Conceptual Models of Demand for Electric Propulsion Aircraft in Intra-Urban and Thin-Haul Markets

Dr. Laurie A. Garrow (corresponding author)  
Professor, Georgia Institute of Technology, School of Civil and Environmental Engineering, 790 Atlantic Drive, Atlanta, GA 30332  
P (404) 385-6634  
laurie.garrow@ce.gatech.edu

Dr. Brian J. German  
Langley Associate Professor, Georgia Institute of Technology, Daniel Guggenheim School of Aerospace Engineering, Atlanta, GA 30332-0150  
P (404) 385-3299  
brian.german@aerospace.gatech.edu

Dr. Mohammad Ilbeigi  
Ph.D. student, Georgia Institute of Technology, School of Building Construction, 280 Ferst Drive, Atlanta, GA 30332, ilbeigi@gatech.edu  
Currently  
Assistant Professor, Bowling State University, Department of Construction Management, Bowling Green, OH, 43403-0001, milbeig@bgsu.edu

5,991 words  
4 tables x 250 = 1000  
2 figures x 250 = 500 equivalent words  
7,491 total word count  
August 1, 2017
Spurred by new battery technologies, many companies are developing prototypes for distributed electric propulsion aircraft with vertical take-off-and-landing (VTOL) capabilities. These piloted or autonomous aircraft have the potential to dramatically reduce commuting times in urban areas with congested roadway networks, i.e., instead of sitting in 20 miles of traffic for hours, one could simply fly over the traffic in 15 minutes. This paper highlights ongoing research on distributed electric propulsion aircraft designs and describes how this research could complement and/or compete with other emerging technologies (most notably autonomous vehicles). Given the novelty of these aircraft, we conducted four focus groups to better understand potential travelers’ perceptions and willingness to travel in these aircraft and pay for flights. We examined two use cases: one for intra-urban operations using aircraft with VTOL capabilities and the second for thin-haul markets serving destinations up to about 300 miles with an aircraft having nine or fewer seats. Based on insights gained from these focus groups, we present two conceptual models of factors that will likely influence demand for these aircraft in intra-urban and thin-haul markets.
INTRODUCTION

Excitement is growing within the aviation community as improvements in battery technologies offer the potential for dramatically lower operating costs for new classes of electric propulsion aircraft. By reducing aircraft operating costs by as much as 30%, electric propulsion could transform both air and surface transportation (1). There are currently two key markets that are envisioned by the aviation community to be suitable for battery electric propulsion aircraft in the near-term: (1) on-demand mobility and (2) thin haul aviation. The term “on-demand mobility” (ODM) has been interpreted in an aviation context as an air service between origin-destination pairs located at dispersed locations – not necessarily airports – that operates in an unscheduled (“on-demand”) paradigm; when called by a user, typically via a smartphone app, and aircraft is dispatched to the nearest departure origin. There is now widespread belief that ODM missions could be served by smaller electric propulsion aircraft with vertical take-off-and-landing (VTOL) capabilities that operate from heliports or similar infrastructure. It is envisioned that these electric-VTOL (eVTOL) aircraft could provide air-taxi service for trips between 20 to 70 miles within congested urban areas (2). Flights within urban areas become more attractive with battery-powered electric aircraft – particularly those with so-called “distributed” propulsion – as they hold the potential of operating at much lower noise levels than helicopters. Dozens of companies have publicly-acknowledged designing eVTOL aircraft including Airbus, Boeing, Embraer, Joby Aviation, and Pipistrel. See (3-12) for images and videos of proposed eVTOL designs, some of which are in the testing phase.

Thin-haul markets refer to traditional airport origin-destination pairs located approximately 150 to 300 miles apart, which would be served by conventional takeoff and landing fixed wing aircraft. Today, it is not possible to economically serve these thin-haul markets with scheduled commercial airline service because demand is too low (or “thin”). Aircraft with electric propulsion technologies may provide an economically-viable solution. Several designs for thin-haul markets serving origin-destination pairs have been discussed in the literature (see 13-15). Aircraft with nine or fewer seats are particularly attractive (both for eVTOL as well as thin-haul operations) because under FAA Part 135 operations, pilots are responsible for performing security checks, thus passengers do not need to wait in long security lines (16).

