Introducing Advanced Aviation Technologies to the General Public

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Abstract

The aviation industry has come a long way since the first scheduled commercial flight in 1914. Some of the larger advancements include the rise of automation through technologies such as fly-by-wire systems and satellite communications, as well as the development of composite materials and their inclusion in commercial airliners. However, the public is still looking for more, particularly the introduction of zero-emission aircraft, greater accessibility, and lower costs. While zero-emission aircraft technology is still in the early development phase, another technology that may open the door to increased efficiency transportation by air is the area of urban air mobility and the broader category of advanced air mobility. While there is a good understanding of the public's perception towards conventional air transportation, the feelings of the general population towards urban air mobility and advanced air mobility are unclear. This paper aims to evaluate past studies conducted on the measurement of public perception surrounding urban air mobility. Past studies have shown that people are not entirely comfortable when it comes to trusting various automated technologies, and the degree to which is investigated here. The findings from this investigation will shape a study to be conducted on the Canadian population regarding the acceptance of advanced aviation technologies. The key topics addressed are the perception of commercial aviation and flight behaviours, feelings toward different autonomous technologies, evaluation of risk through different environmental and security factors,, and lastly, an exploration of the transportation needs of members of the public and how they would plan to incorporate urban air mobility into their lives. Finally, a framework for disseminating survey results and presenting advanced aviation technologies to the public is presented and focuses on engaging the public at every stage of the development.

Keywords: Urban air mobility, public perception, willingness to fly, automation, air taxi, cargo drone, advanced aviation technologies

1 Introduction

Humankind has always relied on manual labor to accomplish everyday tasks. Whether it be for applications such as gathering food or transportation, people would always need to invest some of their own energy towards task completion. The industrial revolution saw a shift towards mechanical intervention to assist people and reduce their energy expenditure. Eventually aviation came along and introduced an entirely new transportation system. In the early days, the flight of an aircraft was heavily based on human inputs, as pilot actions directly controlled aircraft behaviour. As both passenger and military aircraft became larger and more advanced, pilots transitioned to more of a systems management role; their workload focused on specific phases of flight and to act in case of system failures and emergencies. The technological capabilities of aircraft have even reached a stage where the majority of accidents are no longer caused by mechanical failures, but rather human error [1].

Advanced technologies are becoming a more regular part of life with smartphones managing every moment of our day. Throughout the home, devices such as smart refrigerators and robot vacuum cleaners operate without much overthought from their owners. As the world shifts to a greater reliance on automated "smart" technologies, we are beginning to see examples of these technologies in a variety of different locations and industries. The aviation industry is on the verge of another technological revolution with the rise of advanced aviation technologies which include remotely piloted aircraft systems (RPAS) and urban air mobility (UAM). RPAS are becoming increasingly popular with the public and studies have reported that the usage varies by location with 2019 numbers around 13% in Canada [2] and 31% in the United States [3]. On the other hand, most of the public is unfamiliar with the concept of UAM and as such, more work in necessary to better understand the public perception towards this technology.

There are very few studies that directly investigated the public perception of UAM aircraft. The most complete study to date was conducted by Shaheen *et al.* in which a survey, coupled with a series of focus groups examined different factors including willingness to fly, travel needs of participants, previous flight frequency, and environmental and security considerations [4]. Survey respondents expressed excited (31%), happy (22%), or neutral (25%) reactions to the technology with men, younger participants, and wealthier respondents expressing a higher degree of excitement. When asked about trip purpose, it was found that respondents favoured UAM for travel to or from the airport and long-distance recreational trips and passengers would be more comfortable flying with others known to them in comparison to flying alone or with passengers they did not know. There was a strong preference towards the aircraft having a pilot on board, which was in line with surveys measuring willingness to fly on fully autonomous commercial aircraft [5]–[8].

