AN EXPLORATORY EMPIRICAL ANALYSIS OF WILLINGNESS TO PAY FOR AND USE FLYING CARS

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ABSTRACT

From the early years of aviation, flying cars have constituted an appealing topic for science-fiction scenarios. Currently, recent technological developments demonstrate that flying cars will be introduced in the traffic fleet over the next few years. Despite their forthcoming penetration in the automobile market, the level of anticipated acceptance from the traveling population has not been investigated yet in travel demand literature. This study aims – for the first time to the authors' knowledge – to provide a preliminary investigation of individuals' perceptions and expectations towards the adoption of flying cars. For this purpose, 692 individuals were questioned in the context of an online survey about their willingness to pay for and willingness to use flying cars for various pricing and trip scenarios, as well as about the benefits and concerns that will arise from the introduction of flying cars in the traffic fleet. To understand the determinants of individuals' expectations, their willingness to pay for and use flying cars was statistically modeled, by employing a grouped random parameters bivariate probit framework, which accounts for multiple layers of unobserved heterogeneity in the respondent's decision-making process. The statistical analysis revealed that various individual-specific socio-demographic, behavioral and driving attributes, as well as individuals' attitudinal perspectives towards the cost, safety, security and environmental implications of the flying cars, affect their willingness to adopt this emerging transportation technology. Despite the current limited awareness about the operation of flying cars, the findings of this study can provide insights regarding critical challenges that should be addressed by policymakers, legislative companies, and manufacturing companies after the introduction of flying cars in the traffic fleet.

Keywords: Flying cars; Willingness to pay; Willingness to use; Grouped random parameters; Bivariate probit models.

1. INTRODUCTION

The steady expansion of the transportation infrastructure aims to accommodate the constantly growing traffic volumes, but at the same time, induces new challenges arising from individuals' desire for safe, reliable, affordable and sustainable mobility. Addressing such transportation challenges in combination with rapid advances in automobile technology has led to the emergence of advanced transportation technologies and systems, such as, electric vehicles, shared mobility schemes, and automated transportation systems. Electric vehicles provide environmentally friendly mobility by reducing vehicle-generated CO_2 emissions (Egbue and Long, 2012; Dias et al., 2017; Tischer et al., 2019), while the hybrid nature (public and private) of the mobility service provided by the carsharing or ridesharing systems has the potential to alleviate traffic congestion (Shaheen et al., 2006; Kopp et al., 2015). The various levels of vehicle automation, ranging from vehicle-specific advanced driver assistance systems (ADAS) to the forthcoming self-driving autonomous vehicles, are expected to significantly modify traffic patterns as well as commuters' driving habits (Shin et al., 2015; Bansal et al., 2016; Fagnant and Kockelman, 2018). Even though the fully autonomous and connected vehicles have not been introduced in the traffic fleet yet, a growing amount of current research focuses on the anticipated consumer acceptance, as reflected by travelers' perceptions, concerns and expectations (Kyriakidis et al., 2015; Bansal et al., 2016; Fagnant and Kockelman, 2018).

Over the last few decades, a growing amount of research has focused on emerging technologies for aircraft and aerospace systems (Wendel et al., 2006; Cacan et al., 2015; Puente et al., 2018) and, specifically, on Unmanned Aerial Vehicles (Fabiani et al., 2007; Kontogiannis and Ekaterinaris, 2013; Sazdovski et al., 2015; Ramasamy et al., 2016; Panagiotou et al., 2016; Goh et al., 2017; Yu et al., 2017; Tyan et al., 2017; Hu et al., 2018; Oh and Kim, 2018; Dai et al., 2018;

Saderla et al., 2018l; Liu et al., 2018; Mir et al., 2018; Wu et al., 2018; Jia et al., 2018; Radmanesh et al., 2018). Even though this type of aerial vehicles is primarily used for freight deliveries or military purposes, recent advances in automotive technology (Trancossi et al., 2017; Sudirja and Adhitya, 2018) have paved the way for the forthcoming penetration of an emerging transportation technology that further enhances automation and connectivity in urban mobility patterns without *a priori* requiring the concurrent interaction with the other components of the conventional transportation networks. Specifically, a new generation of vehicles that can simultaneously accommodate ground and air transportation, namely the flying cars, aim to provide automated or semi-automated transportation either in a private or shared mobility context (Eker et al, 2019; Eker et al., 2020). Recent developments show that the flying cars will be available in the automotive market until 2025 (Becker, 2017; Oppitz and Tomsu, 2018). Interestingly, Terrafugia, has already developed a flying car prototype and intends to commercialize a personal aircraft-flying car by 2023. Through the Uber Elevate project, Uber is currently developing an on-demand, aerial taxi service that will be operated through electrical aircrafts with vertical take-off and landing capabilities and will be price-competitive to the current on-demand ground transportation service (Uber Elevate, 2016; Siebenmark, 2019. Several other manufacturing companies have also disclosed their intention to launch flying cars in the automotive market, such as, Airbus, Cora, Ehang184, Lilium, Workhorse and Volocopter.

According to the technical specifications provided by various designers, flying cars have the potential to provide hybrid operation in two spatial dimensions: (i) on the existing surface transportation network, since they can operate as conventional cars with automated or semi-automated capabilities; and (ii) in the air, since they can operate as private/shared aircrafts with travel range up to 500 miles and cruise speed ranging from 100 to 200 mph. With regard to the flying operations, flying cars will take off and land vertically; to that end, runways are not necessarily required for their aforementioned operations, since clearance zones of at least 100 feet (in diameter) are adequate for safe take-off and landing operations. With regard to their passenger capacity, flying cars will accommodate from two to four passengers, including the operator who should be appropriately trained and certified with a pilot's license. As far as their technical operation is concerned, the flying car engine will be fully electric or will operate on premium unleaded automotive gasoline, while the navigation will be conducted on the basis of automated/self-driving features. Flying cars will be also equipped with all modern automotive safety and crash avoidance features, rear-view cameras as well as with a full vehicle parachute. Regarding their pricing characteristics, it is anticipated that a typical flying car will be priced as a high-end luxury car, with predicted prices ranging from $100,000 to $500,000.

The inclusion of the third spatial dimension into the urban mobility patterns is expected to have considerable appeal, especially in terms of its effect on travel time, reliability, safety and comfort. The non-involvement of flying cars in the congestion mechanisms of the ground transportation systems will likely decrease travel times and will possibly alleviate the congestion of the conventional transportation networks. Specifically, due to their automated navigation capabilities, the shortest air path between trip origin and destination will be leveraged, resulting in lower and more reliable travel times. Since the flying cars network will be deployed in the airspace and their ground operation will not differ from the conventional vehicles' operation, construction of major infrastructure elements (such as, highways, bridges, tunnels or runways) will not be required. Interestingly, according to the current developments, rooftops of multi-level buildings (such as, skyscrapers or parking garages), existing helipads and unused land parcels in the vicinity of highways are likely to serve as take-off/landing facilities. Such origin-destination flexibility is also expected to facilitate the mobility patterns of commuter groups with limited accessibility in the conventional transportation systems, such as elderly commuters or non-drivers. However, the emergence of such a revolutionary transportation mode will also bring to the surface significant challenges that may critically affect their adoption by the commuting population. Specifically, the acquisition, operation and maintenance cost of flying cars may constitute key factors of concern, especially from the perspective of potential travelers. In addition, security, safety, privacy and environmental issues as well as the absence of policy and regulatory frameworks may introduce additional barriers to the successful deployment of flying cars.

All these technological advancements imply that the emergence of flying cars is not anymore a science-fiction script, but, potentially, a reality in the near future. Over the last few years, various stakeholders have been contributing to the development of a new mobility concept, i.e., the urban air mobility (UAM), which aims to provide ubiquitous transportation for passengers and goods in urban settings by extensively exploiting the airspace (Thipphavong et al., 2018; Vascik et al., 2018; Unmanned Airspace, 2018). Through the Urban Air Mobility Grand Challenge, NASA focuses on identifying the appropriate technological, legislative, and policy provisions that will allow for a smooth integration of UAM with the existing surface and air transport systems (NASA 2017, 2018a; 2018b). Despite all the global initiatives, the impact of flying cars on the future mobility systems, in terms of acceptance and adoption by the commuting population is still uncertain. Such uncertainty is further enhanced by the limited awareness of travelers, especially with regard to flying cars' capabilities and features. Under these uncertain circumstances, the establishment of a regulating policy framework for their operation as well as the future trajectory of manufacturing investments are highly dependent on the degree of short- and long-term demand for this new transportation technology. Currently, an assessment of the future demand can be derived from the pre-roll-out willingness of travelers to adopt this new technology, with the understanding of such demand dimension having critical implications on the policy decisions of manufacturing companies, policymakers, and legislative entities (Palm and Handy, 2018).

To shed more light on the key components that are likely to determine the demand for flying cars, this study provides a preliminary, exploratory investigation of individuals' perceptions and expectations towards the adoption of flying cars. Specifically, an online survey was designed and disseminated to obtain individuals' attitudinal perspectives with respect to two fundamental aspects of demand for flying cars: willingness to pay for and willingness to use flying cars. To identify the key determinants of individuals' willingness to pay for and use flying cars, and at the same time, to control for their socio-demographic and behavioral background, discrete outcome statistical models are estimated using the survey data. Specifically, the grouped random parameters bivariate probit econometric framework is employed, which allows the simultaneous modeling of pairs of willingness-to-pay and willingness-to-use scenarios, and accounts for significant statistical modeling issues, namely, unobserved heterogeneity, unbalanced panel effects, and cross-equation error term correlation. These issues may arise from the presence of systematic unobserved variations among the individuals' perceptions.

2. SURVEY DESIGN AND DATA OVERVIEW

The online survey was designed on SurveyMonkey (a web-based survey platform) and disseminated through 35 students and employees at the University at Buffalo. The survey was conducted during March 2017 and the 35 survey collectors gathered socio-demographic, behavioral and attitudinal information from 692 survey respondents. With regard to the socio-demographic background of the respondents, 60% of the sample consists of male respondents (the remaining 40% of the sample consists of female respondents), with 72% of the respondents having earned a Bachelor’s or a Postgraduate degree. The average respondent age is approximately 30 years old, while the median annual household income of the respondents ranges from $50,000 to $75,000, which is consistent with the median household income of United States ($59,039) in 2016 (Semega et al., 2017). Regarding the ethnicity characteristics of the sample, 23% of the respondents are Asian, 57% are Caucasian/White, and the remaining 20% of the sample reflects respondents of other origins (e.g., African American, American Indian, and Hispanic). The information about the country of residence of the respondents was extracted through the Internet Protocols (IP) of the online surveys; specifically, 583 surveys were found to be responded in United States, 50 in India, and the remaining 59 surveys were conducted in seventeen different countries worldwide.[1]

The survey questionnaire was composed of three distinct sections. In the first survey section, a detailed description of a typical flying car model was provided along with a video session and representative images that could enable respondents to be familiarized with the operations and the features of the new transportation mode. Specifically, technical details about operations on the ground and in the air were provided (e.g., take-off and landing requirements, cruise speed and range, weight requirements, technical specifications, etc.) along with information about the expected prices and safety features of the flying cars. To capture awareness regarding automated vehicles technologies and advanced driver assistant systems (ADAS), respondents were asked

[1] These seventeen countries include Australia, Canada, Dominican Republic, Greece, Iran, Nepal, New Zealand, Nigeria, Oman, Qatar, Saudi Arabia, Sri Lanka, Switzerland, Thailand, Turkey, United Arab Emirates, and United Kingdom.

about their level of familiarity with various emerging vehicle features, such as emergency automatic braking, lane keeping assistant/lane centering, adaptive cruise control, left turn assist, adaptive headlights, and blind spot monitoring. Respondents were also asked whether they have ever owned a car with any of the aforementioned vehicle features.