Different timelines for the introduction of electric-propulsion aircraft have been discussed in the literature, but there is a general consensus that “electric propulsion is going to be achievable during the next 10 to 20 years” (17). NASA is spearheading much of the research in this area. Since 2015, NASA has sponsored an On-Demand Mobility Forum, and On-Demand Mobility Roadmapping Workshop, a joint SAE, AHS, AIAA and NASA Transformative Vertical Flight Workshop and a joint NASA-FAA Workshop on ODM and Emerging Technologies. Presentations for all of these forums and workshops are available online (18). Based in part on input from these workshops, NASA developed a report detailing their strategic framework for on-demand air mobility (19).

Uber has been very active in ODM. In 2016, Uber published a white paper describing their vision for intra-urban trips, and in 2017 they held an Uber Elevate Summit at which they described their efforts to launch revenue ODM flights in Dallas and Dubai by 2024 (20-21). In
February of 2017, Uber hired former NASA engineer Mark Moore to lead its ODM program (22). Presentations and videos from the Uber Elevate Summit are available online (21).

Numerous research questions are being investigated to support the development of distributed electric propulsion aircraft for ODM and thin-haul missions and to assess the public’s willingness to fly in these new aircraft. Safety and pilot availability are two major concerns. What safety level is acceptable for ODM flights? It may be unrealistic to expect the same level of safety for ODM flights as that achieved today by commercial aviation, but what level will the public accept? If ODM were two to ten times safer than automobiles (as defined by fatality rates per passenger mile) would this be acceptable (23-26)? Should safety features such as ballistic recovery systems which use a rocket to launch a whole-airplane parachute be incorporated to improve safety (27)? Will the public accept autonomous eVTOL aircraft? Assuming fully-autonomous flights are further in the future, will operators be able to hire an adequate number of highly-qualified pilots to fly these aircraft in the near term? Given that many Army personnel are trained to fly helicopters, can ODM provide a new career path for these former military personnel (28)? These are but some of the many research questions related to safety and pilot shortages being discussed by the aviation community.

Another key area of research involves battery technologies. NASA researchers have stated that an 8% annual improvements in battery power technology would make it possible to develop a nine-passenger battery electric or hybrid electric aircraft within five to seven years, when battery specific energy levels reach 300-400 Wh/kg at the pack level; by comparison, Tesla cars use 250 Wh/kg battery cells (17; 29). Several startup companies are exploring new battery chemistries including SolidEnergy, Pellion Technologies and PolyPlus, who presented at the Uber Elevate Summit (30). Battery recharging technologies are critical to the success of eVTOL and thin-haul operations. At the Uber Elevate Summit, ChargePoint announced they were exploring the potential for charge rates up to 500kW, which would enable an eVTOL aircraft to recharge adequately for a subsequent short-range intra-urban trip in approximately five minutes (31). To put this power level in context, current charge rates of 145 kW are in use for electric automobiles, as exemplified by the Tesla Supercharger (32). The impact of recharging a fleet of eVTOL aircraft at such fast rates could place a large load on the current electric grid, particularly during peak periods when electricity prices are highest. Justin and colleagues generate power demand profiles for different recharging strategies for thin-haul commuter aviation operators Cape Air and Mokulele Airlines and find peak demands at these airlines’ busiest airports could exceed 800 to 1000 kW in Boston and 500 kW in Kona Airport or Molokai Airport.

Safety, pilot shortages, and the development of new battery technologies are just a few of the many research questions being asked by government agencies, academic institutions, and private companies with respect to eVTOL and thin-haul aircraft designs. However, in order for these aircraft to penetrate the market, individuals need to be willing to fly on these aircraft and pay for flights. Given the novelty of these aircraft, we conducted four focus groups to better understand potential travelers’ perceptions and willingness to travel in these aircraft and pay for flights. Based on insights from these focus groups, we develop two conceptual models of factors that will likely influence demand for these aircraft in intra-urban and thin-haul markets.
The remainder of this paper contains three sections. First, we describe the focus groups and key feedback received from participants. Next, we present two conceptual models of demand: one for intra-urban flights and the second for thin-haul markets. We conclude with directions for future research as it pertains to predicting demand for electric propulsion aircraft.