To gain some level of insight on the public perception of UAM, one should look to studies of similar technologies to develop a baseline. For RPAS, sometimes also referred to as unmanned/uninhabited aerial vehicles (UAVs) or "drones", surveys have shown a mixed degree of results with missions such as search and rescue and disaster monitoring gathering higher levels of support than law enforcement or surveillance applications [9]. Demographics also play a role in acceptance rates, with men more likely to support the use of RPAS than women [8], [10] (other than for law enforcement applications [11]), and younger individuals (age 35 and below) are also more accepting of the technology [8], [10]. These results were in line with the UAM study conducted by Shaheen *et al.*[4]. Many of these past surveys indicated that the public is unaware or has a poor understanding of RPAS and their applications [11]. One approach to address this was to use a brief aptitude test consisting of 5 simple true-or-false questions embedded in the survey. Reddy and DeLaurentis used this technique and found that majority of the public answered 2 or 3 questions out of 5 correctly, while those with background on RPAS (hobbyists, pilots, researchers using RPAS, etc.) scored on average between 4 and 5 [10]. By measuring the aptitude, one could divide the results between scores to determine if there is a correlation between score and acceptance rate.

Another field of interest towards better understanding public perception of UAM is autonomous vehicles. Autonomous vehicles (AVs) or self-driving cars have received an incredible amount of attention over the past decade and most major automakers have invested billions of USD into the technology. The Institute of Electrical and Electronics Engineers (IEEE) even projects that by 2040, AVs will account for up to 75% of vehicles on the road [12]. However, as quickly as the market is moving, public acceptance is still the major hurdle to clear before the technology is to become widely adopted. There are several major factors surrounding the public attitude towards AVs including the difference between AV safety and perceived AV safety, the challenges surrounding the programming of the vehicle, and the current regulatory framework for AV operators and manufacturers [13]. AVs are projected to be safer than driver operated vehicles as human error will be eliminated; however, new hazards will arise such as system and sensory failures as well as unexpected vehicle response behaviours to unique environmental factors. A survey by Otonomo found that 74% of people do not trust AV technology [14] and also believe AVs do not perform better than a normal driver. Attitudes such as this may make it difficult to introduce higher degrees of autonomous technologies into society.

From examining these different fields, one can better understand the factors surrounding public perception towards advanced technologies. The main objective of this paper is to apply these past findings on public perception of autonomous technologies into the development of surveys to measure public acceptance of UAM. The four major areas of inquiry of the survey are perception of aviation technologies, feelings toward automation, evaluation of risk, and societal need (Figure 1).

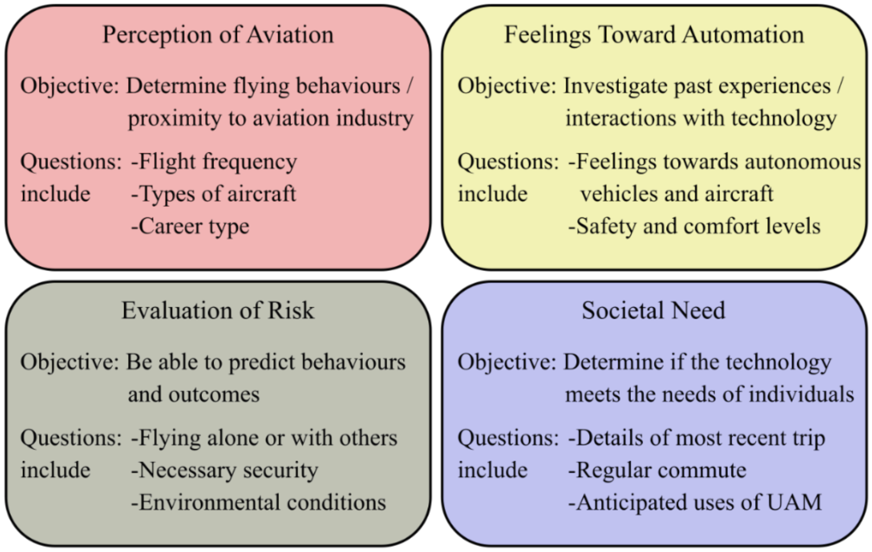

Figure 1: Major areas of inquiry in the survey.

