A Survey to Model Demand for eVTOL Trips to Airports

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In this paper, we present details of a survey we designed to estimate air travelers' willingness to pay for electric vertical take-off and landing (eVTOL) flights in urban areas in the United States for the bias of traveling from home to a commercial airport. The survey was administered from January 8 to June 14, 2021 and responses were obtained from 2,820 individuals who had taken at least two round-trips by air in 2019 (before COVID-19), had annual household incomes of at least $75K, and who resided in the Atlanta, Boston, Chicago, Dallas-Ft. Worth, New York City, San Francisco Bay Area, or Los Angeles combined statistical areas (CSAs). A stratified sample was used to ensure a minimum number of responses for different household income brackets, pre-COVID-19 air travel frequencies, and trip purposes (reimbursed business trips and self-paid leisure trips).

I. Introduction

Many companies are developing prototypes for electric vertical take-off-and-landing (eVTOL) aircraft to serve as air taxis in cities. At the time of this writing, the Vertical Flight Society, which tracks progress in eVTOL aircraft, had catalogued over 300 eVTOL aircraft in development by different organizations worldwide (eVTOL news™, 2021). Companies are making investments based on the hypothesis that there will be strong consumer demand. However, to date very little work has been published about the potential demand for eVTOL air taxi services. As noted in Garrow et al., "demand estimation is challenging because, as an entirely new transportation mode, there is no past market data that would facilitate estimates" (Garrow et al., 2020b). In these cases, it is common to design stated preference surveys and ask consumers what mode they would take under hypothetical situations. In 2018 and 2019, we conducted two stated preference surveys that were focused on understanding market size and willingness to pay for an on-demand *commuting* air taxi service for high-income individuals in five U.S. cities. The 2018 survey focused on a near-term scenario representing the insertion of eVTOL into *current* market conditions, i.e., an electric air taxi service and traditional ground vehicles and the 2019 paper focused on a longer-term scenario of *future* market conditions, i.e., competition among electric air taxis, autonomous ground vehicles, and traditional ground vehicles. We published the details of these first two surveys as AIAA conference proceedings (Binder et al., 2018; Garrow et al., 2019). In this paper, we describe a survey we conducted in 2021 that focused on understanding market size and willingness to pay for an on-demand *airport shuttle* mission for a longer-term scenario of *future* market conditions. Given our 2021 survey overlaps in several ways with our prior two surveys, we draw text directly from our prior AIAA conference papers to provide the reader with a self-contained description of our 2021 survey.

II. Sampling Plan

We are using a commercial opinion panel to survey air travelers in seven metropolitan areas in the U.S. Specifically, we included individuals who had a home zip code within the Census-defined Combined Statistical Areas (CSAs) for Atlanta, Boston, Chicago, Dallas-Ft. Worth, Los Angeles, New York City, and the San Francisco Bay Area, and shown in Figure 1. (Online databases were used to find the shapefiles for roads (United States Census Bureau, 2019c), airports (Federal Aviation Administration, 2020), cities (ArcGIS Hub, 2020), states (Esri, 2020), and CSAs (United States Census Bureau, 2019b) that we used to generate Figures 1-8). We surveyed 2,820 individuals with household before-tax annual incomes of at least $75,000. Our motivations for selecting these seven CSAs are described below.

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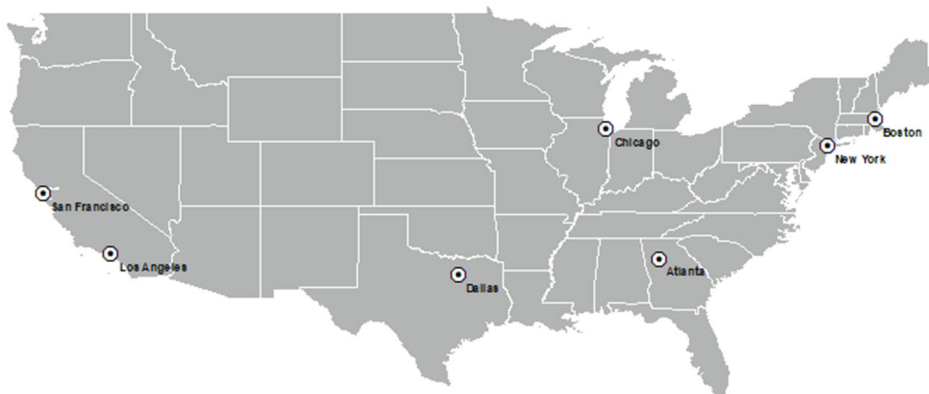
Figure 1. Survey Cities

Atlanta is a land-locked city in the Southeast that has no geographic features that help prevent outward growth expansion in the region. The sprawling region provides a spoke interstate system to different areas of the region and has many large employment centers along the Interstate 285 perimeter that surrounds Atlanta. The automobile-dominant mode share of the region, combined with the lack of natural boundaries that limit outward expansion and the spoke interstate feature, set the region apart from the other survey cities. Additionally, Atlanta's airport, Hartsfield-Jackson Atlanta International Airport (ATL), is ranked the number one commercial service airport by number of yearly enplanements according to the Federal Aviation Administration (FAA) (2018). The airport serves a massive population of not only Atlanta residents, but residents of surrounding Georgia cities. ATL is 9.2 miles[+] from the city center, and with Atlanta's car-dependence and infamous ground traffic congestion, residents may be willing to use air taxis to bypass this ground traffic congestion for their airport trips.
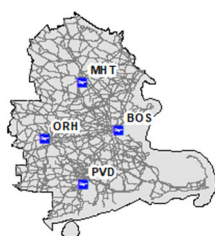
Figure 2. Atlanta CSA

Boston is a city on the East Coast that is part of the Northeast Corridor. The Boston CSA has geographic features and transportation alternatives that influence airport trip mode choice. The Boston CSA borders the Atlantic Ocean and includes parts of Connecticut, New Hampshire, Massachusetts, and Rhode Island. The City of Providence, Rhode Island, lies within the Boston CSA. The Boston Harbor, Cape Cod Bay, and Charles River are all geographic features that affect traffic patterns. The transit mode share is higher in the Boston region than for any other CSAs in our survey. Boston's main airport, Boston Logan International Airport (BOS), is located only 3.8 miles[+] from the city center, making it the most central airport in this study. However, the airport is separated by water from most of the rest of the city, meaning there are limited route options by ground transportation. Boston Logan has some competition with other airports in the Boston CSA, including Worcester Regional Airport (ORH), Manchester-Boston Regional Airport (MHT), and T.F. Green Airport (PVD), each of which are much further from the Boston city center, but serve demand of people living in the surrounding area.

Figure 3. Boston CSA

[+] These distances were found using Google Maps by mapping the shortest driving distance from the city to the airport.

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Dallas-Ft. Worth is similar to Atlanta in that it lacks geographic features that limit sprawl and influence development patterns. Distinct from Atlanta, the interstate network was constructed in a grid-pattern between Dallas and Ft. Worth with many large business-attracting areas between the cities near the City of Arlington and along the perimeter of the cities. Dallas is one of two cities in the U.S. that Uber selected for testing eVTOL flights (Repko, 2018). The Dallas-Ft. Worth area's busiest airport is Dallas/Fort Worth International Airport (DFW), which is ranked as the fourth busiest airport based on number of yearly enplanements according to the FAA (2018). DFW is 20 miles[+] from the city center of Dallas, and 23 miles[+] from the city center of Fort Worth, making it the least central airport in this study. The other major airport in the CSA is Dallas Love Field Airport (DAL). DFW and DAL are close in proximity to one another (16.7 miles[+]), so they likely compete for much of the same traveler demand.
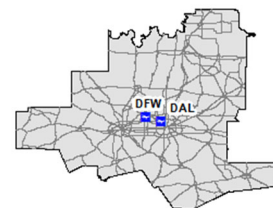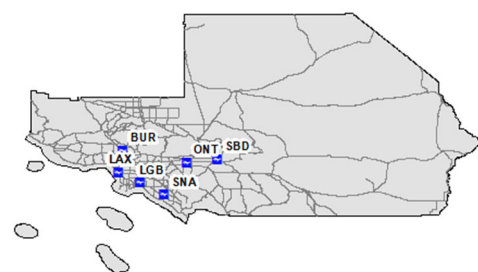

Figure 4. Dallas-Ft. Worth CSA

Figure 5. Los Angeles CSA

Los Angeles is the second city in the U.S. that Uber selected for testing eVTOL flights and is one of two West Coast CSAs included in our study (Repko, 2018). The region is infamous for long commute times and for having one of the most congested interstate systems in the nation (Romero, 2016). Los Angeles has geographic features that act as barriers to development in particular areas of the region, e.g., the CSA borders the Pacific Ocean and has terrain features (such as mountains) that impact where development occurs and where the transportation network can be located. Los Angeles is unique among the other cities in that from the 1970s until 2014, it had regulations requiring buildings above a certain height to have a heliport on their roof to assist in evacuations (Smith, 2014). This sets Los Angeles apart from other cities in that it already has an existing infrastructure in a downtown area that could potentially be converted to vertiports. Los Angeles' main airport is Los Angeles International Airport (LAX), which is ranked as the second busiest airport based on number of yearly enplanements according to the FAA (2018). This airport is 16.6 miles[+] from the city center, and similar to Atlanta, it is likely that the limited transit options and car-dependence in Los Angeles combined with the saturated roadways will push air travelers to choose an air taxi service that bypasses ground traffic as an alternative option for airport trips. Los Angeles also has many airports that potentially compete with LAX including Ontario International Airport (ONT), John Wayne Airport (SNA), San Bernardino International Airport (SBD), Hollywood Burbank Airport (BUR), and Long Beach Airport (LGB). These airports are spread out within the CSA, ranging from 22.3 miles[+] to 77.6 miles[+] from LAX and likely serve air travelers living in the areas surrounding the city of Los Angeles.

