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Commuter choice of UAM-friendly neighborhoods

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ABSTRACT

Urban Air Mobility (UAM) which provides swift intra- and intercity transportation services has the potential to induce shifts in individuals' commuting and residential decisions. It is anticipated that, in residential areas, UAM services would enhance accessibility for residents. An UAM-friendly neighborhood represents a novel, integrated neighborhood concept that provides the infrastructure and travel environment required to facilitate UAM services, thereby promoting sustainable neighborhood development and improving accessibility. To gain a deeper understanding of commuters' choice behavior in UAM-friendly neighborhoods, we designed a stated choice experiment. Using data collected in Beijing city, we estimated a mixed logit model with interaction effects to identify the choice preferences of different people while capturing the unobserved preference heterogeneity. We found that individuals generally prefer to reside in such neighborhoods where the access distance to UAM vertiports is within one kilometer, the parking fee is either low (5 yuan/day) or free, the commuting time by UAT is 15 min, and drone window-docking delivery services are available. Households with high incomes (>400,000 yuan/year) and those owning a car are likely to adopt these novel neighborhoods. There is a varying degree of heterogeneity observed regarding residential location and distance to UAM vertiports among individuals in different age groups. Results of the elasticity analysis indicate that UAT commuting cost has the greatest impact on the likelihood of residing in UAM-friendly neighborhoods.

1. Introduction

Driven by the advancement of autonomous and drone technology, a growing shift from ground transportation to urban air mobility has been emerging in recent years. Since flying could bypass congested urban areas and routes, UAM may potentially bring disruptive innovation to urban transportation. In addition to passenger transport services like Urban Air Taxi (UAT), the extended concept of UAM also encompasses cargo applications, such as drone delivery, emergency pharmaceutical transport, and the supply of goods to remote areas (Long et al., 2023). Furthermore, UAM also extends its scope to additional offerings like urban monitoring, fire detection, air sightseeing, surveying, and mapping (Reiche et al., 2018). Envisioning the gradual integration of various air services into urban areas particularly residential areas, our living environment could be beneficial to the improved convenience.

On the other hand, concerns about low-altitude aircraft also arise, including issues related to safety, privacy, noise, and aesthetics (Cohen and Shaheen, 2021). To some extent, these pertinent externalities may be mitigated or minimized through concurrent technological advancements. The recently promoted electric Vertical Takeoff and Landing (eVTOL) aircraft are considered promising because of the enhanced features of quietness, safety, and less emission. Many global companies are committed to designing eVTOL

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aircraft capable of offering UAM services, including Joby Aviation (Joby Aviation, 2023), Volocopter (Volocopter, 2019), EHang (EHang, 2020), SkyDrive (SkyDrive, 2024), among others.

These new air services, when integrated into residential areas, are expected to offer a wide range of benefits to the residents. For instance, residents in these neighborhoods could benefit from the additional travel option to reach distant locations. Furthermore, the availability of drone services may streamline parcel deliveries for these communities. The innovative window-docking delivery drones that dock outside windows or balconies can make the process of sending and receiving parcels swift and effortless (Jedsy, 2022). These innovations are poised to trigger a profound transformation in urban infrastructure and land use development, potentially leading to a shift in long-term population migration.

This implies people may want to reside in locations that are even farther from suburban areas due to the availability of new air services (Peeta et al., 2008). A recent exploration suggests that people might make relocation decisions in the era of UAM (Ahmed et al., 2022). The potential shifts in the preferences of residential location choice have significant implications for urban and transportation policy development. Thus, it is timely for policymakers to envision the shifting dynamics of residential locations and strategically develop plans for infrastructure and services. For instance, coordinated land use and infrastructure investments are needed to optimize the extended urban functions in alignment with the sustainable development of UAM-serviced residential areas. Since the deployment of UAM infrastructure in neighborhoods inevitably affects the existing built environment (i.e., greenery coverage, accessibility) and/or living and transportation costs (i.e., travel cost, residential cost), it is crucial to gain a deeper understanding of people's long-term decision-making behavior in UAM-enabled neighborhoods.

To the best of our knowledge, a noticeable research gap exists in research regarding residential choices in neighborhoods with UAM service. In this context, we aim to introduce a new concept, referred to as a UAM-friendly neighborhood, to describe residential areas that integrate UAM services like urban air taxis and drone delivery services. These neighborhoods are anticipated to improve the convenience of both living and commuting for residents, while also reducing the dependency on private cars. The introduction of this new concept underscores the need for further research to understand how individuals will opt to reside in UAM-friendly neighborhoods.

In light of the above research context, this study seeks to investigate commuters' propensity to reside in UAM-friendly neighborhoods. A dedicated stated preference survey was designed to uncover people's preferences regarding UAM-friendly neighborhoods. Recognizing the varying perceptions of UAM-related services among individuals, we employed a mixed logit model with interaction effects to account for both unobserved and observed heterogeneity. In this regard, we aim to provide urban planners, architects, and transportation engineers with valuable insights for the improved development of future UAM-friendly neighborhoods.

The remaining sections of this paper are structured as follows. Section 2 provides a brief review of existing literature on UAM acceptance and residential choices. Section 3 outlines the design of the choice experiment and analyzes the socio-demographics and commuting characteristics of the respondents. In section 4, a mixed logit model with interaction effects is introduced. Section 5 discusses the estimation results derived from the model. Ultimately, the paper concludes by summarizing the key findings and discussing prospective directions for future research.

2. Literature review

In recent years, a growing body of research has focused on UAM. Researchers have explored demand forecasting for UAM (Fu et al., 2022; Haan et al., 2021; Rajendran et al., 2021; Rimjha et al., 2021), potential vertiport locations (Chen et al., 2022; Rajendran and Zack, 2019; Rath and Chow, 2022; Sells et al., 2021; Shin et al., 2022; Yedavalli and Cohen, 2022; Zhao and Feng, 2023), and flight route planning (Dai et al., 2021; Hildemann and Verstegen, 2023; Kotwicz Herniczek and German, 2022; Tang et al., 2021; Wu et al., 2022). To facilitate the successful market implementation of UAM, exploring the public acceptance and willingness to use UAM services has gained significant attention.

According to Uber's white paper, a multitude of factors including safety, noise, emissions, privacy, and visual disturbances exert a significant influence on public acceptance concerning UAM (Holden and Goel, 2016). Among these considerations, safety concerns represent the primary factor affecting the acceptance of UAM (Al Haddad et al., 2020; EASA, 2021; Reiche et al., 2018; Yedavalli and Mooberry, 2019). For instance, perceived safety has been found to contribute the most to people's trust in UAM technology which positively affects their intention to use UAM (Kim et al., 2022). Similarly, Karami et al. (2023) explored the factors influencing the adoption of UAM in Tehran, revealing that safety concerns negatively correlate with the intention to use UAM. Eker et al. (2019) found that younger individuals are likely to favor the safety benefits associated with UAM (e.g., fewer crashes), whereas the elderly tend to have concerns over safety consequences induced by equipment or system failure. Despite some safety concerns, such as collision risk, operation under adverse weather conditions, and the reliability of electric engines, air taxis are generally regarded as highly safe (Behme and Patrick, 2020).

Noise emerges as another significant constraint in the use of UAM, particularly when UAM services are fully operational (Straubinger et al., 2020). For instance, residents generally desire quiet environments, especially at night, thereby having concerns about privacy and noise disturbances from low-altitude aircraft flying over their residential areas (Pons-Prats et al., 2022). A market study on public acceptance of UAM indicates that the public not only considers the magnitude of noise but also its type. For example, the volume of noise is expected to be below or near the level of a bee-buzzing or car passing, but not the sound of a truck or helicopter (Yedavalli and Mooberry, 2019). Given the nature of low-altitude flight over densely populated urban areas and scaled operations, UAM needs to adhere to more stringent noise standards (Wang et al., 2023). As the UAM market matures, it seems promising that noise impacts on ground bystanders could be further mitigated through technological advancements, higher cruising altitudes, and avoiding noise-sensitive zones (Vascik et al., 2018).

