specific surveys and not combined survey results as in the previous part of this results section.

Public Perception & Acceptance of eVTOL (Specific Survey Results)

a) Respondents were asked about how important the following factors are when stepping onto an aircraft and to rate their response on the appropriate Likert Scale.

	Extremely Unimportant	Unimportant	Neutral / I'm not sure	Important	Extremely Important	Responses
Safety Count Row %	8 1.6%	6 1.2%	19 3.8%	81 16.0%	392 77.5%	506
Comfort Count Row %	5 1.0%	9 1.8%	32 6.3%	226 44.7%	234 46.2%	506
Privacy Count Row %	7 1.4%	17 3.4%	65 12.8%	148 29.2%	269 53.2%	506
Customer Experience & Service Count Row %	6 1.2%	6 1.2%	45 8.9%	179 35.4%	270 53.4%	506
Totals Total Responses						506

Fig.9 Public Perception & Acceptance of eVTOL – "Important Factors"

Ranked by Extreme Importance: 1) Safety, 2) Customer Experience & Service, 3) Privacy, 4) Comfort. Safety is the leading important factor by a significant margin. Worthy of note is that whereas other factors fall off by an average of 34.5% from "Extremely Important" to "Important", Comfort only drops by 1.5%.

b) Safety Perception of Specific Aircraft: Respondent were asked to rate how safe they would feel flying in a particular aircraft (a picture was shown of each aircraft, view angle, lighting and other variables were kept as equal as possible to limit perceptive variables). Combining percentages of responses of "very unsafe" and "unsafe," the lowest ranking aircraft was found at least "unsafe" by 18% of all individuals tested and the highest-ranking aircraft was found at least unsafe by 3% of all individuals tested.

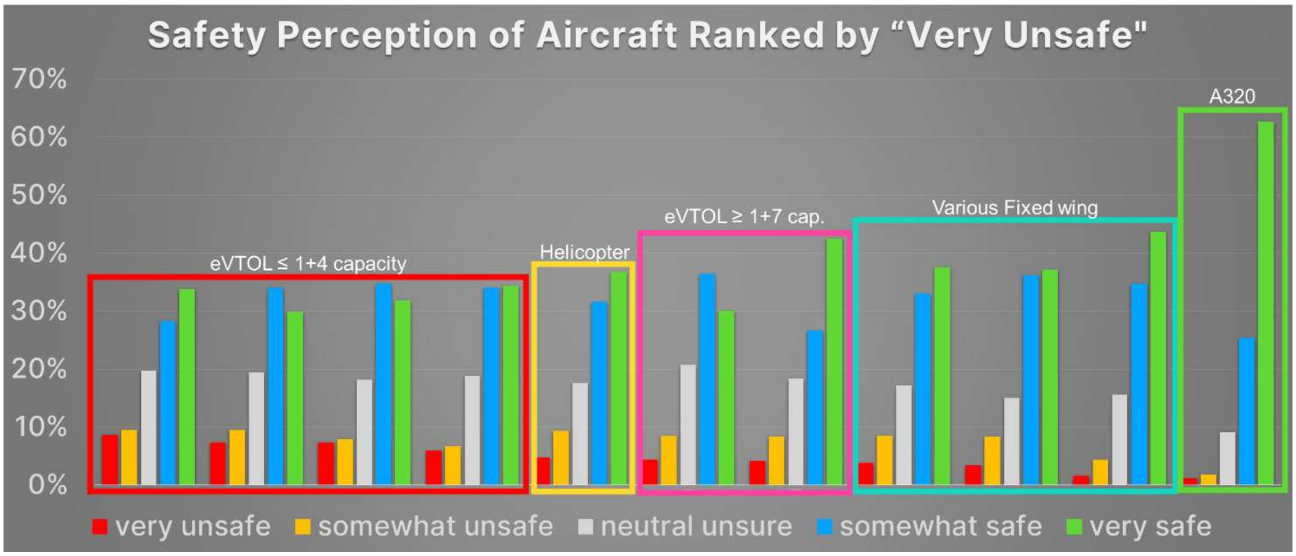


Fig.10 Safety Perception of Aircraft Ranked by "Very Unsafe"

Pearson correlation coefficient was used to test how the dependent variable of "safety" and independent variable of "fuselage length related.