The San Francisco CSA was chosen because of its unique geographic features and reputation as an incubator of new technologies (Rampton, 2014). The Bay Area has three major cities (Oakland, San Francisco, and San Jose) within the San Francisco CSA. The San Francisco Bay only has four existing bridge crossings from the East Bay to areas in San Francisco and the cities of Silicon Valley. This physical barrier makes for challenging traffic patterns and could be an ideal pattern for future eVTOL air-taxi service. There are also key geographic features in the terrain that impact the location of existing transportation connections along the interstates, highways, and transit. San Francisco's major airport, San Francisco International Airport (SFO), is ranked as the seventh busiest airport based on number of yearly enplanements according to the FAA (2018). Other major airports in the area include Oakland
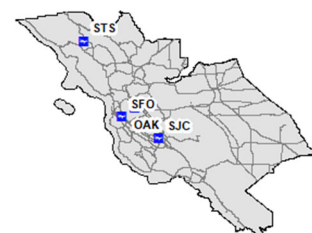

Figure 6. San Francisco CSA

[+] These distances were found using Google Maps by mapping the shortest driving distance from the city to the airport.

International Airport (OAK), San Jose International Airport (SJC), and Charles M. Schulz-Sonoma County Airport (STS). These airports, particularly OAK and SJC, are likely to compete with SFO for travelers living closer to San Jose or Oakland.
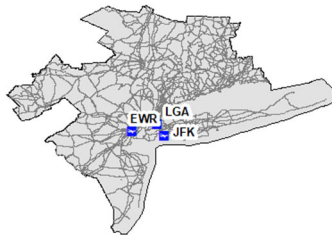

Figure 7. New York City-Newark CSA

Next, the New York City-Newark CSA was chosen because of existing successful helicopter services, Blade and Uber Copter, operating in this region. Blade offers an airport shuttle service between New York City and three area airports (JFK, LaGuardia, and Newark) (BLADE, 2020). Uber Copter offers a narrower service, with an airport shuttle traveling only from downtown Manhattan to JFK airport (Uber, 2020). While the city has a relatively robust transit network, there is existing demand for these air travel services for airport trips, which indicates that a similar on-demand eVTOL service may also be successful. The New York City-Newark CSA was also chosen because of its massive size; with a population of over 22.5 million residents, this CSA ranks as the largest by population in the United States according to 2019 estimates by the U.S. Census Bureau (2019a). The busiest airport in this CSA, by FAA's latest ranking, is John F Kennedy International Airport (JFK), which has the sixth most yearly enplanements of all commercial airports in the U.S. (Federal Aviation Administration, 2018). This is also the furthest airport from the NYC city center (17.8 miles[+] away). The other two major airports in this region, Newark Liberty (EWR) and LaGuardia (LGA), both rank in the top 21 busiest airports, and they are both more than 10 miles[+] from the NYC city center as well (Federal Aviation Administration, 2018). Both the frequency of flights taking place at these regional airports and the relatively far distances from the city center to these airports indicate that the NYC-Newark CSA may be one of the CSAs with high demand for an air taxi service.

Finally, the Chicago-Naperville CSA was chosen primarily because of the large population, the presence of two major international airports, and the existing ground traffic problems. The Chicago-Naperville CSA is the only Midwest CSA chosen, and it borders Lake Michigan, which acts as a barrier for development to the east. Chicago is home to Chicago O'Hare International Airport (ORD) and Chicago Midway International Airport (MDW), both of which rank within the top 30 busiest airports based on number of yearly enplanements according to the FAA (2018), and both of which are more than 10 miles[+] from the Chicago city center. Chicago has some of the worst ground traffic congestion in the U.S., with major congestion on both the I-290 and I-90/I-94 corridors (INRIX, 2019). The Chicago-Naperville CSA is the third largest CSA by population in the U.S. according to 2019 estimates by the Census Bureau (2019a).
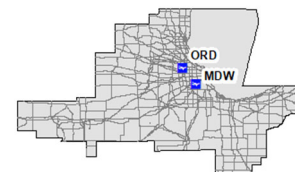

Figure 8. Chicago-Naperville CSA

III. Survey Instrument

The survey instrument contained 11 parts. It included approximately 90 questions in all, but some questions were not shown to all respondents, e.g., respondents were only asked if they paid for parking at the airport if they indicated that they arrived at the airport via a private vehicle. Appendix 1 provides complete details of the survey instrument and associated programming logic described in this section.

A. Institutional Review Board Consent and Screening Questions

The first section contains the required Institutional Review Board (IRB) statement, provides compensation information, and asks respondents whether they agree to participate in the study. We stated that as a participant, "You will complete a survey that asks you about your attitudes, travel patterns, and air travel experiences." We did not

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[+] These distances were found using Google Maps by mapping the shortest driving distance from the city to the airport.

explicitly refer to an air taxi service in the introduction, to minimize biasing recruitment (people may have been less inclined to respond if they had no interest in the service) and results (those who did respond may have been more likely to answer favorably toward questions involving air travel service if they knew that was our primary interest in conducting the survey).

The first section also contains screening questions used to ensure only responses are gathered from the target population. Only those individuals 18 years or older who took at least two roundtrips by air in 2019 (before COVID-19), had not moved residences since January 1, 2019, and had an annual household income of at least $75K were eligible to participate in the study. In addition, the individual must have taken either one business trip that was reimbursed by their company, a client, or other organization or one leisure trip that the individual paid for in cash or credit (versus miles) in 2019 (before COVID-19). Individuals that work in the aviation industry or are full-time students were also excluded. Only those individuals who typically drive themselves to the airport, take a cab, or use a ride-hailing service such as Lyft or Uber qualified for the study. We used the home zip code to ensure that the respondent lived within one of the seven CSAs included in the study.

Some questions included in this section were used to stratify the sample and ensure minimum and/or maximum quotas were satisfied. The distribution of responses associated with reimbursed business trips, household income, and air travel frequency in 2019 are shown in Tables 1 to 3. The sample over-represents higher-income households, individuals who are frequent air travelers, and individuals who travel for business. We hypothesize that all of these characteristics will be associated with higher air taxi adoption rates.

Table 1. Distribution of responses based on trip purpose and geography
Total number of respondents = 2,820

	Atlanta	Boston	Chicago	Dallas-Ft. Worth	Los Angeles	New York	San Francisco	Total
Total number of respondents	315	216	375	336	584	643	351	2820
Number (% in column) answering survey based on a reimbursed business trip in 2019	236 (75%)	123 (57%)	251 (67%)	248 (74%)	466 (80%)	476 (74%)	285 (81%)	2085 (74%)
Number (% in column) answering survey based on a self-paid leisure trip in 2019	79 (25%)	93 (43%)	124 (33%)	88 (26%)	118 (20%)	167 (26%)	66 (19%)	735 (26%)

Table 2. Distribution of responses based on annual household income
Total number of respondents = 2,820

Annual HH income	Count (%)
75-99K	462 (16%)
100-149K	848 (30%)
150-199K	755 (27%)
200K+	755 (27%)

Table 3. Distribution of responses based on air travel frequency in 2019 (before COVID-19)
Total number of respondents = 2,820

# Trips by air in 2019	2	3-6	7-12	13-24	25+
Count (%)	665 (24%)	1,256 (45%)	557 (20%)	225 (8%)	117 (4%)

Based on our prior experience in conducting other studies of air travelers using a commercial online panel, we also imposed quotas based on working status to ensure that leisure trips were not dominated by retirees or those who were not working. Overall 83% of respondents (2,348) indicated that they were currently working full-time for pay, and a 6.7% of respondents (190) indicated that they were retired, a homemaker, and/or currently not working; the remaining responses were associated with working part-time, having reduced hours, etc. The question asking about the respondent's employment status includes more options than typical. Due to the nature of the COVID-19 pandemic,

there are more common possibilities for employment statuses. COVID-19-specific employment statuses were added to the traditional set of statements. For instance, if a person became furloughed or laid off during the pandemic, they can indicate that specifically instead of choosing "I currently do not work." This is an important distinction to capture because it indicates that the respondent's employment status is not typical, and therefore the past travel experiences they draw from to answer later questions may differ in the future as a result of their current employment status. Employment statuses related to the COVID-19 pandemic may also be temporary setbacks; as the economic impact of the pandemic decreases, individuals may return to their original employment statuses. See Question 11 in Appendix 1 for more details.