As for the mode choice of UAM, factors associated with travel, notably travel time and travel cost, are considered to be of great significance. A stated preference analysis conducted in the United States concluded that travel distance, service fare, and facility location constitute key determinants influencing users' choices regarding on-demand air services (Peeta et al., 2008). People are more likely to switch to this service when the facility location is close to their neighborhoods for personal trips and near their workplaces for business-related journeys. Fu et al. (2019) conducted a stated preference survey in Munich to investigate individuals' mode choice behavior among four alternative options: private car, public transportation, autonomous taxis, and autonomous air taxis. They found that travel time, travel cost, and safety are critical determinants in the adoption of autonomous transportation modes.

Haan et al. (2021) carried out a stated preference survey to identify potential air taxi commuting routes in 40 U.S. cities. The results revealed that access/egress time and aircraft operational cost are pivotal factors influencing the demand for air taxis. Ilahi et al. (2021) also investigated respondents' travel mode choice behavior concerning emerging modalities, encompassing on-demand transport and UAM, in the context of the Greater Jakarta area of Indonesia, and found that variable travel costs, congestion charging, and access time of UAM exert negative significance on the adoption of UAM. Furthermore, Hwang and Hong (2023) delineated three distinct UAM operational scenarios (i.e., intracity short-haul travel, intracity long-haul travel, and intercity travel) and explored the willingness of residents to use UAM in the Seoul metropolitan area, South Korea. The results highlighted that cost and access time significantly impact the inclination to use UAM across all scenarios, while the influence of waiting time, boarding time, and autonomous driving on UAM utilization varies according to different scenarios.

Those studies on the willingness to use UAM offer useful insights for policymakers to improve infrastructure development. Nevertheless, these studies are often conducted in isolation from the residential decision, even though it fundamentally influences how people choose to travel. On the other hand, existing literature on residential choices often underscores the mutual interdependence between land use and transportation. Recent studies on residential choices are typically featured with transportation consideration, encompassing, for example, transit-oriented development neighborhoods (Huang et al., 2021), transit-oriented communities (Luckey et al., 2018), car-free neighborhoods (Borges and Goldner, 2015; Kushner, 2005; Morris et al., 2009; Selzer, 2021), and carsharing-facilitating neighborhoods (Wang et al., 2021a, 2021b). These new mobility services enabled neighborhoods to collectively make significant contributions to promoting sustainable transportation and improving the neighborhood environment. For instance, Wang et al. (2021b) investigated the preferences of Dutch residents regarding carsharing-facilitating neighborhoods and found that preferences for such neighborhoods are predominantly shaped by factors including carsharing cost, required carsharing booking time, green space density, housing cost, housing type, housing size, and housing building year.

Indeed, the issue of general residential choices has been extensively investigated in the literature. It is broadly believed that housing and transportation costs exert an influence on individuals' decision on where to live (Akbari et al., 2020; Guo et al., 2020a; Kim et al., 2005; Tillema et al., 2010; Wang et al., 2021b; Zhang and Guhathakurta, 2021). Individuals and/or households tend to live in residential locations characterized by lower housing prices, shorter commuting times, lower transportation costs, and lower residential density (Kim et al., 2005; Zhang and Guhathakurta, 2021). Accessibility and dissatisfaction are widely acknowledged to affect residential decisions (Gehrke et al., 2019a, 2019b; Kim et al., 2005; Krueger et al., 2019; Luckey et al., 2018; Tian et al., 2015; Torres et al., 2013). People tend to reside in proximity to workplaces and/or local services such as shopping, and public transportation stations (Tian et al., 2015).

Essentially, the advantages such as improved efficiency, reliability, and convenience, as well as the additional flexibility offered by emerging mobility options, such as autonomous vehicles, are anticipated to influence people's residential choices (Carrese et al., 2019; Gelauff et al., 2019; Kim et al., 2020; Zhang and Guhathakurta, 2021). In the context of UAM, Ahmed et al. (2022) discussed the impacts of flying cars on residential relocations. They indicated that socio-demographic characteristics and individual perceived advantages and challenges associated with flying cars have a notable influence on the decision of residential relocations. The time advantage brought by flying cars further enhances people's intention to live in suburban areas. However, the study lacks useful insights into the choice of neighborhoods that are equipped with air services.

Based on the research context mentioned above, a clear research gap exists in the assessment of people's intention to live in UAM-friendly neighborhoods. Studies mentioning this potential seem limited to offer useful insights for policy decision-makings. Therefore, in this study, we attempt to bridge this research gap by examining commuters' residential choices regarding UAM-friendly neighborhoods. To be specific, this research focuses on the following research questions: 1) what factors impact commuters' choices towards UAM-friendly neighborhoods, 2) how people's preferences for UAM-friendly neighborhoods vary according to their social-demographical characteristics, and 3) to what extent preference heterogeneity exists among different individuals. To this end, our goal is to contribute to a deeper understanding of a relatively unexplored issue: how individuals make residential choices among neighborhoods that support UAM.

3. Survey and experimental design

3.1. Experimental design

Given that the envisioned UAM-friendly neighborhood has not yet materialized, stated choice experiments represent a feasible method to investigate residential choice behavior. To design the stated choice experiment, we select relevant attributes and attribute levels based on the existing research and practices related to UAM and residential decisions. As revealed through the literature review, attributes including residential location, residential cost, surrounding greenery, accessibility to various living amenities and transportation facilities, accessibility to UAM infrastructure, as well as commuting time and cost via urban air taxis are considered to impact commuters' residential choices of UAM-friendly neighborhoods.

Here, the UAM-friendly neighborhoods we envisioned can either be newly constructed or redeveloped areas. In the experiment, we introduce this concept as places where the travel environment and service facilities are conducive for individuals to utilize UAM services, such as the presence of vertiports within the neighborhood, and the availability of a drone delivery docking pad outside the window of each house. Urban air taxi service is conceptualized as a novel aerial ride-hailing service, operated by a pilot flying eVTOL aircraft capable of accommodating 1–4 passengers. This air taxi service provides multimodal journeys, with travelers initially using ground transportation modes to access the departure vertiport from their starting point. Following their flight from the departure vertiport to the arrival vertiport through UAT, they then utilize ground transportation to reach their final destination (Zhao and Feng, 2023). In this context, vertiports function as the stations for UAT takeoff and landing. The drone delivery docking pad is explained as a platform specifically designed for the sending and receiving of parcels through drones. This allows recipients to conveniently send or receive parcels directly via docking pads located outside the window, without the need to visit traditional courier stations. Our objective is to assess the impact of such drone delivery services on their neighborhood choices.

The residential location attribute comprises four levels related to the location of urban areas, including city center, inner suburban, outer suburban, and rural area. Inner suburban can be understood as suburban areas closer to the city center, while outer suburban denotes the suburban areas nearer to rural areas. As for the attribute of residential cost (i.e., housing price, rental price), we use the percentage of the price (relative to the actual cost of respondents' current housing price that was asked in the questionnaire) to ease the potential imaginary burdens that may happen in the experiment. The residential costs encompass housing mortgage or rent, parking fees, property management fees, utility costs, gas fees, heating fees, internet fees, and maintenance costs, among others. Additionally, we also included the attribute related to the surrounding greenery that systematically varies across two levels, low and high.

Concerning the accessibility of various living amenities and transportation facilities, we selected three attributes: distance to the shopping mall, distance to public transport (PT) stations, and distance to UAM vertiports. Four levels are set for each of the attributes considering the actual situation of Beijing. Note that the setting of four levels allows us to sufficiently capture the variations and possible nonlinear effects of the main attributes. The lowest level of distance to UAM vertiports is set as 0.2 km, aiming to represent scenarios where a vertiport is located within the neighborhood. In this context, the access distance and time to urban air taxis are almost negligible. We intend to incorporate the effects of extreme circumstances. Furthermore, to encourage private car owners to park and use urban air taxis, vertiports are designed to offer a certain number of parking spaces. Parking fees, considered as one of the attributes, systematically vary across four levels. Specifically, the lowest level of parking fee is set as free. The fees at other levels are determined by the standard parking fee in the research area.

The availability of commuting via UAT represents a distinctive feature of UAM-friendly neighborhoods. Commuting time and cost associated with using UAT are important attributes that may affect residents' willingness to choose UAM-friendly neighborhoods. Initially, we set four levels of commuting distances, which were subsequently transformed into corresponding levels of commuting time and cost based on an average UAT travel speed of 160 km per hour. Furthermore, it is important to account for additional factors such as access/egress time, waiting time, and boarding time. The pricing of UAT services was based on Uber's expectation of reducing UAT price to $1.84 per mile (approximately 8.39 yuan per kilometer) through ride-hailing services (Garrow et al., 2021). Ultimately, the choice experiment comprises ten main attributes, as delineated in Table 1.