In the second survey section, respondents were questioned about their expectations and perceptions towards the adoption of the flying cars. Specifically, they were asked about their willingness to buy a flying car, for 5 different pricing scenarios ($100,000; $150,000; $200,000; $250,000; and $300,000 or more). Furthermore, respondents were asked about their willingness to use flying cars for several trip scenarios. The latter were specified in terms of: (i) trip purpose (traveling to work, traveling to education activities, traveling to short-term shopping activities, traveling to long-term shopping activities, and traveling to entertainment- or sports-related activities); (ii) trip distance (short-, medium, long-, and very long- distance trips); and (iii) time-of-the-day for the trip (morning, afternoon, evening, and night trips). Table 1 provides all the pricing and trip scenarios that were incorporated in the questions relating to respondents' willingness to pay for and willingness to use a flying car, as well as some key statistics on the distribution of the survey responses.

Another set of questions focused on the respondents' level of concern about various potential issues that may arise from the introduction of flying cars (e.g., safety consequences of equipment/system failure, interaction with other flying cars or vessels on the airway, ease of access to take-off/landing facilities, flying car performance in poor weather, and security against hackers/terrorists). In similar fashion, respondents were surveyed about their opinions on possible benefits of flying cars in traffic safety and travel characteristics (e.g., fewer crashes on the roadway, lower travel time to destination, more reliable travel time to destination, and more in-vehicle non-driving activities). Subsequently, travelers were asked about their expectations to relocate to another area (e.g., city center, urban area, suburban area, or rural area) after the introduction of flying cars. The second survey section also included questions about respondents' opinions on the effectiveness of various suggested measures that can potentially address security issues that may arise after the introduction of flying cars (e.g., use of existing FAA regulations for air traffic control, profiling of the flying car operators, establishment of no-fly zones in sensitive areas, and air-road police enforcement). It should be noted that all the questions included in the second survey section were expressed on a 4-point Likert scale with the respondents rating the likelihood of the question statement as "very unlikely", "somewhat unlikely", "somewhat likely" or "very likely".

The third survey section included questions about the demographic and socio-economic background (e.g., gender, age, ethnicity, marital status, level of education, and household annual income) of the respondents, as well as about their driving experience and behavioral patterns (e.g., driving speed in different speed limit scenarios, driving behavior in the presence of a traffic signal, accident history, and annual vehicle miles traveled). The respondent-specific information of the third survey section was collected either through open-ended or multiple-choice questions. Given the extensive amount of the collected data elements, Table 2 summarizes descriptive statistics of key variables.

Table 1 Distribution of willingness-to-pay and willingness-to-use responses across the survey respondents

Dependent variables	Overall unlikely[a]	Overall likely[b]
Willingness to buy a flying car, if it is priced as		
About $100,000	57.41%	42.59%
About $150,000	73.69%	26.31%
About $200,000	86.62%	13.37%
About $300,000 or more	92.71%	7.29%
Willingness to use a flying car for		
Traveling to work	54.82%	45.18%
Traveling to education activities	59.49%	40.51%
Traveling to entertainment/sports activities	50.87%	49.13%
Traveling to short-term shopping activities	62.29%	37.72%
Traveling to long-term shopping activities	48.89%	51.11%
Making trips from/to the city center (downtown)	56.99%	43.01%
Making short distance trips (less than 50 miles)	58.15%	41.85%
Making medium distance trips (50-100 miles)	40.00%	60.00%
Making long distance trips (100-300 miles)	32.17%	67.83%
Making very long distance trips (greater than 300 miles)	31.17%	68.83%
Making morning trips (6 AM to 12 PM)	44.06%	55.94%
Making afternoon trips (12 PM to 6 PM)	43.97%	56.03%
Making evening trips (6 PM to 12 AM)	46.76%	53.25%
Making night trips (12 AM to 6 AM)	51.51%	48.49%

[a] The percentage corresponding to the “overall unlikely” includes the respondents who chose the “very unlikely” or “somewhat unlikely” survey response.

[b] The percentage corresponding to the “overall likely” includes the respondents who chose the “somewhat likely” or “very likely” survey response.

Table 2 Descriptive statistics of key variables

Variable Description	Mean	Std. Dev.	Min.	Max.
Socio-demographic characteristics				
Gender indicator (1 if the respondent is female, 0 otherwise)	0.398	-	0	1
Gender indicator (1 if the respondent is male, 0 otherwise)	0.596	-	0	1
Marital status indicator (1 if the respondent is single, 0 otherwise)	0.691	-	0	1
Age of the respondent	30.432	12.729	16	94
Square root of the age of the respondent	5.417	1.045	4	9.7
Age indicator (1 if the respondent is younger than 30, 0 otherwise)	0.707	-	0	1
Age indicator (1 if the respondent is older than 40, 0 otherwise)	0.199	-	0	1
Current living area indicator (1 if the respondent lives in suburban area, 0 otherwise)	0.444	-	0	1
Ethnicity indicator (1 if the respondent is Asian, 0 otherwise)	0.226	-	0	1
Education level indicator (1 if respondent's highest level of education includes a high school diploma or partial attendance of high school, 0 otherwise)	0.225	-	0	1
Education indicator (1 if respondent's highest education level includes a high school diploma or a technical college degree, 0 otherwise)	0.269	-	0	1
Education indicator (1 if respondent's highest education level includes a college degree or a post graduate degree, 0 otherwise)	0.720	-	0	1
Income indicator (1 if the respondent's annual household income is between $10,000 and $30,000, 0 otherwise)	0.122	-	0	1
Income indicator (1 if the respondent's annual household income is between $20,000 and $40,000, 0 otherwise)	0.123	-	0	1
Income indicator (1 if the respondent's annual household income is between $20,000 and $50,000, 0 otherwise)	0.193	-	0	1
Income indicator (1 if the respondent's annual household income is between $30,000 and $50,000, 0 otherwise)	0.130	-	0	1
Income indicator (1 if the respondent's annual household income is between $30,000 and $75,000, 0 otherwise)	0.290	-	0	1
Income indicator (1 if the respondent's annual household income is between $10,000 and $40,000, 0 otherwise)	0.662	-	0	1
Income indicator (1 if the respondent's annual household income is between $40,000 and $75,000, 0 otherwise)	0.230	-	0	1
Income indicator (1 if the respondent's annual household income is between $75,000 and $100,000, 0 otherwise)	0.148	-	0	1
Income indicator (1 if the respondent's annual household income is between $50,000 and $100,000, 0 otherwise)	0.308	-	0	1

Variable Description	Mean	Std. Dev.	Min.	Max.
Income indicator (1 if the respondent's annual household income is between $50,000 and $150,000, 0 otherwise)	0.492	-	0	1
Working household members indicator (1 if the respondent is the only household member who works outside the home, 0 otherwise)	0.110	0.314	0	1
Opinions and Preferences				
Vehicle safety features indicator (1 if the respondent never owned a car with an advanced safety feature, 0 otherwise)	0.459	-	0	1
Vehicle safety features indicator (1 if the respondent is not familiar with advanced safety features, 0 otherwise)	0.139	-	0	1
Driving speed indicator (1 if the respondent normally drives faster than 70 mph on an interstate with a 65 mph speed limit and little traffic, 0 otherwise)	0.477	-	0	1
Speed limit opinion indicator (1 if the respondent disagrees or completely disagrees with the statement: "Speed limits on high speed freeways should only be suggestive", 0 otherwise)	0.298	-	0	1
Speed limit opinion indicator (1 if the respondent agrees or completely agrees with the statement: "Speed limits on high speed freeways should only be suggestive", 0 otherwise)	0.311	-	0	1
Driver preference indicator (1 if the respondent generally prefers to drive herself/himself when there are more than two licensed drivers in a vehicle on a trip, 0 otherwise)	0.454	-	0	1
Accident history indicator (1 if the respondent has had at least one non-severe or severe accident in the last 5 years, 0 otherwise)	0.327	-	0	1
Square root of annual mileage driven	89.491	50.191	0	223.6
Annual mileage indicator (1 if the respondent annually drives less than 5,000 miles, 0 otherwise)	0.305	-	0	1
Annual mileage indicator (1 if the respondent annually drives more than 15,000 miles, 0 otherwise)	0.185	-	0	1
Annual mileage indicator (1 if the respondent drives more than 20,000 miles per year, 0 otherwise)	0.092	-	0	1
Cost concern indicator (1 if the respondent is very concerned about the purchase cost of a flying car, compared to a conventional vehicle, 0 otherwise)	0.515	-	0	1
Cost concern indicator (1 if the respondent is moderately or very concerned about the purchase cost of a flying car, compared to a conventional vehicle, 0 otherwise)	0.808	-	0	1
Safety concern indicator (1 if the respondent is very concerned about accidents on the airway with the introduction of flying cars, 0 otherwise)	0.557	-	0	1

Variable Description	Mean	Std. Dev.	Min.	Max.
Operation concern indicator (1 if the respondent is moderately or very concerned about learning to operate/use a flying car with the introduction of flying cars, 0 otherwise)	0.660	-	0	1
Driving joy concern indicator (1 if the respondent is moderately or very concerned about loss of driving joy with the introduction of flying cars, 0 otherwise)	0.440	-	0	1
Safety benefit indicator (1 if the respondent thinks that fewer crashes are somewhat or very likely to occur on the roadway with the introduction of flying cars, 0 otherwise)	0.660	-	0	1
Travel time benefit indicator (1 if the respondent thinks that more reliable travel time to destination is somewhat or very likely to occur with the introduction of flying cars, 0 otherwise)	0.791	-	0	1
Cost benefit indicator (1 if the respondent thinks that lower fuel expenses are somewhat or very unlikely to occur with the introduction of flying cars, 0 otherwise)	0.708	-	0	1
Cost benefit indicator (1 if the respondent thinks that lower vehicle maintenance expenses are somewhat or very unlikely to occur with the introduction of flying cars, 0 otherwise)	0.737	-	0	1
Cost benefit indicator (1 if the respondent believes that lower insurance rates are very unlikely to occur with the introduction of flying cars, 0 otherwise)	0.494	-	0	1
Cost benefit indicator (1 if the respondent thinks that lower insurance rates are somewhat or very unlikely to occur with the introduction of flying cars, 0 otherwise)	0.767	-	0	1
Cost benefit indicator (1 if the respondent thinks that lower insurance rates are somewhat or very likely to occur with the introduction of flying cars, 0 otherwise)	0.233	-	0	1
Environmental benefit indicator (1 if the respondent thinks that lower CO_2 emissions are very unlikely to occur with the introduction of flying cars, 0 otherwise)	0.320	-	0	1
Environmental benefit indicator (1 if the respondent thinks that lower CO_2 emissions are somewhat or very unlikely to occur with the introduction of flying cars, 0 otherwise)	0.646	-	0	1
Trip purpose indicator (1 if the respondent is somewhat or very unlikely to use flying cars for traveling to entertainment/sports activities, 0 otherwise)	0.509	-	0	1
Trip purpose indicator (1 if the respondent is somewhat or very likely to use flying cars for traveling to entertainment/sports activities, 0 otherwise)	0.491	-	0	1

Variable Description	Mean	Std. Dev.	Min.	Max.
Relocation indicator (1 if the respondent is somewhat or very likely to relocate to an urban area – but outside the city center – with the introduction of flying cars, 0 otherwise)	0.352	-	0	1
Security measure indicator (1 if the respondent thinks that using existing FAA regulations for air traffic control is somewhat or very likely improve security against hackers/terrorists, 0 otherwise)	0.607	-	0	1
Security measure indicator (1 if the respondent thinks that establishing air-road police enforcement – with flying police cars – is somewhat or very likely to improve security against hackers/terrorists, 0 otherwise)	0.701	-	0	1
Security measure indicator (1 if the respondent thinks that detailed profiling and background checking of flying car owners/operators is somewhat or very likely to improve security against hackers/terrorists, 0 otherwise)	0.744	-	0	1
Security measure indicator (1 if the respondent thinks that establishing no-fly zones for flying cars near sensitive locations – such as, military bases, power/energy plants, governmental buildings, major transportation hubs, etc. – is somewhat or very likely to improve security against hackers/terrorists, 0 otherwise)	0.783	-	0	1

3. METHODOLOGICAL APPROACH

To shed more light on the decision-making mechanism of the travelers with regard to the future adoption of flying cars, the determinants of their willingness to pay for and use flying cars are investigated. To that end, statistical models of respondents' willingness to pay for various pricing scenarios, and willingness to use for various trip scenarios are estimated using the survey-collected information.