B. Opinions about Travel

The second section of the survey asks participants about their views on a variety of issues directly or indirectly related to travel. We will use the questions in this section (as well as those collected later in the survey) to conduct factor and cluster analyses, which will provide insights into the types of consumers for which air taxi service is most attractive. See Garrow et al. (2020a) and Garrow et al. (2020b) for examples of factor and cluster analysis that have been used for market segmentation analysis in the context of UAM.

To conduct a factor analysis, we need to identify constructs that we hypothesize will influence demand for air taxi services. We include six constructs in this section, shown in Table 4. Twelve questions were asked, to obtain measurements associated with these constructs. For each question, respondents reported how much they agree or disagree with the statement using a Likert-type scale with five categories: strongly disagree, disagree, neutral, agree, and strongly agree.

In factor analysis, it is common to ask at least two questions associated with each construct, and preferable to vary the directionality of the questions to be (collectively) both "positively" and "negatively" associated with a given construct. Stated another way, the wording of the two questions associated with the construct is designed so that an individual who selected "agree" or "strongly agree" on one question would tend to select "disagree" or "strongly disagree" on the other question. The questions were ordered differently in the survey than in Table 4, to minimize the consistency bias associated with having the items pertaining to the same construct adjacent to each other, to counteract respondents' tendencies to fall into an automatic response pattern (e.g. a predictable alternation of positively and negatively oriented questions), and to reduce any unintended carryover effects from one question to the next.

Finally, we included a "trap question" in this section, in which we asked participants to select "Agree" to confirm they were reading the questions. We terminated the survey for those who did not select the correct response, given it is more likely these individuals were not paying attention to the survey questions (and would potentially bias survey results if they completed the entire survey).

Table 3. Constructs and Survey Questions Related to Opinions about Travel

Survey Question	Construct	Direction
[2]I am fine with not owning a car, as long as I can use or rent one any time I need to	Pro-collective modes	+
[3]Using a ride-sharing service, such as Lyft or Uber, is more convenient than driving	Pro-collective modes	+
[3]Whenever practical, I prefer to drive rather than take transit	Pro-collective modes	-
[3]I like meeting new people through ridesharing	Travel Sociability	+
[3]I'm uncomfortable traveling in the same car with strangers	Travel Sociability	-
[1]I don't mind sharing a ride with strangers if it reduces my costs	Travel Sociability	+
[2]I would tend to feel sick if I tried to read while in a moving vehicle	Motion sickness	+
[4]I rarely consider the impact on the environment in my travel choices	Pro-environment	-
[5]I limit my driving to help improve air quality	Pro-environment	+
[1]Even if I can use my travel time productively, I still expect to reach my destination as fast as possible	Productivity	+
[5,6]I would usually rather have someone else who is trustworthy do the driving	Control	-
[6,7]Being in a car makes me nervous if someone else is driving	Control	+

Notes: [1]Lavieri and Bhat (2019) [2]Kim, Mokhtarian, and Circella (2019) [3]Garrow et al. (2019) [4]Al Haddad et al. (2020) [5]Mokhtarian, Salomon, and Redmond (2001) [6]Haboucha, Ishaq, and Shiftan (2017) [7]Circella (2020)

C. Opinions About Air Travel

The third section asks participants about their opinions related to air travel. Similar to the previous section, the results from these questions will also be used to perform factor and cluster analysis. This section includes four constructs composed of eleven statements. These statements and their corresponding constructs are listed in Table 5. The same Likert scale choices used for the previous section were listed for each statement in this section in order to measure the respondent's level of agreement with the statement.

Table 5. Constructs and Survey Questions Related to Opinions About Air Travel

Survey Question	Construct	Direction
I prefer to drive and park at or near the airport	Airport Mode Preference	+/-
I prefer to take a ride-hailing service such as Lyft or Uber to the airport	Airport Mode Preference	+/-
I prefer to have family or friends drop me off at the airport	Airport Mode Preference	+/-
I prefer to take public transit to the airport	Airport Mode Preference	+/-
[1]I like traveling by airplane	Air Mode Preference	+
[1]Traveling by air makes me nervous	Air Mode Preference	-
I am willing to spend extra time getting to and from the airport in order to save money	Cost Sensitivity	+
I like getting to and from the airport as quickly as possible, even if it costs more	Cost Sensitivity	-
[2]Self-driving cars are appealing to me because they will allow me to use my travel time to the airport more productively	Pro-AV Attitude	+
Self-driving cars are appealing to me since I would not need to park at or near the airport	Pro-AV Attitude	+
Driving is safer overall than using a self-driving car	Pro-AV Attitude	-

Note: [1]Garrow et al. (2019) [2]Lavieri and Bhat (2019)

D. Current Travel Behavior

The fourth section of the survey asks questions about the individual's current travel behavior including:

- Household car ownership
- Whether the individual had taken a ride-hailing service and if so, how the individual typically used these services
- How the individual expects his or her travel to change after COVID-19
- How the individual expects his or her residential location to change after COVID-19

This section also asks questions about the individual's air travel experience including:

- Whether the individual had traveled in a small aircraft
- The individual's preferred mode choice to travel to the airport and what influences this choice
- The individual's comfort level with traveling by air during the COVID-19 pandemic
- The number of round-trips the individual has taken by air since April 1, 2020

E. Most Recent Air Trip

The fifth section of the survey asks questions about the individual's most recent air trip. If the individual indicates in the screening questions that they had taken at least one business-related trip paid for by their company or an

organization in 2019, they would be asked about their most recent business-related trip of this nature until a minimum number of responses for business travel was obtained. Otherwise, the individual would be asked about their most recent leisure trip that they paid for themselves. Questions about the trip include:

- When the air travel trip took place
- Whether or not the trip was international
- How far in advance the ticket was purchased
- How much the air travel ticket costed
- The reason for taking the air travel trip
- How many total people the individual traveled with and among those how many were children
- How long the trip was
- How many bags the individual and their party checked and carried on the plane
- Whether or not the individual paid baggage fees
- The class of service used on the trip and whether or not a free upgrade was used
- Which airport the individual flew out of (only major airports in the individual's CSA were displayed as choices; these choices include the airports shown in Figures 2 to 8)
- The travel mode used by the individual to arrive at the airport
- Whether or not the individual paid to park at the airport, and if so how much parking cost
- Where the individual started their trip to the airport and how far it was from the airport
- Whether or not the individual experienced traffic congestion during their trip to the airport
- Which airport the individual flew into at their destination
- How the individual got from the destination airport to his or her final destination

F. Introduction to Self-Driving Cars

The sixth part of the survey introduces the concept of self-driving cars and shows participants three images based on designs reported in the press. At the time of this publication, these images were available at Caricos.com (2019), Thepositive.com (2019), and Media.treehugger.com (2019). We edited these images for the survey, e.g., we removed a steering wheel to better reflect a fully-autonomous vehicle. We used a bullet-pointed list to describe the self-driving cars and included information about the design, operation, and safety features. The description, which was based on Mokhtarian (2017), included the following:

- Driverless cars would be at least as safe as today's cars are and they would be generally affordable.
- The car could be equipped with services such as an office, a television, or a small fridge for snacks.
- The car could be equipped with power outlets to keep your laptop and phone fully charged.
- You could send an empty self-driving car somewhere to pick up your children or groceries, or to park after dropping you off at work or other locations.
- You could let a self-driving car take you places while you are sleeping.

Based on this initial description, we asked individuals how appealing the design was to them and how likely they would be to use or own it. Consistent with Al Haddad et al. (2020), we also asked a question about when the individual would be likely to adopt self-driving cars (in its first year of operation, in its second or third year of operation, … never). We then presented respondents with potential features of the self-driving car and asked them if they would be more or less likely to use it with these characteristics. The tested features included ownership status, the presence of other passengers, and activities that would be possible during the trip. Next, we ask whether or not the respondent would move to a different residential location and whether or not the respondent would change the number of vehicles his or her household owns if he or she could regularly take a self-driving car to and from work.

G. Introduction to Air Taxis

The seventh part of the survey introduces the concept of eVTOL aircraft for air taxi service and shows participants three images based on designs reported in the press. At the time of this publication, these images were available at eVTOL news™ (2020) and Transport Up (2020). We used a bullet-pointed list to describe the aircraft and included information about the design, operation, and safety features that are consistent with how we described these aircraft on prior surveys (Binder et al., 2018; Garrow et al., 2019):

- Are battery powered
- Carry two to four passengers
- Travel up to 50 miles within a city at cruise speeds of 150 mph
- Have efficient security checks with no lines
- In the near-term, would be flown by certified pilots on-board the aircraft
- Take off and land vertically like a helicopter
- Take off and land at locations in a city called vertiports such as tops of buildings and parking decks
- Operate out of vertiports that would be located 0-5 miles from your home and airport locations
- Have limits on how much baggage you can bring onboard, just like a commercial aircraft
- Are much quieter than helicopters, both for the community and for the occupants of the aircraft
- Travel at about the altitude where traffic helicopters fly
- Do not fly in hazardous weather conditions (such as thunderstorms)
- Meet stringent safety requirements mandated by the U.S. Federal Aviation Administration

Images of three aircraft were then shown to respondents.