The experiment involves a total of eight four-level attributes and two two-level attributes. In the case of full factorial design, this results in $4^8 \times 2^2$ possible profiles, which is deemed impractical. Therefore, to reduce the number of choice tasks, we adopted an orthogonal fractional factorial design consisting of 64 configurations. Compared to orthogonal designs, efficient designs with priori information are often considered superior as they can produce lower standard errors and improved estimates (Bliemer and Rose, 2011; Rose et al., 2008). However, due to the absence of priori parameter information, orthogonal design is considered adequate and thus adopted in this study. Subsequently, the 64 profiles were divided into eight blocks. Respondents were randomly assigned to one block and instructed to complete eight specified choice tasks. A screenshot of the choice experiment is presented in Fig. 1. Respondents were required to select one UAM-friendly neighborhood or the "None of them" option if neither of the two options was preferred.

3.2. Data collection and sample characteristics

The data was collected from April to June 2023 in Beijing, China. Beijing, as the capital of China, is a megacity. It comprises 16

Table 1
Attributes and corresponding levels of the stated choice experiment.

Attributes	Level 1	Level 2	Level 3	Level 4
Residential location	City center	Inner suburban	Outer suburban	Rural area
Residential cost compared with your current housing cost	−50 %	−25 %	+25 %	+50 %
Surrounding greenery	Low	High		
Drone window-docking delivery service	Yes	No		
Distance to shopping mall (km)	0.5	1	2	3
Distance to PT station (km)	0.5	1	2	3
Distance to UAM vertiport (km)	0.2	1	2	3
Parking fee at nearby vertiport (yuan/day)	Free	5	10	15
Commuting time by UAT (min)	15	20	25	30
Commuting cost by UAT (yuan)	80	120	160	200

Note: 1 Chinese yuan = 0.141 US dollars in May 2024.

Task 1 of 8

	Neighborhood A	Neighborhood B	None of them
Residential location	Inner suburban	City center	
Residential cost compared with your current house	+50%	+25%	
Surrounding greenery	High	Low	
Drone window-docking delivery service	Yes	No	
Distance to shopping mall (km)	2 km	1 km	
Distance to PT station (km)	1 km	0.5 km	
Distance to UAM vertiport (km)	1 km	2 km	
Parking fee at nearby vertiport (yuan/day)	5 yuan per day	5 yuan per day	
Commuting time by UAT (min)	15 min	25 min	
Commuting cost by UAT (yuan)	80 yuan	120 yuan	
Your choice	○	○	○

Fig. 1. An example of the stated choice experiment (translated from Chinese).

districts, covering a total land area of 16,410 square kilometers, with a population of 21.85 million residents. According to the "2023 China Major Cities Commuting Report" (CAUPD and Baidu, 2023), Beijing stands out with the most extensive commuting spatial scale, boasting a commuting spatial radius of 41 km. This signifies that Beijing's urban transportation necessitates supporting a spatial scale of 41 km. UAM emerges as a highly promising solution in this regard.

The questionnaire is composed of four sections: stated choice experiments, sociodemographic characteristics, work and travel characteristics, and attitudes. The link to the questionnaire was randomly distributed through a professional online survey platform to those aged 18 and above, working in Beijing and commuting to work at least one day per week. To avoid issues of comprehension difficulty, detailed introductions were presented before respondents' engagement, encompassing explanations of concepts regarding UAT, vertiport, UAM-friendly neighborhoods, and drone window-docking delivery services. Moreover, participants were presented with a promotional video introducing the entire process and realistic scenarios of utilizing UAT services.

The introductory information is seen as a highly important instrument to warrant reliable responses, e.g., people may not fully imagine the situation because of unfamiliarity. For example, to reduce hypothetical bias, we conducted several actions before people responded to the choice of UAM-friendly neighborhoods. At the beginning of the survey, we provided detailed textual descriptions, schematic diagrams, and a promotional video from Uber urban air services to detail the entire process of traveling with urban air taxis. Before starting the SP experiment, we thoroughly explained an example of the experiment to help respondents understand various attributes and become familiar with the decision-making process (screenshots included in appendix).

A pilot study was first conducted in April 2023 before the large-scale surveys, yielding 19 responses. Any issues detected during this process were fixed, e.g., we revised the statements of the survey questions that were ambiguously phrased and difficult for respondents to understand. Afterward, the complete survey was carried out through a professional survey company from April to June 2023. A total of 535 completed questionnaires were collected. The average completion time for the questionnaire was 31 min. After cleaning invalid data (e.g., due to excessively short completion time, and repetitive answers), the final sample used for model estimation ultimately includes 3,736 observations from 467 respondents.

The descriptive statistics of respondents' socio-demographic and commuting characteristics are presented in Table 2. The data illustrates a relatively balanced gender distribution among the respondents, with all participants being over 18 years old. Notably, given the target population of this survey is employed individuals, the respondents are predominantly young and middle-aged adults. More specifically, 14.4 % of the respondents fall within the age bracket of 18 to 24, while 74.5 % belong to the 25 to 54 age group, with the remaining 11.1 % being 55 years or older. The respondents generally possess higher levels of education surpassing that of the overall population of Beijing. Within the sample, 12.8 % of respondents live alone, 67.3 % reside with their families, and 19.1 % share accommodations with friends or colleagues.

Regarding the distribution of annual household income, approximately 65.0 % of respondents report annual household incomes ranging from 200,000 to 600,000 yuan, while 9.2 % indicate even higher. The rest of the respondents report relatively lower annual household incomes, falling below 200,000 yuan. In terms of commuting, 83.3 % of respondents come from households with cars, whereas 16.7 % lack car ownership in their households. Public transportation (bus or subway) serves as the primary commuting mode for 40.1 % of the sample. Private car usage for commuting is reported by 27.4 % of respondents, while 20.3 % opt for active transportation methods such as biking or walking. In addition, 28.5 % of respondents have previous experience of using helicopters.

Moreover, commuting distance and time represent the characteristics of commuting trips in Beijing. Results shown in Table 2 demonstrate that about 10.9 % of respondents travel 20 km or longer for a single commuting trip and about 56.8 % of respondents have a workplace reachable within 10 km. Regarding one-way commuting time, 15.2 % of respondents spend less than 15 min. The majority of respondents (41.1 %) spend 15–30 min for their commuting. People who spend 30–60 min and 60 more minutes take 36.0 % and 7.7 %, respectively.

Table 2
Socio-demographics and commuting characteristics of the respondents.

Variables	Categories	Cases	Percentage (%)	Percentage of population in Beijing
Gender	Male	227	48.6	51.0 %
	Female	240	51.4	49.0 %
Age	18–24	67	14.4	15–24: 7.7 %
	25–34	85	18.2	25–34: 18.6 %
	35–44	141	30.2	35–44: 18.3 %
	45–54	122	26.1	45–54: 14.5 %
	55–59	50	10.7	55–59: 7.5 %
	≥60	2	0.4	≥60: 21.3 %
Education level	High school and below	14	3.0	43.8 %
	Vocational	19	4.1	22.2 %
	Bachelor	300	64.2	26.6 %
	Master	121	25.9	6.4 %
	Doctorate	12	2.6	1.0 %
	Other	1	0.2	
Household composition	Living alone	60	12.8	–
	Couple without children	69	14.8	
	Couple with children	190	40.7	
	Living with parents	55	11.8	
	Shared living with friends/ colleagues	89	19.1	
	Other	4	0.9	
Household income (yuan/year)	<100,000	36	7.7	Personal annual income: 178,476 on average for employed people
	100,000–200,000	85	18.2	
	201,000–300,000	71	15.2	
	301,000–400,000	84	18.0	
	401,000–500,000	74	15.9	
	501,000–600,000	74	15.9	
	>600,000	43	9.2	
Household car ownership	Have cars	389	83.3	60 cars per 100 households
	No cars	78	16.7	
Helicopter experience	Have experience	133	28.5	–
	No experience	334	71.5	
Public transport accessibility (km)	<0.5	127	27.2	–
	0.5–1	202	43.3	
	1.1–1.5	94	20.1	
	1.6–2	22	4.7	
	>2	22	4.7	
Main commuting mode	Bus/Subway	187	40.1	–
	Private car	128	27.4	
	Private (e)bike/Shared bike	85	18.2	
	Taxi/Ride-sharing	53	11.3	
	Walk	10	2.1	
	Other	4	0.9	
One-way commuting distance (km)	<5	124	26.6	13.2 on average
	5–10	141	30.2	
	10.1–15	102	21.8	
	15.1–20	49	10.5	
	>20	51	10.9	
One-way commuting time (min)	<15	71	15.2	51 on average
	15–30	192	41.1	
	30.1–45	78	16.7	
	45.1–60	90	19.3	
	>60	36	7.7	

Note: One-way commuting distance and time data are from the Beijing Transport Institute (2023), and other statistics on the overall population in Beijing are from the Beijing Municipal Bureau of Statistics (2023).