2 Perception of Aviation Technologies

The aim of UAM developers and proponents is to integrate these aircraft into existing transportation networks and provide an alternative mode of transport that can circumvent ground traffic congestion. It could also be useful for intercity travel such as between New York City and Philadelphia or Los Angeles and San Diego. Most UAM concepts in development or production are small (up to 4 passengers) and capable of vertical take-off and landing (VTOL), meaning they could bring people close to their destination if there is an open area or vertiport nearby. Like any new technology, the public will be hesitant to give it a try and this work aims to serve as the basis for developing the survey criteria to better understand the public's position.

The first commercial flight took place in 1914 and lasted just 23 minutes [15]. Since then, the industry took off and today, billions of passenger trips are made every year. The period between 1980 and 2020 is shown in Figure 2 with the number of passenger trips growing by 15% per year up to 2019, meanwhile global population has grown by 1.83% per year over the same time period. There have been several decreases in demand for air travel mainly due to financial crises, disease outbreaks, and war/terrorism incidents; however, the demand has always rebounded. The COVID-19 pandemic resulted in the greatest decrease in travel on record as many jurisdictions introduced movement restrictions and passengers cancelled trips on their own volition that hampered the airline industry. Travel is eventually expected to return to pre-pandemic levels, but many believe this will not happen until at least 2023 [16].

Regardless of the specific reason, the demand for air travel historically declines due to increases in perceived level of risk by the public. One of the key factors for UAM acceptance is reducing the perceived level of risk that the public may have towards the technology. This would likely take time and only be accomplished by demonstrating that the actual level of risk is less than perceived and is on par with risks individuals take in their everyday lives. Regardless, establishing the acceptable level of risk and identifying the different risk factors between UAM and commercial aviation should be one of the major exploratory topics when developing a survey to measure public perception of UAM. Some people may choose not to fly on a commercial flight for any reason and this is important to identify and leads to the following questions:

- How frequently do you fly on a commercial aircraft (prior to the pandemic)?
- Which categories of aircraft have you previously piloted or flown onboard?

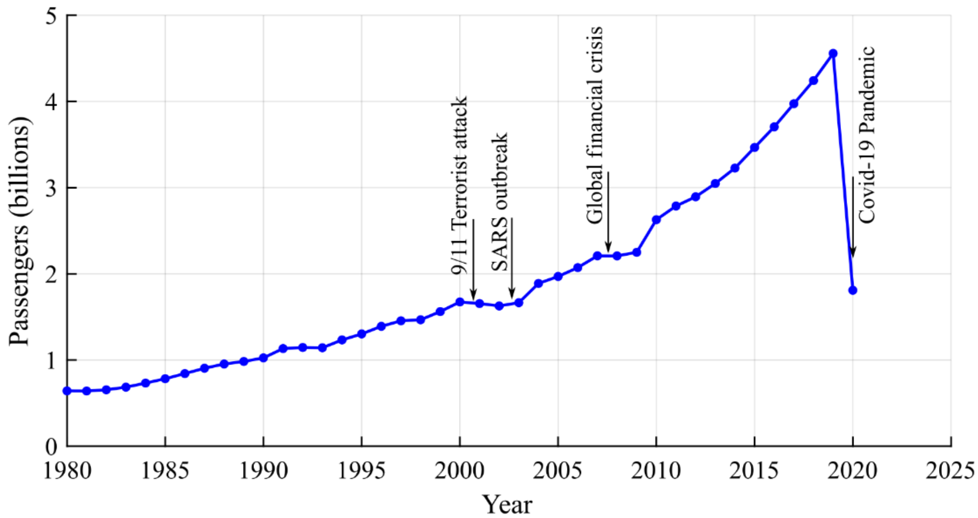

Figure 2: Air passengers carried since 1980. Data obtained from Ref [17].