Based on this initial description, we ask individuals how appealing the design was to them, how likely they would be to use it, and when they would be likely to use it. We then present respondents with potential features of the eVTOL aircraft and ask them if they would be more or less likely to use it with these characteristics. The tested features include fuel/battery combinations, a parachute for the aircraft, and multiple propellers for redundancy. We then ask how appealing it would be to use an air taxi for different trip purposes, including airport and non-airport trips, and how much more or less likely they would be to use an air taxi if it used certified autonomy, included a ride guarantee, or operated in different weather conditions. We included two questions related to how frustrated the individual with be with different delays and what refund policy would be appropriate for a given delay. We continued by asking six questions related to eVTOL perceptions (reaction to battery technologies, pros/cons of proximity, and overall impressions, shown in Table 6. Next, we ask whether or not the respondent would move to a different residential location and whether or not the respondent would change the number of vehicles his or her household owns if he or she could regularly take an air taxi to and from work.

Table 6. Constructs and Survey Questions Related to Perceptions about eVTOL Aircraft

Survey Question	Construct	Direction
[1]I like that these aircraft can take off and land close to my home and work locations	Proximity	+
[1]I would be concerned to fly in an aircraft that takes off and lands vertically within a city with tall buildings	Proximity	-
[1]I like the idea of battery-powered aircraft for helping the environment	Battery technology	+
[1]I would be concerned to travel in a battery-operated aircraft	Battery technology	-
[1]I would find it exciting to travel in one of these eVTOL aircraft	Overall impression	+
[1]These aircraft would cause more problems than they would solve	Overall impression	-

Note: [1]Garrow et al. (2019)

H. Trade-off Questions

The eighth part of the survey contains eight questions as shown in Figure 9 (these images, and others included in the survey, are reprinted here from the Creative Commons Attribution license (Icons8, 2020; Kaito, 2020; Oleynic, 2020). Each question presented three hypothetical options for traveling to the airport and asked which one the respondent would choose. The introduction to the trade-off questions was presented to respondents as follows (using the business trip context as an example):

We would like for you to compare three hypothetical options for traveling to the airport. The first option is to drive yourself and park at the airport using a conventional auto. The second option is to use a ride-hailing company (Lyft/Uber) to travel to the airport. The third option is for you to take an air taxi.

In all cases, we show you the door-to-door travel time to go from your home to the check-in area at the airport.

For the auto option:
- The round-trip cost includes gas and parking in the daily lot at the airport.
- It is possible that when you arrive at the airport, the daily parking lot is full, in which case you would have to park in the economy lot. For example, a parking availability probability of 90% means that you would be able to park in the daily lot 9 out of 10 times you went to the airport.

For the ride-hail option:
- The trip may be in a conventional auto with a driver or it may be in an autonomous (driverless) auto.

For the air taxi option:
- The vertiport (or location) where the air taxi departs is within 5 miles of your home.
- You can drive your car to the vertiport and park for free or have someone drop you off.
- The vertiport where the air taxi lands is located at the airport.
- A ride guarantee may be provided, meaning that if the air taxi can't fly, you get preferential access to a Lyft or Uber ride at a price that is the same or lower than the air taxi.
- The air taxi can be flown by a pilot or it can be flown autonomously (without a pilot on board).
- Air taxi operators have different on-time performance records. For example, an on-time performance of 99% means that 99 out of every 100 air taxi trips arrive at the airport on-time.

For the questions that follow, assume you are traveling **after COVID-19 on a four-day/three-night business trip that will be reimbursed by your company or a client.**

Figure 9. Example Trade-Off Question

We included several attributes in our trade-off questions including travel time, cost, and the other attributes shown in Table 7. For travel times and travel costs, we set levels based on distance ranges to the airport. We determined distance ranges based on the distribution of distances from residences with household incomes greater than $75K to the nearest airport. The number of high-income households in each zip code were found using the CSA boundaries and household incomes at the zip code level (United States Census Bureau, 2019b; ArcGIS Hub, 2018). The centroids of each zip code were located, then distances were calculated between the centroids and each major airport in the CSA (Federal Aviation Administration, 2020). Plots illustrating these distances are included in (Leonard, 2020)

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Four distance ranges were used to generate choice sets: less than ten miles, 11 to 20 miles, 21 to 40 miles, and 41 miles or more. For the auto mode, we selected four levels to represent door-to-check-in times that would reflect realistic ground travel times under free-flow and congested traffic conditions as well as time to travel from the parking lot of the airport to the check-in area. Given ride-hailing is subject to the same traffic conditions as auto and includes a wait time at the start of the trip yet eliminates the need to travel from the parking lot of the airport to the check-in area, we used two travel times as levels for ride-hailing that were the same as the two middle levels used for auto. For the air taxi, we based travel times on an average cruise speed of 150 mph and included 5 to 10 minutes of access and egress times.

For costs, we assumed that individuals would be traveling for a four-day/three-night trip. For the auto mode, we used airport websites to obtain information on the cost of parking in the daily lot at the major airport(s) in the study areas. For Atlanta and Dallas DFW airports, the daily cost of parking was about $20 per day whereas at the other airports, the daily cost of parking was about $40. For shorter trips, the cost of gas did not change the overall potential range of realistic prices too much, whereas for longer trip ranges, the cost of gas did have a larger influence.

For ride-hailing, we based our cost estimates on a formula provided for Uber that is $0.80 base fare + $0.21 per minute + $1.10 and used a formula to estimate cost to the airport, also allowing for specific airport fees that may be added on (HyreCar, 2020). For air-taxi, we loosely based prices on the short-term and near-term price-per miles reported in the literature but rounded prices to the nearest $25 and ensured some air prices for some cities were less than a per-person bases for shorter distances to represent longer-term competitive cost structures.

Table 7. Attributes and Levels included in Trade-Off Questions (Excluding Time and Cost)

Attribute	Definition	Levels
Daily parking lot availability	Probability (%) the daily parking lot is available when you arrive at the airport	50, 75, 95, 99
Automation	For ride-hailing, whether or not there is a driver For air taxi, whether or not there is a pilot on board	Driver present, no driver present or Pilot on board, pilot not on board
Air taxi on-time performance	Probability (%) the air taxi arrives to the airport on-time	90, 95, 99, 99.9
Ride guarantee	Whether or not a discounted ride on Uber/Lyft is provided if the air taxi cannot fly (e.g., due to bad weather)	Yes, No

Table 8. Travel Time Levels Included in Trade-Off Questions

Distance	Auto	Ride-hailing	Air Taxi
Less than 10 miles	20, 25, 30, 35	25, 30	15, 20, 25
11 to 20 miles	25, 30, 35, 40	30, 35	15, 20, 25, 30
21 to 40 miles	35, 45, 55, 65	45, 55	20, 25, 30, 35
41 miles or more	45, 60, 75, 90	60, 75	25, 30, 35, 40

Table 9. Per-Person, One-Way Cost Levels Included in Trade-Off Questions

Distance	Auto – Atlanta and Dallas	Auto – Other Cities	Ride-hailing	Air Taxi
Less than 10 miles	40, 45	80, 90	15, 20	50, 75, 100, 125
11 to 20 miles	45, 50	80, 90	20, 25, 30	50, 75, 100, 125
21 to 40 miles	45, 50, 55	80, 90	30, 40, 50, 60	75, 100, 125, 150
41 miles or more	50, 60, 70	90, 100, 110	55, 65, 75, 85	75, 100, 125, 150

Given the number of attributes in our trade-off questions, combined with the number of levels that we wanted to test, we would have had to ask each individual respondent 32 trade-off questions, which clearly is not realistic. In these cases, it is common to create blocks of questions so that each respondent sees no more than eight tradeoff questions. Respondents are then randomly assigned to one block (which contains eight questions). We created a total of 256 trade-off questions, representing a total of 4 distance ranges × 2 daily parking rates × 4 blocks × 8 questions per block. See Leonard (2020) for the levels corresponding to the 256 trade-off questions. The design was generated

using Ngene (ChoiceMetrics, 2018) and utility functions were based on prior studies of air taxi mode choice for commuters (Boddupalli, Garrow, and German, 2020; Garrow, Roy, and Newman, 2020).

As part of this section we kept track of the number of times the respondent selected each mode. If the individual never selected air taxi, we asked a 9th trade-off question where air taxi clearly dominated the choices along all dimensions to help determine whether the individual was a "never adopter" or whether the individual was sensitive to time-cost trade-offs.