4. Model specification

In this study, we use a mixed logit model (ML) based on random utility theory (Train, 2009) to quantify the impact of selected attributes on the choice of UAM-friendly neighborhoods. The observed heterogeneity is captured by taking into consideration the interactions between socio-demographic variables (such as age and household income) and the main attributes. Individual $i(i \in I)$ opts for the alternative with the highest utility after evaluating all the alternatives $j(j \in J)$ in choice situation $s(s \in S)$. The utility of alternative j evaluated by individual i in choice situation s can be expressed using the subsequent equation.

$$U_{ijs} = \boldsymbol{X}_{ijs}\boldsymbol{\beta}_{ji} + \boldsymbol{Z}_i\boldsymbol{\theta}_{ij} + \left(\boldsymbol{Z}_i \bigotimes \boldsymbol{X}_{ijs}\right)\boldsymbol{\gamma}_{ij} + \varepsilon_{ijs} \tag{1}$$

In this context, $\boldsymbol{X}_{ijs}$ represents a vector of alternative-specific attributes, encompassing both neighborhood attributes and the attributes associated with UAM services. $\boldsymbol{Z}_i$ stands for a vector of socio-demographic variables of individual i. $\boldsymbol{Z}_i \bigotimes \boldsymbol{X}_{ijs}$ denotes a vector of two-way interactions between socio-demographic variables and main attributes. It indicates whether the combination of socio-demographic variables and main attributes leads to a higher or lower utility than the separate effects. $\boldsymbol{\beta}_{ji}$, $\boldsymbol{\theta}_{ij}$, and $\boldsymbol{\gamma}_{ij}$ are vectors of parameters to be estimated. ε_{ijs} is a random error term following a Gumble distribution.

To account for the preference differences among individuals, we specify the random parameters with certain distributions (Hensher and Greene, 2003; Hess and Polak, 2005). The random parameter for attribute k of alternative j for individual i can be defined as follows:

$$\boldsymbol{\beta}_{jki} = \overline{\boldsymbol{\beta}_{jk}} + \sigma_k v_{jki} \tag{2}$$

where $\overline{\boldsymbol{\beta}_{jk}}$ represents the population mean, v_{jki} stands for a normally distributed random term with zero mean and a standard deviation of one. σ_k denotes the standard deviation of the distribution of $\boldsymbol{\beta}_{jki}$.

As a result, the conditional choice probability for individual i choosing alternative j in choice situation s is expressed as follows:

$$P_{ij} = \frac{\exp\left(\boldsymbol{X}_{ijs}\boldsymbol{\beta}_{ji} + \boldsymbol{Z}_i\boldsymbol{\theta}_{ij} + \left(\boldsymbol{Z}_i \bigotimes \boldsymbol{X}_{ijs}\right)\boldsymbol{\gamma}_{ij}\right)}{\sum_{n=1}^{N}\exp(\boldsymbol{X}_{ins}\boldsymbol{\beta}_{ni} + \boldsymbol{Z}_i\boldsymbol{\theta}_{in} + (\boldsymbol{Z}_i \bigotimes \boldsymbol{X}_{ins})\boldsymbol{\gamma}_{in})} \tag{3}$$

The unconditional choice probability for individual i regarding alternative j in choice situation s is:

$$P_{ijs} = \iint \left(\left(P_{ijs}|\boldsymbol{\beta}_{ij}\right) f\left(\boldsymbol{\beta}_{ij}|\boldsymbol{X}_i, \boldsymbol{Z}_i\right) \right) d\boldsymbol{\beta}_{ij} \tag{4}$$

The complete log-likelihood function is defined as follows:

$$LL = \sum_{i=1}^{I} \log \prod_{s=1}^{S} \prod_{j=1}^{J} \left(P_{ijs}\right)^{\delta_{ij}} \tag{5}$$

Here, if individual i selects alternative j, $\delta_{ij} = 1$; otherwise, $\delta_{ij} = 0$.

5. Results

Before model estimation, effect coding was employed for all attributes, taking the last level of each attribute as the reference level. We used R programming language to estimate several models with different settings, including a simple multinomial logit model (MNL) without and with socio-demographics, an MNL + with interaction terms, and a mixed logit model with random parameters. The selection of socio-demographics, interaction terms, and random parameters is based on our theoretical assumptions, relevant literature, and testing of different models. The final mixed logit model included six random parameters: residential location, residential cost compared with your current house, distance to UAM vertiports, parking fee at nearby vertiports, commuting time by UAT, and commuting cost by UAT, all assumed to follow a normal distribution. We tried different numbers of Halton draws for the random parameter estimations, ranging from 100 to 1000. The results reported in this study are based on 1000 Halton draws. The detailed estimation results of the MNL + with interaction terms and the mixed logit model are presented in Table 3.

The log-likelihood (LL) for the MNL + model is −3137.71, while the LL for the mixed logit model is −3032.2. The adjusted Rho-squared value increased from 0.221 (MNL +) to 0.243 (ML), indicating that the mixed logit model that considers random parameters yields a better goodness of fit. As depicted in Fig. 2, the prediction accuracy of the mixed logit model exceeds 60 %. Furthermore, the sign of the estimated coefficients between the two models are consistent and align with theoretical expectations, with most parameters of the main attributes being significant. In the subsequent discussion, we primarily focus on the results of the mixed logit model.

5.1. *Effects of alternative-specific attributes*

It is evident from Table 3 that the majority of the alternative-specific attributes significantly influence commuters' choices concerning UAM-friendly neighborhoods. Individuals tend to select UAM-friendly neighborhoods located in the city center or inner suburban areas rather than in outer suburban or rural areas. The presence of high-level amenities in urban areas enhances the appeal of the city center. Variations in residential cost have been observed to significantly impact the decision to reside in UAM-friendly neighborhoods. Previous studies revealed that people show a higher preference for lower housing prices (Kim et al., 2005; Wang et al., 2021b; Zhang and Guhathakurta, 2021). Similar findings are also obtained in the current study. The residential costs are considered in percentage change relative to individuals' current residential costs. Results show that, if the residential cost in UAM-friendly neighborhoods is 25% or even higher than their current residential cost, people are unlikely to adopt such a neighborhood. The probability of people living in UAM-friendly neighborhoods increases with the reduced residential cost.

Moreover, previous research indicates that access time negatively influences individuals' willingness to utilize UAM services (Hwang and Hong, 2023; Ilahi et al., 2021). As an important indicator of accessibility, the distance to UAM vertiport from home plays an important role in practical planning. We found that people's willingness to live in UAM-friendly neighborhoods is high if the

Table 3
Estimation results of multinomial logit model and mixed logit model.