The authors hypothesize that those who fly frequently and fly in different types of aircraft (large airliner, regional airliner, long range jet, small airplane, helicopter, and recreational aircraft such as ultra-lights and gliders) are less likely to be dissuaded from flying on an UAM aircraft. Flight frequency establishes an approximate demand and comfort level with commercial aviation (relative to the associated costs), whereas type of aircraft makes a difference as there is a higher accident rate for smaller aircraft, suggesting those who fly in smaller aircraft such as recreational aircraft and helicopters are more willing to take risks than those who do not.

3 Automation, Autonomy, and Risk in Commercial Aviation

Over time, the use of automation and autonomy has increased in commercial aviation with the integration of fly-by-wire systems and autopilots into the flight deck. These technologies are even debuting in general aviation aircraft and a study found that most general aviation pilots' level of trust, overall competency, and attitude towards the technology improve after receiving automation training [18]. Furthermore, it was reported that the performance of these pilots significantly improved when the autopilot was used during the flight. This poses the question: if pilots overwhelmingly trust the automation-related technologies used in aircraft, why do these technologies have a poorer perception amongst the public?

Commercial aviation ranks as the safest mode of transport with a fatality rate of 0.07 per billion passenger miles compared to bus (0.11), rail (0.43), vehicle (7.28) and motorcycle (212.57), as presented by Savage [19]. It should be noted that Savage performed this analysis excluding acts of terrorism, sabotage, or suicide as these events bias the data and are generally exclusive to aviation accidents. The International Air Transport Association (IATA) reported a jet hull loss rate of 0.20 per million flights (meaning that there is one major accident every five million flights) for the period between 2016-2020 [20]. These numbers are down from an accident rate of approximately 0.6 per million flights for the period between 2001 and 2010 [21], providing further evidence that as the amount of automation in aircraft increases and pilots are better trained on how to use the technology, the level of risk decreases.

Although, there have been some notable recent aviation accidents that were caused by automation-related technologies. Two of these accidents were caused by system failures on the Boeing 737 MAX 8 aircraft model (Lion Air Flight 610 in October 2018 and Ethiopian Airlines Flight 302 in March 2019) resulting in a grounding of the entire fleet by the Federal Aviation Administration (FAA). The accidents were on the minds of many immediately following the accident; however, an analysis of recent data suggests that passengers made little to no avoidance of the 737 MAX 8 once it had returned to service [22]. This suggests that the poorer public risk perception is a result of the negative press coverage rather than a thorough understanding of the technology and associated risks. This reasoning is in line with results from Anania *et al.* who reported that participants in a survey were more willing to ride in AVs after receiving positive information about them and less willing to ride after receiving negative information about the vehicles [23]. This can be problematic as social media is becoming an increasing utilized source for sharing information and there are very few safeguards to protect the public from misinformation. For example, in a survey about RPAS, 85.5% of respondents indicated that their primary source of information about the technology was from electronic and print media [24], whereas those who use and better understand the technology get their information from a variety of more technical sources such as scientific journals and textbooks [10], [25].

Additionally, in RPAS surveys, those who report having previously experienced flying a drone have fewer privacy concerns [3] and higher levels of acceptance towards the use of drones [10]. A parallel can be drawn to automation, where people not involved in developing, testing, or troubleshooting automated technologies intrinsically have lower confidence towards them due to their relatively little exposure. This problem is exacerbated by the media which tends to report happenings (i.e., anomalies) rather than the status quo. For example, an accident involving an AV would be reported and appear in both print and digital media, whereas motor vehicle accidents rarely appear in these forms unless a headline could be generated to catch the eye of a reader. In fact, these numbers are published by various government agencies (such as the National Highway Traffic Safety Administration in the United States); however, the public does not actively seek out this information. If accidents involving AVs were to be treated in a similar light to conventional automobiles by the media, the public may view the technology more positively.