With regard to the willingness-to-pay models, the dependent variables are derived from the question "How likely is it for you to buy a flying car" for four different pricing scenarios ($100,000; $150,000; $200,000; and $300,000 or more), with the answers indicating how likely is for the respondent to buy a flying car at the specified price. From a statistical perspective, the factors that affect respondents' willingness to pay may differ across the various pricing scenarios. Since the choice for each pricing scenario is made by the same respondent, the consideration of relatively lower and higher pricing scenarios may also lead to the presence of commonly shared unobserved characteristics, especially across the cases that comprise the lower (e.g., $100,000, and $150,0000) and the higher (e.g., $200,000, and $300,000 or more) pricing scenarios.

In a similar fashion, the dependent variables for the willingness-to-use models are derived from the survey question "How likely is it for you to use flying cars" for various trip purpose, trip distance, and time-of-the-day scenarios. Five trip purpose scenarios were considered in the analysis: (1) Traveling to work; (2) Traveling to education activities; (3) Traveling to entertainment/sports activities; (4) Traveling to short-term shopping activities; an (5) Traveling to long-term shopping activities. The trip distance scenarios used for the willingness-to-use models are the following: (1) Trips from/to the city center (downtown); (2) Short distance trips (less than 50 miles); (3) Medium distance trips (50-100 miles); (4) Long distance trips (100-300 miles); and

(5) Very long distance trips (greater than 300 miles). With regard to the time-of-the-day, four scenarios were considered: (1) Morning trips (6 AM to 12 PM); (2) Afternoon trips (12 PM to 6 PM); (3) Evening trips (6 PM to 12 AM); and (4) Night trips (12 AM to 6 AM). Another source of common unobserved variations may arise from the nature of the ordinal answers in the Likert-style questions focusing on respondents' willingness to pay for and willingness to use a flying car. Specifically, answers that reflect either positive or negative perspectives of the respondents towards the question statement may share similar or same unobserved variations. To capture such commonly shared unobserved characteristics in a computationally manageable manner, the "very unlikely" and "somewhat unlikely" responses as well as the "somewhat likely" and "very likely" responses were aggregated, respectively, in two homogeneous, yet discrete outcomes, namely: (a) "overall unlikely"; and (b) "overall likely". Due to the aforementioned outcome aggregation, the binary outcome framework was employed for model estimation.[2]

From a statistical perspective, the possible presence of same or similar unobserved characteristics among the scenario-specific responses may result in correlation of the error terms corresponding to the dependent variables reflecting willingness to pay for and use a flying car. Not accounting for such cross-equation error-term correlation may yield biased parameter estimates and inaccurate inferences (Washington et al., 2011; Russo et al., 2014; Anastasopoulos and Mannering, 2016; Anastasopoulos, 2016; Sarwar et al., 2017a; Sarwar et al., 2017b; Pantangi

[2] It should be noted that the joint modeling of all possible outcomes of the survey questions requires estimation of multivariate ordered probit/logit models. Estimation of this class of models with simultaneous consideration of multiple layers of unobserved heterogeneity (i.e., unobserved heterogeneity across survey responses, unbalanced panel effects, and cross-equation error term correlation) is not computationally feasible yet – to the authors' knowledge. In addition, the main outcomes arising from the estimation of such models are not necessarily expected to differ significantly from the findings of the employed methodological approach, given that the parameter estimates of the ordered models provide the effect on two outcomes, and particularly on the highest and lowest ordered outcomes (i.e., the "very likely" and "very unlikely" outcomes). Nevertheless, development of a computational framework that will allow the estimation of such class of models constitutes an important direction for further work.

et al., 2019; Fountas et al., 2020). To that end, the survey responses for various willingness-to-pay and willingness-to-use scenarios are modeled simultaneously in the context of a bivariate probit framework. The latter allows for the joint modeling of two interrelated dependent variables, accounting, at the same time, for their cross-equation error term correlation. The bivariate probit model can be defined as (Sarwar et al., 2017a; Greene, 2017; Pantangi et al., 2019),

$$\begin{aligned} \mathrm{Y}_{i,1} &= \boldsymbol{\beta}_{i,1}\mathbf{X}_{i,1} + \varepsilon_{i,1}, \quad \mathrm{y}_{i,1} = 1 \text{ if } \mathrm{Y}_{i,1} > 0, \text{ and } \mathrm{y}_{i,1} = 0 \text{ otherwise} \\ \mathrm{Y}_{i,2} &= \boldsymbol{\beta}_{i,2}\mathbf{X}_{i,2} + \varepsilon_{i,2}, \quad \mathrm{y}_{i,2} = 1 \text{ if } \mathrm{Y}_{i,2} > 0, \text{ and } \mathrm{y}_{i,2} = 0 \text{ otherwise} \end{aligned} \tag{1}$$

with the cross-equation correlated error terms being expressed as,

$$\begin{pmatrix} \varepsilon_{i,1} \\ \varepsilon_{i,2} \end{pmatrix} \sim N\left[\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} 1 & \rho \\ \rho & 1 \end{pmatrix}\right] \tag{2}$$

where, **X** is a vector of explanatory variables that affect respondents' willingness to pay for and use a flying car, **β** is a vector of estimable parameters corresponding to **X**, y corresponds to integer binary outcome (zero or one for both dependent variables), ε is a normally distributed random error term (with mean equal to zero and variance equal to one), and ρ denotes the contemporaneous (cross-equation) correlation coefficient of the error terms. The bivariate probit model and its log-likelihood function are respectively defined as (Greene, 2017),

$$\Phi\left(Y_1, Y_2, \rho\right) = \frac{\exp\left[-0.5(Y_1^2 + Y_2^2 - 2\rho Y_1 Y_2)/(1-\rho^2)\right]}{\left[2\pi\sqrt{(1-\rho^2)}\right]} \tag{3}$$

and

$$\begin{aligned} &\sum_{i=1}^{N}[y_{i,1}y_{i,2}\ln\Phi(\boldsymbol{\beta}_{i,1}\mathbf{X}_{i,1}, \boldsymbol{\beta}_{i,2}\mathbf{X}_{i,2}, \rho) + (1-y_{i,1})y_{i,2}\ln\Phi(-\boldsymbol{\beta}_{i,1}\mathbf{X}_{i,1}, \boldsymbol{\beta}_{i,2}\mathbf{X}_{i,2}, -\rho) \\ &+(1-y_{i,2})y_{i,1}\ln\Phi(\boldsymbol{\beta}_{i,1}\mathbf{X}_{i,1}, -\boldsymbol{\beta}_{i,2}\mathbf{X}_{i,2}, -\rho) + (1-y_{i,1})(1-y_{i,2})\ln\Phi(-\boldsymbol{\beta}_{i,1}\mathbf{X}_{i,1}, -\boldsymbol{\beta}_{i,2}\mathbf{X}_{i,2}, \rho)] \end{aligned} \tag{4}$$

where $\Phi(.)$ is the cumulative distribution function of the bivariate normal distribution, and all other terms are as previously defined.

Given that the survey data were collected by 35 collectors, common unobserved variations may be present within the group of survey responses gathered by each collector. Specifically, due to the different number of surveys disseminated by each collector, the model formulation should account for unbalanced panel effects (Sarwar et al., 2017a; Fountas et al., 2018a; Fountas et al., 2018b). In addition, a fair amount of research in travel demand modeling and traffic safety (Mannering et al., 2016; Anastasopoulos et al., 2017; Fountas and Anastasopoulos, 2017; Zhu et al., 2017; Paleti and Balan, 2017; Benedyk and Peeta, 2018; Fountas et al., 2018c; Guo et al., 2018, 2020; Fountas et al., 2019; Guo and Peeta, 2020) has shown that the effect of independent variables may vary across the observational units, due to unobserved heterogeneity (i.e., the effect of unobserved characteristics on respondents' perceptions). In order to address these two model misspecification issues, grouped random parameters are introduced in the estimation of the bivariate probit models (Wu et al., 2013; Sarwar et al., 2017a; Sarwar et al., 2018). The grouped random parameters can be defined as (Washington et al., 2011; Sarwar et al., 2017a):

$$\boldsymbol{\beta}_j = \boldsymbol{\beta} + u_j \quad (5)$$

where, $\boldsymbol{\beta}$ denotes the vector of estimable parameters and u_j represents a randomly distributed term for each collector j with mean zero and variance σ^2. Note that in this grouped random parameters setting, each $\boldsymbol{\beta}$ corresponds to a different data collector, instead of an individual respondent. As opposed to the traditional random parameter scheme, this approach simultaneously accounts for unobserved factors that may vary systematically across the various collector-specific groups of survey responses as well as for systematic variations within each collector-specific group of survey responses.

For the estimation of the grouped random parameters bivariate probit models, a simulated maximum likelihood estimation approach was employed. To optimize the efficiency of the required numerical simulations, Halton draws were used (Halton, 1960). As opposed to earlier research that has shown that 200 Halton draws provide adequate numerical integrations for model estimation (Train, 2003; Bhat, 2003), 500 Halton draws were required herein for ensuring parameter stability (Anastasopoulos, 2016; Fountas and Anastasopoulos, 2017).

To provide deeper insights into the implications of the determinants of individuals' willingness to pay for and use a flying car, the averaged – across all observations – pseudo-elasticities were calculated. Pseudo-elasticities provide the effect on the dependent variable, due to a change in the value of an indicator variable from "0" to "1", and can be computed as (Washington et al., 2011):

$$E = \Phi\left(\frac{\beta_j X_{j,1}}{\sigma} \middle| X_i = 1\right) - \Phi\left(\frac{\beta_j X_{j,1}}{\sigma} \middle| X_i = 0\right) \tag{6}$$

where $\Phi(.)$ is the cumulative distribution function of the standard normal distribution and all other terms are as previously defined.

4. ANALYSIS RESULTS AND DISCUSSION

To identify which scenario-based responses of individuals share similar unobserved characteristics, multivariate binary probit models were initially estimated. Using the results of the multivariate probit models, pairs of willingness-to-pay and willingness-to-use scenarios with strong cross-equation error term correlation were identified. The findings from the multivariate probit models verified the pairs of dependent variables, for which, commonly shared unobserved variations were intuitively anticipated. Due to the estimation complexities of the multivariate probit models as well as their inherent limitations in accounting for unobserved heterogeneity, the aforementioned pairs of dependent variables are subsequently modeled using the grouped random parameters bivariate probit framework. Tables 3 through 6 present the model estimation results and pseudo-elasticities for the willingness-to-pay models, whereas Tables 7 through 21 present the model estimation results and pseudo-elasticities for the willingness-to-use models.[3]

For model estimation, all possible variables and variable interactions were examined, and only the variables that were found to be statistically significant at 0.90 level of confidence or greater were included in the model specifications. In addition, the statistical models were estimated using sets of responses with complete information for all the explanatory variables included in the model specifications. Given that different variable combinations may result in different numbers of responses with missing information, the number of responses used for model estimation varies across the models. For the bivariate models, the statistical significance (with greater than 0.95 level of confidence) and the magnitude (with coefficient values being close to 1) of the cross-equation error term correlation strongly support the use of the bivariate modeling approach.

[3] Due to the relatively low cross-equation error term correlation between the variable reflecting willingness-to-use a flying car for entertainment or sport-related activities and the other trip purpose-specific variables, a univariate grouped random parameters binary probit model was estimated for the specific trip purpose.

