Case Studies on Transport Policy 10 (2022) 500–506

Contents lists available at ScienceDirect

Case Studies on Transport Policy

journal homepage: www.elsevier.com/locate/cstp

Vertiport and air taxi features valued by consumers in the United States and India

Stephen Rice [a], Scott R. Winter [a,*], Sean Crouse [a], Keith J. Ruskin [b]

[a] Embry-Riddle Aeronautical University, 1 Aerospace Blvd., Daytona Beach Fl 32114, United States
[b] University of Chicago, 5841 S Maryland Avenue, MC4028, Chicago, IL 60637, United States

ARTICLE INFO

Keywords:
Vertiports
Air taxis
Safety
Security
Consumer perceptions

ABSTRACT

Background: Urban Air Mobility aircraft (UAMs) have been proposed as a fast, efficient way to move people through congested areas. However, while nearly everyone is familiar with commercial airline operations and assume they are safe, UAMs remain a nascent product that have yet to be widely understood by the public. In this study, we identify factors that might affect the flying public's choice of vertiports and air taxis.
Methods: We sampled 1125 people from the United States and India. In stage 1, participants were asked to identify concerns regarding vertiports and UAMs. In stage 2, they were asked to rate the importance of each concern.
Results: We found that potential passengers are primarily concerned about UAM safety and security, both for vertiports and UAMs. Convenience items also appeared, but were generally rated as less important than safety and security items.
Discussion: Future vertiport and air taxi developers will benefit from a better understanding of potential passengers' concerns. Messaging should include education about how safety and security is ensured for both UAMs and vertiports.

1. Introduction

Urban Air Mobility vehicles (UAMs) have been proposed as a fast, efficient way to move people through congested areas. UAM is a "safe and efficient air traffic operations in a metropolitan area for manned aircraft and unmanned aircraft systems" (Thipphavong et al., 2018). UAM operations can include parcel delivery and passenger services for both civilian and governmental agencies. Gipson (2019) estimates that by 2030, there will be up to 500 million flights per year for package delivery and 750 million flights per year for air transportation.

As urban areas continue to develop, the increase in ground transportation will also increase. Aviation has the unique advantage to be able to avoid heavily congested roads and construction. A study of the adoption of UAM in Silicon Valley found that air travel was three to six times faster than ground transportation (Antcliff et al., 2016). While the demand for UAM solutions continues to increase, an understanding consumer concerns for the implementation of these services is essential, and there is a paucity of research on potential passengers' concerns. We hypothesize that potential UAM passengers have specific questions about the safety and convenience of these operations. Addressing these concerns may be essential to the success of commercial UAM operations.

2. Literature review

UAMs have been described as a "revolutionized way to move people within and around cities by shortening commute times, bypassing ground congestion, and enabling point-to-point flights across cities" (Shaheen et al., 2018, p. 6). In response to this opportunity, a variety of new and established aerospace manufacturers are developing vertical take-off and landing (VTOL) aircraft. These aircraft can reduce the need for large facilities and will allow UAMs to operate in urban environments, move passengers quickly, safely, and efficiently. Electric VTOL (eVTOL) aircraft offer the additional advantages of quiet operations and reduced (or zero) emissions.

Commuters in the United States and other countries experience high levels of congestion when traveling on roads and highways. In 2019, the *traffic indices* (the time that traffic congestion would add to what should be a 30-minute drive) for Los Angeles, New York City, and San Francisco were 42%, 37%, and 36%, respectively (TomTom, 2020). For example, a 30-minute drive in Los Angeles would take 42% longer, or 42.6 min, due

* Corresponding author.
E-mail address: scott.winter@erau.edu (S.R. Winter).

https://doi.org/10.1016/j.cstp.2022.01.010
Received 21 October 2021; Received in revised form 5 January 2022; Accepted 13 January 2022
Available online 31 January 2022

to traffic congestion. UAMs may not, however, be an ideal solution for routine travel within cities. Pukhova et al. (2021) compared a model of UAM transportation within selected urban environments and found no reduction in the distance that would be traveled by automobile. Moreover, when transportation to vertiports is included, the distance traveled by automobile was slightly increased. Pukhova concluded that UAMs may not alleviate congestion but could serve selected markets such as emergency transportation or longer trips between remote areas, between which other transportation networks are not as well developed.

2.1. UAM demand

Planning for the development of vertiports requires an understanding of the demand for UAM flights, and several models of UAM utilization have been developed. Haan et al. (2021) found that demand for UAMs is concentrated in a small number of urban areas. In their study, New York City, Los Angeles, and Washington, DC would be responsible for 33% of the overall demand for UAM operations. Rajendran et al. (2021) developed a model that predicts the level of demand (categorized as *Low*, *Moderate*, and *High*) for UAMs during specific time periods and at various locations. Factors related to service (e.g., vertiport locations, distance, time of the day, and day of the week) and environmental factors (e.g., temperature, adverse weather, and visibility) were found to affect the demand for UAM transportation. Other models of UAM demand in an urban environment predicted that passengers' willingness to fly had a linear effect upon number of aircraft, while the distance of surface travel had an exponential effect (Rajendran and Shulman, 2020; Rajendran, 2021). With an estimated utilization rate of 66%, the number of UAMs required to provide efficient service in New York City was estimated to be 84 vehicles.