FOCUS GROUPS

From May 3, 2017 to June 28, 2017 we conducted four focus groups in Atlanta, Georgia. The first two focus groups were designed to represent a mix of different socio-demographic and socio-economic characteristics and a range of commuting distances. Different commuting distances were used as a qualifying criterion as we hypothesize that those travelling longer distances will have different willingness-to-pay than those commuting shorter distances. One of these focus groups recruited individuals from high-income households (defined as those with an annual income of at least $200,000) and the second recruited Millennials. We hypothesize that the high-income households will be early adopters of flights with electric propulsion (due to their ability to pay/higher potential values of time). We hypothesize that Millennials will have different perceptions of safety and technologies than the general and may be more willing to purchase flights with electric propulsion than older populations, particularly if the price is competitive with surface modes.

The last two focus groups explored the ability to use electric propulsion aircraft for rural medicine. Provision of medical services in rural America is a costly – yet increasing important – issue. Today, “Rural America” accounts for 83% of the nation’s land, 21% of its population, and 14% of its jobs (33). On average, residents in rural areas tend to be older, poorer, less educated and with fewer employment prospects (34). Rural public transit systems help meet demand for medical care. Rural public transit systems are typically small, demand-responsive systems. Revenues are generally not sufficient to cover the system’s costs, and the Federal Transit Association (FTA) § 5311 provides capital, planning and operating assistance in support of these systems. State DOTs are responsible for allocating 5311 funding to sub-recipients. In FY2015, more than $400 million in 5311 funding was allocated nationwide for rural transit. Several researchers have shown the benefit-cost ratios of rural public transit funding are greater than 1, particularly when a large fraction of trips served are for medical care. For example, Southworth and colleagues estimate that the foregone costs of medical care in Tennessee are $92.17 (adjusted for 2017 dollars) per trip (35). We hypothesize that using electric propulsion aircraft to serve rural communities – particularly for medical applications – may be particularly valuable given the large costs associated with foregone medical care and potential federal funding available to subsidize these trips.

The next sub-sections describes characteristics of participants from each focus group and key feedback from the participants.

High-Income Households

For the “high-income” focus group, we recruited five individuals with annual household incomes of more than $200,000. A mix of ages, gender, and commute times were represented. Three participants had one-way commute times in excess of an hour. Participant 1 commuted one-way...
37 miles from East Cobb to Lawrenceville; this commute took anywhere from 1.5 to 2.5 hours depending on the time of day and traffic. Participant 3 commuted one-way about 50 miles from Hall County into Buckhead; this commute took anywhere from 50 minutes to 3 hours.

Key feedback from the high-income households includes the following:
- Individuals with long commutes were interested in using eVTOL aircraft for daily commutes. The ability to board the eVTOL aircraft before they encountered traffic congestion was important, as was the ability to land close to their places of work. The ability to avoid a long commute equated to more time with family and less stress (e.g., the ability to read the paper and avoid stop-and-go traffic).
- Internet access for eVTOL would allow individuals to be productive during the flight, although if the flight was 15 minutes or less this was not viewed as an essential feature.
- One participant noted he was an introvert and would not use an eVTOL aircraft for commuting as he enjoyed the time alone driving to and from work.
- One individual who traveled 25 to 40 minutes to work noted she would not use an eVTOL aircraft as she already solved her commute problem by purchasing an electric vehicle.
- Participants were shown different aircraft designs and preferred those that had exposed and multiple propellers, such as those by Joby and Zunum (8, 15). None felt comfortable getting in the e-volo aircraft that “looked like a drone” (7).
- Willingness to pay for a thin-haul flight from Atlanta, Georgia to Huntsville, Alabama was higher than in the Millennial focus group. In general, individuals would be willing to spend $100-$150 one-way for a flight, particularly if they were being reimbursed by their companies.
- One participant noted that when travelling for work, he felt more “time pressure” to get to the hotel and prep for the next day and that eVTOL flights could help reduce the time it takes to get to the hotel from the airport.