Although it may not be recognized at first glance, there is actually a significant amount of automation and autonomy in modern day motor vehicles. These features vary in scope from assistive automation (which simplifies a task – such as the automatic unlocking of vehicle doors after the push of a button) to conditional automation (features programmed into the vehicle computers that engage if a set of conditions are met – such as automatic door locking once the vehicle reaches a safe speed). Many of these features have been introduced over time and include the following:

- automatic transmission
- cruise control/adaptive cruise control
- auto-navigation/wayfinding
- automatic lights in poor lighting conditions
- lane departure/blind spot warning systems
- automatic parallel park
- automatic emergency braking

With each of these features, the driver is still in control of the vehicle; however, they have handed over some of the workload to the central control unit. Although these features introduce some degree of automation (and even in some instances, autonomy) into the driving experience, SAE International defines each of these items as driver support features rather than automated driving features [26]. In fact, the SAE designation classifies an adaptive cruise control paired with automatic lane centering as Level 2 automation (where the driver is still in control), whereas anything beyond this, the vehicle is in control and can send alerts to the send alerts to the driver if necessary. Although drivers consistently use the aforementioned features to aid them during their commutes, they often do not make the connection that these features are the introduction of automated technologies into motor vehicles. Since the public overwhelmingly supports these features, the public should be introduced to higher levels of automation in a similar way.

Due to the successful introduction of these automated features into vehicles, we propose a distinction between well-executed automation and poorly executed automation:

- Well-executed automation: the feature presents benefits, and the deficiencies do not attract the attention of the user.
- Poorly executed automation: the user recognizes the actions of the technology and believes they can do better (no matter how true the belief).

For example, a cruise control system on board of an automobile is an example of well-executed automation. The system operates by sensing the current speed of the vehicle in relation to the desired speed and actuates the throttle as required. The system is useful as it reduces driver fatigue during longer trips and saves the average driver fuel. However, the system is not perfect as it lacks a predictive component and will sometimes rapidly increase the throttle to compensate for an increase in force felt by the wheels in a scenario such as a car going up a hill. Although this is the case, the majority of drivers are not bothered by knowing that the upcoming terrain will cause a temporary acceleration of the vehicle and choose to leave cruise control engaged for this segment. The alternative of disengaging the cruise control, accepting a small decrease in speed as the vehicle passes the crest of a hill, and then reengaging the cruise control is more efficient; however, most drivers choose not to invoke this strategy. More modern cruise control systems do have some sensing capabilities; however, would not be able to prevent the aforementioned scenario. Thus, if the public is slowly introduced to well-executed automation features, they will begin to develop a greater level of trust in automation and autonomy, leading to wider acceptance and use of the technology. This justifies including questions such as the following to gauge people's comfort level at present (brackets indicate different variants of the question):

- Do you support the use of self-driving cars?
- Would you be willing to fly [with a pilot on board] / [on a remotely piloted aircraft [with / without] a flight attendant on board] / [on a fully autonomous aircraft [with / without] a flight attendant on board]?
- Would you feel safe [with a pilot on board] / [on a remotely piloted aircraft [with / without] a flight attendant on board] / [on a fully autonomous aircraft [with / without] a flight attendant on board]?

It is hypothesized that answers to these questions could be linked to the previous questions surrounding flight frequency and aircraft type. Those who have flown on small recreational aircraft would feel safe without a flight attendant, whereas others may not. A similar hypothesis can be envisioned for supporting self-driving cars as those involved in the development and testing would have a much clearer viewpoint surrounding their safety. Winter *et al.* suggests that a previous consumer model could be applied to the willingness to ride in air taxis [27]. The first to fly would be the *innovators*, followed by the *early adopters*, then the *early majority*, the *late majority*, and finally the *laggards*. The innovators would include those with a good understanding of the automation and risk involved in the technology while the early adopters would follow the innovators once the technology has been proven safe. Afterwards, the other groups would join in, leading to widespread acceptance of the technology.