2.2. UAM air taxi research and development

Multiple UAMs are currently under development, including an electric VTOL (eVTOL) aircraft currently being tested by Volocopter GmbH (Bruchsal, Germany). Volocopter's eVTOLs are designed to provide UAM taxi services in major metropolitan areas (Volocopter, n.d.). Joby Aviation has developed a working eVTOL, expects to begin commercial operations in 2023, and has already applied for US Federal Aviation Administration certification as a Part 135 commercial air taxi operator (Khalili, 2020). Wisk is a joint venture between the Boeing Company and Kitty Hawk Corporation that has also developed an eVTOL that can fly over ground traffic. Wisk (2021) has designed their aircraft to be used in areas that include airports, rooftops, and parking lots. Established aerospace manufacturers such as Airbus, Lilium, Kitty Hawk, Bell, Embraer, Hyundai, Rolls-Royce, and Toyota are also working in the Air Taxis Services market (Rajendran & Srinivas, 2020).

Safe and efficient deployment of UAMs requires that they ultimately operate with a high level of automation. Endsley and Kaber (1999) have defined five levels of automation: manual control, decision support, automation with operator consent, monitoring with automatic implementation unless vetoed, and full automation with no operator interaction. The FAA has described UAM automation as falling into "human-within-the-loop, in which a pilot is always in direct control of the automation; "human-on-the-loop," wherein the pilot supervises and monitors the automated systems and can take full control if necessary' and "human-over-the-loop," during which the pilot passively monitors the UAM and can be engaged by the automation to intervene when necessary. This assumes that a pilot will be on board the aircraft with access to flight controls during the initial and midterm stages of UAM integration into the national airspace system. Fully autonomous operation with no pilot on board may only be considered after UAMs have reached maturity. NASA has further identified six levels of UAM Maturity (UMLs) (Fig. 1).

2.3. Vertiports

Full implementation of UAMs requires the development of an extensive vertiport infrastructure. Under the US Federal Air Regulations, a *vertiport* is defined a heliport, but no refueling, maintenance, repair, or storage is permitted (Zoldi, 2020). Vertiports require space for a touchdown and liftoff area that includes a final and takeoff path and a safety area, taxiways, staging areas, and gates. Vertiport capacity is governed by operational parameters that include taxi time, turnaround time, UAM staging, and the characteristic of specific approach and departure procedures (Vascik and John Hansman, 2019). Several design considerations for vertiports have been proposed, including a linear topology, a satellite topology, and a "pier" topology, among others. Each of these approaches has features that are designed to maximize passenger and UAM throughput in a constrained, urban space.

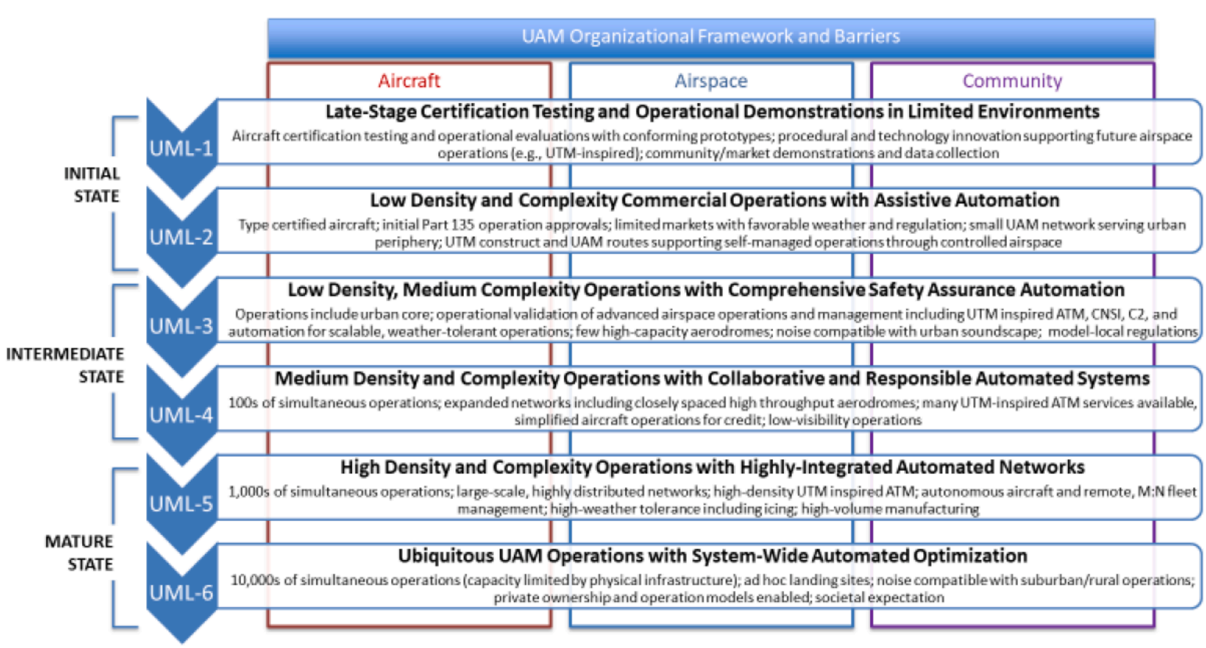

Fig. 1. In-Depth Description of the Various UAM UMLs. *Note*. From the UAM Vision ConOps/UAM Maturity Level 4 (NASA, 2021), in the public domain.

Consumer support for additional vertiports in metropolitan areas may be negatively impacted by factors that affect health, safety, and quality of life. Noise has been cited as a primary impediment to the development of new vertiports (Tokarev and Makarenko, 2021). Ferretto et al. (2021) describe the effects of congestion, crashes, and noise and air pollution on human health and quality of life and then use a major European metropolitan area as an example of how these external factors could be mitigated.