We asked a final trade-off question that only included traditional auto and ride-hailing with a driver to represent current market conditions. This last trade-off question can be used to weight the survey data to represent current market shares for the drive-and-park and ride-hailing modes. See Glerum et al. (2016) for details on this adjustment procedure.

I.   Lifestyle and Attitudes

The ninth section asks participants about their personal lifestyle and opinions not directly related to travel. Similar to sections B and C, the results from these questions will also be used to perform factor and cluster analysis. This section includes four constructs composed of nine statements. These statements and their corresponding constructs are listed in Table 9. The same Likert scale choices used for sections B and C were listed for each statement in this section in order to measure the respondent's level of agreement with the statement.

Table 9. Constructs and Survey Questions Related to Lifestyle and Attitudes

Survey Question	Construct	Direction
[1]I like to wait a while rather than being the first to buy a new product	Early Adopter	-
[1,2,3]I often introduce new trends to my friends or family	Early Adopter	+
I like that companies can tailor products to my preferences, even if it requires me to provide personal information	Privacy Concern	-
I'm concerned that technology invades my privacy too much	Privacy Concern	+
[3]For me, a lot of the fun of having something nice is showing it off	Status-Oriented	+
When making a purchase, I value functionality more than the status of its brand	Status-Oriented	-
I feel as if I need to make the most of every minute	Time Pressure	+
[4]Having to wait can be a useful pause in a busy day	Time Pressure	-
[4]Having to wait is an annoying waste of time	Time Pressure	+

Note: [1]Kim, Mokhtarian, and Circella (2019) [2]Mokhtarian, Ory, and Cao (2009) [3]Neufeld and Mokhtarian (2012) [4]Garrow et al. (2019)

J. Use of Technology

Given prior studies that have found adoption of new transportation modes is associated with current use of technology, we asked how often individuals used smartphones, desktop computers, wearable technologies such as a smart watch of Fitbit and how often they post on Facebook, Twitter, Instagram, LinkedIn, and WhatsApp and similar applications (Kim, Circella, and Mokhtarian, 2019; Al Haddad, 2020).

K. Additional Socio-economic Information

We conclude the survey by asking for socio-demographic and socio-economic information that was not already obtained for screening or quotas. These questions included whether the individual lives in an urban, suburban, small town, or rural area, gender, education level, number of adults and number of children under 18 living in the household before COVID-19, and ethnicity. A trap question to check for fatigue was also included in this section.

IV.   Next Steps/Conclusion

This paper described the sampling plan and survey instrument we will use to forecast air taxi demand for airport trips. Given the high cost of daily parking at many airports and the high cost of ride-hailing for longer distances, air taxi may be more competitive with traditional modes, particularly for reimbursed business trips. Future work will focus on mode choice modeling and modeling the timing adoption for air taxis and autonomous ground vehicles.

Appendices

Appendix 1 contains the survey instrument.

Acknowledgments

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Appendix 1: Air Taxi Survey Instrument

SECTION 1: IRB, Screening and Qualification Criteria

Programming notes: IRB consent form is shown and participant agrees to consent to participating in the survey.

1. What is your five-digit home zip code?

Programming notes: Zip codes are validated and must be a zip code in the CSAs of Atlanta, Boston, Chicago, Dallas-Ft. Worth, New York, Los Angeles, or San Francisco.

2. What was your five-digit home zip code on *January 1, 2019*?

Programming note: If zip code is different than zip code from Q1, new zip code must be within the same CSA as the first zip code from Q1.

3. What is your age in years?

    ○ 17 and younger

    ○ 18 - 24 years

    ○ 25 - 34 years

    ○ 35 - 44 years

    ○ 45 - 54 years

    ○ 55 - 64 years

    ○ 65 and older

Programming note: Must be 18 or older to participate.

4. What was your total household income before taxes and deductions during the past 12 months?

    ○ $0 - $74,999

    ○ $75,000 - $99,999

    ○ $100,000 - $149,999

    ○ $150,000 - $199,999

    ○ $200,000 or more

Programming note: Must have an annual household income of 75K or more to participate.

5. How many round-trips by air did you take in 2019 *(before COVID)*?

16

○ None

○ 1

○ 2

○ 3 to 6

○ 7 to 12

○ 13 to 24

○ 25 or more

Programming note: Must have taken 2 or more trips in 2019 to participate.

6. Did you take any **business-related** air trips in 2019 *(before COVID)* that your company or some other organization paid for?

○ Yes

○ No

7. Did you take any **leisure-related** air trips in 2019 *(before COVID)* that you personally paid for? Don't include trips that someone else paid for or that you used miles for.

○ Yes

○ No

Programming note: Must answer yes to either Q6 or Q7.

8. In 2019 *(before COVID)*, how did you typically travel to the airport?

○ I drove myself

○ I took public transit

○ I had a friend or family member drive me

○ I took a taxi cab

○ I used a ride-hailing service (such as Lyft or Uber)

○ Other

Programming note: Must answer "I drove myself" or "I took a taxi cab" or "I used a ride-hailing service (such as Lyft or Uber)" to participate.

9. Do you work in the aviation industry?

○ Yes

○ No

Programming note: Must answer no to participate.

10. Which statement most accurately describes your student status?

○ I am a full-time student

○ I am a part-time student

○ I am not a student

Programming note: Must not be a full-time student to participate.

11. Which of the statements best describe your current employment situation during the COVID-19 pandemic? Please select **ALL** that apply.

☐ I work full-time for pay

☐ I work part-time for pay

☐ I have two or more jobs

☐ I am furloughed with pay from my previous job

☐ I am furloughed without pay from my previous job

☐ I was let go from my job during the COVID-19 pandemic

☐ My place of employment went out of business during the COVID-19 pandemic

☐ I am working fewer hours during the COVID-19 pandemic

☐ I am working more hours during the COVID-19 pandemic

☐ I only do unpaid work (i.e. volunteering, unpaid internship)

☐ I am a homemaker or unpaid caregiver

☐ I am retired

☐ I currently do not work

☐ Other, please specify

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SECTION 2: Opinions About Travel

12. For each of the following statements, please check the response that best expresses your opinion of travel in 2019 **(before COVID).**

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Being in a car makes me nervous if someone else is driving	○	○	○	○	○
Using a ride-hailing service, such as Lyft or Uber, is more convenient than driving	○	○	○	○	○
I like meeting new people through ride-hailing	○	○	○	○	○
I rarely consider the impact on the environment in my travel choices	○	○	○	○	○

13. Please check the response that best expresses your opinion of travel in 2019 **(before COVID).**

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
I would usually rather have someone who is trustworthy do the driving	○	○	○	○	○
Whenever practical, I prefer to drive rather than take transit	○	○	○	○	○
I'm uncomfortable traveling in the same car with strangers	○	○	○	○	○
I limit my driving to help improve air quality	○	○	○	○	○

14. Please check the response that best expresses your opinion of travel in 2019 **(before COVID).**

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
I would tend to feel sick if I tried to read while in a moving vehicle	○	○	○	○	○
I don't mind sharing a ride with strangers if it reduces my costs	○	○	○	○	○
Even if I can use my travel time productively, I still expect to reach my destination as fast as possible	○	○	○	○	○
Please select "Agree"	○	○	○	○	○
I am fine with not owning a car, as long as I can use or rent one any time I need to	○	○	○	○	○

Programming note: Must answer "Agree" to the attention check question in order to participate.

SECTION 3: Opinions About Air Travel

15. For each of the following statements, please check the response that best expresses your opinion of air travel in 2019 *(before COVID).*

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
I like getting to and from the airport as quickly as possible, even if it costs more	○	○	○	○	○
Traveling by air makes me nervous	○	○	○	○	○
I prefer to have family or friends drop me off at the airport	○	○	○	○	○
Driving is safer overall than using a self-driving car	○	○	○	○	○

16. Please check the response that best expresses your opinion of air travel in 2019 *(before COVID)*.

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
I prefer to drive and park at or near the airport	○	○	○	○	○
I am willing to spend extra time getting to and from the airport in order to save money	○	○	○	○	○
Self-driving cars are appealing to me since I would not need to park at or near the airport	○	○	○	○	○
I prefer to take a ride-hailing service such as Lyft or Uber to the airport	○	○	○	○	○

17. Please check the response that best expresses your opinion of air travel in 2019 *(before COVID)*.

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
I prefer to take public transit to the airport	○	○	○	○	○
Self-driving cars are appealing to me because they allow me to use my travel time to the airport more productively	○	○	○	○	○
I like traveling by airplane	○	○	○	○	○

SECTION 4: Your Current Travel

18. How many vehicles does your household own or lease?

○ None

○ One

○ Two

○ Three or more

19. Do you own or lease a hybrid or battery-powered vehicle?

○ Yes

○ No

Programming note: Display Q19 only if Q18 is not equal to "None".

20. In 2019 *(before COVID)*, how often did you use ride-hailing services, such as Lyft or Uber?

○ Once a week or more often

○ Two or three times a month

○ Once a month

○ Less than once a month

○ Never

21. Which of the following explains how you have used ride-hailing services *(before COVID)*?
Please select *ALL* that apply.