Variables	Description	Multinomial logit model		Mixed logit model	
		Coefficient	p-statistics	Coefficient	p-statistics
Random parameters					
Residential location	City center	0.137***	0.002	0.192***	0.003
	Inner suburban	0.060	0.172	0.099*	0.093
	Outer suburban	−0.007	0.886	−0.015	0.801
	Rural area	−0.191		−0.276	
Residential cost compared with your current house	−50 %	0.564***	0.000	0.784***	0.000
	−25 %	0.305***	0.000	0.431***	0.000
	+25 %	−0.186***	0.000	−0.231***	0.000
	+50 %	−0.684		−0.985	
Distance to UAM vertiport (km)	0.2 km	0.095**	0.035	0.189***	0.002
	1 km	0.096**	0.028	0.127**	0.029
	2 km	0.034	0.455	−0.021	0.736
	3 km	−0.225		−0.296	
Parking fee at nearby vertiport (yuan/day)	Free	0.108**	0.019	0.134**	0.032
	5 yuan/day	0.117***	0.009	0.187***	0.002
	10 yuan/day	−0.150***	0.001	−0.211***	0.001
	15 yuan/day	−0.074		−0.109	
Commuting time by UAT (min)	15 min	0.158***	0.000	0.165**	0.015
	20 min	−0.039	0.383	−0.019	0.756
	25 min	−0.051	0.255	−0.027	0.669
	30 min	−0.067		−0.118	
Commuting cost by UAT (yuan)	80 yuan	0.716***	0.000	1.002***	0.000
	120 yuan	0.233***	0.000	0.327***	0.000
	160 yuan	−0.257***	0.000	−0.304***	0.000
	200 yuan	−0.692		−1.025	
Non-random parameters					
Surrounding greenery	High	0.050*	0.061	0.035	0.335
	Low	−0.050		−0.035	
Drone window-docking delivery service	Yes	0.096***	0.000	0.112***	0.001
	No	−0.096		−0.112	
Distance to shopping mall (km)	0.5 km	0.123***	0.006	0.195***	0.001
	1 km	0.077*	0.090	0.108*	0.090
	2 km	−0.077*	0.093	−0.155**	0.014
	3 km	−0.123		−0.148	
Distance to PT station (km)	0.5 km	0.203***	0.000	0.255***	0.000
	1 km	0.007	0.886	0.029	0.633
	2 km	0.028	0.543	0.047	0.466
	3 km	−0.237		−0.331	
Socio-demographic characteristics					
Gender	Male	0.114**	0.028	0.107*	0.076
	Female	−0.114		−0.107	
Age	18–34	−0.152**	0.036	−0.186**	0.027
	35–44	−0.015	0.837	0.031	0.714
	≥ 45	0.167		0.154	
Education level	Bachelor and below	0.366***	0.000	0.404***	0.000
	Master and above	−0.366		−0.404	
Household size	1–2 persons	−0.301***	0.000	−0.349***	0.000
	≥ 3 persons	0.301		0.349	
Household income (yuan/year)	<200,000	−0.177**	0.031	−0.147	0.120
	200,000–400,000	−0.241***	0.001	−0.317***	0.000
	>400,000	0.419		0.465	
Car ownership	Yes	0.970***	0.000	1.089***	0.000
	No	−0.970		−1.089	
Helicopter experience	Yes	−0.591***	0.000	−0.577***	0.000
	No	0.591		0.577	
Two-way interaction					
Residential location × Age (18–34 yr.)	City center	0.100	0.116	0.107	0.235
	Inner suburban	0.139**	0.028	0.214**	0.011
	Outer suburban	−0.056	0.388	−0.070	0.415
	Rural area	−0.183		−0.251	
Residential location × Age (35–44 yr.)	City center	−0.118*	0.065	−0.154*	0.092
	Inner suburban	−0.026	0.680	−0.055	0.512
	Outer suburban	−0.043	0.514	−0.051	0.552
	Rural area	0.187		0.260	
Distance to UAM vertiport (km) × Age (18–34 yr.)	0.2 km	0.115*	0.071	0.104	0.226
	1 km	−0.090	0.148	−0.135*	0.095

(*continued on next page*)

Table 3 (*continued*)

Variables	Description	Multinomial logit model		Mixed logit model	
		Coefficient	*p*-statistics	Coefficient	*p*-statistics
	2 km	−0.039	0.538	−0.021	0.804
	3 km	0.014		0.052	
Distance to UAM vertiport (km) × Age (35–44 yr.)	0.2 km	−0.022	0.736	0.020	0.818
	1 km	0.095	0.130	0.144*	0.078
	2 km	−0.118*	0.069	−0.174**	0.043
	3 km	0.045		0.011	
Relative residential cost × Household income (<200,000 yuan/year)	−50 %	0.287***	0.000	0.346***	0.003
	−25 %	0.071	0.312	0.106	0.281
	+25 %	−0.135*	0.059	−0.168*	0.063
	+50 %	−0.223		−0.284	
Relative residential cost × Household income (200,000–400,000 yuan/year)	−50 %	−0.034	0.598	−0.001	0.991
	−25 %	0.082	0.208	0.103	0.263
	+25 %	0.045	0.492	0.056	0.502
	+50 %	−0.092		−0.158	
Commuting cost by UAT (yuan) × Household income (<200,000 yuan/year)	80 yuan	0.153**	0.026	0.245**	0.028
	120 yuan	0.117	0.111	0.137	0.160
	160 yuan	−0.107	0.140	−0.174*	0.080
	200 yuan	−0.162		−0.208	
Commuting cost by UAT (yuan) × Household income (200,000–400,000 yuan/year)	80 yuan	0.068	0.291	0.098	0.343
	120 yuan	−0.032	0.627	−0.069	0.438
	160 yuan	0.086	0.192	0.174*	0.056
	200 yuan	−0.121		−0.202	
Standard deviation of random parameters					
Residential location	City center			0.572***	0.000
	Inner suburban			0.159	0.437
	Outer suburban			0.307*	0.051
Residential cost compared with your current house	−50 %			0.929***	0.000
	−25 %			0.558***	0.000
	+25 %			0.061	0.768
Distance to UAM vertiport (km)	0.2 km			0.012	0.959
	1 km			0.063	0.581
	2 km			0.137	0.446
Parking fee at nearby vertiport (yuan/day)	Free			0.324**	0.019
	5 yuan/day			0.053	0.732
	10 yuan/day			0.337**	0.012
Commuting time by UAT (min)	15 min			0.537***	0.000
	20 min			0.225	0.248
	25 min			0.431***	0.001
Commuting cost by UAT (yuan)	80 yuan			0.876***	0.000
	120 yuan			0.343***	0.020
	160 yuan			0.446***	0.000
LL(0)		−4104.42		−4104.42	
LL(β)		−3137.71		−3032.2	
Rho²		0.236		0.261	
Rho² adjusted		0.221		0.243	

Note: ***, **, * means the level of significance at 1%, 5%, and 10% respectively.

distance to the vertiport is 1 km or shorter. When the distance is as long as 2 km or 3 km, the parameters become negative. However, the estimates are not statistically significant. This suggests that placing vertiport within 1 km of residential location can generally promote the adoption of UAM-friendly neighborhoods.

Parking fee at nearby vertiports is found to significantly impact the decision on UAM-friendly neighborhoods. To encourage private car owners to park and use air taxis, we included the level of free parking. When the parking fee is set at free or as cheap as 5 yuan per day, individuals are willing to reside in UAM-friendly neighborhoods. However, as the parking fees increase to 10 yuan or 15 yuan per day, the probability of choosing UAM-friendly neighborhoods decreases.

Commuting time and cost by UAT also significantly influence the choice of UAM-friendly neighborhoods. People intend to live in such neighborhoods in the case of 15-minute commuting time by UAT. When the time becomes longer, there is a tendency that people are unlikely to live in UAM-friendly neighborhoods, although the effects are insignificant. This indicates people generally expect short UAT commuting time. This observation may be useful for UAT operators considering the importance of service reliability, e.g., to ensure smooth transfers induced by the multi-stage UAT trips. Furthermore, respondents in general prefer the neighborhoods with commuting costs by UAT of 80 yuan and 120 yuan. As commuting costs increase to 160 yuan, the probability decreases. This indicates that individuals are cost-sensitive in their commuting decisions, and generally consider travel costs exceeding 160 yuan to be expensive. These findings are in line with the existing studies on residential choices that concluded people favor residential areas featuring shorter commuting times and lower commuting costs (Kim et al., 2005; Zhang and Guhathakurta, 2021), and those on UAM

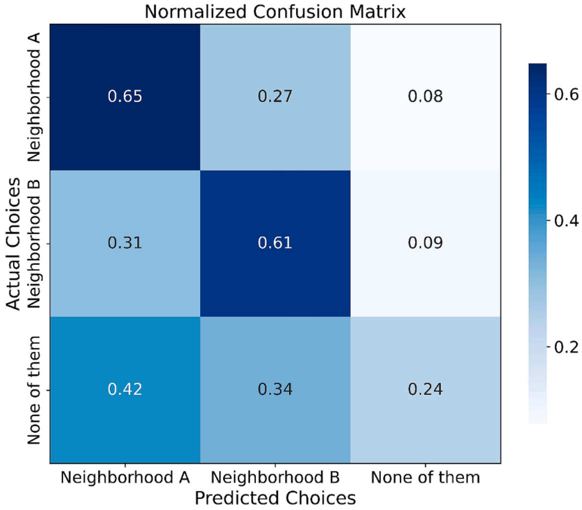


Fig.2. Normalized confusion matrix for UAM-friendly neighborhoods.

mode choices that revealed the adverse effects of travel time (Fu et al., 2019) and travel costs (Fu et al., 2019; Hwang and Hong, 2023; Ilahi et al., 2021; Peeta et al., 2008).