**Millennials**

For the “Millennial” focus group, we recruited seven individuals between the ages of 18 to 34. A mix of gender, annual household incomes, and commute times were represented. Compared to the high-income households who all used personal vehicles to travel to work, the Millennials were much more likely to take public transportation (MARTA). Participant 6 is a divorced father who lives in Buckhead and commutes to Atlanta but will often drive if he needs to take his daughter to school near Peachtree City, approximately 40 miles south of Buckhead. Participant 1 has a significant other who also works in media and is transferred to different locations in the Southeastern U.S.

Key feedback from the Millennials includes the following:
- Millennials were most likely to integrate Uber and other car-sharing services into their routines. One participant noted she had several friends who regularly took Uber, especially those that did not have a car, or were making ends meet, or needed to go places
that MARTA did not serve. Another participant noted that he took Uber to and from work in the evenings due to the fact he worked in clubs in “sketchy neighborhoods” and it was less expensive and safer to take Uber. This individual also often took UberPool to work instead of MARTA as the price was the same as MARTA.

- One participant who owned a motorcycle noted he would be more interested in flying the aircraft himself than trusting someone else to pilot.
- The decision as to whether to drive or take a thin-haul flight of 150 miles from Atlanta, Georgia to Huntsville, Alabama depended on various factors including trip purpose (and whether a car would be needed at the destination), number of nights away from home, and whether individuals genuinely liked driving. The willingness to pay for this flight was about $50-$75 one-way across Millennials, unless they were being reimbursed by their companies for the trip.
- Various aircraft designs were shown to participants. In contrast to the high-income focus group, the Millennials liked the Lilium design (8) that they equated with “looking like a Mac versus a PC.” They liked the “clean, slick feel” associated with the Lilium design.

Physicians

For the “physician” focus group, we recruited four physicians and one owner of a primary health care center with a large number of telemedicine patients. The physicians included a cardiologist, neurologist, general surgeon and medical director. Three of these physicians worked out of multiple offices.

[Insert Table 3 about here]

Key feedback from the physicians and owner of a primary health care center includes the following:

- For specialty care, it is easier to bring the patients to the doctors (in urban areas) than the doctors to rural areas. For primary care (such as gathering and entering patient information in electronic systems or ordering labs) it is easier to use telemedicine and “bring the front-line” to the patients to determine if further specialty care is warranted.
- eVTOL aircraft may be particularly useful for on-call doctors. The neurologist noted that when he is on call, he has an obligation to get to the hospital as fast as he can to confirm treatment for stroke patients. Further, there are metrics Medicare uses to determine funding levels based on how long it takes the stroke patient to receive treatment (and that other specialties have similar metrics tied to funding). Thus, there is a financial incentive for the hospitals to invest in dedicated eVTOL aircraft that could be used to transport on-call physicians more quickly to the hospitals.
- Rural hospitals will often cover their emergency rooms (ERs) using physicians based in urban areas and may be interested in paying for eVTOL or thin-haul flights to reduce the amount of time it takes physicians to travel to their facility (which in turn could reduce the amount of time the ER is not covered by a physician).
- The owner of a primary health care center stated she would use eVTOL or thin-haul flights to travel out to see patients in rural communities, and that having satellite offices would help her improve patient care (by seeing patients in person).
Physicians valued having secure internet access on thin-haul flights so they could be productive, e.g., by accessing patient charts.

Caretakers

For the “caretakers” focus group, although we recruited individuals who traveled for medical care at least once a month for different one-way commuting times, only those in the 1-2 hour and 3+ hour ranges showed for the focus group. All participants were women, five were employed full-time (one was retired), three were between the ages of 46-55, two between the ages of 55-65, and one was between the ages of 26-35. A range of household incomes were represented and included one with a household income of 22-44K/year; one between 45-79K/year; one between 10-100K/year and three between 151-250K/years. For those travelling long distances (3 or more hours one way for medical care), one travelled monthly to Texas by air, one recently stopped travelling 350 miles one-way by auto to Mississippi, and one currently travels at least monthly in a handicap van from rural Georgia to Atlanta for medical care.