Table 3 . Estimation results of the willingness-to-pay (WTP) model for pricing scenarios of $100,000 and $150,000

Variables	**WTP for $100k**		**WTP for $150k**	
	Coeff.	***t*-stat**	**Coeff.**	***t*-stat**
Constant	-	-	0.569	1.68
Socio-demographic characteristics				
Age of the respondent	-0.014	-2.44	-0.035	-2.94
Education indicator (1 if respondent's highest education level includes a college degree or a post graduate degree, 0 otherwise)	-0.094	-0.67	-	-
Standard deviation of parameter distribution	0.169	2.64	-	-
Income indicator (1 if the respondent's annual household income is between $50,000 and $150,000, 0 otherwise)	-	-	-0.212	-1.13
Standard deviation of parameter distribution	-	-	0.406	3.77
Opinions and Preferences				
Vehicle safety features indicator (1 if the respondent never owned a car with an advanced safety feature, 0 otherwise)	-0.283	-1.80	-0.391	-2.14
Annual mileage indicator (1 if the respondent drives more than 20,000 miles per year, 0 otherwise)	-	-	0.375	2.16
Cost concern indicator (1 if the respondent is very concerned about the purchase cost of a flying car, compared to a conventional vehicle, 0 otherwise)	-0.331	-1.84	-0.407	-2.61
Safety benefit indicator (1 if the respondent thinks that fewer crashes on the roadway are somewhat or very likely to occur with the introduction of flying cars, 0 otherwise)	0.552	5.04	-	-
Trip purpose indicator (1 if the respondent is somewhat or very unlikely to use flying cars for traveling to entertainment/sports activities, 0 otherwise)	-0.342	-2.54	-0.644	-4.80
Relocation indicator (1 if the respondent is somewhat or very likely to relocate to an urban area – but outside the city center – with the introduction of flying cars, 0 otherwise)	0.952	6.15	0.835	4.80
Cross equation correlation	0.968		28.78	
Number of survey collectors	35			
Number of respondents	514			
Log-likelihood at convergence	-413.71			
Log-likelihood at zero	-678.66			
Akaike information criterion (AIC)	863.4			
Aggregate distributional effect of the random parameters across the observations				
	Above zero		**Below zero**	
Education indicator (1 if respondent's highest education level includes a college degree or a post graduate degree, 0 otherwise)	28.90%		71.10%	
Income indicator (1 if the respondent's annual household income is between $50,000 and $150,000, 0 otherwise)	30.08%		69.92%	

Table 4. Pseudo-elasticities (averaged over all observations) of the willingness-to-pay (WTP) model for pricing scenarios of $100,000 and $150,000

Variables	WTP for $100k	WTP for $150k
Socio-demographic characteristics		
Age of the respondent	-0.001	-0.002
Education indicator (1 if respondent's highest education level includes a college degree or a post graduate degree, 0 otherwise)	-0.029	-
Income indicator (1 if the respondent's annual household income is between $50,000 and $150,000, 0 otherwise)	-	-0.050
Opinions and Preferences		
Vehicle safety features indicator (1 if the respondent never owned a car with emergency automatic braking, lane keeping assist/lane centering, adaptive cruise control, left turn assist, adaptive headlights or blind-spot monitoring, 0 otherwise)	-0.089	-0.093
Annual mileage indicator (1 if the respondent drives more than 20,000 miles per year, 0 otherwise)	-	0.095
Cost concern indicator (1 if the respondent is very concerned about the purchase cost of a flying car, compared to a conventional vehicle, 0 otherwise)	-0.104	-0.096
Safety benefit indicator (1 if the respondent thinks that fewer crashes on the roadway are somewhat or very likely to occur with the introduction of flying cars, 0 otherwise)	0.173	-
Trip purpose indicator (1 if the respondent is somewhat or very unlikely to use flying cars for traveling to entertainment/sports activities, 0 otherwise)	-0.111	-0.155
Relocation indicator (1 if the respondent is somewhat or very likely to relocate to an urban area – but outside the city center – with the introduction of flying cars, 0 otherwise)	0.331	0.219

Table 5 Estimation results of the willingness-to-pay (WTP) model for pricing scenarios of $200,000 and $300,000 or more

Variables	**WTP for $200k**		**WTP for $300k or more**	
	Coeff.	***t*-stat**	**Coeff.**	***t*-stat**
Socio-demographic characteristics				
Gender indicator (1 if the respondent is female, 0 otherwise)	-0.327	-1.87	-	-
Standard deviation of parameter distribution	0.680	5.14	-	-
Age of the respondent	-0.033	-3.24	-0.040	-4.87
Ethnicity indicator (1 if the respondent is Asian, 0 otherwise)	-	-	0.513	3.41
Education indicator (1 if respondent's highest education level includes a high school diploma or a technical college degree, 0 otherwise)	-	-	0.328	2.15
Standard deviation of parameter distribution	-	-	0.439	3.2
Income indicator (1 if the respondent's annual household income is between $50,000 and $100,000, 0 otherwise)	-	-	-0.697	-2.57
Standard deviation of parameter distribution	-	-	0.875	3.52
Opinions and Preferences				
Vehicle safety features indicator (1 if the respondent never owned a car with an advanced safety feature, 0 otherwise)	-0.460	-2.71	-	-
Cost concern indicator (1 if the respondent is moderately or very concerned about the purchase cost of a flying car, compared to a conventional vehicle, 0 otherwise)	-0.392	-2.27	-	-
Cost benefit indicator (1 if the respondent thinks that lower insurance rates are somewhat or very unlikely to occur with the introduction of flying cars, 0 otherwise)	-0.491	-2.16	-1.015	-3.93
Trip purpose indicator (1 if the respondent is somewhat or very likely to use flying cars for traveling to entertainment/sports activities, 0 otherwise)	0.605	3.21	-	-
Relocation indicator (1 if the respondent is somewhat or very likely to relocate to an urban area – but outside the city center – with the introduction of flying cars, 0 otherwise)	0.564	3.83	-	-
Cross-equation error term correlation coefficient	0.994		85.96	
Number of survey collectors	35			
Number of respondents	547			
Log-likelihood at convergence	-237.857			
Log-likelihood at zero	-357.89			
Akaike information criterion (AIC)	507.7			
Aggregate distributional effect of the random parameters across the observations				
	Above zero		**Below zero**	
Gender indicator (1 if the respondent is female, 0 otherwise)	31.53%		68.47%	
Education indicator (1 if respondent's highest education level includes a high school diploma or a technical college degree, 0 otherwise)	77.25%		22.75%	
Income indicator (1 if the respondent's annual household income is between $50,000 and $100,000, 0 otherwise)	21.28%		78.72%	

Table 6 Pseudo-elasticities (averaged over all observations) of the willingness-to-pay (WTP) model for pricing scenarios of $200,000 and $300,000 or more

Variables	**WTP for $200k**	**WTP for $300k or more**
Socio-demographics		
Gender indicator (1 if the respondent is female, 0 otherwise)	-0.049	-
Age of the respondent	-0.001	-0.001
Ethnicity indicator (1 if the respondent is Asian, 0 otherwise)	-	0.055
Education level indicator (1 if respondent's highest education level includes a high school diploma or a technical college degree, 0 otherwise)	-	0.033
Income indicator (1 if the respondent's annual household income is between $50,000 and $100,000, 0 otherwise)	-	-0.051
Opinions and Preferences		
Vehicle safety features indicator (1 if the respondent never owned a car with an advanced safety feature, 0 otherwise)	-0.070	-
Cost concern indicator (1 if the respondent is moderately or very concerned about the purchase cost of a flying car, compared to a conventional vehicle, 0 otherwise)	-0.068	-
Cost benefit indicator (1 if the respondent thinks that lower insurance rates are somewhat or very unlikely to occur with the introduction of flying cars, 0 otherwise)	-0.087	-0.125
Trip purpose indicator (1 if the respondent is somewhat or very likely to use flying cars for traveling to entertainment/sports activities, 0 otherwise)	0.093	-
Relocation indicator (1 if the respondent is somewhat or very likely to relocate to an urban area – but outside the city center – with the introduction of flying cars, 0 otherwise)	0.095	-

Table 7 Estimation results of the willingness-to-use (WTU) model for work- and education-related trips

Variables	WTU for work-related trips		WTU for education-related trips	
	Coeff.	***t*-stat**	**Coeff.**	***t*-stat**
Socio-demographic characteristics				
Marital status indicator (1 if the respondent is single, 0 otherwise)	0.204	1.93	-	-
Age indicator (1 if the respondent is younger than 30, 0 otherwise)	-	-	0.181	1.79
Ethnicity indicator (1 if the respondent is Asian, 0 otherwise)	0.549	3.77	0.367	2.86
Income indicator (1 if the respondent's annual household income is between $40,000 and $75,000, 0 otherwise)	-	-	-0.238	-2.45
Opinions and Preferences				
Vehicle safety features indicator (1 if the respondent is not familiar with advanced safety features, 0 otherwise)	-0.371	-2.41	-0.436	-2.31
Speed limit opinion indicator (1 if the respondent disagrees or completely disagrees with the statement: "Speed limits on high speed freeways should only be suggestive", 0 otherwise)	-	-	-0.039	-0.47
Standard deviation of parameter distribution	-	-	0.406	4.71
Operation concern indicator (1 if the respondent is moderately or very concerned about learning to operate/use a flying car with the introduction of flying cars, 0 otherwise)	0.013	0.18	-	-
Standard deviation of parameter distribution	0.266	5.23	-	-
Cost benefit indicator (1 if the respondent believes that lower insurance rates are very unlikely to occur with the introduction of flying cars, 0 otherwise)	-0.594	-5.18	-0.668	-5.83
Cross equation correlation	0.978		102.92	
Number of survey collectors	35			
Number of respondents	563			
Log-likelihood at convergence	-531.24			
Log-likelihood at zero	-787.82			
Akaike information criterion (AIC)	1,090.50			

Aggregate distributional effect of the random parameters across the observations

	Above zero	**Below zero**
Speed limit opinion indicator (1 if the respondent disagrees or completely disagrees with the statement: "Speed limits on high speed freeways should only be suggestive", 0 otherwise	46.17%	53.83%
Operation concern indicator (1 if the respondent is moderately or very concerned about learning to operate/use a flying car with the introduction of flying cars, 0 otherwise)	51.95%	48.05%

Table 8 Pseudo-elasticities (averaged over all observations) of the willingness-to-use (WTU) model for work- and education-related trips

Variables	WTU for work-related trips	WTU for education-related trips
Socio-demographic characteristics		
Marital status indicator (1 if the respondent is single, 0 otherwise)	0.074	-
Age indicator (1 if the respondent is younger than 30, 0 otherwise)	-	0.064
Ethnicity indicator (1 if the respondent is Asian, 0 otherwise)	0.204	0.134
Income indicator (1 if the respondent's annual household income is between $40,000 and $75,000, 0 otherwise)	-	-0.083
Opinions and Preferences		
Vehicle safety features indicator (1 if the respondent is not familiar with advanced safety features, 0 otherwise)	-0.133	-0.148
Speed limit opinion indicator (1 if the respondent disagrees or completely disagrees with the statement: "Speed limits on high speed freeways should only be suggestive", 0 otherwise)	-	-0.014
Operation concern indicator (1 if the respondent is moderately or very concerned about learning to operate/use a flying car with the introduction of flying cars, 0 otherwise)	0.005	-
Cost benefit indicator (1 if the respondent believes that lower insurance rates are very unlikely to occur with the introduction of flying cars, 0 otherwise)	-0.225	-0.247

Table 9 Estimation results of the willingness-to-use (WTU) model for entertainment- or sport-related trips