☐ To get to or from the airport

☐ To get to or from work on a regular basis

☐ To get to or from work occasionally such as when my car is in the shop

☐ To go to a large event where parking may be difficult such as a ball game or concert

☐ To get home after a night out

☐ Other, please specify

Programming note: Display Q21 only if Q20 is not equal to "Never".

22. Please think of **your life as it will be after COVID and a return to normal**: how often do
you expect to do the following activities **compared to your life before COVID**?

	Much less often	Somewhat less often	About the same	Somewhat more often	Much more often
Work at a regular workplace(s)	○	○	○	○	○

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Telecommute and/or work from home	○	○	○	○	○
Make long-distance trips by air for work/business purposes	○	○	○	○	○
Make long-distance trips by air for leisure/personal purposes	○	○	○	○	○

23. Please think of **your life as it will be after COVID and a return to normal:** which statement best represents your vision for where you will be living?

○ I will be living in the same location

○ I will be moving closer to work

○ I will be moving further from work (e.g., to a more attractive or more spacious location)

Your Air Travel Experience

24. Have you ever flown as a passenger in the types of aircraft listed below?

	No	Yes	I'm not sure
A small plane with no overhead bins that carries *at most 9 passengers*	○	○	○
A helicopter	○	○	○

25. Please check the response that best expresses your opinion.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Before COVID, I selected my flights to avoid traffic congestion on the way to or from the airport	○	○	○	○	○
Before COVID, I selected my flights on a of the week that I knew I could find parking at my departure airport	○	○	○	○	○
Before COVID, I liked to arrive to the airport early before my flight	○	○	○	○	○

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Before COVID, I liked to park at my departure airport	○	○	○	○	○
Before COVID, I liked to take a ride-hailing service to my departure airport	○	○	○	○	○
Before COVID, I would have taken a ride-hailing service to my departure airport more often if I lived closer to the airport	○	○	○	○	○

26. How many round-trips have you taken by air since COVID (or *since April 1, 2020*)?

○ None

○ 1

○ 2

○ 3 to 5

○ 6 to 10

○ 11 or more

27. Please check the response that best expresses your opinion.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
I would travel by air today	○	○	○	○	○
I would be comfortable traveling by air as soon as the US population was vaccinated for COVID-19	○	○	○	○	○
I would be comfortable traveling by air as soon as I was vaccinated for COVID-19	○	○	○	○	○
I am unsure of when I will feel comfortable traveling by air again	○	○	○	○	○

SECTION 5: Your Most Recent Air Trip

28. Think about the last air trip you took starting from home when you flew for business when a company or organization paid for the ticket or reimbursed you for travel. When did you

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make this air trip?

Year
Month

Programming note: drop-down list allows respondent to select a month and year between January of 2019 and January of 2021. Question 28 appears only if individual selected yes to Q6 (business trip quota is filled first).

28B. Think about the last air trip you took starting from home when you flew for leisure for a trip that you paid for (do not think about a trip that someone else paid for or that you used miles for). When did you make this air trip?

Year
Month

Programming note: drop-down list allows respondent to select a month and year between January of 2019 and January of 2021. Question 28B appears only if individual selected no to Q6 and yes to Q7 (leisure trip quota is filled last).

29. Did your trip begin or end in an airport outside of the United States?

○ No

○ Yes

30. How long before your trip did you purchase your ticket?

○ 0 to 6 days

○ 7 to 13 days

○ 14 to 20 days

○ 21 to 30 days

○ More than 30 days

○ I don't know

31. Approximately how much was the airfare for your most recent trip by air? Do not include the cost of any tickets you might have purchased for others you traveled with.

○ $1 to $249

○ $250 to $499

○ $500 to $999

○ $1,000 to $2,499

○ $2,500 to $4,999

○ $5,000 or more

○ I don't know

32. What was the primary reason you flew?

○ Business

○ Attend a conference

○ Vacation

○ Visit friends or relatives

○ Other, please specify _____

Programming note: This is used for validation to ensure that if they answered Yes to Q6 they are actually answering the "business" trip questions.

33. How many people, associates, friends, or family members did you travel with?

○ I traveled alone

○ I traveled with 1 other person

○ I traveled with 2 other people

○ I traveled with 3 other people

○ I traveled with 4 other people

○ I traveled with 5 or more other people

34. Including yourself, how many children, young adults, and adults did you travel with?
    Children aged 0-5
    Children aged 6-13
    Young adults aged 14-17
    Adults aged 18 and older

Programming note 1: Drop-down lists are provided for 0, 1, 2 and 3 or more for each of the categories above.
Programming note 2: Display this question only if response to Q33 is not equal to "I traveled alone"

35. How many nights were you away on your trip?

○ 0

○ 1

○ 2

○ 3

○ 4

○ 5

○ 6

○ 7 or more

36. How many bags did you check?

○ 0 bags

○ 1 bag

○ 2 bags

○ 3 or more bags

○ I don't know

Programming note: Q36 is displayed if individual traveled on business (Q6=Yes) or individual traveled on leisure alone (Q7=Yes and Q33=I traveled alone).

37. How many bags did you carry on the plane?

○ 0 bags

○ 1 bag

○ 2 bags

○ 3 or more bags

○ I don't know

Programming note: Q36 is displayed if individual traveled on business (Q6=Yes) or individual traveled on leisure alone (Q7=Yes and Q33=I traveled alone).

36A. How many bags did you and the people you traveled with check?

○ No bags

○ 1 bag

○ 2 bags

○ 3 bags

○ 4 bags

○ 5 bags

○ 6 bags

○ 7 bags

○ 8 or more bags

○ I don't know

Programming note: Q35A is displayed if individual traveled on leisure (Q6=No and Q7=Yes) with at least one other person (Q33 is not equal to "I traveled alone").

37A. How many bags did you and the people you traveled with carry on the plane?

○ No bags

○ 1 bag

○ 2 bags

○ 3 bags

○ 4 bags

○ 5 bags

○ 6 bags

○ 7 bags

○ 8 or more bags

○ I don't know

Programming note: Q35A is displayed if individual traveled on leisure (Q6=No and Q7=Yes) with at least one other person (Q33 is not equal to "I traveled alone").

38. Did you pay any baggage fees?

○ No

○ Yes

39. What class of service did you use on your trip?

○ Economy or coach

○ Premium economy

○ Business or first class

40. Did you receive a free upgrade to business or first class on your flight?

○ No

○ Yes

Programming note: Display Q40 if Q39= "Business or first class"

41. Did you receive a free upgrade to premium economy on your flight?

○ No

○ Yes

Programming note: Display Q41 if Q39= "Premium economy"

42. Which airport did you fly out of?

○ Hartsfield-Jackson Atlanta International Airport (ATL)

○ Other, please specify _____

Programming note: Display Q42 if zip code in Q1 corresponds to Atlanta CSA.

42A. Which airport did you fly out of?

○ San Francisco International Airport (SFO)

○ Oakland International Airport (OAK)

○ Norman Y. Mineta San Jose International Airport (SJC)

○ Charles M. Schulz-Sonoma County Airport (STS)

○ Other, please specify _____

Programming note: Display Q42A if zip code in Q1 corresponds to San Francisco CSA.

42B. Which airport did you fly out of?

○ Los Angeles International Airport (LAX)

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○ Ontario International Airport (ONT)

○ John Wayne Airport (SNA), Orange County, CA

○ San Bernardino International Airport (SBD)

○ Hollywood Burbank Airport (BUR)

○ Long Beach Airport (LGB)

○ Other, please specify _____

Programming note: Display Q42B if zip code in Q1 corresponds to Los Angeles CSA.

42C. Which airport did you fly out of?

○ Dallas/Fort Worth International Airport (DFW)

○ Dallas Love Field Airport (DAL)

○ Other, please specify _____

Programming note: Display Q42C if zip code in Q1 corresponds to Dallas-Ft. Worth CSA.

42D. Which airport did you fly out of?

○ Boston Logan International Airport (BOS)

○ Worcester Regional Airport (ORH)

○ Manchester-Boston Regional Airport (MHT)

○ T.F. Green Airport (PVD), Warwick, RI

○ Other, please specify _____

Programming note: Display Q42D if zip code in Q1 corresponds to Boston CSA.

42E. Which airport did you fly out of?

○ John F. Kennedy International Airport (JFK)

○ LaGuardia Airport (LGA)

○ Newark Liberty International Airport (EWR)

○ Other, please specify _____

Programming note: Display Q42E if zip code in Q1 corresponds to New York City CSA.

42F. Which airport did you fly out of?