$r = (\Sigma((X - \bar{X})(Y - \bar{Y}))) / \mathrm{sqrt}(\Sigma((X - \bar{X})^2) * \Sigma((Y - \bar{Y})^2))$

Where:

- r represents the Pearson correlation coefficient.
- Σ represents the sum of the indicated values.
- X and Y are the values of Likert Scale rating of Level of Safety (1-5) and Fuselage Length (in units of feet)
- $\bar{X}$ and $\bar{Y}$ are the means (averages) of X and Y, respectively.

We found a positive relationship of r=.31 which indicates a present but low-level relationship.

Public Acceptance of Flight Standards & Aviation Customer Experience (Specific Survey Results)

a) Respondents were asked about how important the following physical factors are when flying in an aircraft and to rate their response on the appropriate Likert Scale.

	Not at all important	Low importance	Neutral / I'm not sure	Moderate importance	Extremely important	Responses
Seatbelt Fit & Adjustability Count Row %	7 1.4%	11 2.2%	36 7.1%	165 32.7%	286 56.6%	505
Seat cushioning / ergonomics Count Row %	6 1.2%	15 3.0%	42 8.3%	240 47.5%	202 40.0%	505
Headrest height / adjustability Count Row %	4 0.8%	15 3.0%	50 9.9%	240 47.5%	196 38.8%	505
Armrests – size, adjustability Count Row %	3 0.6%	16 3.2%	44 8.7%	231 45.7%	211 41.8%	505
Seat width Count Row %	5 1.0%	13 2.6%	56 11.1%	205 40.6%	226 44.8%	505
Seat height Count Row %	9 1.8%	18 3.6%	56 11.1%	220 43.6%	202 40.0%	505
Leg room Count Row %	2 0.4%	10 2.0%	46 9.1%	233 46.1%	214 42.4%	505
Personal space (next to other passengers) Count Row %	3 0.6%	8 1.6%	41 8.1%	231 45.7%	222 44.0%	505
Sightlines (privacy) Count Row %	4 0.8%	21 4.2%	57 11.3%	218 43.2%	205 40.6%	505
Personal & Mood Lighting Count Row %	4 0.8%	24 4.8%	55 10.9%	224 44.4%	198 39.2%	505
Window placement Count Row %	4 0.8%	18 3.6%	68 13.5%	218 43.2%	197 39.0%	505
Door placement Count Row %	8 1.6%	26 5.1%	59 11.7%	209 41.4%	203 40.2%	505
Luggage Storage (checked bags) Count Row %	5 1.0%	17 3.4%	45 8.9%	219 43.5%	218 43.3%	504
Small luggage carry-on storage (backpack, pocketbook, laptop, etc) Count Row %	2 0.4%	10 2.0%	44 8.7%	220 43.6%	229 45.3%	505
Special passenger cargo (i.e. gulf clubs, medical equipment) Count Row %	10 2.0%	24 4.8%	58 11.5%	198 39.3%	214 42.5%	504
Boarding easily Count Row %	2 0.4%	17 3.4%	38 7.5%	228 45.1%	220 43.6%	505
Egressing (Exiting) easily Count Row %	5 1.0%	9 1.8%	39 7.7%	223 44.2%	228 45.2%	504
Accessibility (mobility, vision, hearing) Count Row %	8 1.6%	15 3.0%	45 8.9%	214 42.4%	223 44.2%	505

Fig 11. Physical Factor Importance

b) Respondents were asked about how important the following physical aspects are if / when experienced flying in an aircraft and to rate their response on the appropriate Likert Scale.