Variables	**WTU for entertainment- or sports-related trips**	
	Coeff.	***t*-stat**
Constant	0.522	2.49
Socio-demographic characteristics		
Age indicator (1 if the respondent is older than 40, 0 otherwise)	-0.409	-2.79
Ethnicity indicator (1 if the respondent is Asian, 0 otherwise)	0.414	2.51
Income indicator (1 if the respondent's annual household income is between \$20,000 and \$50,000, 0 otherwise)	-0.068	-0.38
Standard deviation of parameter distribution	0.592	3.7
Opinions and Preferences		
Speed limit opinion indicator (1 if the respondent agrees or completely agrees with the statement: "Speed limits on high speed freeways should only be suggestive", 0 otherwise)	-0.359	-1.86
Mileage indicator (1 if the respondent drives more than 20,000 miles per year, 0 otherwise)	-0.060	-0.24
Standard deviation of parameter distribution	1.225	3.8
Cost benefit indicator (1 if the respondent think that lower insurance rates are very unlikely to occur with the introduction of flying cars, 0 otherwise)	-0.514	-3.48
Environmental benefit indicator (1 if the respondent thinks that lower CO_2 emissions are somewhat or very unlikely to occur with the introduction of flying cars, 0 otherwise)	-0.574	-4.22
Security measure indicator (1 if the respondent thinks that establishing air-road police enforcement – with flying police cars – is somewhat or very likely to improve security against hackers/terrorists, 0 otherwise)	0.292	1.99
Number of survey collectors	35	
Number of respondents	534	
Log-likelihood at convergence	-322.41	
Log-likelihood at zero	-370.08	
Akaike information criterion (AIC)	666.80	

Aggregate distributional effect of the random parameters across the observations

	Above zero	**Below zero**
Income indicator (1 if the respondent's annual household income is between \$20,000 and \$50,000, 0 otherwise)	45.43%	54.57%
Mileage indicator (1 if the respondent drives more than 20,000 miles per year, 0 otherwise)	48.05%	51.95%

Table 10 Pseudo-elasticities (averaged over all observations) of the willingness-to-use (WTU) model for entertainment- or sport-related trips

Variables	**WTU for entertainment- or sports-related trips**
Socio-demographic characteristics	
Age indicator (1 if the respondent is older than 40, 0 otherwise)	-0.064
Ethnicity indicator (1 if the respondent is Asian, 0 otherwise)	0.071
Income indicator (1 if the respondent's annual household income is between $20,000 and $50,000, 0 otherwise)	-0.010
Opinions and Preferences	
Speed limit opinion indicator (1 if the respondent agrees or completely agrees with the statement: "Speed limits on high speed freeways should only be suggestive", 0 otherwise)	-0.088
Mileage indicator (1 if the respondent drives more than 20,000 miles per year, 0 otherwise)	-0.004
Cost benefit indicator (1 if the respondent think that lower insurance rates are very unlikely to occur with the introduction of flying cars, 0 otherwise)	-0.210
Environmental benefit indicator (1 if the respondent thinks that lower CO_2 emissions are somewhat or very unlikely to occur with the introduction of flying cars, 0 otherwise)	-0.298
Security measure indicator (1 if the respondent thinks that establishing air-road police enforcement – with flying police cars – is somewhat or very likely to improve security against hackers/terrorists, 0 otherwise)	0.171

Table 11 Estimation results of the willingness-to-use (WTU) model for traveling to short-term and long-term shopping activities

Variables	WTU for traveling to short-term shopping activities		WTU for traveling to long-term shopping activities	
	Coeff.	***t*-stat**	**Coeff.**	***t*-stat**
Socio-demographic characteristics				
Age of the respondent	-0.013	-2.53	-0.009	-2.36
Education level indicator (1 if respondent's highest education level includes a high school diploma or a technical college degree, 0 otherwise)	0.095	0.79	-	-
Standard deviation of parameter distribution	0.513	5.18	-	-
Income indicator (1 if the respondent's annual household income is between $10,000 and $30,000, 0 otherwise)	-0.321	-2.69	-	-
Opinions and Preferences				
Driver preference indicator (1 if the respondent generally prefers to drive herself/himself when there are more than two licensed drivers in a vehicle, 0 otherwise)	-0.225	-2.06	-	-
Standard deviation of parameter distribution	0.377	4.26	-	-
Square root of annual mileage driven	-0.002	-1.83	-0.004	-3.40
Accident history indicator (1 if the respondent has had at least one non-severe or severe accident in the last 5 years, 0 otherwise)	0.275	2.32	-	-
Safety benefit indicator (1 if the respondent thinks that fewer crashes on the roadway are somewhat or very likely to occur with the introduction of flying cars, 0 otherwise)	0.600	4.28	0.662	5.40
Cost benefit indicator (1 if the respondent thinks that lower vehicle maintenance expenses are somewhat or very unlikely to occur with the introduction of flying cars, 0 otherwise)	-0.648	-5.25	-	-
Security measure indicator (1 if the respondent thinks that using existing FAA regulations for air traffic control is somewhat or very likely improve security against hackers/terrorists, 0 otherwise)	0.467	4.38	-	-
Security measure indicator (1 if the respondent thinks that detailed profiling and background checking of flying car owners/operators is somewhat or very likely to improve security against hackers/terrorists, 0 otherwise)	-	-	0.321	2.10
Cross equation correlation	0.919		(33.26)	
Number of survey collectors	35			
Number of respondents	523			
Log-likelihood at convergence	-521.46			
Log-likelihood at zero	-732.77			
Akaike information criterion (AIC)	1074.9			

Variables	WTU for traveling to short-term shopping activities	WTU for traveling to long-term shopping activities
Aggregate distributional effect of the random parameters across the observations		
	Above zero	**Below zero**
Education level indicator (1 if respondent’s highest education level includes a high school diploma or a technical college degree, 0 otherwise)	57.35%	42.65%
Driver preference indicator (1 if the respondent generally prefers to drive herself/himself when there are more than two licensed drivers in a vehicle, 0 otherwise)	27.53%	72.47%

Table 12 Pseudo-elasticities (averaged over all observations) of the willingness-to-use (WTU) model for traveling to short-term and long-term shopping activities

Variables	WTU for traveling to short-term shopping activities	WTU for traveling to long-term shopping activities
Socio-demographic characteristics		
Age of the respondent	-0.001	-0.001
Education level indicator (1 if respondent's highest education level includes a high school diploma or a technical college degree, 0 otherwise)	0.030	-
Income indicator (1 if the respondent's annual household income is between $10,000 and $30,000, 0 otherwise)	-0.098	-
Opinions and Preferences		
Driver preference indicator (1 if the respondent generally prefers to drive herself/himself when there are more than two licensed drivers in a vehicle on a trip, 0 otherwise)	-0.072	-
Square root of annual mileage driven	-0.001	-0.001
Accident history indicator (1 if the respondent has had at least one non-severe or severe accident in the last 5 years, 0 otherwise)	0.089	-
Safety benefit indicator (1 if the respondent thinks that fewer crashes on the roadway are somewhat or very likely to occur with the introduction of flying cars, 0 otherwise)	0.192	0.250
Cost benefit indicator (1 if the respondent thinks that lower vehicle maintenance expenses are somewhat or very unlikely to occur with the introduction of flying cars, 0 otherwise)	-0.224	-
Security measure indicator (1 if the respondent thinks that using existing FAA regulations for air traffic control somewhat or very likely improve security against hackers/terrorists, 0 otherwise)	0.151	-
Security measure indicator (1 if the respondent thinks that detailed profiling and background checking of flying car owners/operators is somewhat or very likely to improve security against hackers/terrorists, 0 otherwise)	-	0.118

Table 13 Estimation results of the willingness-to-use (WTU) model for trips from or to the city center (downtown)

Variables	**WTU for trips from/to the city center (downtown)**	
	Coeff.	***t*-stat**
Socio-demographic characteristics		
Gender indicator (1 if the respondent is male, 0 otherwise)	0.136	1.04
Standard deviation of parameter distribution	0.351	3.83
Young female indicator (1 if the respondent is female and younger than 25, 0 otherwise)	0.518	2.62
Ethnicity indicator (1 if the respondent is Asian, 0 otherwise)	0.362	1.86
Education level indicator (1 if respondent's highest level of education includes a high school diploma or partial attendance of high school, 0 otherwise)	-0.247	-1.67
Income indicator (1 if the respondent's annual household income is between $10,000 and $40,000, 0 otherwise)	-0.250	-1.65
Opinions and Preferences		
Vehicle safety features indicator (1 if the respondent never owned a car with an advanced safety feature, 0 otherwise)	-0.308	-2.04
Mileage indicator (1 if the respondent annually drives less than 5,000 miles, 0 otherwise)	0.282	2.1
Safety concern indicator (1 if the respondent is very concerned about accidents on the airway with the introduction of flying cars, 0 otherwise)	-0.396	-3.22
Cost benefit indicator (1 if the respondent thinks that lower fuel expenses are somewhat or very unlikely to occur with the introduction of flying cars, 0 otherwise)	-0.550	-4.67
Security measure indicator (1 if the respondent thinks that establishing no-fly zones for flying cars near sensitive locations – such as, military bases, power/energy plants, governmental buildings, major transportation hubs, etc. – is somewhat or very likely to improve security against hackers/terrorists, 0 otherwise)	0.631	4.77
Number of survey collectors	35	
Number of respondents	529	
Log-likelihood at convergence	-317.21	
Log-likelihood at zero	-362.67	
Akaike information criterion (AIC)	656.40	
Aggregate distributional effect of the random parameters across the observations		
	Above zero	**Below zero**
Gender indicator (1 if the respondent is male, 0 otherwise)	65.08%	34.92%

Table 14 Pseudo-elasticities (averaged over all observations) of the willingness-to-use (WTU) model for trips from or to the city center (downtown)

Variables	**WTU for trips from/to the city center (downtown)**
Socio-demographic characteristics	
Gender indicator (1 if the respondent is male, 0 otherwise)	0.075
Young female indicator (1 if the respondent is female and younger than 25, 0 otherwise)	0.074
Ethnicity indicator (1 if the respondent is Asian, 0 otherwise)	0.068
Education level indicator (1 if respondent's highest level of education includes a high school diploma or partial attendance of high school, 0 otherwise)	-0.052
Income indicator (1 if the respondent's annual household income is between $10,000 and $40,000, 0 otherwise)	-0.146
Opinions and Preferences	
Vehicle safety features indicator (1 if the respondent never owned a car with an advanced safety feature, 0 otherwise)	-0.126
Mileage indicator (1 if the respondent annually drives less than 5,000 miles, 0 otherwise)	0.074
Safety concern indicator (1 if the respondent is very concerned about accidents on the airway with the introduction of flying cars, 0 otherwise)	-0.203
Cost benefit indicator (1 if the respondent thinks that lower fuel expenses are somewhat or very unlikely to occur with the introduction of flying cars, 0 otherwise)	-0.353
Security measure indicator (1 if the respondent thinks that establishing no-fly zones for flying cars near sensitive locations – such as, military bases, power/energy plants, governmental buildings, major transportation hubs, etc. – is somewhat or very likely to improve security against hackers/terrorists, 0 otherwise)	0.455

Table 15 Estimation results of the willingness-to-use (WTU) model for short and medium distance trips

Variables	**WTU for short distance trips (less than 50 miles)**		**WTU for medium distance trips (50-100 miles)**	
	Coeff.	***t*-stat**	**Coeff.**	***t*-stat**
Socio-demographic characteristics				
Income indicator (1 if the respondent's annual household income is between $30,000 and $50,000, 0 otherwise)	-0.406	-2.7	-	-
Income indicator (1 if the respondent's annual household income is between $50,000 and $150,000, 0 otherwise)	-0.396	-3.6	-	-
Income indicator (1 if the respondent's annual household income is between $75,000 and $100,000, 0 otherwise)	-	-	-0.382	-2.53
Opinions and Preferences				
Square root of annual mileage driven	-0.004	-4.43	-0.001	-0.7
Standard deviation of parameter distribution	0.003	5.84	0.002	4.08
Accident history indicator (1 if the respondent has had at least one non-severe or severe accident in the last 5 years, 0 otherwise)	-	-	0.234	2.09
Driving joy concern indicator (1 if the respondent is moderately or very concerned about loss of driving joy with the introduction of flying cars, 0 otherwise)	-	-	-0.271	-3.09
Safety benefit indicator (1 if the respondent thinks that fewer crashes are somewhat or very likely to occur on the roadway with the introduction of flying cars, 0 otherwise)	0.599	5.94	0.667	7.34
Cross equation correlation	0.834	25.30		
Number of survey collectors	35			
Number of respondents	527			
Log-likelihood at convergence	-576.24			
Log-likelihood at zero	-722.02			
Akaike information criterion (AIC)	1176.50			