Key feedback from the caretakers include the following:

- Medical appointments tend to be hard constraints, meaning that if individuals are not in the doctor’s office by the appointment time, they often will not be seen. Caregivers need to account for potential travel delays – on every trip – and leave a large buffer time for traveling to doctors’ appointments.
- Parking at medical facilities takes “significant time” and could be avoided if an eVTOL aircraft were to land on a medical facility and/or if a ridesharing service met a thin-haul aircraft and drove individuals to the medical facility.
- One participant was vehemently opposed to using VTOL or thin-haul aircraft, noting that “At least if you bump into somebody, you are already on the ground. If you bump into someone 60 feet in the air then you’re dropping.”
- Participants noted they typically pay $20 for parking at the medical facility and would like to pay $20 for an electric propulsion aircraft… but that up to $100 for 35 miles for 2 people would be possible, particularly if the costs could be absorbed in part by medical insurance (e.g., through paying a co-pay).
- Participants noted they would be willing to drive 5-10 miles to take a thin-haul or eVTOL aircraft at the home location and would be willing to wait 10-15 minutes for a thin-haul or VTOL aircraft for the return home.
- Participants thought electric propulsion aircraft would improve quality time with those they were taking care of, due to the reduction of stress associated with driving.
- More generally, individuals indicated they would eVTOL and thin-haul aircraft for other trip purposes, such as accessing rural scenic areas, or bypassing Atlanta traffic on weekends, or avoiding traffic to head to vacation spots in North Carolina.

CONCEPTUAL MODELS

Based on insights gained during the focus groups, we developed a conceptual model of demand for intra-urban flights that could be served via new eVTOL aircraft designs, shown in Figure 1.
During the focus groups, we observed that individuals’ attitudes and perceptions were influenced by multiple factors. Prior experience with battery technologies, small aircraft, and ridesharing services influenced individuals’ perceptions of what they would experience if they flew in an eVTOL aircraft. Those who had previously flown in small aircraft with nine or fewer seats mentioned noise and weight limits as potential concerns (specifically whether they would have to provide their weight in order to board an aircraft). Those who had previously taken auto ridesharing services noted that certain information that ridesharing apps provided – namely tracking of the vehicle and estimated arrival times – would be attractive in eVTOL operations. The ability to verify pilot credentials on the app was also viewed as a positive addition, and one that would help alleviate their safety concerns.

Individuals perceived different aircraft features as being “safer” than others – although specific characteristics differed by socio-economic and socio-demographic characteristics. Millennials preferred the “sleeker” designs and the (older) higher-income participants preferring the “robust” designs with multiple exposed rotors. Onboard amenities, including wifi and restrooms were not viewed as essential on eVTOL flights, given their short duration. Ride quality (i.e., how bumpy or smooth the ride was) and the ability to travel in all-weather conditions were viewed as important characteristics.

During each of the focus groups, participants asked numerous questions about the new aircraft designs. Questions related to safety, pilot shortages, and battery requirements were raised in all four focus groups. Participants viewed “safety” along multiple dimensions – from boarding the aircraft with moving propellers nearby, to surviving a mid-air incident, to protecting pedestrians and high-value property in densely-populated neighborhoods. Participants were sharply divided on what would make them feel more safe – with some preferring autonomy, others preferring a pilot, and others preferring to maintain control by piloting the aircraft himself. Some participants viewed the risks associated with intra-urban flying as too high, and would continue to drive.

Finally, the focus groups revealed that attitudes and perceptions varied across socio-economic and socio-demographic characteristics. The sharpest distinction was by age – with Millennials being more likely to consider an eVTOL solution to avoid driving, i.e., several Millennials actively avoiding driving to work and would take MARTA (with a longer commute time than driving) to avoid “unsafe drives on Snapchat.” Personality characteristics, such as whether the individual was an introvert or extrovert and whether the individual liked to impress friends, also influenced individuals’ attitudes. Household income greatly influenced willingness-to-pay and willingness to make multiple transfers (e.g., driving to a veriport, taking an eVTOL flight, taking a rideshare vehicle to the final destination) with higher-income households having higher willingness to pay and less tolerance for connections and connection times.