	Not at all concerned	Slightly concerned	Somewhat concerned	Moderately concerned	Extremely concerned	Responses
Takeoff Count Row %	19 3.8%	27 5.3%	53 10.5%	177 35.0%	229 45.3%	505
Landing Count Row %	20 4.0%	13 2.6%	62 12.3%	206 40.8%	204 40.4%	505
Turbulence / Bad weather Count Row %	17 3.4%	16 3.2%	44 8.7%	192 38.1%	235 46.6%	504
Vibrations Count Row %	18 3.6%	17 3.4%	71 14.1%	190 37.6%	209 41.4%	505
Aircraft Noise Count Row %	21 4.2%	32 6.3%	55 10.9%	210 41.6%	187 37.0%	505
Feeling too warm Count Row %	21 4.2%	27 5.3%	71 14.1%	197 39.0%	189 37.4%	505
Feeling too cold Count Row %	25 5.0%	25 5.0%	64 12.7%	189 37.4%	202 40.0%	505
Air circulation Count Row %	15 3.0%	19 3.8%	62 12.3%	197 39.0%	212 42.0%	505
Condensation / leakage Count Row %	18 3.6%	19 3.8%	62 12.3%	172 34.1%	234 46.3%	505

Fig 11. Physical Experience Importance

c) Respondents were asked about how important the following psychological / overall experience factors when flying in the aircraft and to rate their response on the appropriate Likert Scale.

	Not at all important	Low importance	Neutral / I'm not sure	Moderate importance	Extremely important	Responses
Being familiar with the airline brand Count Row %	8 1.6%	16 3.2%	65 12.9%	191 37.8%	225 44.6%	505
Privacy Count Row %	8 1.6%	19 3.8%	46 9.1%	221 43.8%	211 41.8%	505
Security check (TSA) Count Row %	6 1.2%	13 2.6%	42 8.3%	204 40.4%	240 47.5%	505
Trip progress / Knowing your ETA Count Row %	4 0.8%	6 1.2%	52 10.3%	226 44.8%	217 43.0%	505
Knowing you're on the "right" aircraft for your destination Count Row %	6 1.2%	10 2.0%	53 10.5%	205 40.6%	231 45.7%	505
Waiting accommodations Count Row %	8 1.6%	16 3.2%	49 9.7%	225 44.6%	207 41.0%	505
Payment / ticketing experience Count Row %	9 1.8%	13 2.6%	43 8.5%	201 39.8%	239 47.3%	505
Check-in experience Count Row %	9 1.8%	8 1.6%	34 6.7%	205 40.6%	249 49.3%	505

Fig 12. Psychological Experience Importance

d) Respondents were asked about how concerned they are with the following aspects of flying in an aircraft and to rate their response on the appropriate Likert Scale.

	Not at all concerned	Slightly concerned	Somewhat concerned	Moderately concerned	Extremely concerned	Responses
Seated facing another passenger Count Row %	21 4.2%	29 5.7%	51 10.1%	181 35.8%	223 44.2%	505
Terrorism Count Row %	19 3.8%	25 5.0%	61 12.1%	192 38.0%	208 41.2%	505
Aircraft is Fully Autonomous (flown by auto-pilot computer system) Count Row %	13 2.6%	20 4.0%	58 11.5%	202 40.0%	212 42.0%	505
No Pilot Present in Aircraft (flown by Pilot on the ground) Count Row %	11 2.2%	15 3.0%	54 10.7%	194 38.5%	230 45.6%	504
Aircraft is an Electric Vehicle (battery-powered) Count Row %	15 3.0%	24 4.8%	49 9.7%	199 39.4%	218 43.2%	505
Aircraft is wingless (e.g., helicopter) Count Row %	21 4.2%	15 3.0%	53 10.5%	206 40.8%	210 41.6%	505
Aircraft has no flight attendant Count Row %	17 3.4%	28 5.6%	49 9.7%	173 34.3%	237 47.0%	504

Fig 13. Concerns of flying eVTOL

The following graphically represents the extremes of the Likert scale responses showing the percentages of the lowest rank concern "Terrorism" to the highest ranked concern "Aircraft has no flight attendant."