Aggregate distributional effect of the random parameters across the observations		
	Above zero	**Below zero**
Square root of annual mileage driven [*short distance trips*]	9.12%	90.88%
Square root of annual mileage driven [*medium distance trips*]	30.85%	69.15%

Table 16 Pseudo-elasticities (averaged over all observations) of the willingness-to-use (WTU) model for short and medium distance trips

Variables	**WTU for short distance trips (less than 50 miles)**	**WTU for medium distance trips (50-100 miles)**
Socio-demographic characteristics		
Income indicator (1 if the respondent's annual household income is between \$30,000 and \$50,000, 0 otherwise)	-0.141	-
Income indicator (1 if the respondent's annual household income is between \$50,000 and \$150,000, 0 otherwise)	-0.144	-
Income indicator (1 if the respondent's annual household income is between \$75,000 and \$100,000, 0 otherwise)	-	-0.141
Opinions and Preferences		
Square root of annual mileage driven	-0.001	-0.0002
Accident history indicator (1 if the respondent has had at least one non-severe or severe accident in the last 5 years, 0 otherwise)	-	0.083
Driving joy concern indicator (1 if the respondent is moderately or very concerned about loss of driving joy with the introduction of flying cars, 0 otherwise)	-	-0.098
Safety benefit indicator (1 if the respondent thinks that fewer crashes are somewhat or very likely to occur on the roadway with the introduction of flying cars, 0 otherwise)	0.217	0.251

Table 17 Estimation results of the willingness-to-use (WTU) model for long and very long distance trips

Variables	WTU for long distance trips (100-300 miles)		WTU for very long distance trips (greater than 300 miles)	
	Coeff.	***t*-stat**	**Coeff.**	***t*-stat**
Socio-demographic characteristics				
Age indicator (1 if the respondent is younger than 30, 0 otherwise)	0.531	3.01	0.455	3.01
Income indicator (1 if the respondent's annual household income is between $20,000 and $40,000, 0 otherwise)	-0.187	-1.23	-	-
Standard deviation of parameter distribution	0.690	3.53	-	-
Income indicator (1 if the respondent's annual household income is between $50,000 and $150,000, 0 otherwise)	-0.272	-2.69	-	-
Standard deviation of parameter distribution	0.162	2.93	-	-
Opinions and Preferences				
Mileage indicator (1 if the respondent drives more than 15,000 miles per year, 0 otherwise)	-0.267	-2.09	-	-
Standard deviation of parameter distribution	0.419	2.91	-	-
Driving joy concern indicator (1 if the respondent is moderately or very concerned about loss of driving joy with the introduction of flying cars, 0 otherwise)	-0.574	-3.80	-0.471	-3.23
Safety benefit indicator (1 if the respondent thinks that fewer crashes are somewhat or very likely to occur on the roadway with the introduction of flying cars, 0 otherwise)	0.407	2.45	0.374	2.32
Standard deviation of parameter distribution	-	-	0.218	3.62
Travel time benefit indicator (1 if the respondent thinks that more reliable travel time to destination is somewhat or very likely to occur with the introduction of flying cars, 0 otherwise)	0.878	5.10	0.695	4.3
Environmental benefit indicator (1 if the respondent thinks that lower CO_2 emissions are somewhat or very unlikely to occur with the introduction of flying cars, 0 otherwise)	-0.537	-4.47	-0.512	-4.42
Cross equation correlation	0.974	74.59		
Number of survey collectors	35			
Number of respondents	538			
Log-likelihood at convergence	-428.58			
Log-likelihood at zero	-701.996			
Akaike information criterion (AIC)	893.20			
Aggregate distributional effect of the random parameters across the observations				
	Above zero		**Below zero**	
Income indicator (1 if the respondent's annual household income is between $20,000 and $40,000, 0 otherwise)	39.32%		60.68%	

Income indicator (1 if the respondent's annual household income is between $50,000 and $150,000, 0 otherwise)	4.66%	95.34%
	Above zero	**Below zero**
Mileage indicator (1 if the respondent drives more than 15,000 miles per year, 0 otherwise)	26.20%	73.80%
Safety benefit indicator (1 if the respondent thinks that fewer crashes are somewhat or very likely to occur on the roadway with the introduction of flying cars, 0 otherwise)	95.69%	4.31%

Table 18 Pseudo-elasticities (averaged over all observations) of the willingness-to-use (WTU) model for long and very long distance trips

Variables	WTU for long distance trips (100-300 miles)	WTU for very long distance trips (greater than 300 miles)
Socio-demographic characteristics		
Age indicator (1 if the respondent is younger than 30, 0 otherwise)	0.164	0.143
Income indicator (1 if the respondent's annual household income is between \$20,000 and \$40,000, 0 otherwise)	-0.056	-
Income indicator (1 if the respondent's annual household income is between \$50,000 and \$150,000, 0 otherwise)	-0.080	-
Opinions and Preferences		
Mileage indicator (1 if the respondent drives more than 15,000 miles per year, 0 otherwise)	-0.081	-
Driving joy concern indicator (1 if the respondent is moderately or very concerned about loss of driving joy with the introduction of flying cars, 0 otherwise)	-0.172	-0.144
Safety benefit indicator (1 if the respondent thinks that fewer crashes are somewhat or very likely to occur on the roadway with the introduction of flying cars, 0 otherwise)	0.126	0.118
Travel time benefit indicator (1 if the respondent thinks that more reliable travel time to destination is somewhat or very likely to occur with the introduction of flying cars, 0 otherwise)	0.295	0.236
Environmental benefit indicator (1 if the respondent thinks that lower CO_2 emissions are somewhat or very unlikely to occur with the introduction of flying cars, 0 otherwise)	-0.156	-0.151

Table 19 Estimation results of the willingness-to-use (WTU) model for morning and afternoon trips

Variables	WTU for morning trips		WTU for afternoon trips	
	Coeff.	***t*-stat**	**Coeff.**	***t*-stat**
Socio-demographic characteristics				
Marital status indicator (1 if the respondent is single, 0 otherwise)	-	-	-0.005	-0.04
Standard deviation of parameter distribution	-	-	0.339	5.09
Age of the respondent	-0.020	-3.76	-0.017	-3.51
Ethnicity indicator (1 if the respondent is Asian, 0 otherwise)	-0.269	-1.90	-	-
Standard deviation of parameter distribution	0.558	3.83	-	-
Education level indicator (1 if respondent's highest level of education includes a high school diploma or partial attendance of high school, 0 otherwise)	-0.114	-0.90	-	-
Standard deviation of parameter distribution	0.454	3.86	-	-
Working household members indicator (1 if the respondent is the only household member who works outside the home, 0 otherwise)	-	-	-0.009	-0.04
Standard deviation of parameter distribution	-	-	0.544	2.61
Opinions and Preferences				
Safety benefit indicator (1 if the respondent thinks that fewer crashes are somewhat or very likely to occur on the roadway with the introduction of flying cars, 0 otherwise)	0.369	2.51	0.342	1.89
Travel time benefit indicator (1 if the respondent thinks that more reliable travel time to destination is somewhat or very likely to occur with the introduction of flying cars, 0 otherwise)	0.525	2.35	0.562	3.26
Environmental benefit indicator (1 if the respondent thinks that lower CO_2 emissions are very unlikely to occur with the introduction of flying cars, 0 otherwise)	-0.381	-2.56	-0.521	-3.27
Security measure indicator (1 if the respondent thinks that detailed profiling and background checking of flying car owners/operators is somewhat or very likely to improve security against hackers/terrorists, 0 otherwise)	0.446	2.92	0.287	1.91
Cross equation correlation	0.87	33.86		
Number of survey collectors	35			
Number of respondents	563			
Log-likelihood at convergence	-574.01			
Log-likelihood at zero	-790.63			
Akaike information criterion (AIC)	1186			

Aggregate distributional effect of the random parameters across the observations

	Above zero	**Below zero**
Marital status indicator (1 if the respondent is single, 0 otherwise)	49.41%	50.59%

Ethnicity indicator (1 if the respondent is Asian, 0 otherwise)	31.49%	68.51%
	Above zero	**Below zero**
Education level indicator (1 if respondent's highest level of education includes a high school diploma or partial attendance of high school, 0 otherwise)	40.09%	59.91%
Working household members indicator (1 if the respondent is the only household member who works outside the home, 0 otherwise)	49.34%	50.66%

Table 20 Pseudo-elasticities (averaged over all observations) of the willingness-to-use (WTU) model for morning and afternoon trips

Variables	WTU for morning trips	WTU for afternoon trips
Socio-demographic characteristics		
Marital status indicator (1 if the respondent is single, 0 otherwise)	-	-0.002
Age of the respondent	-0.002	-0.002
Ethnicity indicator (1 if the respondent is Asian, 0 otherwise)	-0.093	-
Education level indicator (1 if respondent's highest level of education includes a high school diploma or partial attendance of high school, 0 otherwise)	-0.039	-
Working household members indicator (1 if the respondent is the only household member who works outside the home, 0 otherwise)	-	-0.003
Opinions and Preferences		
Safety benefit indicator (1 if the respondent thinks that fewer crashes are somewhat or very likely to occur on the roadway with the introduction of flying cars, 0 otherwise)	0.132	0.122
Travel time benefit indicator (1 if the respondent thinks that more reliable travel time to destination is somewhat or very likely to occur with the introduction of flying cars, 0 otherwise)	0.189	0.204
Environmental benefit indicator (1 if the respondent thinks that lower CO_2 emissions are very unlikely to occur with the introduction of flying cars, 0 otherwise)	-0.135	-0.188
Security measure indicator (1 if the respondent thinks that detailed profiling and background checking of flying car owners/operators is somewhat or very likely to improve security against hackers/terrorists, 0 otherwise)	0.159	0.101

Table 21 Estimation results of the willingness-to-use (WTU) model for evening and night trips

Variables	**WTU for evening trips**		**WTU for night trips**	
	Coeff.	***t*-stat**	**Coeff.**	***t*-stat**
Socio-demographic characteristics				
Marital status indicator (1 if the respondent is single, 0 otherwise)	0.185	1.37	-	-
Standard deviation of parameter distribution	0.170	3.03	-	-
Square root of the age of the respondent	-0.159	-3.58	-0.261	-5.73
Current living area indicator (1 if the respondent lives in suburban area, 0 otherwise)	-0.213	-1.42	-0.067	-0.54
Standard deviation of parameter distribution	0.203	3.17	0.211	3.11
Income indicator (1 if the respondent's annual household income is between $30,000 and $75,000, 0 otherwise)	-	-	0.299	2.83
Opinions and Preferences				
Driving speed indicator (1 if the respondent normally drives faster than 70 mph on an interstate with a 65 mph speed limit and little traffic, 0 otherwise)	0.237	1.82	0.341	2.44
Driving joy concern indicator (1 if the respondent is moderately or very concerned about loss of driving joy with the introduction of flying cars, 0 otherwise)	-0.290	-2.21	-	-
Safety benefit indicator (1 if the respondent thinks that fewer crashes are somewhat or very likely to occur on the roadway with the introduction of flying cars, 0 otherwise)	0.472	2.77	0.469	2.84
Travel time benefit indicator (1 if the respondent thinks that more reliable travel time to destination is somewhat or very likely to occur with the introduction of flying cars, 0 otherwise)	0.717	4.22	0.399	2.21
Cost benefit indicator (1 if the respondent thinks that lower insurance rates are somewhat or very unlikely to occur with the introduction of flying cars, 0 otherwise)	-0.588	-4.16	-	-
Cost benefit indicator (1 if the respondent thinks that lower insurance rates are somewhat or very likely to occur with the introduction of flying cars, 0 otherwise)	-	-	0.874	6.06
Security measure indicator (1 if the respondent thinks that detailed profiling and background checking of flying car owners/operators is somewhat or very likely to improve security against hackers/terrorists, 0 otherwise)	0.615	3.24	0.402	1.99
Cross equation correlation	0.937	41.36		
Number of survey collectors	35			
Number of respondents	557			
Log-likelihood at convergence	-515.62			
Log-likelihood at zero	-782.28			
Akaike information criterion (AIC)	1073.20			