Several other factors also influenced individuals’ willingness to take an eVTOL flight (and their willingness to pay to fly). Individuals who needed a vehicle at the destination were less likely to consider an eVTOL flight. Trip purpose also influenced willingness to consider an eVTOL flight, with commuters, those travelling to Atlanta Hartsfield-Jackson Airport, and those taking a business or leisure day trip representing distinct segments. Individuals using eVTOL solutions
for daily commuting were interested in purchasing a “subscription service” versus paying for each individual trip. Those using an eVTOL aircraft to travel to work need to be able to return home if weather conditions prevent aircraft from taking off. Solutions that combined eVTOL with automobile ride-sharing services (such as taking an aircraft to work but returning to the boarding veriport via an automobile) could help alleviate these concerns about “getting stuck” if weather grounded eVTOL flights.

Those travelling to the airport to take a commercial flight (for either business or leisure travel) were interested in driving to a veriport close to home and taking an eVTOL flight to the airport, particularly if parking costs at the veriport were lower than at the Atlanta airport. Higher-income households were more likely to see the potential for using eVTOL aircraft for weekend trips with their family, e.g., to travel from the suburbs into Atlanta for the day and “avoid the traffic that is always on in the interstates.” All focus groups saw the potential for using eVTOL flights for business day trips to more quickly reach potential clients (or patients) and/or to increase productivity by spending less time traveling. eVTOL flights were particularly attractive for trips with actual or perceived time pressures, e.g., for responding to medical emergencies and/or for arriving at a hotel for a business trip sooner.

Many of the factors discussed above were “screening criteria” individuals used to decide if they would even consider an eVTOL flight. For example, those given a fear of flying or recent accident would simply not consider taking an eVTOL flight. Trip-characteristics, most notably the need to have a vehicle at the destination, was also more often viewed by participant as a screening criteria, i.e., if you need a vehicle at the destination you are more likely to drive. Given the willingness to consider an eVTOL flight, individuals then made trade-offs among various characteristics associated with the eVTOL flight and competing modes (most notably personal automobile). These characteristics included per-person cost for the trip (thus if a group of four family members was travelling it would be four times more expensive to fly than if one individual was travelling), door-to-door travel times, number of transfers, amount of time spent in automobile traffic congestion (which included the amount of time spent in traffic congestion getting to and from the veriports), and time spent waiting for an eVTOL flight. For intra-urban applications, it was common for participants to consider parking costs and time spent finding parking in their final mode choice decision.

In summary, the conceptual model of demand for intra-urban flights recognizes that there is a two-stage decision process: the first is a screening process in which an individual decides whether to consider an eVTOL flight as an option. For intra-urban flights, this initial decision was heavily influenced by attitudes and perceptions and to a lesser extent by the need to have an automobile at the destination. The second stage of the decision process involved individuals making trade-offs among various factors, many of which are similar to those included in traditional mode choice models.

The conceptual model of demand for thin-haul flights, shown in Figure 2, is similar to the conceptual model of demand presented for intra-urban flights, with a few distinctions. Aircraft design features were less important for thin-haul flights because the proposed aircraft designs were similar to current commercial aircraft designs. Safety concerns were also less for thin-haul flights, with the main concerns arising from the use of battery technologies. Prior experiences –
and particularly prior prices paid for short-haul flights provided an anchor for some individuals in terms of what they would be willing to pay to take a thin-haul flight.