In addition, although not statistically significant, results show that individuals prefer residing in UAM-friendly neighborhoods characterized by higher levels of greenery. This finding aligns with the conclusion from carsharing-facilitating neighborhood choice (Wang et al., 2021b). Moreover, drone window-docking delivery services are found to significantly promote the residing intention of people in UAM-friendly neighborhoods. Therefore, offering facilities supporting drone delivery services is an appealing factor for those considering living in UAM-friendly neighborhoods.

Results of the accessibility indicators show consistent findings with the previous studies in the sense that accessibility to transit and living amenities affect individuals' residential choices (Luckey et al., 2018; Tian et al., 2015). In our study, we found that individuals prefer residing in a neighborhood located within 1 or 0.5 km of a shopping mall. As the distance increases to 2 km or longer, the probability of living in UAM-friendly neighborhoods decreases. Similarly, respondents possibly live in UAM-friendly neighborhoods if the distance to PT stations is 0.5 km. As this distance increases, the probability of opting for UAM-friendly neighborhoods declines. This indicates that, in addition to the UAM services offered at the neighborhood level, the accessibility to public transportation and living facilities is equally important.

5.2. *Effects of socio-demographic characteristics*

Before model estimation, some variables related to socio-demographic characteristics were grouped into categories to render their influence representatively. According to the estimation results presented in Table 3, males are in general likely to live in UAM-friendly neighborhoods. Younger commuters (between 18 and 34) are less likely to opt for UAM-friendly neighborhoods. While there is a tendency for people older than 45 to live in such neighborhoods, the effect is not statistically significant. Education level also plays a significant role in the decision-making process, with respondents holding bachelor's degrees or lower expressing a greater inclination to reside in UAM-friendly neighborhoods, while those with master's degrees or higher exhibit a lower probability.

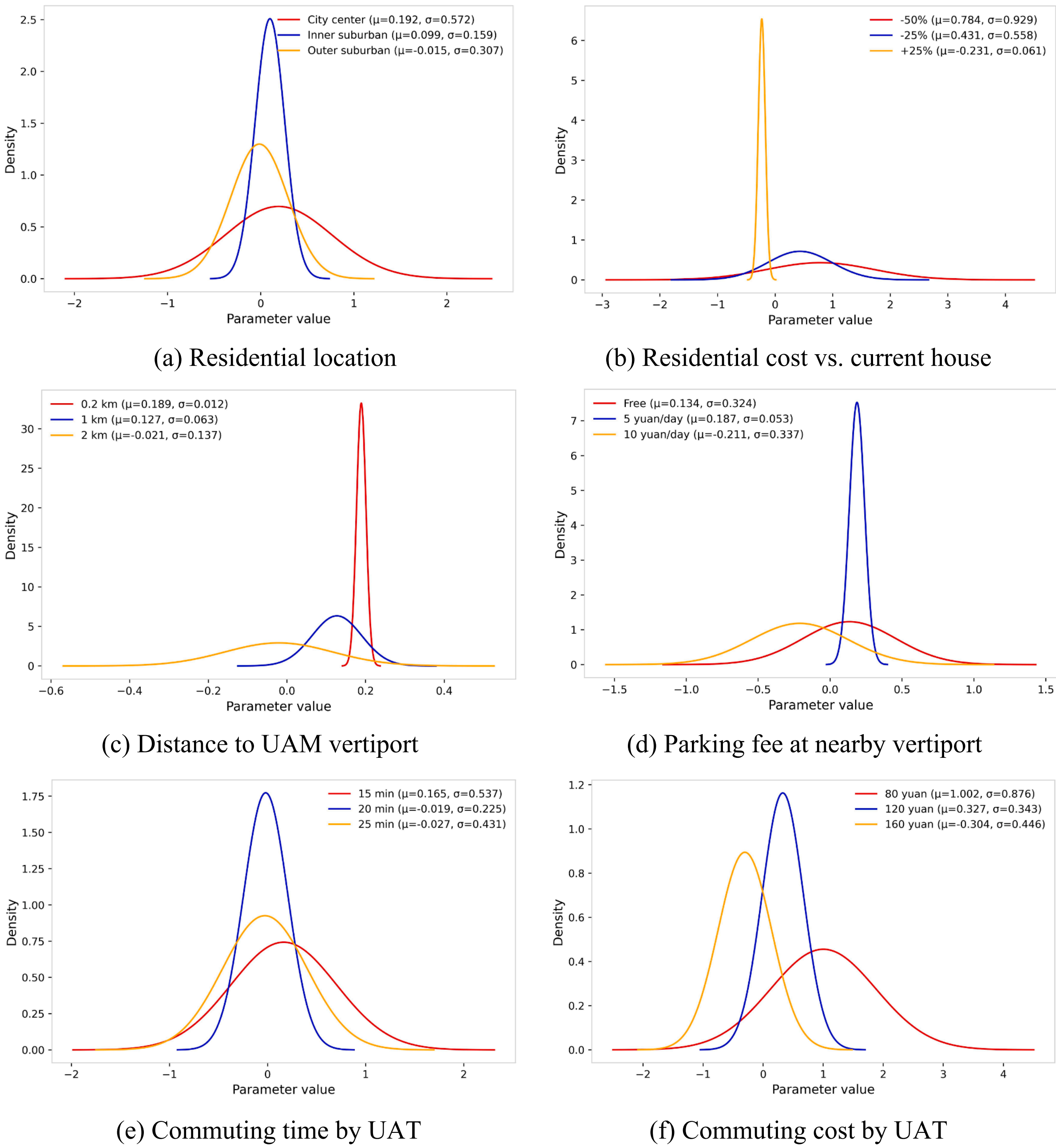
Regarding household size, when the household comprises 1 to 2 individuals, the estimated effect is negative, implying that respondents from smaller households are less likely to opt for UAM-friendly neighborhoods. Furthermore, it is found that household income significantly impacts the choice of UAM-friendly neighborhoods. The coefficients for the low (<200,000 yuan/year) and moderate (200,000–400,000 yuan/year) levels of household income are negative, indicating that respondents having low- and middle-household income are reluctant to adopt UAM-friendly neighborhoods. Conversely, there is a tendency for respondents with high annual household incomes exceeding 400,000 yuan/year to reside in UAM-friendly neighborhoods.

Interestingly, we found that people who have a car in their households are prone to live in UAM-friendly neighborhoods. This finding holds considerable importance, especially for promoting sustainable and integrated neighborhood development to reduce car-dependent commuting. On the other hand, car ownership enables UAM to a greater extent as it opens options for park and fly or someone dropping them by the vertiport. Finally, results of helicopter experience suggest that respondents with helicopter experience have a low tendency to opt for UAM-friendly neighborhoods. This is understandable due to negative helicopter experiences, such as noise and safety concerns during unclear weather conditions. It's important to note that helicopter experience serves as a close approximation of UAM experience, although current UAM producers typically claim reduced noise and enhanced safety levels. However, concerns may still arise when flying with UAM in urban canyons or foggy weather, unless technological advancements prove sufficient to consistently deliver positive experiences. At this stage, it remains unclear to what extent these improvements will be enough to achieve widespread community acceptance.

5.3. Two-way interaction between socio-demographic and alternative-specific attributes

To identify observed heterogeneity, we estimated two-way interaction effects between socio-demographic characteristics and alternative-specific attributes. These interaction effects are analyzed in combination with the main attributes. We found that the probability of adopting UAM-friendly neighborhoods located in city centers or inner suburban areas is higher for young people (18–34 years old). Furthermore, although people generally favor neighborhoods in city centers, the probability of living in such neighborhoods decreases for the middle-aged group (35–44 years old). This means that setting specific locations for UAM-friendly neighborhoods would influence the adoption rate among different age groups.