Variables	WTU for evening trips	WTU for night trips
Aggregate distributional effect of the random parameters across the observations		
	Above zero	**Below zero**
Marital status indicator (1 if the respondent is single, 0 otherwise)	86.18%	13.82%
Current living area indicator (1 if the respondent lives in suburban area, 0 otherwise) [*evening trips*]	14.70%	85.30%
Current living area indicator (1 if the respondent lives in suburban area, 0 otherwise) [*night trips*]	37.54%	62.46%

Table 22 Pseudo-elasticities (averaged over all observations) of the willingness-to-use (WTU) model for evening and night trips

Variables	WTU for evening trips	WTU for night trips
Socio-demographic characteristics		
Marital status indicator (1 if the respondent is single, 0 otherwise)	0.062	-
Square root of the age of the respondent	-0.003	-0.005
Current living area indicator (1 if the respondent lives in suburban area, 0 otherwise)	-0.070	-0.022
Income indicator (1 if the respondent's annual household income is between $30,000 and $75,000, 0 otherwise)	-	0.099
Opinions and Preferences		
Driving speed indicator (1 if the respondent normally drives faster than 70 mph on an interstate with a 65 mph speed limit and little traffic, 0 otherwise)	0.078	0.113
Driving joy concern indicator (1 if the respondent is moderately or very concerned about loss of driving joy with the introduction of flying cars, 0 otherwise)	-0.095	-
Safety benefit indicator (1 if the respondent thinks that fewer crashes are somewhat or very likely to occur on the roadway with the introduction of flying cars, 0 otherwise)	0.161	0.160
Travel time benefit indicator (1 if the respondent thinks that more reliable travel time to destination is somewhat or very likely to occur with the introduction of flying cars, 0 otherwise)	0.245	0.133
Cost benefit indicator (1 if the respondent thinks that lower insurance rates are somewhat or very unlikely to occur with the introduction of flying cars, 0 otherwise)	-0.192	-
Cost benefit indicator (1 if the respondent thinks that lower insurance rates are somewhat or very likely to occur with the introduction of flying cars, 0 otherwise)	-	0.296
Security measure indicator (1 if the respondent thinks that the detailed profiling and background checking of flying car owners/operators is somewhat or very likely to improve security against hackers/terrorists, 0 otherwise)	0.208	0.133

4.1. Socio-demographic characteristics

A number of socio-demographic characteristics are found to affect individuals' willingness to pay for and willingness to use flying cars. Focusing on the effect of gender, the majority of the female respondents (68.48%, as shown in Table 5) are less willing to buy a flying car priced around $200,000, while the remaining female respondents (31.52%, as shown in Table 5) are more willing to buy a flying car. With regard to respondents' willingness to use a flying car, Table 13 shows that the majority of male respondents (65.14%, as shown in Table 13) are more likely to use a flying car for conducting trips from or to the city center (downtown), while the opposite trend is observed for the remaining 34.86% of the male drivers. This finding indicates that the non-involvement of the flying cars in the traffic patterns of the city center's transportation network may constitute a strong incentive for travelers to use flying cars for trips within areas susceptible to high traffic volumes and congestion. Young females (less than 25 years old) are more likely (by 0.074, as indicated by the pseudo-elasticities in Table 14) to use a flying car for trips to the city center (downtown). This finding is in line with the current state of knowledge about the intra-urban travel patterns of young females, who are generally expected to travel more in urban context, especially when compared with young males (Tilley and Houston, 2016). In this context, young females may find merits in the use of flying cars, due to their potential for reduced travel times and automated capabilities.

With regard to the marital status, single respondents are more willing to use flying cars for various trip purposes and time slots during the day. For example, the variable reflecting "single" marital status increases the likelihood of a traveler to use a flying car for traveling to work (by 0.074, as indicated by the pseudo-elasticities in Table 8). Furthermore, Table 19 shows that the same variable has mixed effects on respondents' willingness to use a flying car for afternoon trips;

specifically, 50.55% of the single respondents (as shown in Table 19) are less likely to use a flying car for afternoon trips, while the remaining 49.45% are more willing to use a flying car for such trips. As opposed to the afternoon trips, the vast majority of single respondents (86.27%, as shown in Table 21) are more willing to use a flying car for evening trips, with the remaining 13.73% of single individuals being less willing to use a flying car during this time slot of the day. The capacity characteristics of the flying cars – they can accommodate 2-4 passengers – as well as the flexibility in the origin and destination characteristics of the trips conducted by the single individuals may constitute underlying sources of such variations in the effect of marital status.

The effect of age is found to be consistent across the willingness-to-buy models for all pricing scenarios ($100,000, $150,000, $200,000, and $300,000 or more). Specifically, Table 3 and Table 5 show that older respondents are associated with lower likelihood to buy a flying car. Similar effect of age characteristics is also observed in the willingness-to-use models. With regard to the trip purpose scenarios, older respondents are less willing to use a flying car for traveling to short-term and long-term shopping activities as well as for traveling to entertainment- or sports-related activities. In addition, older respondents are less likely to use a flying car regardless of the time of the day the trip is conducted (morning, afternoon, evening or night). In contrast, young respondents – 30 years old or younger – are more willing to use a flying car for traveling to education activities, conducting long-distance trips and very long-distance trips. Such findings likely capture the intuitive concerns of older travelers with regard to the cost, operation and safety implications of this new transportation technology.

Regarding the location-specific characteristics of the respondents, the vast majority of those who are located in a suburban area (85.31%, as shown in Table 21) are less willing to use a flying car for evening trips; the opposite is observed for the remaining 14.69% of the respondents (as shown in Table 21). Similarly, the majority of the respondents who are located in suburban area (62.5%, as shown in Table 21) are less willing to use a flying car for night trips (i.e., trips conducted between 12 AM and 6 AM), while the opposite is observed for the remaining 37.5% of the respondents (as shown in Table 21). These findings perhaps reflect safety concerns of travelers, especially for flying car-operated trips during dark conditions. Such concerns may also be enhanced for travelers who live in suburban areas, due to the presence of limited lighting infrastructure in the suburban transportation networks.

Focusing on the effect of ethnicity, Asian respondents are consistently found to be more willing to buy and use a flying car. Specifically, these respondents are more likely to buy a flying car priced around $300,000 or more, use a flying car for traveling to work, use a flying car for traveling to education activities, use a flying car for traveling to entertainment or sports activities, and use a flying car for conducting trips from or to the city center (downtown). However, Table 19 shows that Asian ethnicity has mixed effect on travelers' willingness to use a flying car for morning trips; the majority of Asian respondents (68.49%, as shown in Table 19) are less willing to use a flying car for morning trips, whereas the remaining 31.51% of Asian respondents (as shown in Table 19) are more willing to conduct trips with a flying car during morning hours.

The education level of individuals has varying effects on their willingness to pay for and use a flying car. Table 14 shows that the likelihood of an individual to use a flying car for trips from or to the city center (downtown) decreases (by -0.052, as indicated by the pseudo-elasticities in Table 14), if the respondent's highest level of education includes a high school diploma or partial attendance of high school. The majority of the same respondents (59.9%, as shown in Table 19) are also less willing to use a flying car for morning trips, whereas the remaining 40.1% of these respondents (as shown in Table 19) are more willing to use a flying car for morning trips. Such findings may reflect the concerns of travelers with lower education level to use a flying car for their daily activities. In contrast, the majority of respondents whose highest education level includes a high school diploma or a technical college degree (57.33%, as shown in Table 11) are more willing to use a flying car for traveling to short-term shopping activities. The majority of the same respondents (77.23%, as shown in Table 5) are also more willing to buy a flying car priced around $300,000 or more; the opposite is observed for the remaining 22.77% of respondents with the specific educational background. Respondents with a college or postgraduate degree exhibit heterogeneous willingness to pay for flying cars, with the majority of them (71.24%, as shown in Table 3) being less likely to buy a flying car priced around $100,000.

The level of the annual household income is also found to have heterogeneous effect on respondents' willingness to pay for and use a flying car. For the willingness to pay for a flying car, the vast majority of respondents with annual household income between $50,000 and $150,000 (70%, as shown in Table 3) are less willing to buy a flying car priced around $150,000. Similarly, Table 5 shows that 78.72% of respondents with medium annual household income (between $50,000 and $100,000) are less likely to buy a flying car priced around $300,000 or more. With regard to respondents' willingness to use a flying car, Tables 7 through 23 show that variables reflecting low annual income level decrease the likelihood of respondents to use a flying car for various trip purposes. Members of households with annual income up to $50,000 are associated with lower willingness to use a flying car for traveling to short-term shopping activities, conducting short distance trips, conducting long-distance trips (the specific effect is evident for 60.68% of the respondents, as shown in Table 17) and conducting trips from or to the city center (downtown). Variables reflecting low or medium income levels (between $30,000 and $75,000) decrease the likelihood of a respondent to use a flying car for education-related trips (by -0.083, as shown by the pseudo elasticities in Table 8), and increase the likelihood of a respondent to use a flying car for night-time trips (by 0.099, as shown by the pseudo elasticities in Table 22). Respondents with medium or high household income (between $50,000 and $100,000) are less willing to use a flying car for conducting medium distance trips. Similar findings are observed for respondents with annual household income between $50,000 and $150,000, who are less likely to use a flying car for conducting short distance trips and long distance trips. Overall, the findings are intuitive and likely reflect travelers' concerns about the cost implications of this new transportation technology as well as the importance of pricing policy in travelers' decision-making mechanism associated with the adoption of a flying car.

4.2. Opinions and preferences

Turning to the behavioral and attitudinal determinants of willingness to pay for a flying car, respondents who have never owned a vehicle with advanced safety features are consistently less willing to buy a flying car, under the pricing scenarios of $100,000, $150,000, and $200,000. The same respondents are also associated with lower likelihood to use a flying car for conducting trips from or to the city center (downtown). Similarly, respondents who are not familiar with the use of such vehicle safety features are less willing to conduct work- or education-related trips with a flying car. These findings may reflect the perceptions of a population group that is not familiar with the benefits of the emerging driver's assistance systems and automated technologies, and, expectedly, is more reluctant to the adoption of such a revolutionary, yet unknown transportation technology as the flying car.

With regard to the effect of driving behavior characteristics, respondents who normally drive with speed greater than the posted speed limit (for example, they drive faster than 70 mph on an interstate with a 65 mph posted speed limit and little traffic) are more willing to use a flying car for conducting evening and night trips. This finding may imply that the perceptions of possibly risk-taking drivers (as evidenced from their highway speeding behavior) towards the use and operation of flying cars are not affected by the limited lighting conditions during the evening or night trips. In addition, respondents who overall disagree with suggestive speed limits on high-speed freeways have heterogeneous perceptions regarding the use of flying cars for education-related trips; Table 7 shows that 53.87% of such respondents are less likely to use a flying car, whereas the opposite trend is observed for the remaining 46.13% of these respondents. In contrast, Table 9 indicates that supportive opinions on the suggestive nature of the speed limits decrease the likelihood of a respondent (by -0.099, as indicated by the pseudo-elasticities in Table 10) to use a flying car for traveling to entertainment- or sports-related activities. Driving confidence constitutes another behavioral characteristic that has mixed effects on respondents' willingness to use a flying car. Specifically, the majority (72.49%, as shown in Table 11) of the respondents who generally prefer to drive themselves when there are more than two licensed drivers in a vehicle are more willing to use a flying car for traveling to short-term shopping activities. This result may capture unobserved variations in the perceptions of drivers with regard to the cost, parking, and travel time considerations of flying cars. For example, some travelers may expect that using a flying car for short-term shopping activities may result in significantly lower travel times, whereas other drivers may prefer transportation modes of lower cost (e.g., conventional car or public transportation means) to conduct the – typically – low-distance trips for short-term shopping activities.