The locations with the highest demand for UAMs, and therefore vertiports, are expected to be in high-density urban environments with limited space. Some environments, such as San Francisco, have little or no open space for new vertiports, which would require situating them on rooftops or other locations that may not accommodate more than three UAMs at a time (Rimjha and Trani, 2021). Vertiports must therefore be designed to maximize the number of operations within a compact surface footprint. Additional design factors include passenger convenience, the ability for passengers to easily move from one UAM to another for connecting service, adequate parking for both passenger operations and charging of eVTOL aircraft, and safe departure and arrival operations (Zelinski, 2020). Numerous studies have explored the infrastructure requirements of UAM vehicles (Batty et al., 2012; Caragliu et al., 2011; Niklaß et al., 2020; Preis et al., 2021; Rothfeld et al., 2018; Straubinger et al., 2020; Taylor et al., 2020). Adapting existing heliports (German, 2019; Kleinbekman et al., 2018) to better fit the needs of UAM operations has also been proposed as a solution to these problems. Taking advantage of existing resources may speed the implementation of UAMs.

2.4. Cultural considerations

UAMs represent a potentially disruptive new technology, and potential users may therefore education as to their benefits and safety features. In a recent study of public UAM acceptance, al Haddad et al (2020) found that potential passengers expressed their affinity to automation, concerns about safety and trust, and other factors. Factors such as socio-demographics, the value of time savings, costs, and service reliability, were also highly. This study implies that cultural differences may also affect the adoption of UAM aircraft and vertiports. The effects of nationality and ethnicity upon perceptions of autonomous flight systems has been extensively studied (Ragbir et al., 2018; Rice et al., 2019; Winter et al., 2020). Although these studies did not explore consumer' expectations of the technology, they did explore willingness to fly in various scenarios. These scenarios highlighted considerable cultural differences when faced with decision-making.

The populations of the United States and India differ with respect to their culture and mindset about aviation. Prior studies have shown that people from the United States are individualistic while those from India tend to adopt a more collective attitude (Hofstede, 1980, 2001; Markus & Kitayama, 1991; Robbins et al., 2013). People living within individualist cultures tend to be motivated through personal gain, while collectivists' cultures will sacrifice individual benefits for the benefit of society (Ball, 2001). These cultural differences may influence how individuals perceive comfort and convenience. Individuals who are motivated through personal gain would likely want items have a direct benefit to them, while people living in collectivist cultures tend to value increasing comfort and convenience for all. These might include items that enhance safety, such as first aid devices or fire extinguishers, or other various items that are beneficial to the entire group.

Hofstede's cultural value by nation index can be used to identify if a country is more individualist or collectivistic (Hofstede, 1980). Using this index, the United States is scored 91 out of 100, (Clearly Cultural, n.d.) making it a highly individualist society. Conversely, India scored 48 out of 100 (Clearly Cultural, n.d.), suggesting a more collective society. Urbanek (2021) explored consumer perception of using public transportation in Poland, which scores a 60 out of 100 on Hofstede's cultural index (Clearly Cultural, n.d.), and found that speed is a key factor influencing the selection of a mode of transportation, and that despite a small increase in total travel time and additional cost, respondents would rather travel by private car than on public transportation (Urbanek, 2021).

Additionally, cultural differences influence the way consumers perceive and respond to risks. Rice et al. (2014) explored passenger perceptions between participants in the United States and India about autopilots for commercial flights. They found participants from the United States to express positive thoughts about a human pilot and respond negatively to autopilots and remote-controlled piloted aircraft. Americans also have more trust in a human pilot than Indian participants (Rice et al., 2014). This finding is consistent with studies that find collective cultures are more willing and trustworthy of automation than that of an individualist culture (Wu & Jang, 2008) and collective cultures are more likely to be early adopters of new technologies (Wu et al., 2020). While the Rice et al. (2014) study examined commercial airlines, its findings may apply to the acceptance of the technology and cultural impacts on consumer preferences.

2.5. Current study

The current study evaluates consumer perceptions regarding desired features in vertiports and air taxis and factors that consumers expect in the design of vertiports and air taxis. Two studies were conducted with two stages in each study. Study 1 focused on participants from the United States while Study 2 examined participants from India. Except for the population surveyed, the two studies were identical. In Stage 1, participants were asked to generate the items, which reduced the possibility of bias introduced by the members of the research team. In Stage 2, participants provided a rating of each item generated in Stage 1, creating a ranked order of importance. From these ranked ordered variables, items could be reviewed to determine themes within the ranked ordered lists.

3. Study 1: United States

3.1. Study 1: Stage 1 – Methods

3.1.1. Participants

One hundred and seventy (86 females) people took part in the study. The mean age was 36.60 ($SD = 10.61$). Participants were recruited from Amazon's Mechanical Turk (MTurk), which is a platform by which participants can access and complete surveys for monetary compensation. MTurk has been shown to provide data at least as reliable as laboratory data, with equal or better external validity than typical university "subject pool" data (Buhrmester et al., 2011; Germine et al., 2012; Rice et al., 2017).

3.1.2. Materials and stimuli and procedure

Participants first signed an electronic consent form, followed by reading instructions for the study. These instructions included definitions of Vertiports and Air Taxis. Participants were then presented with the following: In the context of a Vertiport, please enter 5 items that you feel should be present at every vertiport (e.g., a drink machine or a waiting lounge, etc.). This was repeated for UAMs. After participants had provided the items, they were asked for their demographics, debriefed, and compensated.