Results of the interaction effects between distance to UAM vertiport and age also exhibit varying degrees of heterogeneity. The overall effect of one km distance to a UAM vertiport diminishes in the case of young people (18–34 years old) and becomes larger in the case of middle-aged people (35–44 years old). The effect of 0.2 km distance to a UAM vertiport shows a homogeneous tendency



(a) Residential location
(b) Residential cost vs. current house
(c) Distance to UAM vertiport
(d) Parking fee at nearby vertiport
(e) Commuting time by UAT
(f) Commuting cost by UAT

Fig. 3. The probability distributions for the random parameters.

between two groups of people, despite the partially significant parameters. This perhaps suggests that placing UAM vertiports further away increases the degree of preference difference among various age groups.

To examine the partial effects of household income on the probability of living in UAM-friendly neighborhoods, we included the interaction effects between relative residential costs and household income. We found that the overall probability of living in such neighborhoods with low relative residential costs (−50 %) increases for low-income households (<200,000 yuan/year). This provides useful insight for specifying residential costs when developing UAM-friendly neighborhoods, as low-income households are most attracted when residential costs are 50 % lower than their current costs.

Another important investigation was conducted for the interaction between commuting costs by UAT and household income. It is evident that the overall probability of residing in UAM-friendly neighborhoods with commuting costs as low as 80 yuan increases for low-income households (<200,000 yuan/year). However, the probability diminishes in the case of 160-yuan commuting costs. Notably, the overall negative effect of 160-yuan commuting costs becomes smaller for middle-income households (200,000–400,000 yuan/year). This indicates different preferences regarding UAT pricing among different income groups. Therefore, stakeholders should be aware of such heterogeneity when setting UAT prices.

5.4. Standard deviation of random parameters

According to the estimation results of the random parameters, significant standard deviations are observed across two levels of residential location, namely city center and outer suburban. This implies that, apart from the heterogeneity analyzed through interaction effects, also significant unobserved heterogeneity exists. This is because different people have varying preferences for different residential locations, especially for the city center. This is consistent with previous studies (Guo et al., 2020a; Tillema et al., 2010). Some individuals value the complete amenities and opportunities offered by the city center, while others may dislike the noisy and compact urban environment in central areas. Moreover, significant heterogeneity is also found for two levels of the reduced residential costs, whereas no significant heterogeneity is observed for increased residential costs (+25 %). This observation suggests that even when residential costs decrease, some respondents may still not choose UAM-friendly neighborhoods. In contrast, respondents' preferences become more homogeneous when residential costs increase by 25 %.

In addition, the estimation results indicate that the standard deviations associated with the distance to the UAM vertiport are not statistically significant, while are significant for parking fee at nearby vertiports, commuting time and commuting cost by UAT. This underscores that people do indeed have varying preferences for different parking fees, commuting times and costs by UAT. We observe the highest standard deviation at the lowest level for UAT commuting time and commuting cost, suggesting that respondents' choice behavior varies the most when UAT commuting time and cost are at a minimal level.

Fig. 3 presents the distributions of the random parameters based on normal distributions. Taking Fig. 3 (a) as an example, a higher mean and a wider spread are manifested, indicating a general preference among individuals for UAM-friendly neighborhoods situated in city centers. In Fig. 3 (b), the distributions for a 50 % and 25 % reduction in residential costs show positive means and wide tails, revealing respondents' preference for UAM-friendly neighborhoods with reduced living costs and high preference heterogeneity.

5.5. Elasticity analysis

To further elucidate the policy implications concerning UAM-friendly neighborhoods, we conducted an elasticity analysis on several key attributes, including the residential cost compared to their current house, distance to UAM vertiport, parking fee at nearby vertiport, and commuting cost by UAT. Here, the elasticity is measured as the percentage change in the probability of choosing UAM-friendly neighborhoods in response to a 1 % change in an attribute. The results of the elasticity are presented in Table 4.

According to Table 4, the elasticity of residential cost change is −0.340, indicating that an increase in residential costs decreases the likelihood of respondents choosing UAM-friendly neighborhoods. Specifically, with all other conditions remaining unchanged, for every 1 % increase in the percentage change of residential costs, the probability of choosing a UAM-friendly neighborhood decreases by 0.340 %. To promote the adoption in such neighborhoods, appropriate welfare policies, such as housing subsidies, tax incentives, and property fee reductions, may be implemented.

The elasticity is −0.041 for distance to UAM vertiport and −0.044 for parking fee at nearby vertiports, suggesting that a 1 % increase in distance to vertiport and parking fee respectively lead to 0.041 % and 0.044 % decrease in the likelihood of individuals choosing UAM-friendly neighborhoods. The elasticity of commuting cost by UAT is −0.446, making it the most sensitive attribute, indicating that a 1 % increase in UAT commuting cost will result in 0.446 % reductions in the probability of residents choosing UAM-friendly neighborhoods. Existing research has also reported the elasticity of transportation costs in residential relocation choices (Papaioannou et al., 2020). They found that a 1 % increase in current transportation costs leads to 0.45 % increase in the probability of

Table 4
Results of elasticity.

Attributes	Elasticity effects
Residential cost compared with your current housing cost	−0.340
Distance to UAM vertiport	−0.041
Parking fee at nearby vertiport	−0.044
Commuting cost by UAT	−0.446

choosing to relocate to a new residence. This elasticity value is very close to the elasticity of UAT commuting costs observed in this study, further highlighting the importance of transportation costs in residential choice. Given the high sensitivity to UAT commuting costs, it is evident that policies should prioritize promoting financial incentives, such as discounts or incorporation into monthly mobility packages, to better facilitate the choice of UAM-friendly neighborhoods.

6. Summary and discussion

6.1. Summary

As a consequence of the progressing autonomous technology and flying car advancements, the integration of UAM services and associated facilities into residential areas would have a great impact on people's daily lives. Certainly, the planning and establishment of UAM-friendly neighborhoods will encounter various challenges, particularly at the initial stage of market development, one should not overlook the great potential of improved accessibility and its impact on residential re-location, e.g., people may live further away. The decisions of people on where to live will have a profound impact on urban and land use planning. Therefore, it is crucial to analyze and comprehend commuters' choice behavior concerning UAM-friendly neighborhoods for informed policy decisions.

The UAM-friendly neighborhood represents an innovative concept of a sustainable residential area that integrates UAM services and facilities within the neighborhood setting, ultimately enhancing convenience for its residents. However, existing research lacks adequate evidence regarding individuals' decisions to choose neighborhoods with UAM services and amenities. Recognizing this research gap, we conducted a stated choice experiment to gain further knowledge regarding commuters' choice of UAM-friendly neighborhoods. To account for preference heterogeneity among commuters, a mixed logit model with interaction effects was applied to assess the impact of neighborhood attributes, socio-demographic characteristics, and their interactions on the choice of UAM-friendly neighborhoods.

The results indicate that residential location, the relative residential costs, distance to the shopping mall, and distance to PT station are significant determinants for the choice of UAM-friendly neighborhoods. In general, individuals are inclined to opt for the UAM-friendly neighborhoods that are located in the city center or inner suburban areas, with lower residential costs, and closer to shopping malls and PT stations. UAM services, such as drone window-docking delivery service, distance to UAM vertiport, parking fee at nearby vertiport, commuting time by UAT, and commuting costs by UAT, are also crucial factors influencing the choice of UAM-friendly neighborhoods. Generally, individuals are likely to choose the UAM-friendly neighborhoods that are equipped with a drone docking pad outside the window for drone delivery services, are closer to vertiports, offer affordable parking facilities at vertiports, have shorter UAT commuting time, and have lower UAT commuting costs.

Moreover, males, individuals aged 45 and above, with bachelor's degrees or lower, households comprising three or more members, those with annual household income exceeding 400,000 yuan, households owning cars, and individuals lacking helicopter experience are inclined to choose UAM-friendly neighborhoods. The findings also reveal significant taste variations among individuals. The varying degree of observed heterogeneity is manifested among different age and income groups. Additionally, significant unobserved preference heterogeneity among individuals is observed regarding residential location, residential costs compared with the current house, parking fee at nearby vertiports, commuting time by UAT, and commuting cost by UAT. Among the main attributes, commuting cost has the highest elasticity, indicating that the likelihood of residing in UAM-friendly neighborhoods changes the most if commuting cost changes.