Further questions on the topics of automation and risk perception could be explored through focus groups where follow up questions can reveal feelings and more detailed reasoning surrounding willingness to fly. Focus groups can be a useful tool to dive deeper into a particular issue such as risk tolerance to build consumer profiles. They are also valuable as they can be used to put participants through different scenarios to observe their behaviour. Human behaviour is highly variable, and several accidents involving self-driving cars occurred because the individual took an action that the vehicle did not predict [28].

One of the drawbacks of autonomy and machine learning is that the technology is more susceptible to failure during situations where the input conditions can be more difficult to predict. These situations can be caused by either environmental factors (such as low illumination during the evening twilight period or ice accumulation on a roadway) or unexpected behaviours by the human operator or observers. Since these scenarios pose a higher level of risk, it is beneficial to learn if participants are more or less likely to fly if some of these situations are encountered. As such, our survey includes the following questions:

- Would you be willing to fly alone/with people you know/do not know?
- Would you pay a premium fare to fly alone, without any other passengers?
- Should passengers on a UAM go through a security screening process?
- Would you feel comfortable flying in [rain] / [snow] / [fog] / [at night] / [moderate winds and turbulence]?

Recently, there has been an increase in the number of incidents related to unruly passenger behaviour [29]. These events can cause significant consequences such as extreme actions taken by crew members, flight delays, and even cancellations. Passenger behaviour can be modulated by the presence of a flight attendant; however, UAM concept aircraft are small and may not have the space for a flight attendant onboard. As such, establishing the benefit-risk relationship in regard to the presence of other passengers is important for UAM aircraft manufacturers when developing vehicle requirements. The same can be said for the various weather conditions as they determine the operational limits of the vehicle.

4 Societal Needs

The final category of questions deals with societal need. Understanding the current transportation needs of individuals can go a long way towards developing an efficient and effective transit network. While short-term projections for the UAM market see the technology as a supplement to existing infrastructure that passengers would take occasionally for specialized trips, longer term goals would include a more complete integration into public transit and ride-sharing services.

At the city planning level, there are several key considerations for successful integration proposed by the World Economic Forum. These considerations include safety, sustainability, equity of access, low noise, multimodal connectivity, local workforce development, and purpose-driven data sharing [30]. In the short-term, emphasis should be placed on the safety, low noise, and data sharing aspects to demonstrate the capabilities of the technology to the *early adopters* and to rapidly respond to the needs of users. The longer-term outlook should highlight the improvement in environmental outcomes and equitable access in mobility for disadvantaged communities. With investment into UAM technology comes the development of the local workforce as the American Public Transportation Association estimates that every $1 billion invested in public transportation creates and supports approximately 50,000 jobs [31]. Some factors that may make a particular city more attractive for UAM supplementation include city size, population, presence of airport(s), proximity to other large cities, average commute time, and economic sector distribution. City size and population have always driven the need for public transportation while the presence of an airport is important as respondents in the Shaheen *et al.* study selected transit to or from the airport as the second most popular use of UAM after long-distance recreational travel (travel between cities) [4]. Reducing commute times would be one of the key highlights of UAM, making it an appealing option in cities with notorious traffic congestion, while cities with an above average percentage of the population working in the advanced technologies sector would likely serve as good technology demonstration cities as there would be a good number of *innovators* and *early adopters*. With these factors in mind, it is important to gather this data through the survey by asking questions such as the following:

- Describe your most recent trip (trip type, distance, duration, mode(s) of travel).
- How do you typically commute to work or school?
- For which trip purposes would you consider using an Urban Air Mobility aircraft?
- Would you be willing to travel to a vertiport and what is your maximum allowable travel time to the vertiport?

The answers to these questions would go towards ensuring that the UAM solution is sized for the specific market. In the early days of incorporating the technology, perception may still play the biggest factor as survey results for five major U.S. cities showed no difference in willingness to fly despite significant differences in city characteristics, race, education level, and household income [4].