3.1.3. Ethics

This research followed ethical protocol for human participants research, with oversight from the Institutional Review Board at the authors' university. All researchers have current CITI certificates, and all participants were provided with consent forms.

3.2. Study 1: Stage 1 – Results

Ninety-six unique items were listed for Vertiports, and 114 unique items were listed for Air Taxis. These items were included in Stage 2.

3.3. Study 1: Stage 2 – Methods

3.3.1. Participants

Two hundred and five (68 females) people took part in the ranking of Vertiport items. Two hundred and three (79 females) people took part in the ranking of Air Taxi items. The mean age was 37.40 ($SD = 10.32$). Participants were again recruited from Amazon's Mechanical Turk (MTurk).

3.3.2. Materials and stimuli and procedure

Participants first signed an electronic consent form and then read instructions for the study. As with Stage 1, these instructions included definitions of Vertiports and UAMs. Participants were then presented with the following: In the context of a Vertiport, please rate the importance of having each of the items below in a Vertiport. Participants provided their rating on a scale from Not at all important (0) to Extremely Important (4). This was repeated for UAMs. Once participants had provided their ratings, they were asked demographics questions, debriefed, and compensated.

3.4. Study 1: Stage 2 – Results

3.4.1. Vertiports

Table 1 presents the Top 35 items from this stage. As the data shows, the most important item that consumers want in a Vertiport is an Emergency Exit. The other top items show that consumers want safety and security services, along with basic amenities like restrooms, clocks, and check-in counters.

Table 1
Top 35 ranked items for Vertiports by consumers from the United States. Scale ranges from 0 to 4.

Mean	SD	SE	Item
3.03	1.06	0.07	[Emergency exit]
2.95	1.06	0.07	[Restrooms]
2.91	1.04	0.07	[Security cameras]
2.91	1.06	0.07	[Security personnel]
2.91	1.10	0.08	[Emergency phone]
2.89	1.01	0.07	[Clock]
2.87	1.05	0.07	[Fire extinguisher]
2.87	1.02	0.07	[Check-in machine]
2.85	1.06	0.07	[Emergency kit]
2.85	1.05	0.07	[Check-in counter]
2.83	1.02	0.07	[Customer service]
2.82	1.07	0.08	[Comfortable seating]
2.78	1.06	0.07	[Charging station]
2.77	1.11	0.08	[First aid center]
2.77	1.06	0.07	[Parking lot]
2.75	1.08	0.08	[Hand sanitizer]
2.74	1.05	0.07	[Free wifi]
2.74	1.03	0.07	[Waiting area]
2.74	1.04	0.07	[Schedule board]
2.74	1.08	0.08	[Trash cans]
2.73	1.02	0.07	[Attendant]
2.72	1.02	0.07	[Information desk]
2.72	1.08	0.08	[Ticket counter]
2.71	1.07	0.07	[ATM machine]
2.70	1.08	0.08	[Good lighting]
2.70	1.12	0.08	[Restroom]
2.69	1.05	0.07	[Electrical outlets]
2.68	1.11	0.08	[Safety supplies]
2.68	1.02	0.07	[Air conditioning / heating]
2.67	1.06	0.07	[Air filtration]
2.65	1.05	0.07	[Travel schedules]
2.62	1.10	0.08	[Maps]
2.61	1.12	0.08	[Napkins]
2.61	1.03	0.07	[Vending machine]
2.60	1.10	0.08	[Sanitation area]

3.4.2. UAMs

Table 2 presents the data from this stage. The data again shows that safety and security is the top concern among consumers. They want safety belts, fire, and other emergency remediations, along with secondary convenience items to make the trip more pleasurable.

3.5. Study 1 – Discussion

The data from Study 1 was straightforward. Most participants were interested in ensuring that safety and security features and equipment were present in both vertiports and air taxis. Convenience items were also listed, with a strong focus on comfort and stellar service.

4. Study 2: India

4.1. Study 2 – Introduction

The purpose of Study 2 was to examine any possible differences in attitudes between Americans and Indians. This study was conducted identically to Study 1, except that all participants were recruited from India.

4.2. Study 2: Stage 1 – Methods

4.2.1. Participants

One hundred and thirty-three (46 females) took part in the study. The mean age was 29.82 ($SD = 5.89$). As with Study 1, participants were recruited from Amazon's Mechanical Turk (MTurk).

4.2.2. Materials and stimuli and procedure

Study 2 was identical to Study 1 except that participants were

Table 2
Top 35 ranked items for Air Taxis by consumers from the United States. Scale ranges from 0 to 4.

Mean	SD	SE	Item
3.48	0.83	0.06	[Safety belts]
3.42	0.85	0.06	[Fire extinguisher]
3.41	0.90	0.06	[Emergency doors]
3.36	0.84	0.06	[Lights]
3.33	0.91	0.06	[First aid kit]
3.32	0.80	0.06	[Air conditioning]
3.26	0.79	0.06	[Comfortable seating]
3.22	1.06	0.07	[Emergency controls]
3.22	0.91	0.06	[Windows]
3.19	1.04	0.07	[Emergency landing button]
3.19	1.08	0.08	[Life jackets]
3.14	0.86	0.06	[Air vents]
3.14	1.10	0.08	[Oxygen masks]
3.08	1.10	0.08	[Safety manual]
3.08	0.92	0.06	[Climate control]
3.06	1.21	0.08	[Restroom]
3.05	0.92	0.06	[Central air]
3.01	1.06	0.07	[Communication system]
3.00	1.12	0.08	[Rope ladder for emegencies]
2.96	0.96	0.07	[Baggage compartment]
2.96	1.12	0.08	[Handicap seating]
2.94	1.00	0.07	[Leg room]
2.86	1.06	0.07	[Garbage bin]
2.81	1.11	0.08	[UVC ventilation system]
2.80	1.03	0.07	[Head rest]
2.80	1.16	0.08	[Control panel]
2.79	1.06	0.07	[Information display]
2.78	1.02	0.07	[Charging ports]
2.77	1.07	0.08	[Arm rest]
2.77	1.19	0.08	[Free Wi-Fi]
2.74	1.10	0.08	[Window shades]
2.73	1.17	0.08	[Defibrillator]
2.70	1.16	0.08	[Electrical outlets]
2.67	1.28	0.09	[Hand sanitizer]
2.67	1.07	0.08	[Fans]

recruited from India rather than the United States.