In terms of trip purposes, some participants did see the possibility of making day trips for work, *e.g.*, to visit a satellite office or for sales calls with clients. In these cases, the thin-haul flights were generally viewed as increasing work productivity by spending less time travelling by automobile or by providing new opportunities to travel for work. For leisure trips, individuals generally viewed thin-haul flights for overnight and multi-day trips. The willingness-to-pay to take a thin-haul flight for leisure trips was heavily influenced by the number of nights away from home and trip duration. One participant noted that for weddings and other “important” events with a rigid schedule, a flight was attractive as it would allow her to spend more time at the event and potentially take less time off of work (due to the ability to leave Friday and return Sunday by air versus the need to leave Friday and return Monday by automobile). Individuals were also more willing to take a thin-haul flight to destinations in which they did not need to rent a vehicle, *e.g.*, beach resorts or major cities. Similar to the intra-urban flights, we observed a two-stage decision process, although the screening criteria were not as pronounced. For thin-haul flights, those who enjoyed driving – either alone or with their families for leisure trips – were less likely to consider thin-haul flights. The need to have a car at the destination was also noted as important, although this was more often included as a characteristic that was traded-off versus a screening criteria (*e.g.*, should I rent a car or take my own car)? Parking costs were not mentioned as frequently as hotel accommodation and car rental costs for thin-haul flights.

CONCLUSIONS AND DIRECTIONS FOR FUTURE RESEARCH

Electric propulsion aircraft and autonomous automobiles are two potentially disruptive new technologies that could transform how we travel within and between cities. To date, research in these two areas have typically been examined independently; however we see many opportunities for collaboration. Research on autonomous automobiles has typically focused on understanding multi-tasking behaviors and productivity increases while individuals are inside the automobile. Our research on eVTOL and thin-haul aircraft show that productivity gains differ, and are constrained not to what else you can do while in transit, but rather what else you can do during the day (*e.g.*, spend more time with family, visit more clients, spend more time in the work office). Based on focus groups, the largest potential market we see for eVTOL operations are for time-sensitive and high-value trips where avoiding traffic congestion and traffic variability are important. Examples include getting on-call doctors to emergency rooms to confirm and administer treatment to stroke or cardiac patients, parking a personal vehicle at a remote eVTOL lot and travelling to the airport for business, arriving at an airport and travelling to a location near the hotel or location where the individual is staying, and using thin-haul flights for business trips. Thin-haul flights could potentially stimulate more air trips and/or increase work productivity, *e.g.*, it would be easier for a sales representative to make more calls by travelling by air to a destination 100-300 miles away then renting an automobile versus using a personal automobile for the entire journey. Other potential markets for eVTOL and thin-haul markets include leisure trips, particularly for destinations where individuals do not need their vehicles.
Based on the feedback from the focus groups and conceptual models presented in this paper, we plan to conduct an online survey of at least 1,500 respondents and use the survey data (which will include a set of discrete-choice trade-off questions) to estimate a model of demand for eVTOL and thin-haul flights. Looking ahead, it would also be interesting to explore trade-offs among current automobiles, self-driving automobiles, and electric propulsion aircraft and to predict not only short-term demand for these modes but longer-term consequences such as residential relocations.

ACKNOWLEDGEMENTS

Funding for this research was provided by a NASA Learn Grant.

REFERENCES


LIST OF TABLES AND FIGURES

TABLE 1    High-income household characteristics
TABLE 2    Millennial characteristics
TABLE 3    Physician characteristics
TABLE 4    Caregiver characteristics

FIGURE 1   Conceptual model of demand for intra-urban flights
FIGURE 2   Conceptual model of demand for thin-haul markets
### TABLE 1 High-income household characteristics

<table>
<thead>
<tr>
<th>ID</th>
<th>Age</th>
<th>Gender</th>
<th>Household Income</th>
<th>One-Way Commute &gt; 1 Hr</th>
<th>Mode Choice 1</th>
<th>Mode Choice 2</th>
<th>Mode Choice 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>45-54</td>
<td>Male</td>
<td>$200,000+</td>
<td>No</td>
<td>Personal Vehicle</td>
<td>Carpool</td>
<td>N/A</td>
</tr>
<tr>
<td>2</td>
<td>35-44</td>
<td>Female</td>
<td>$200,000+</td>
<td>No</td>
<td>Personal Vehicle</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>3</td>
<td>45-54</td>
<td>Male</td>
<td>$200,000+</td>
<td>Yes</td>
<td>Personal Vehicle</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>4</td>
<td>45-54</td>
<td>Male</td>
<td>$200,000+</td>
<td>Yes</td>
<td>Personal Vehicle</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>5</td>
<td>55-64</td>
<td>Female</td>
<td>$200,000+</td>
<td>Yes</td>
<td>Personal Vehicle</td>
<td>Rail</td>
<td>Walk</td>
</tr>
</tbody>
</table>
TABLE 2 Millennial characteristics