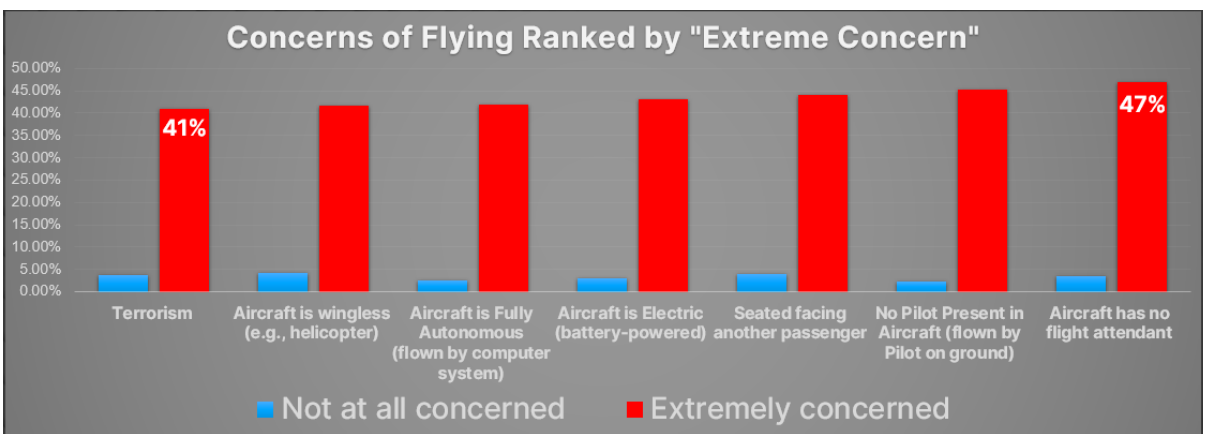


Fig 14. Concerns of flying eVTOL – Bar Graph

Tolerance of Points of Friction & Expectations in eVTOL (Specific Survey Results)

a) Respondents were asked about how unlikely they would be to travel with eVTOL after experiencing a certain point of friction and to rate their response on the appropriate Likert Scale from “extremely unlikely: to fly again with eVTOL to “extremely likely” to fly again. The respondents were explained the following 1) the flight was advertised to be more convenient than their usual method of travel 2) the flight was advertised as being able to save them one hour on overall travel time. We did not indicate the ticket price being more or less than their usual method of travel and operate under the assumption that costs would be held the same so that we could better isolate the point of friction variables. The graph below shows an average of the responses of extremely unlikely from a two-part question. For example, for the “Airstairs & Head bump” The first part details that, *“You are trying an eVTOL Air Taxi for the first time instead of your usual method of travel because it’s a new experience and you think it might be more convenient. You know these aircraft are smaller than most aircraft you have seen or taken before, but when you board the aircraft using a movable stair with no handrail you have to duck to get in the entry and bump your head.”* And the second part details that, *“You have now taken an eVTOL Air Taxi multiple times instead of your usual method of travel because you think it might be more convenient. When you board the aircraft using a movable stair with still no handrail you have to duck to get in the entry and bump your head again.”*