4.3. Study 2: Stage 1 – Results

One hundred unique items were listed for Vertiports, and 88 unique items were listed for Air Taxis. These items were included in Stage 2.

4.4. Study 2: Stage 2 – Methods

4.4.1. Participants

Two hundred and eight (56 females) people took part in the ranking of Vertiport items. Two hundred and six (48 females) people took part in the ranking of Air Taxi items. The mean age was 30.69 ($SD = 5.06$). Participants were again recruited from Amazon's Mechanical Turk (MTurk).

4.4.2. Materials and stimuli and procedure

Study 2 was identical to Study 1 except that participants were recruited from India rather than the United States.

4.5. Study 2: Stage 2 – Results

4.5.1. Vertiports

Table 3 presents the data from this stage. The top items show that consumers want safety and emergency services, along with healthy food, medical services, and convenience items.

4.5.2. Air taxis

Table 4 presents the data from this stage. The top items are dominated by safety and emergency services. Following these are requests for convenience items.

Table 3
Top 35 ranked items for Vertiports by consumers from India. Scale ranges from 0 to 4.

Mean	SD	SE	Item
3.04	0.95	0.07	[Emergency services]
3.03	0.98	0.07	[Emergency exits]
3.02	0.91	0.06	[Healthy food]
3.02	0.91	0.06	[Emergency alarms]
3.00	0.99	0.07	[First aid kit]
2.97	0.96	0.07	[Hand sanitizer]
2.97	0.95	0.07	[Security checkpoint]
2.97	1.02	0.07	[Air ambulance]
2.97	1.00	0.07	[Bathroom / restroom]
2.94	1.01	0.07	[Medical center]
2.94	0.97	0.07	[Safety instructions]
2.94	0.99	0.07	[Customer service center]
2.94	1.01	0.07	[Fire hydrant]
2.92	0.97	0.07	[Flight information display]
2.91	0.93	0.06	[Mobile charging station]
2.91	0.94	0.07	[Information desk]
2.90	0.96	0.07	[Check-in counter]
2.90	0.96	0.07	[Communication board]
2.89	0.95	0.07	[Ticket counter]
2.88	0.95	0.07	[Safety zone]
2.88	0.91	0.06	[Charging ports]
2.86	0.97	0.07	[Sanitary pads machine]
2.86	1.03	0.07	[Chairs]
2.86	0.95	0.07	[Garbage bins]
2.85	0.97	0.07	[e-money payment system]
2.85	0.93	0.06	[Secure approach zone]
2.83	0.95	0.07	[Baggage storage]
2.83	0.97	0.07	[Parking lot]
2.82	1.01	0.07	[Clocks]
2.82	1.02	0.07	[Handicap seating]
2.81	0.98	0.07	[Escalators]
2.81	0.96	0.07	[Air purifier]
2.78	0.94	0.07	[Free Wi-Fi]
2.78	1.02	0.07	[Clear marking and lighting]
2.76	1.07	0.07	[Child care room]

Table 4
Top 35 ranked items for Air Taxis by consumers from India. Scale ranges from 0 to 4.

Mean	SD	SE	Item
3.12	0.95	0.07	[Emergency button]
3.10	0.90	0.06	[First aid kit]
3.08	0.89	0.06	[Emergency equipment]
3.06	0.94	0.07	[Emergency kit]
3.05	0.91	0.06	[Emergency exits]
3.04	0.93	0.07	[Emergency display]
3.03	0.91	0.06	[Seatbelts]
3.02	0.95	0.07	[Life jackets]
3.00	0.89	0.06	[Fire extinguisher]
2.98	0.93	0.07	[Emergency phone]
2.94	0.97	0.07	[Parachute]
2.94	0.89	0.06	[Lights]
2.93	0.96	0.07	[Safety manual / instructions]
2.93	0.94	0.07	[Security]
2.92	0.97	0.07	[Oxygen masks]
2.91	0.87	0.06	[Water bottles]
2.89	0.98	0.07	[Comfortable seating]
2.87	0.97	0.07	[Oxygen level indicator]
2.86	0.91	0.06	[Temperature controls]
2.86	1.02	0.07	[CCTV]
2.85	0.90	0.06	[Charging ports]
2.85	1.03	0.07	[Restrooms]
2.85	0.90	0.06	[Child seats]
2.84	0.92	0.06	[Luggage space]
2.84	0.95	0.07	[Ventilation system]
2.83	0.91	0.06	[Large windows]
2.83	0.96	0.07	[Air purifier]
2.82	1.06	0.07	[Wash room]
2.81	0.93	0.06	[Sanitizing wipes]
2.80	0.96	0.07	[Maps]
2.80	0.93	0.06	[Air pressure meter]
2.78	0.99	0.07	[Wheelchair access]
2.74	1.06	0.07	[Attendant(s)]
2.73	0.90	0.06	[ANA communication board]
2.73	0.95	0.07	[Noise control]

4.6. Study 2 – Discussion

The data from Study 2 closely mirrored that of Study 1. There appeared to be more of a focus on safety and security features, with some minor differences in how important comfort items were rated. In general, as with Americans, Indian participants wanted to ensure that safety was of paramount importance to future developers of vertiports and air taxis.