Moving to the effect of respondents' accident history, respondents with at least one (non-severe or severe) accident over the last 5 years are more likely to use a flying car for traveling to short-term shopping activities and for conducting medium distance trips. Specifically, the likelihood of using a flying car for each of the aforementioned trip scenarios is increased by 0.089 and 0.083, respectively (as indicated by the pseudo-elasticities in Table 12 and Table 16, respectively). It is likely that the automated capabilities of the flying cars, in conjunction with their limited exposure to traffic conflict patterns of the ground transportation networks, cultivate expectations for enhanced safety benefits from the use of flying cars, especially for individuals who have experienced one (or more) accidents in the recent past.

Driving exposure constitutes another behavioral characteristic that affects respondents' perceptions towards the adoption of flying cars. Focusing on its effect on individuals' willingness to pay, the variable reflecting high driving exposure (i.e., annual mileage greater than 20,000 miles) increases the likelihood (by 0.095, as indicated by the pseudo-elasticities in Table 4) of an individual to buy a flying car priced around $100,000. Furthermore, Table 12 shows that greater annual mileage decreases the likelihood of a respondent to use a flying car for traveling to short-term and long-term shopping activities. With regard to its effect on short and medium distance trips, greater annual mileage results in lower willingness to use a flying car, for the vast majority of the respondents (91.88% and 69.15% of the respondents, respectively, as shown in Table 15). Similarly, respondents with low driving exposure (for example, respondents who drive less than 5,000 miles per year) are more willing to use a flying car for trips from or to the city center (downtown). In contrast, the majority (73.81%, as shown in Table 17) of the respondents with high driving exposure (i.e., those who drive more than 15,000 miles per year) are less willing to use a flying car for long distance trips. This finding can be attributed to the high driving confidence of the specific driving population group, as well as to individuals' expectations relating to the operation cost of flying cars. The mixed perceptions of drivers with high driving exposure are also evident as far as the use of a flying car for entertainment- or sport-related trips is concerned. Approximately half of the respondents (51.94%, as shown in Table 9) who drive more than 20,000 miles per year, are more willing to use a flying car for traveling to entertainment- or sports-related activities, while the other half of respondents (48.06%, as shown in Table 9) are less willing to use a flying car.

Moving to the perceptual characteristics of individuals, the purchase cost constitutes a significant determinant of individuals' willingness to pay. Specifically, respondents who are generally concerned about the purchase cost of flying cars compared to the cost of the conventional vehicles are less willing to buy a flying car, regardless of the pricing scenario. Similarly, respondents who believe that the introduction of the flying cars is not likely to result in lower vehicle operation cost (consisting of elements such as fuel expenses; vehicle maintenance expenses; and insurance rates) are less willing to buy a flying car (under the pricing scenarios of $200,000 and $300,000 or more) and to use a flying car for work- and education-related trips, entertainment- or sport-related trips, trips from or to the city center and evening trips. Such findings highlight the major role of purchase and operation cost for the public adoption of flying cars, especially for population groups that are vastly concerned about the cost implications of this new transportation technology.

In a similar fashion, respondents who are concerned about the safety implications of flying cars and, specifically, about the possibility of accidents on the airway, are less willing to use flying cars. However, respondents who expect safety benefits from the flying cars considering that their introduction will result in fewer crashes on the roadway, are more willing to buy a flying car (under the pricing scenario of $100,000) and use a flying car for various trips scenarios (trips for short-term and long-term shopping activities, short-distance trips, medium-distance trips, evening trips, and night trips). Similar findings are observed for respondents who expect more reliable travel times with the introduction of flying cars; they are more willing to use flying cars for long- and very-long-distance trips, as well as for trips throughout all time-slots of the day (morning, afternoon, evening, and night trips). Overall, individuals who appreciate the potential safety and travel time benefits of flying cars are more likely to constitute those groups of traveling population that will likely welcome the use of flying cars upon their penetration in the traffic fleet.

In contrast, respondents concerned about the possible loss of driving joy due to the emergence of flying cars are less likely to use this transportation technology for various trip scenarios (such as, medium-, long-, and very long-distance trips, as well as evening trips). This finding may be capturing the expectations of a driving population group that perceives the driving task not only as a means of commuting, but also as a means of recreation or entertainment. Intuitively, respondents concerned about the level of carbon emissions associated with the operation of flying cars are less likely to choose them for commuting to entertainment- or sport-related activities, for long- and very-long-distance trips, as well as for trips during morning and afternoon hours. This finding sheds light on another perceptual characteristic of individuals, associated with the environmental implications of flying cars. The future policy considerations should account for such environmental concerns, by informing the commuting population about the possible environmental effect of flying cars operation, possibly within a comparative context including conventional vehicles, electric vehicles, as well as the forthcoming connected and autonomous vehicles.

Furthermore, respondents who are likely to relocate to an urban area (but outside the city center) after the introduction of flying cars are more willing to buy a flying car under the $100,000, $150,000, and $200,000 pricing scenarios. This result possibly captures the expectations of some individuals that the flexible mobility provided by the flying cars will facilitate their relocation to an urban area and, at the same time, will enhance their accessibility to downtown, suburban, and rural areas.

As a last point, the perceptions of respondents with regard to the security status of flying cars also affect their willingness to pay for and use flying cars. In this context, respondents who acknowledge the effectiveness of measures aiming to enhance passengers' security are more likely to use flying cars. Interestingly, the use of existing Federal Aviation Administration (FAA) regulations for air traffic control increases the likelihood (by 0.151, as indicated by the pseudo-elasticities in Table 12) of an individual to use a flying car for traveling to short-term shopping activities. Similarly, the establishment of an air-road police enforcement unit (with flying police cars) increases the likelihood (by 0.171, as indicated by the pseudo-elasticities in Table 10) of an individual to use a flying car for entertainment- or sport-related activities. The establishment of no-fly zones near sensitive locations (military bases, power/energy plants, governmental buildings, major transportation hubs, etc.) is also found to increase the likelihood (by 0.455) of an individual to use a flying car for city center-related trips. In a similar manner, the detailed profiling and background checking of flying car owners/operators is also perceived from the respondents as an effective security measure, since it is associated with higher likelihood of flying car use for long-term trips as well as for trips throughout all time-slots of the day (morning, afternoon, evening and night trips). Overall, these findings show that the perceptions of individuals towards the effectiveness of security measures are highly associated with their willingness to use the flying cars for various trip scenarios, highlighting, thus, the critical role of security in their decision-making mechanism. Such information is particularly important for policymakers and legislative entities, who may address the nuances of passengers' security concerns through an integrated policy framework that will include some of the aforementioned (or similar) security measures.

5. CONCLUSIONS

In an era where automation tends to be deployed across all ground mobility systems, the emergence of flying cars expands the fully- or semi-automated transportation operation in two spatial dimensions: on the ground and in the air. Even though the first flying cars are anticipated to be commercially available over the next few years, the travelers' perceptions and expectations towards the adoption of flying cars remain unknown. This study provides a preliminary exploratory empirical investigation of individuals' expectations, by examining two fundamental components that will potentially determine the future demand for flying cars: willingness to pay for flying cars under various pricing scenarios, and willingness to use flying cars for various trip scenarios relating to the trip purpose, distance, and time-of-the-day.

To gain insights with regard to travelers' expectations and attitudes toward this emerging technology, an online survey was conducted, in which socio-demographic, behavioral and attitudinal data from 692 individuals were collected. To identify the factors that determine respondents' willingness to pay for and willingness to use flying cars, grouped random parameters bivariate probit models were estimated. The latter allowed the joint modeling of either willingness-to-pay or willingness-to-use scenarios that encounter commonly shared unobserved effects arising from respondents' systematic perceptual patterns. Furthermore, through the use of grouped random parameters, possible misspecification issues were addressed, such as, unobserved heterogeneity (i.e., the effect of unobserved characteristics varying systematical across observational units), unbalanced panel effects (stemming from the possible presence of systematic variations among the multiple survey responses), and cross-equation error term correlation (stemming from similar or same unobserved variations among sub-groups of willingness-to-pay and willingness-to-use scenarios). It should be noted that the presence of these misspecification issues is primarily due to the limited awareness and mixed perceptions of individuals about such a revolutionary transportation technology.

The results of the statistical analysis revealed that various socio-demographic characteristics (e.g., gender, age, ethnicity, marital status, level of education, and income), individual-specific behavioral and driving attributes (e.g., driving speed in different posted speed limit scenarios, reaction to traffic signal change from green to yellow, and accident history), as well as the attitudinal perspectives towards the implications of this new transportation technology, all affected the willingness to pay for and use flying cars. A number of factors were found to have homogeneous effect on individuals' expectations across the various willingness-to-use and willingness-to-pay scenarios. In all, older individuals and individuals non-familiar with advanced vehicle features or driver's assistance systems are less willing to pay for and use flying cars. In contrast, Asians and individuals who travel a lot on an annual basis are more likely to use flying cars, regardless of the trip purpose or distance. Higher education level is generally associated with greater interest in the adoption of flying cars, whereas individuals with low- or medium-level annual income are less interested to pay and use flying cars, reflecting, thus, their expectations for high acquisition and operation cost. In addition, the identification of mixed effects of various socio-demographic characteristics on individuals' willingness to pay for and use flying cars demonstrates the presence of highly heterogeneous patterns among individuals' expectations.

With regard to the attitudinal perspectives towards the possible benefits and concerns, individuals who are concerned about the purchase cost of flying cars, possible accidents on the airway, and loss of joy relating to the driving task, are all less willing to pay for and use flying cars. Similarly, environmental and cost concerns arising from the operation of flying cars constitute also possible barriers for their adoption by the commuting population. On the opposite end, individuals who believe that the introduction of flying cars may result in more reliable travel times and fewer crashes on the roadway are overall more interested in the use of flying cars. The security level associated with the operation of flying cars is another important aspect in individuals' decision-making mechanism, with the possible enforcement of security-enhancing measures augmenting their willingness to pay for and use flying cars.

Despite their preliminary, exploratory, and empirical nature, the findings of this study suggest that policymakers, manufacturing companies and legislative entities may focus on the development of a policy framework that will shed more light on three fundamental dimensions of flying cars operation: cost, safety, and security. In the context of urban air mobility, various manufacturing companies and service providers have already started developing pilot policy schemes for the deployment of flying taxis and shared flying car services (Thipphavong et al., 2018; Blau, 2020). As the policy and regulatory concepts continue to unfold, future research endeavors should unveil the human or operation-related factors that will determine public willingness to pay for and use on-demand shared mobility services based on flying cars.

The revolutionary capabilities of this new transportation technology do not *a priori* warrant its adoption by the traveling population, while the full awareness of the latter regarding the aforementioned dimensions constitutes a critical step towards the future expansion of flying cars, in terms of demand, implementation, and investments. Even though these findings may be subject to either individuals' limited knowledge or their perceptions for a seemingly unknown advanced technology, what it is explicitly inferred is, that flying cars, under an appealing pricing and regulatory framework, have the potential to rapidly modify the *status quo* of urban mobility and daily travel patterns.

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7. CONFLICT OF INTEREST STATEMENT

On behalf of all authors, the corresponding author states that there is no conflict of interest.

8. AUTHORS' CONTRIBUTIONS

UE and GF: Defining the Topic, Setting-up the Method, Literature Search and Review, Survey Design, Data Preparation, Performing Analysis, and Manuscript Writing; and PCA: Defining the Topic, Setting-up the Method, Survey Design, Manuscript Writing and Editing, and Research Outreach/Correspondence.

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