5 Applications of Study Findings

One of the major keys to conducting a successful survey is to have a plan in advance of how the results will be used. This typically involves having partners who are interested in the results and their implications, regardless of the findings. For studies involving UAM, parties interested in the findings would include those in the aviation industry, representatives for the public at large, and the potential regulators in government.

Starting with the aerospace industry, aircraft manufacturers will need to shift their focus from marketing to airlines and flight operators towards building trust with the public. Safety is one of the major concerns when it comes to flying, hence the necessary redesign of the 737 MAX 8 prior to resuming service. Aircraft certification processes are extremely rigorous and aircraft manufacturers have been developing quality products for decades; however, the public may not be aware of the strict nature of aerospace requirements and how they are validated. Thus, if this information can be clearly presented and/or demonstrated to the public, it would go a long way to gaining their trust. Special consideration should also be given to those in the aerospace industry, such as pilots and air traffic controllers so they can interact with the technology and observe some of the benefits first-hand. Specialized training may even be developed to assist air traffic controllers with the task of integrating UAM aircraft into the airspace.

Organizations that represent the public should also be involved as they can allow the researchers to connect with the public by methods that may not have originally been accessible and these groups may have large followings. During the survey distribution and data gathering phase, this allows for a larger recruitment of participants to the survey, while in the results phase it allows for the results to be disseminated to the public in a more complete and transparent manner. If the researchers aim to collect a larger sample from a specific group of people, this method is particularly useful. In the case of this survey, the researchers are interested in recruiting those from the aviation industry and thus, have circulated the survey amongst pilots, air traffic controllers, engineers, and researchers in addition to having a group comprised of 1000 participants (recruited by Qualtrics) that is representative of the Canadian population.

Survey results should also be used by the media to inform decisions on how the technology is portrayed. As with the case of RPAS, the majority of the public receives their only exposure to the technology through the media. Most people recognize the term drone; however, this term was found to have the most negative association when compared to similar terms (such as RPAS and unmanned aerial vehicle) [8]. Some have even suggested that the word drone not be used in surveys as participants will provide a more negative response [32]. Similar to the case of automation in vehicles, if the public is presented with information about the technology that makes UAM possible, it will lead to greater acceptance. Many have recommended that programs be setup to bring people closer to the technology, such as those that have been done for RPAS, is the key to widespread acceptance [3], [24]. However, the best method and organizer for such a program has not been well established.

Finally, the government has a role to play as they need to develop policies that are in the best interest of the public. The most important role is to keep people safe, thus by regulating UAM similar to the remainder of the aviation industry would invoke the well-established safety practices, while giving the public trust that the airspace above cities is looked after. Studies have indicated that the public favours government regulation surrounding the use of RPAS, with 88% of respondents indicating it was important in one study [33]. Listening to the results of perception studies allows for informed policy making and a better understanding of where the public falls on certain issues. A government that takes a proactive approach to introducing the public to advanced aviation technologies will likely see a larger return on investment with higher acceptance and a greater percentage of the population willing to use the technology.

6 Conclusion

This article presents the major considerations in developing a public perception study about the use and future development of UAM in society. By investigating the current flight behaviours of participants, one can gauge the desire to fly amongst the public and project if those behaviours will translate to UAM aircraft. Understanding respondent feelings towards automation can be used to determine where the public stands on autonomous aircraft at present and what will need to be done to improve their perception. Incorporating risk into the equation allows for a scientific element to see if the public's reservations are due to safety concerns or other feelings. Questions relating to societal need shows the purpose and frequency of how the public would use the technology. Finally, once all the results have been collected and processed, survey organizers must have a plan for how the results will be distributed to maximize their reach. Together, when all these aspects are combined, one can see a framework for improving public acceptance rates for advanced aviation technologies. In addition to the topic of urban air mobility, future surveys should address alternate applications of autonomous technologies, such as in vehicles or industrial applications.

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