5. General Discussion

In this study, we explored consumers' opinions about features that are essential to the development of vertiports and air taxis. UAM services have been forecasted to grow to up to 500 million flights per year (Gipson, 2019), significantly altering the urban transportation dynamic. Consumer perceptions will play a major role in the ultimate success of the UAM industry. Vertiports, and the UAM ecosystem are still in the early stages of development, which is the best time to assess which items are desirable and incorporate them into the design and construction of vertiports.

5.1. Theoretical applications

Vertiports. Participants from both countries identified items related to vertiport safety, or the protection of passengers and the public from harm (e.g., emergency exits, emergency alarms/telephones), security, or protection against deliberate threats (*e.g.*, security cameras, checkpoints), and convenience/comfort (*e.g.*, restrooms, customer service). These findings are consistent with those of a systematic review by Garrow et al. (2021). Because the proposed length of flights on UAM vehicles are relatively short (approximately 30 min) and across larger metropolitan areas (Thipphavong et al., 2018), it is possible that consumers will use these services as a way to commute to and from work (Shaheen et al., 2018).

Air Taxis. In our study, consumers focused primarily on safety items (e.g., emergency equipment, emergency exits). As with vertiports, the primary concern for consumers was related to perceived safety. This may guide stakeholders' research and development efforts and highlights a need for messaging about the safety of air taxi operations. If UAMs ultimately fly autonomously, passengers should be carefully briefed on safety features in the absence of a human pilot or flight attendant.

Cultural Differences. The final goal of the study was to compare the desired items for vertiports and air taxis across two nationalities: the United States and India. In general, there were few differences in the themes generated from the list of items produced. These findings suggest that passengers from at least two large countries exhibit similar preferences, with minor differences in the features they feel would enhance the experience of using UAMs, specifically vertiports and air taxis.

5.2. Practical applications

We found specific items that may help government organizations, manufacturers, and researchers to develop the UAM ecosystem. In general, participants from both India and the United States asked for similar features in vertiports. Participants identified safety and security features at vertiports, while the features most requested for UAMs focus primarily on safety. In addition to their apparent importance to consumers, the consistency of these themes suggest a focal emphasis area for stakeholders within the UAM field. Consumer acceptance will be one of the main pillars that help determine the successful deployment of the UAM platform. Vertiport developers may therefore wish to focus primarily on safety, security, and convenience in vertiport design. Features related to safety and security in the design of vertiports and UAMs should then be included in messaging to consumers. Stakeholders should develop messaging that highlights these features when educating potential passengers about the benefits of UAMs. Future studies should investigate how measures related to safety and security further influence consumers' willingness to use vertiports and willingness to fly in UAMs.

5.3. Limitations

This study has several limitations. We conducted a cross-sectional study, so the data that we collected represent consumers' views at a single point in time. There were some differences in means and standard deviations of age between the participants from India and the United States, with Americans being 6–7 years older, and having a wider range of ages. Consumers' perceptions of UAMs and vertiports will likely evolve as the public becomes more familiar with this mode of transportation. Future studies can map these perceptions in a longitudinal fashion. We also surveyed a convenience of the public sample using Amazon's MTurk, with a further restriction to two countries. This may affect the generalizability of the findings to other nations. Lastly, the current study investigated perceptions only of vertiports and UAMs. Other parts of this ecosystem may influence the overall consumer experience. Future research should continue to research within this area to identify the items that create the best user experience for consumers.

6. Conclusions

We found that potential UAM passengers are primarily concerned about the safety and security of both vertiports and the aircraft on which they will be traveling. Although convenience items were also listed as desirable features, they tended to be lower in priority than safety and security items. These data were consistent for both Americans and Indians, although the latter arguably put even more emphasis on safety/security features. Developers of vertiports and air taxis can use this data to guide research and development, and ensure that the public is educated how safety/security features are designed into their products.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

CRediT authorship contribution statement

Stephen Rice: Conceptualization, Software, Investigation, Data curation, Writing - original draft, Writing - review & editing, Project administration. **Scott R. Winter:** Conceptualization, Writing - original draft, Supervision. **Sean Crouse:** Writing - original draft. **Keith J. Ruskin:** Writing – Revision Draft, Literature Review.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Al Haddad, C., Chaniotakis, E., Straubinger, A., Plötner, K., Antoniou, C., 2020. Factors affecting the adoption and use of urban air mobility. Transp. Res. Part A: Policy Practice 132, 696–712. https://doi.org/10.1016/j.tra.2019.12.020.

Antcliff, K.R., Moore, M.D., Goodrich, K.H., 2016. Silicon Valley as an Early Adopter for On-Demand Civil VTOL Operations. In: 16th AIAA Aviation Technology, Integration, and Operations Conference. American Institute of Aeronautics and Astronautics. https://doi.org/10.2514/6.2016-3466.

Ball, R., 2001. Individualism, collectivism, and economic development. Ann. Am. Acad. Political Social Sci. 573, 57–84. http://www.jstor.org/stable/1049015.