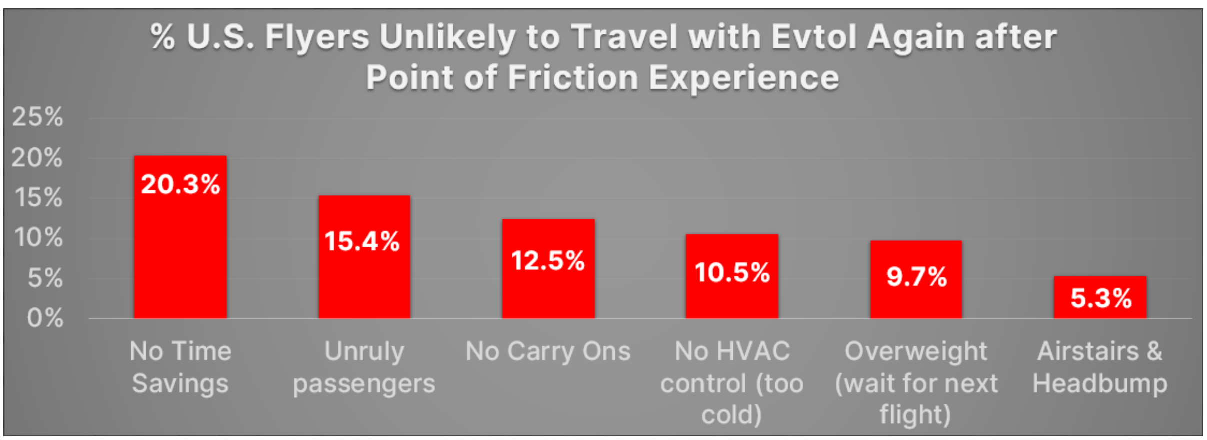


Fig 15. Points of Friction and Unlikeliness to fly again with eVTOL

In every instance, when asked the second part of the question (i.e., they are now more experienced eVTOL travelers who have now taken multiple trips on eVTOL, and it is no longer a new and novel experience) the percentage of those unlikely to travel again with eVTOL increased. This shows that overtime, if these points of friction remain unaddressed, eVTOL operators will face increasing customer attrition.

b) To reveal attitudes regarding time savings respondents were given the following prompt: *"You are trying an eVTOL Air Taxi for the first time instead of your usual method of travel because it's a new experience and you think it might be more convenient. It is advertised that you will save 1 hour of total travel time using this method. How likely are you to try this method of travel on your next trip given the ACTUAL time savings listed below."* Secondarily, respondents were given a second prompt to see what levels of customer attrition would be experienced by operators, if after multiple times of flying eVTOL, their advertised time savings were still not being experienced as advertised: *"You have now taken an eVTOL Air Taxi multiple times instead of your usual method of travel because you think it might be more convenient. It is advertised that you will save 1 hour of total travel time using this method. Although previous trips have not always saved you the amount as advertised. How likely are you to try this method of travel on your next trip given the ACTUAL time savings listed below?"*

As with the other points of friction, people's patience with eVTOL operators deteriorated and respondents were less likely to fly with eVTOL after multiple experiences of a lack of time savings. The graph below shows the average of these two questions showing a rather forgiving populace if the eVTOL flight saves them even a little time. However, it is critical to keep in mind that these responses were made with the following in mind: that ticket fees are assumed to be commensurate with their previous method of travel, and that the experience (despite the lack of time savings) is still convenient.