○ O'Hare International Airport (ORD), Chicago, IL

○ Midway International Airport (MDW), Chicago, IL

○ Other, please specify _____

Programming note: Display Q42F if zip code in Q1 corresponds to Chicago CSA

43. How did you arrive at the airport you used to start your trip?

○ I drove myself

○ I had a friend or family member drive me

○ I took a taxi cab

○ I used a ride-hailing service (such as Lyft or Uber)

○ I took public transit

○ Other, please specify _____

44. Did you pay to park at or near the airport?

○ No

○ Yes

45. How much did you pay per day to park at or near the airport?

○ less than $10 per day

○ $10 - $19 per day

○ $20 - $29 per day

○ $30 - $39 per day

○ $40 - $49 per day

○ $50 or more per day

46. From where did you start your trip to the airport?

○ My home

○ Other residence

○ Business or office

○ Other, please specify _____

47. What is the zip code where you started your trip to the airport?

○ _____

○ I don't know

Programming note: Validate zip codes.

48. Approximately how far was it from your starting location to the airport?

○ Less than 10 miles

○ 10 - 19 miles

○ 20 - 29 miles

○ 30 - 39 miles

○ 40 miles or more

○ I don't know

49. How much traffic congestion did you experience getting to the airport?

○ Little to no congestion

○ Minor congestion

○ Moderate congestion

○ Heavy congestion

50. At which airport did you end your trip?

Programming note: Display dropdown menu with FAA list of commercial airports if respondent ended their trip within the US (Q29 = "no"). Display text entry box if respondent ended their trip outside the US (Q29 = "yes").

51. When you landed at your destination airport, how did you get to your final destination?

○ Picked up by someone else

○ Rental vehicle

○ Ride-hailing service (Uber, Lyft, etc.)

○ Taxi

○ Limo / executive car / town car

○ Shuttle / van

○ Public transit (bus, rail, trolley, etc.)

○ I don't know

○ Other, please specify _____

SECTION 6: Introduction to Self-Driving Cars

In this section, we'd like to know your opinions on self-driving (or driverless) cars. Such vehicles drive themselves and control all operating and safety functions, and are even able to travel without a human inside. For our purposes, we want you to imagine a future where both conventional cars and self-driving cars (that do not need humans driving them) are available.

Specifically, please assume that ...

- Driverless cars would be at least as safe as today's cars are, and they would be generally affordable.
- The car could be equipped with services such as an office, a television, or a small fridge for snacks.
- The car could be equipped with power outlets to keep your laptop and phone fully charged.
- You could send an empty self-driving car somewhere to pick up children or groceries, or to park after dropping you off at work or other locations.
- You could let a self-driving car take you places while you are sleeping.

These figures may help may help you imagine the possibilities:

Programming note: Images of interiors of self-driving vehicles are shown.

52. Based on the description provided so far, how appealing do you find self-driving cars?

  ○ Very unappealing

  ○ Somewhat unappealing

  ○ Neutral

  ○ Somewhat appealing

  ○ Very appealing

53. Carefully considering your circumstances, how likely would you be to **use** a self-driving car for your own local travel?

  ○ Very unlikely

  ○ Somewhat unlikely

  ○ Neutral

  ○ Somewhat likely

  ○ Very likely

54. Carefully considering your circumstances, how likely would you be to **own** a self-driving car for your own local travel?

- ◯ Very unlikely
- ◯ Somewhat unlikely
- ◯ Neutral
- ◯ Somewhat likely
- ◯ Very likely

55. Assuming self-driving cars are affordable, how long after self-driving cars enter the market would you consider using one?

- ◯ In the first year of its operation
- ◯ In the second or third years of its operation
- ◯ In the fourth or fifth years of its operation
- ◯ In the sixth year of its operation or later
- ◯ Never

56. In the following questions, we will present you with potential features of self-driving cars. For each feature, we are interested in knowing how much more or less likely you would be to travel in a self-driving car, compared to a traditional car.

	Much less likely to take self-driving car	Less likely to take self-driving car	Would not affect my decision	More likely to take self-driving car	Much more likely to take self-driving car
You **own** the self-driving car	◯	◯	◯	◯	◯
You arrange for a pick-up from a ride-hailing company (such as Lyft or Uber) and **travel alone**	◯	◯	◯	◯	◯
You arrange for a pick-up from a ride-hailing company and share with **people you know**	◯	◯	◯	◯	◯
You arrange for a pick-up from a ride-hailing company and share	◯	◯	◯	◯	◯

with **strangers**

57. Please indicate how much more or less likely you would be to travel in a self-driving car, compared to a traditional car.

	Much less likely to take self-driving car	Less likely to take self-driving car	Would not affect my decision	More likely to take self-driving car	Much more likely to take self-driving car
You could use your phone to talk, text, and access the internet	◯	◯	◯	◯	◯
You could do work on your laptop	◯	◯	◯	◯	◯
You could sleep	◯	◯	◯	◯	◯

58. About how long did it take you to commute from home to work **before COVID-19?**

   ◯ Less than 20 minutes

   ◯ 21 to 30 minutes

   ◯ 31 to 45 minutes

   ◯ 46 to 60 minutes

   ◯ 61 minutes or more

59. Would you move to a different residential location if you could regularly take a self-driving car to and from work?

   ◯ I would move further from work (e.g., to a more attractive or spacious location)

   ◯ I would move closer to work

   ◯ I would not move

60. Would you change the number of vehicles your household owns or leases if you could regularly take a self-driving car to and from work?

   ◯ Very likely to own fewer

   ◯ Somewhat likely to own fewer

   ◯ More likely to own the same

○ Somewhat likely to own more

○ Very likely to own more

SECTION 7: Introduction to Air Taxis

NASA and many companies are spearheading research on urban air mobility that seeks to develop an air taxi service for cities. The aircraft:

- Are battery powered
- Carry two to four passengers
- Travel up to 50 miles within a city at cruise speeds of 150 mph
- Have efficient security checks with no lines
- In the near-term, would be flown by certified pilots on-board the aircraft
- Take off and land vertically like a helicopter
- Take off and land at locations in a city called vertiports such as the tops of buildings and parking decks
- Operate out of vertiports that would be located 0-5 miles from your home and airport locations
- Have limits on how much baggage you can bring onboard, just like a commercial aircraft
- Are much quieter than helicopters, both for the community and for the occupants of the aircraft Travel at about the altitude where traffic helicopters fly
- Do not fly in hazardous weather conditions such as thunderstorms
- Meet stringent safety requirements mandated by the U.S. Federal Aviation Administration

In this section, we ask you to imagine that you are flying in one of the new electric vertical take off and landing (or eVTOL) air taxis shown below.

Programming note: Three pictures of eVTOL aircraft are shown.

61. Were you familiar with the concept of urban air mobility prior to reading the description above?

○ No

○ Yes

62. Based on the description of the new aircraft provided so far, how appealing do you find this idea?

○ Very unappealing

○ Somewhat unappealing

○ Neither appealing nor unappealing

○ Somewhat appealing

○ Very appealing

63. How likely would you be to use such a service?

○ Very unlikely

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○ Somewhat likely

○ Neither likely nor unlikely

○ Somewhat likely

○ Very likely

64. How long after air taxis enter the market would you consider using one?

○ In the first year of its operation

○ In the second or third years of its operation

○ In the fourth or fifth years of its operation

○ In the sixth year of its operation or later

○ Never

65. How much more or less likely would you be to fly in an air taxi if each feature were present?

	Much less likely	Somewhat less likely	Would not affect my decision	Somewhat more likely	Much more likely
Uses both fuel and batteries	○	○	○	○	○
Has a large parachute for the entire aircraft, so that you and the aircraft could descend safely to the ground if there were an emergency	○	○	○	○	○
Has multiple propellers for redundancy in case of failures	○	○	○	○	○

66. How appealing do you find the idea of using such a service for each of the trip purposes below?

	Very unappealing	Somewhat unappealing	Neither appealing nor unappealing	Somewhat appealing	Very appealing
Daily commuting	○	○	○	○	○

Occasional commuting	○	○	○	○	○
Travel to a concert, sports event, or other large venue	○	○	○	○	○
Sightseeing as part of a vacation, such as over the Grand Canyon	○	○	○	○	○

67. How appealing do you find the idea of using air taxis for the following purposes associated with trips to and from the airport?

	Very unappealing	Somewhat unappealing	Neither appealing nor unappealing	Somewhat appealing	Very appealing
Travel from home or work to your local airport	○	○	○	○	○
Travel from the airport you land at to your final destination	○	○	○	○	○
Travel from your hotel or other destination to the airport for the flight home	○	○	○	○	○

68. How much more or less likely would you be to fly in an air taxi if it was operated in the following way?

	Much less likely	Somewhat less likely	Would not affect my decision	Somewhat more likely	Much more likely
Certified autonomy (no pilot on board)	○	○	○	○	○

The air taxi service may come with a ride guarantee. In the event that the eVTOL option is not available (for example due to bad weather) a ride guarantee makes sure you receive priority for taking a Lyft or Uber car. To compensate you for the inconvenience, the ride-hailing option would be discounted and you would pay less than both what the cost of an eVTOL flight would have been as well as the ride-hail.

This idea is shown in the images below.

Programming note: Images of Lyft app with an eVTOL option are displayed.