Batty, M., Axhausen, K.W., Giannotti, F., Pozdnoukhov, A., Bazzani, A., Wachowicz, M., et al., 2012. Smart cities of the future. Eur. Phys. J. Special Topics 214 (1), 481–518. https://doi.org/10.1140/epjst/e2012-01703-3.

Buhrmester, M., Kwang, T., Gosling, S.D., 2011. Amazon's Mechanical Turk: a new source of inexpensive, yet high-quality, data? Perspect. Psychol. Sci. 6 (1), 3–5. https://doi.org/10.1177/1745691610393980.

Caragliu, A., Del Bo, C., Nijkamp, P., 2011. Smart cities in Europe. J. Urban Technol. 18 (2), 65–82. https://doi.org/10.1080/10630732.2011.601117.

Clearly Cultural. (n.d.). ***Individualism***. http://clearlycultural.com/geert-hofstede-cultural-dimensions/individualism/.

Endsley, M.R., Kaber, D.B., 1999. Level of automation effects on performance, situation awareness and workload in a dynamic control task. Ergonomics 42 (3), 462–492. https://doi.org/10.1080/001401399185595.

Ferretto, L., Bruzzone, F., Nocera, S., 2021. Pathways to active mobility planning. Res. Transp. Econ. 86, 101027. https://doi.org/10.1016/j.retrec.2020.101027.

Garrow, L.A., German, B.J., Leonard, C.E., 2021. Urban air mobility: a comprehensive review and comparative analysis with autonomous and electric ground transportation for informing future research. Transp. Res. Part C: Emerg. Technol. 132, 103377. https://doi.org/10.1016/j.trc.2021.103377.

Germine, L., Nakayama, K., Duchaine, B.C., Chabris, C.F., Chatterjee, G., Wilmer, J.B., 2012. Is the Web as good as the lab? Comparable performance from web and lab in cognitive/perceptual experiments. Psychon. Bull. Rev. 19 (5), 847–857. https://doi.org/10.3758/s13423-012-0296-9.

Gipson, L., 2019. *UAM Overview*. NASA. https://www.nasa.gov/uam-overview/.

Haan, J., Garrow, L.A., Marzuoli, A., Roy, S., Bierlaire, M., 2021. Are commuter air taxis coming to your city? A ranking of 40 cities in the United States. Transp. Res. Part C: Emerg. Technol. 132 (103392), 103392 https://doi.org/10.1016/j.trc.2021.103392.

Hofstede, G., 1980. Motivation, leadership, and organization: do American theories apply abroad? Org. Dyn. 9 (1), 42–63. https://doi.org/10.1016/0090-2616(80)90013-3.

Hofstede, G., 2001. Culture's Consequences: Comparing Values, Behaviors, Institutions and Organizations Across Nations. SAGE Publications.

Khalili, M., 2020. Joby Aviation welcomes new $75m investment from Uber as it acquires Uber Elevate and expands partnership. https://www.jobyaviation.com/news/joby-aviation-welcomes-new-75m-investment-from-uber-as-it-acquires-uber-elevate-and-expands-partnership/.

Kleinbekman, I.C., Mitici, M.A., Wei, P., 2018. eVTOL arrival sequencing and scheduling for on-demand urban air mobility. In: 2018 IEEE/AIAA 37th Digital Avionics Systems Conference (DASC), pp. 1–7. https://doi.org/10.1109/DASC.2018.8569645.

Markus, H.R., Kitayama, S., 1991. Culture and the self: Implications for cognition, emotion, and motivation. Psychol. Rev. 98 (2), 224–253. https://doi.org/10.1037/0033-295X.98.2.224.

National Aeronautics and Space Administration (NASA), 2021. UAM vision ConOps/UAM maturity level 4. https://www.nasa.gov/aeroresearch/uam-vision-conops-uml-4.

Niklaß, M., Dzikus, N., Swaid, M., Berling, J., Lührs, B., Lau, A., Terekhov, I., Gollnick, V., 2020. A collaborative approach for an integrated modeling of urban air transportation systems. Aerospace 7 (5), 50. https://doi.org/10.3390/aerospace7050050.

Preis, L., Amirzada, A., Hornung, M., 2021. Ground operation on vertiports? Introduction of an agent-based simulation framework. In: AIAA SciTech Forum. AIAA Scitech 2021 Forum. American Institute of Aeronautics and Astronautics. https://doi.org/10.2514/6.2021-1898.

Pukhova, A., Llorca, C., Moreno, A., Staves, C., Zhang, Q., Moeckel, R., 2021. Flying taxis revived: Can Urban air mobility reduce road congestion? J. Urban Mobility 1, 100002. https://doi.org/10.1016/j.urbmob.2021.100002.

Ragbir, N.K., Baugh, B.S., Rice, S., Winter, S.R., 2018. How nationality, weather, wind, and distance affect consumer willingness to fly in autonomous airplanes. J. Aviation Technol. Eng. 8 (1), 1. https://doi.org/10.7771/2159-6670.1180.

Rajendran, S., 2021. Real-time dispatching of air taxis in metropolitan cities using a hybrid simulation goal programming algorithm. Expert Syst. Appl. 178, 115056. https://doi.org/10.1016/j.eswa.2021.115056.

Rajendran, S., Shulman, J., 2020. Study of emerging air taxi network operation using discrete-event systems simulation approach. J. Air Transport Manage. 87, 101857. https://doi.org/10.1016/j.jairtraman.2020.101857.

Rajendran, S., Srinivas, S., 2020. Air taxi service for urban mobility: a critical review of recent developments, future challenges, and opportunities. Transp. Res. Part E: Logistics Transp. Rev. 143, 102090. https://doi.org/10.1016/j.tre.2020.102090.