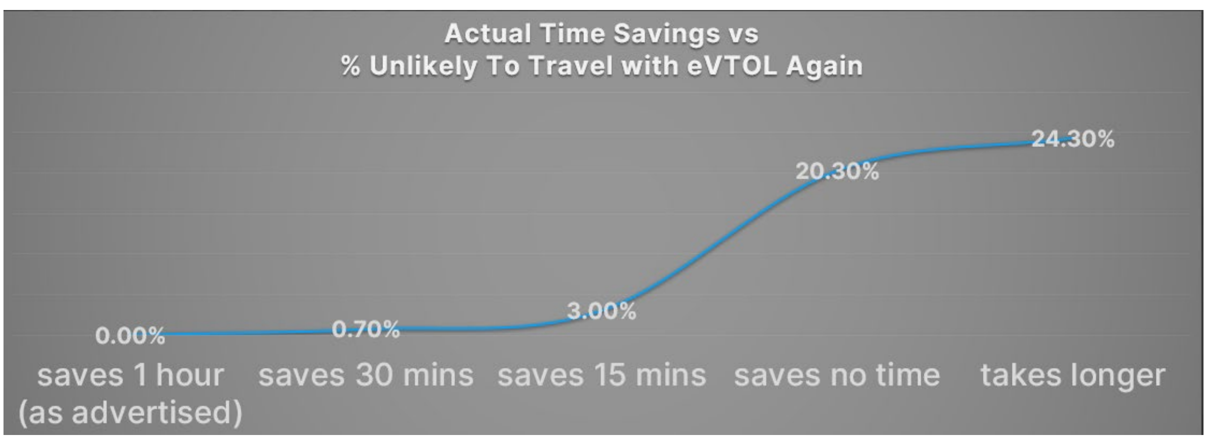


Fig 16. Actual Time Savings and Unlikeliness to fly again with eVTOL

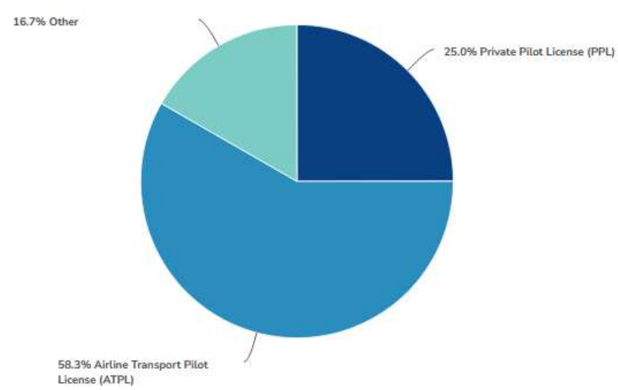
Helicopter & Fixed Wing Pilot Concerns Regarding eVTOL (Specific Focus Group Responses)

a) Pilots were asked how familiar they are with eVTOL.

	Very Unfamiliar	Unfamiliar	Neutral or I'm Not Sure	Familiar	Very Familiar	Responses
- Count Row %	1 8.3%	4 33.3%	1 8.3%	2 16.7%	4 33.3%	12
Totals Total Responses						12

Fig 17. Pilot Familiarity with eVTOL

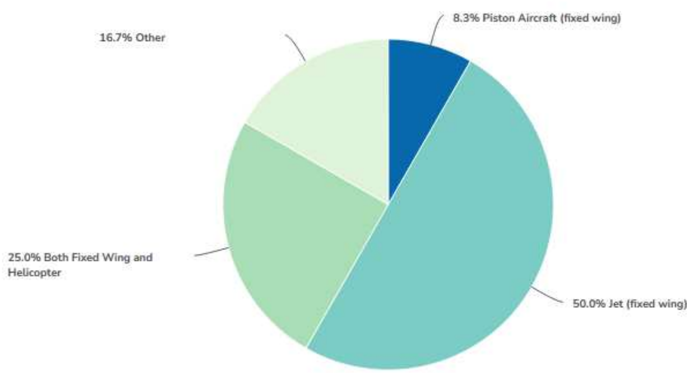
b) Pilots were asked what license/certification level best describes them.



Value	Percent	Responses
Private Pilot License (PPL)	25.0%	3
Airline Transport Pilot License (ATPL)	58.3%	7
Other	16.7%	2

Fig 18. Pilot License/Certification Levels

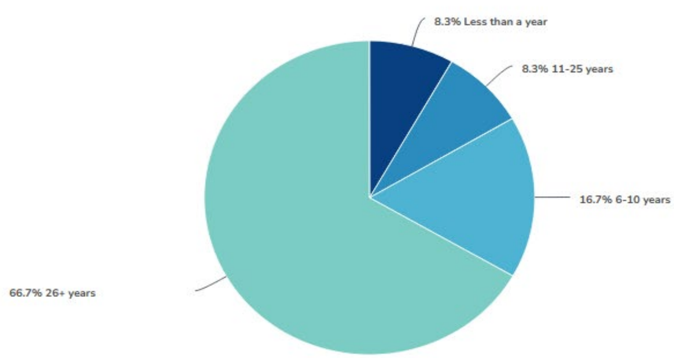
c) Pilots were asked about their aircraft type experience.



Value	Percent	Responses
Piston Aircraft (fixed wing)	8.3%	1
Jet (fixed wing)	50.0%	6
Both Fixed Wing and Helicopter	25.0%	3
Other	16.7%	2

Fig 19. Pilot Aircraft Type Experience

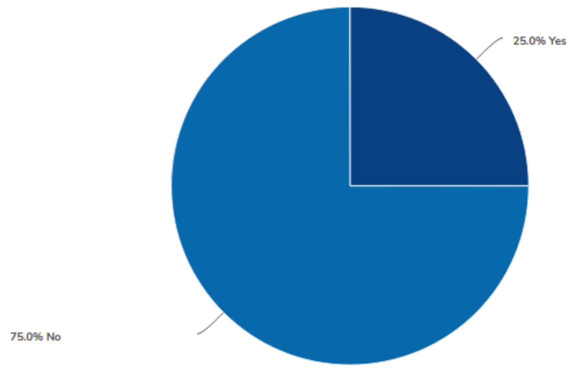
d) Pilots were asked how long they've held their pilot's license.