<table>
<thead>
<tr>
<th>ID</th>
<th>Age</th>
<th>Gender</th>
<th>Household Income</th>
<th>Occupation</th>
<th>Income</th>
<th>Commute</th>
<th>Mode Choice 1</th>
<th>Mode Choice 2</th>
<th>Mode Choice 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>18-24</td>
<td>Female</td>
<td>$35,000-$49,999</td>
<td>Media</td>
<td>No</td>
<td>Personal Vehicle</td>
<td>MARTA</td>
<td>Carpool</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>18-24</td>
<td>Male</td>
<td>$35,000-$49,999</td>
<td>Finance</td>
<td>No</td>
<td>Personal Vehicle</td>
<td>Carpool</td>
<td>MARTA</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>18-24</td>
<td>Female</td>
<td>$75,000-$99,999</td>
<td>Health</td>
<td>No</td>
<td>Personal Vehicle</td>
<td>Carpool</td>
<td>Bus</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>25-34</td>
<td>Female</td>
<td>$150,000-$199,000</td>
<td>Media</td>
<td>No</td>
<td>MARTA</td>
<td>Personal Vehicle</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>25-34</td>
<td>Male</td>
<td>$100,000-$149,999</td>
<td>Tax</td>
<td>Yes</td>
<td>MARTA</td>
<td>Personal Vehicle</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>25-34</td>
<td>Male</td>
<td>$50,000-$74,999</td>
<td>IT</td>
<td>Yes</td>
<td>MARTA</td>
<td>Carpool</td>
<td>Bus</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>25-34</td>
<td>Male</td>
<td>$75,000-$99,999</td>
<td>Engineering</td>
<td>Yes</td>
<td>MARTA</td>
<td>Personal Vehicle</td>
<td>Carpool</td>
<td></td>
</tr>
</tbody>
</table>
**TABLE 3** Physician characteristics

<table>
<thead>
<tr>
<th>ID</th>
<th>Age</th>
<th>Gender</th>
<th>Job Title</th>
<th>Multiple Offices</th>
<th>Telemedicine</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>34-44</td>
<td>Female</td>
<td>Health Center Owner</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>2</td>
<td>45-54</td>
<td>Male</td>
<td>Cardiologist</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>3</td>
<td>55-64</td>
<td>Male</td>
<td>Neurologist</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>4</td>
<td>55-64</td>
<td>Male</td>
<td>Medical Director</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>5</td>
<td>55-64</td>
<td>Male</td>
<td>General Surgeon</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>
TABLE 4 Caregiver characteristics

<table>
<thead>
<tr>
<th>ID</th>
<th>Age</th>
<th>Gender</th>
<th>HH Income</th>
<th>Employment Status</th>
<th>One-way Distance</th>
<th>Travel Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>46-55</td>
<td>Female</td>
<td>$151,000-$250,000</td>
<td>Full-time</td>
<td>1-2 hrs</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>46-55</td>
<td>Female</td>
<td>$151,000-250,000</td>
<td>Full-time</td>
<td>3+ hrs</td>
<td>Flies to Texas</td>
</tr>
<tr>
<td>3</td>
<td>56-65</td>
<td>Female</td>
<td>$80,000-100,000</td>
<td>Full-time</td>
<td>1-2 hrs</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>26-35</td>
<td>Female</td>
<td>$45,000-79,000</td>
<td>Full-time</td>
<td>3+ hrs</td>
<td>Drove to different state</td>
</tr>
<tr>
<td>5</td>
<td>46-55</td>
<td>Female</td>
<td>$151,000-250,000</td>
<td>Full-time</td>
<td>1-2 hrs</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>56-65</td>
<td>Female</td>
<td>$25,000-44,000</td>
<td>Retired</td>
<td>3+ hrs</td>
<td>Owns handicap van</td>
</tr>
</tbody>
</table>
FIGURE 1 Conceptual model of demand for intra-urban flights
FIGURE 2 Conceptual model of demand for thin-haul markets