69. How much more or less likely would you be to use an air taxi to travel to the airport if it had a ride guarantee?

	Much less likely	Somewhat less likely	Would not affect my decision	Somewhat more likely	Much more likely
Includes a ride guarantee	○	○	○	○	○

70. Assuming air taxis are affordable, how long after air taxis enter the market would you consider using one?

○ In the first year of its operation

○ In the second year of its operation

○ In the fourth year of its operation

○ In the sixth year of its operation

○ Never

71. Compared to clear skies, how much more or less likely would you be to take an air taxi to the airport if you checked the weather the night before you flight and learned that the following weather conditions were forecast to occur the day of your flight?

	Much less likely	Somewhat less likely	Would not affect my decision	Somewhat more likely	Much more likely
Fog	○	○	○	○	○
Light rain	○	○	○	○	○
Heavy rain	○	○	○	○	○
Lightning and thunderstorms	○	○	○	○	○

72. How frustrated would you be if the following delays happened while you were waiting to take the air taxi to the airport?

Not at all frustrated   Completely frustrated

	0 1 2 3 4 5 6 7 8 9 10
10 minute delay	slider at 5
20 minute delay	slider at 5
30 minute delay	slider at 5
45 minute delay	slider at 5
60 minute delay	slider at 5
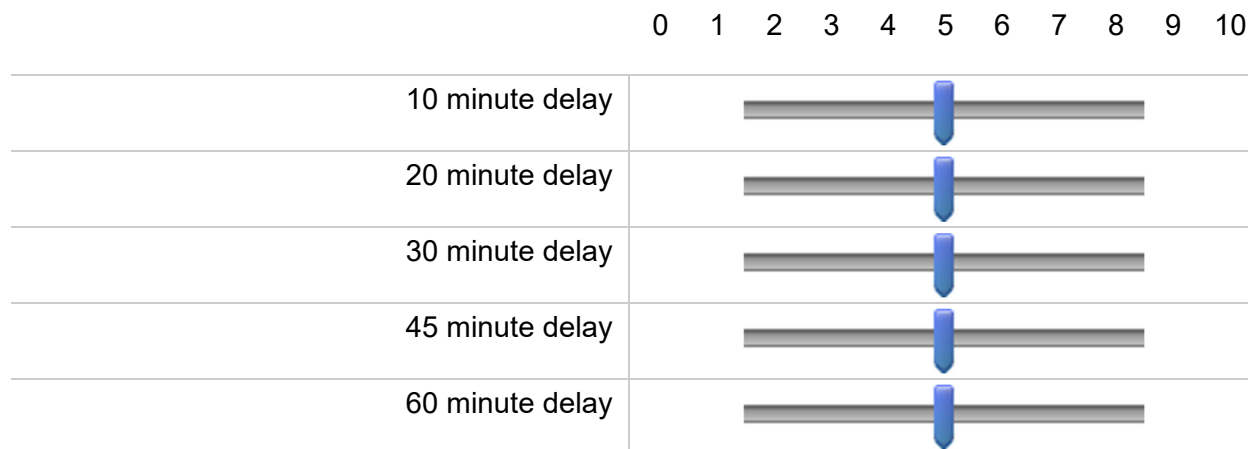
73. Which refund policy do you think is most appropriate for those who are using air taxis to go to the airport if they experience the following delays?

	No refund	Partial refund	Full refund
15 minute delay	○	○	○
30 minute delay	○	○	○
45 minute delay	○	○	○
60 or more minute delay	○	○	○

74. For each of the following statements, please check the response that best expresses your opinion.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
I would be concerned to fly in an aircraft that takes off and lands vertically within a city with tall buildings	○	○	○	○	○
I would find it exciting to travel in one of these eVTOL aircraft	○	○	○	○	○
I would be concerned to travel in a battery-operated aircraft	○	○	○	○	○
I like that these aircraft can take off and land close to my home and work locations	○	○	○	○	○

| These aircraft would cause more problems than they would solve | ○ | ○ | ○ | ○ | ○ |
| I like the idea of battery-powered aircraft for helping the environment | ○ | ○ | ○ | ○ | ○ |

75. Would you move to a different residential location if you could regularly take an air taxi to and from work?

○ I would move further form work (e.g., to a more attractive or spacious location)

○ I would move closer to work

○ I would not move

76. Would you change the number of vehicles your household owns or leases if you could regularly take an air taxi to and from work?

○ Very likely to own fewer

○ Somewhat likely to own fewer

○ Most likely to own the same

○ Somewhat likely to own more

○ Very likely to own more

SECTION 8: Mode Trade-Off Questions

We would like for you to compare three hypothetical options for traveling to the airport. The first option is to drive yourself and park at the airport using a conventional auto. The second option is to use a ride-hailing company (Lyft/Uber) to travel to the airport. The third option is for you to take an air taxi.

 In all cases, we should you the door-to-door travel time to go from your home to the check-in area at the airport.

For the auto option:
- The round-trip cost includes gas and parking in the daily lot at the airport.
- It is possible that when you arrive at the airport, the daily parking lot is full, in which case you would have to park in the economy lot. For example, a probability that the daily lot is free of 90% means that you would be able to park in the daily lot 9 out of 10 times you went to the airport.

For the ride-hail option:
- The trip may be in a conventional auto with a driver or it may be in an autonomous (driverless) auto.

For the air taxi option:
- The vertiport (or location) where the air taxi departs is within 5 miles of your home.
- You can drive your car to the vertiport and park for free or have someone drop you off.
- The vertiport where the air taxi lands is located at the airport.
- A ride guarantee may be provided, meaning that if the air taxi can't fly, you get preferential access to a Lyft or Uber ride at a price that is the same or lower than the air taxi.
- The air taxi can be flown by a pilot or it can be flown autonomously (without a pilot on board).
- Air taxi operators have different on-time performance records. For example, an on-time performance of 99% means that 99 out of every 100 air taxi trips arrive at the airport on-time.

Programming note: Display the statement below for business trip purposes:

For the questions that follow, assume you are traveling **after COVID on a four day/three-night business trip that will be reimbursed by your company or a client.**

Programming note: Display the statement below for leisure trip purposes:

*For the questions that follow, assume you are taking an air trip similar to the most recent leisure air trip you described earlier (same flights, same travel companions, same baggage, etc.) and that your trip is **after COVID for a four day/three-night trip that you are paying for yourself.***

Programming note: Display 8 trade-off questions per logic described in paper.

SECTION 9: Lifestyle and Attitudes

77. Please check the response that best expresses your opinion.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
I like to wait a while rather than being the first to buy a new product	○	○	○	○	○
I like that companies can tailor products to my preferences, even if it requires me to provide personal information	○	○	○	○	○
I feel as if I need to make the most of every minute	○	○	○	○	○
For me, a lot of the fun of having something nice is showing it off	○	○	○	○	○
Having to wait can be a useful pause in a busy day	○	○	○	○	○

78. Please check the response that best expresses your opinion.

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
I often introduce new trends to my friends or family	○	○	○	○	○
When making a purchase, I value functionality more than the status of its brand	○	○	○	○	○
I'm concerned that technology invades my privacy too much	○	○	○	○	○
Having to wait is an annoying waste of time	○	○	○	○	○

SECTION 10: Your Use of Technology

79. How often do you use the following devices and services?

	Never or rarely	Sometimes	Often	Constantly
Smartphone	○	○	○	○
Desktop computer	○	○	○	○
Wearable technology, e.g., smart watch or Fitbit	○	○	○	○

80. How often do you post on the following?

	Never	Monthly or less	Weekly	Daily	Constantly
Facebook	○	○	○	○	○
Twitter	○	○	○	○	○
Instagram	○	○	○	○	○

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LinkedIn ○ ○ ○ ○ ○

WhatsApp, WeChat, Viber, or similar ○ ○ ○ ○ ○

SECTION 11: Some Information about Yourself

81. How would you characterize the area where you live now?

- ○ Urban part of a city or region

- ○ Suburban part of a city or region

- ○ Small town

- ○ Rural area

82. What is your gender?

- ○ Male

- ○ Female

- ○ Non-binary

- ○ Prefer not to answer

83. What is the highest degree or level of school you have completed?

- ○ Less than high school

- ○ High school

- ○ Some college or technical school

- ○ Associate degree

- ○ Bachelor degree

- ○ Master degree

- ○ Doctoral degree

- ○ Professional degree (for example: MD, DDS, DVM, LLB, JD)

84. Including yourself, how many adults ages 18 and older lived in your household as of January 1, 2020 *(before COVID)?*

- ○ 1 adult

- ○ 2 adults

- ○ 3 adults

- ○ 4 adults

- ○ 5 or more adults

85. How many children under the age of 18 lived in your household as of January 1, 2020 *(before COVID)?*

○ No children

○ 1 child

○ 2 children

○ 3 children

○ 4 children

○ 5 or more children

86. Please select 5.

○ 1

○ 2

○ 3

○ 4

○ 5

Programming note: Attention check at end of survey.

87. What is your ethnicity?

○ Caucasian or White

○ African or African-American or Black

○ Asian or Asian-American

○ Hispanic or Latino

○ Other, please specify _____

○ Prefer not to answer