Value	Percent	Responses
Less than a year	8.3%	1
11-25 years	8.3%	1
6-10 years	16.7%	2
26+ years	66.7%	8

Fig 20. Pilot License Experience

e) Pilots were asked if they've flown for the military.



Value	Percent	Responses
Yes	25.0%	3
No	75.0%	9

Fig 21. Pilot Military Experience

g) Pilots were asked their level of agreement with the following statements.

	Strongly Disagree	Disagree	Neutral / I'm not sure	Agree	Strongly Agree	Responses
eVTOL aircraft are the future of aviation. Count Row %	1 10.0%	1 10.0%	7 70.0%	1 10.0%	0 0.0%	10
It will be easy to adapt to the the flight characteristics of eVTOL aircraft. Count Row %	1 10.0%	3 30.0%	4 40.0%	2 20.0%	0 0.0%	10
As batteries improve, eVTOL aircraft will be safe and capable in most weather conditions, including extreme cold. Count Row %	1 10.0%	2 20.0%	4 40.0%	3 30.0%	0 0.0%	10
The cockpit does not need to be separated by a barrier from passengers on a scheduled commercial flight. Count Row %	5 50.0%	3 30.0%	0 0.0%	1 10.0%	1 10.0%	10
Taking on the additional role of a flight attendant on short commercial flights (1 hour or less) will NOT add significant stress or fatigue. Count Row %	6 60.0%	0 0.0%	0 0.0%	4 40.0%	0 0.0%	10
Assisting passengers load their luggage on to the aircraft will NOT add significant stress or fatigue Count Row %	5 50.0%	2 20.0%	0 0.0%	3 30.0%	0 0.0%	10
Flying twenty 10-minute flights of the same route in one day will NOT impart significant stress or fatigue. Count Row %	5 50.0%	3 30.0%	2 20.0%	0 0.0%	0 0.0%	10

Fig 22. Pilot Opinion on eVTOL

g) Pilots were asked to discuss their main concerns regarding eVTOL aircraft. Their responses are individually summarized below.

1. Dealing with unruly/dangerous passengers: I would be concerned about handling situations involving disruptive or dangerous passengers during eVTOL flights.
   Fleet sustainability using rare earth metal batteries: The use of rare earth metal batteries in eVTOL aircraft raises concerns about the long-term sustainability of the fleet.
   Vertiport security: I am concerned about the security measures and protocols in place at vertiports, which are essential for eVTOL operations.
2. My main concern as an airline pilot would be insuring extensive training for all eVTOL operations specifically around major airports and in busy airspace. The nation's largest airports are already extremely congested so insuring proper traffic management of eVTOL aircraft would be of utmost importance.
3. This pilot shared no specific concerns related to flying eVTOL in the AAM sector.
4. MGWT limits range infrastructure: The limited range imposed by Maximum Gross Weight Takeoff (MGWT) poses challenges for eVTOL operations Vertiport Landing Infrastructure: Particularly in urban areas.
5. This pilot shared no specific concerns related to flying eVTOL in the AAM sector.
6. Separation of airspace and protection for pilots: Battery powered aircraft in my opinion, will fill a niche in the densely populated areas. You will still need conventional aircraft for long-haul flights. Therefore, you will need rules carving out separate air spaces for these two distinctly different aircraft. Regarding safety, how many Uber drivers have been attacked physically while driving their cars? The pilots of these aircraft will need some degree of protection. I imagine these aircraft are highly automated. The flying will not be fatiguing. What's fatiguing will be managing the radios, talking to multiple ATC centers, and avoiding other aircraft. Dealing with people is fatiguing. Ask any service worker.
7. Cost, airspace congestion, and battery weight: Some pilots find eVTOL too expensive for average taxi services in the "real world." They also highlight concerns about increasing airspace congestion due to drones and traditional aircraft operations, along with the weight and energy capacity limitations of batteries.
8. None: Another pilot has no specific concerns to list.
9. Infrastructure and technology readiness: While eVTOL holds promise for addressing noise and fossil fuel use, pilots believe that the current infrastructure and technology are not yet fully prepared to fulfill that role.