Rajendran, S., Srinivas, S., Grimshaw, T., 2021. Predicting demand for air taxi urban aviation services using machine learning algorithms. J. Air Transp. Manage. 92, 102043. https://doi.org/10.1016/j.jairtraman.2021.102043.

Rice, S., Kraemer, K., Winter, S.R., Mehta, R., Dunbar, V., Rosser, T.G., Moore, J.C., 2014. Passengers from India and the United States have differential opinions about autonomous auto-pilots for commercial flights. Int. J. Aviation, Aeronaut., Aerospace 1 (1), 3. https://doi.org/10.15394/ijaaa.2014.1004.

Rice, S., Winter, S.R., Doherty, S., Milner, M., 2017. Advantages and disadvantages of using internet-based survey methods in aviation-related research. J. Aviation Technol. Eng. 7 (1), 5. https://doi.org/10.7771/2159-6670.1160.

Rice, S., Winter, S.R., Mehta, R., Ragbir, N.K., 2019. What factors predict the type of person who is willing to fly in an autonomous commercial airplane? J. Air Transp. Manage. 75, 131–138. https://doi.org/10.1016/j.jairtraman.2018.12.008.

Rimjha, M., Trani, A., 2021. Urban air mobility: factors affecting vertiport capacity. Integr. Commun. Navigation Surveillance Conference (ICNS) 2021, 1–14. https://doi.org/10.1109/ICNS52807.2021.9441631.

Robbins, S.P., Judge, T.A., et al., 2013. Organizational Behavior. Pearson Education, New Jersey.

Rothfeld, R., Balac, M., Ploetner, K.O., Antoniou, C., 2018. Agent-based simulation of urban air mobility. In: AIAA AVIATION Forum. 2018 Modeling and Simulation Technologies Conference. American Institute of Aeronautics and Astronautics. https://doi.org/10.2514/6.2018-3891.

Shaheen, S., Cohen, A., & Farrar, E., 2018. The potential societal barriers of urban air mobility (UAM). doi:10.7922/G28C9TFR.

Straubinger, Anna, Rothfeld, Raoul, Shamiyeh, Michael, Büchter, Kai-Daniel, Kaiser, Jochen, Plötner, Kay Olaf, 2020. An overview of current research and developments in urban air mobility – setting the scene for UAM introduction. J. Air Transp. Manage. 87, 101852. https://doi.org/10.1016/j.jairtraman.2020.101852.

Taylor, M., Saldanli, A., Park, A., 2020. Design of a vertiport design tool. In: 2020 Integrated Communications Navigation and Surveillance Conference (ICNS). https://doi.org/10.1109/ICNS50378.2020.9222989.

Thipphavong, D. P., Apaza, R. D., Barmore, B. E., Battiste, V., Belcastro, C. M., Burian, B. K., Dao, Q. V., Feary, M. S., Go, S., Goodrich, K. H., Homola, J. R., Idris, H. R., Kopardekar, P. H., Lachter, J. B., Neogi, N. A., Ng, H., Oseguera-Lohr, R. M., Patterson, M. D., & Verma, S. A., 2018. Urban air mobility airspace integration concepts and considerations. AIAA Aviation Forum (Aviation 2018). https://ntrs.nasa.gov/citations/20180005218.

Tokarev, Vadim, Makarenko, Vitalii, 2021. Prediction of noise generated by small unmanned aerial vehicles' operation in vertiport vicinity. Int. J. Sustainable Aviation 7 (2), 165–185.

TomTom, 2020. Traffic Index 2020. https://www.tomtom.com/en_gb/traffic-index/ranking/?country=US.

Urbanek, Anna, 2021. Potential of modal shift from private cars to public transport: a survey on the commuters' attitudes and willingness to switch – a case study of Silesia Province, Poland. Res. Transp. Econ. 85, 101008. https://doi.org/10.1016/j.retrec.2020.101008.

Parker D. Vascik and R. John Hansman. Development of vertiport capacity envelopes and analysis of their sensitivity to topological and operational factors. AIAA 2019-0526. AIAA Scitech 2019 Forum. January 2019.

Volocopter. (n.d). We bring urban air mobility to life. https://www.volocopter.com/en/.

Winter, Scott R., Rice, Stephen, Lamb, Tracy L., 2020. A prediction model of consumer's willingness to fly in autonomous air taxis. J. Air Transp. Manage. 89, 101926. https://doi.org/10.1016/j.jairtraman.2020.101926.

Wisk, 2021. Autonomous urban air mobility starts here. https://wisk.aero/.

Wu, C., Jang, L., 2008. The moderating role of referent of focus on purchase intent for consumers with varying levels of allocentric tendency in a collectivist culture. J. Int. Consumer Mark. 20 (3–4), 5–22. https://doi.org/10.1080/08961530802129128.

Wu, Jingwen, Liao, Hua, Wang, Jin-Wei, 2020. Analysis of consumer attitudes towards autonomous, connected, and electric vehicles: a survey in China. Res. Transp. Econ. 80, 100828. https://doi.org/10.1016/j.retrec.2020.100828.

Zelinski, S., 2020. Operational analysis of vertiport surface topology. In: 2020 AIAA/IEEE 39th Digital Avionics Systems Conference (DASC), pp. 1–10. https://doi.org/10.1109/DASC50938.2020.9256794.

Zoldi, D., 2020. Vertiport infrastructure: New tech, old regulations. https://insideunmannedsystems.com/vertiport-infrastructure-new-tech-old-regulations/.