Discussion:

This study sheds light on critical concerns voiced by both mass-market consumers (representing potential eVTOL passengers) and pilots within the aviation industry. These issues predominantly revolve around cabin and flight-deck design which influences the fuselage design, emphasizing the significance of designing the overall in-flight experience from the start. Taking inspiration from the visionary Bill Lear, who championed the idea of designing from the inside out, it becomes clear that success hinges on understanding the needs of those onboard.

One point to raise awareness of is the evolving physical dimensions of passengers. The current FAA regulations employ 170-pound male test dummies, not accounting for the fact that the average weight of the American male, aged 20+ years, has now shifted closer to 200 pounds, according to the CDC. Additionally, 95^{th}-percentile "people of size," both male and female, should not be ignored. This prompts important considerations such as spatial maneuverability (headroom), socio-pedal personal space, and the need for ergonomic and adjustable features.

Seating orientation also emerges as a focal point, as passengers value privacy and are concerned about facing one another. This raises questions about the seating layout and the desire to avoid potential conflicts with unruly passengers. Relatedly, the absence of flight attendants onboard raises concerns among passengers and experienced pilots alike. Pilots, who must take on the added role and responsibilities of flight attendants, believe they will have increased stress and fatigue. Not to mention the limited space for passengers' baggage and carry-ons, as well as overall weight limitations, further exacerbates these challenges.

While big windows in eVTOL aircraft offer panoramic views, they also pose challenges in terms of environmental temperature control. The expansive glass surfaces allow solar heat to penetrate the cabin, potentially leading to uncomfortable heat levels. Conversely, the proximity to wide window openings can result in the discomfort of cold elbows, particularly in colder climates. It is crucial to consider that not all eVTOL aircraft are intended solely for VIP or touring purposes. In Gilmores' mass market surveys, they discovered that the issue of being too cold emerged as a clear concern among potential passengers.

Furthermore, eVTOL designers must acknowledge their departure from familiar commercial airline and automotive designs. eVTOL aircraft are generally smaller than commercial aircraft, boast widely different fuselage/cabin shapes & sizes, and feature a greater number of motors and propellers. Additionally, the issue accessibility for disabled persons and controlled egress in landing areas remains largely unaddressed, calling for solutions that prioritize inclusivity and operational safety.

We would also note that across survey response data, females, on average, displayed a more risk-averse nature compared to men. This finding suggests that gender may influence the perception of risk in air travel, with women, on average, exhibiting a greater propensity for risk aversion.

Through a thematic analysis of pilot responses obtained from the focus group, several recurring themes emerged, encompassing safety and operations, technology and infrastructure, separation and protection, cost and readiness, and the positive potential of eVTOL.

In their responses, pilots expressed the fatiguing nature of dealing with humans as a concern in the context of eVTOL operations. They drew parallels to service workers who often encounter fatigue from interacting with customers. Pilots emphasized that while the act of flying eVTOL aircraft may not be inherently fatiguing due to increased automation and reduced physical demands, the challenges lie in managing radios, communicating with multiple Air Traffic Control (ATC) centers, and avoiding other aircraft.

Pilots noted that these communication and coordination tasks require continuous attention and mental effort, particularly in busy airspace or when operating near major airports. The complex nature of managing interactions with various ATC centers and coordinating with ground personnel and other pilots can contribute to mental fatigue. This aspect underscores the need for effective training programs and operational standards that address communication skills, workload management, and situational awareness to mitigate potential fatigue-related risks.

Conclusion:

As the eVTOL industry advances rapidly, it is imperative for designers and manufacturers to heed these insights; both anthropometric and psychological human-factor considerations must be incorporated into design and operational protocol. By working with pilots and by addressing passenger concerns such as seating orientation, safety systems, baggage space, and accessibility, the industry can create airside and landside experiences that ensure comfort and safety. By embracing holistic human-centric design principles using a Human Experience Design approach, eVTOL aircraft will pave the way for a new era of efficient, inclusive, and enjoyable air transportation.

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