The findings of this study hold practical significance for policy decisions. Our results can aid government authorities, real estate developers, and UAM operators in identifying potential locations suitable for UAM-friendly neighborhoods and tailoring them to meet the distinct needs of different social groups. The insights gained regarding people's choice behavior of UAM-friendly neighborhoods provide essential guidance for urban planners in planning future neighborhoods that facilitate integrated UAM services.

6.2. Discussion

Despite the great promise of the UAM-friendly neighborhood concept, research on this subject is scarce. This scarcity is partly because the concept relies on UAM which has not yet been deployed in the market, making real case studies currently impossible. This presents a challenge when exploring people's residential choice behavior in such a context, which could also be considered a limitation of this study. At present, there are numerous practical issues related to the UAM services that have yet to be resolved. These issues include but are not limited to noise impact, safety concerns, conflict of air vehicles, regulations, and pricing.

While it is unrealistic to consider all the factors mentioned above in developing residential choice models, some major policy concerns need to be addressed systematically. One of the main concerns is related to the noise generated by flying vehicles. The extent to which these vehicles can be quiet enough for people to accept them remains unclear. In the current study, we attempted to simulate the noise through video, which may not accurately represent reality. Therefore, it is both interesting and necessary for future research to expand the residential choice models by including the impact of various noise levels.

In our experiment, we assume UAM service is offered at the neighborhood level, differing from many existing studies where vertiport locations are typically situated in commercial areas, such as the city center or hospital rooftops for evacuation purposes. Constructing vertiports in neighborhoods will inevitably face practical constraints, such as limited space and unsuitable rooftops of residential buildings. However, this is where policy makers should play a strategic role, ensuring future land and building developments accommodate vertiport spaces and implement higher standards for rooftop construction to support heavy loads.

Another critical aspect of UAM is the issue of equity. Recent studies indicate that early adopters of UAM tend to be high-income individuals, leading demand prediction to focus on private car or taxi users. For UAM services at the neighborhood level, a more general population should benefit. Thus, the cost of using UAM must be comparable to existing ground transportation. Encouragingly, recent pilot projects have announced prices competitive with taxis. Our study found as prices rise to a certain level, the likelihood of residing in UAM-friendly neighborhoods decreases. This means exploring the effectiveness of welfare measures that benefit individual members or households would be intriguing in this context. Therefore, establishing feasible pricing for UAM in neighborhoods, considering factors beyond investment recovery, seems to be crucial.

Furthermore, some individuals may avoid using UAM because of safety concerns. Issues like extreme weather and unexpected situations may never be eliminated, meaning people's attitudes, such as their judgment on technological innovation and risk avoidance personality, will play a significant role. Thus, investigating the impacts of these latent attitudes and perceptions on the choice of UAM-friendly neighborhoods is worthwhile.

Essentially, choosing UAM-friendly neighborhoods is an integrated decision involving both transportation and residential location choices, often modeled at the household level due to the involvement of multiple household members (Guo et al., 2020b). The current study focused on individual decision-making, independent of other family members' utility. In this regard, a group decision model based on household survey data may be needed to provide more nuanced insights.

In addition, our study focused on commuters' residential choices. As a result, our sample comprises the working population, which does not represent the choice behavior of the general population including unemployed individuals and/or the elderly. Therefore, further research on the general population is needed. Furthermore, to what extent would UAM-friendly neighborhoods induce changes in mode choice deserves further research.

Finally, this study is based on stated preference data, which may not fully reflect residents' actual choice behavior regarding UAM-friendly neighborhoods. The actual use of UAM also depends on people's familiarity with the technology and their positive experiences with it. Our inclusion of the helicopter experience may not fully represent the reality of using UAM. As the UAM era progresses, empirical data will shed light on individuals' actual residential decisions concerning such neighborhoods.

CRediT authorship contribution statement

Ying Zhao: Writing – original draft, Visualization, Software, Investigation, Formal analysis, Data curation, Conceptualization. **Tao Feng:** Writing – review & editing, Validation, Supervision, Resources, Project administration, Methodology, Funding acquisition, Formal analysis, Conceptualization.

Declaration of competing interest

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

Appendix

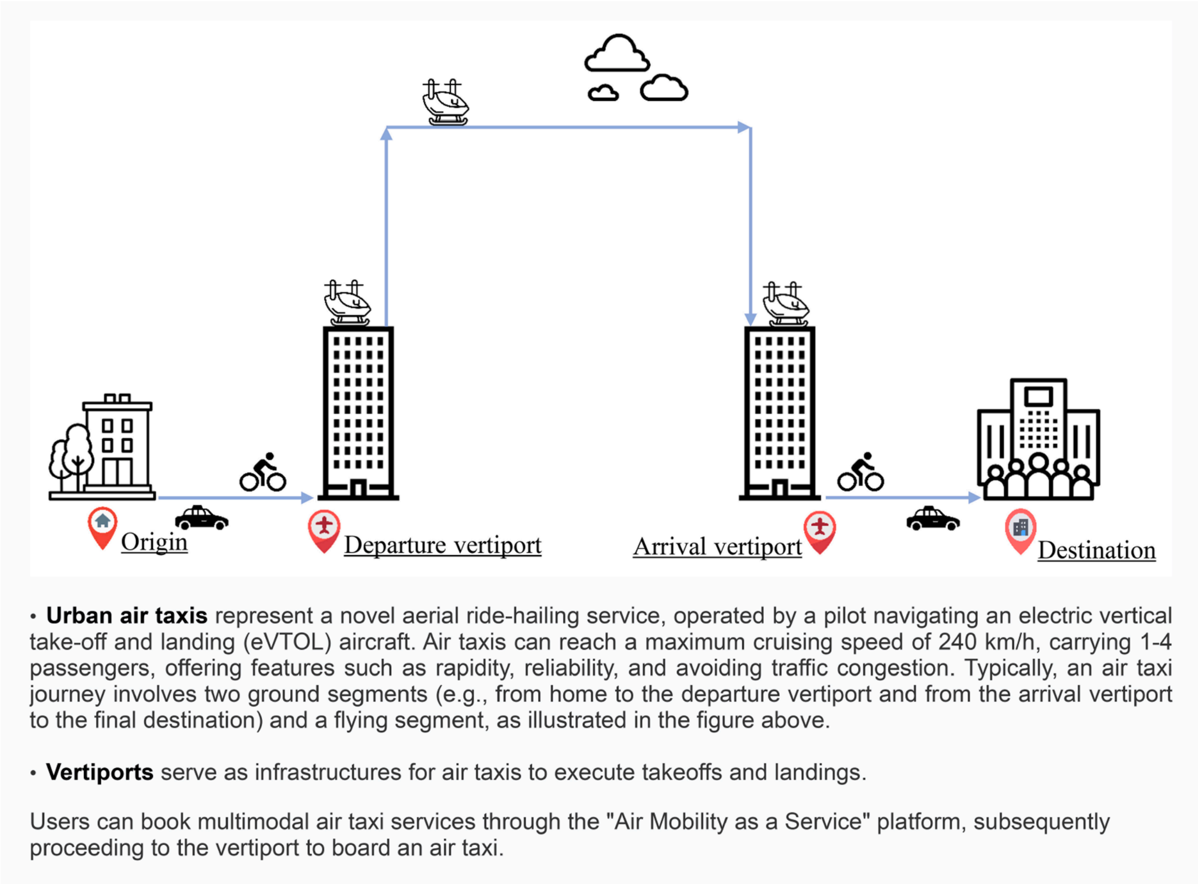


Fig. A1. A screenshot explaining urban air taxis and vertiports (translated from Chinese).

Fig. B1. A screenshot of the promotional video from Uber detailing the usage process of the air taxi service (translated from Chinese).

Residential Choice Experiment

UAM-friendly neighborhoods are defined as those residential areas where the travel environment and service facilities are suitable for people to use UAM services, such as having vertiports within the neighborhood or nearby, and drone delivery docking pads outside the residential windows.

Based on different facility conditions in the neighborhoods (such as location, residential cost, greenery, and accessibility), select the neighborhood you think is optimal (Neighborhood A or B). If you are not satisfied with either alternative provided, you can also choose "None of them". Before beginning the experiment, please understand the following concepts:

• **Residential cost compared with your current housing cost** refers to the increase or decrease percentage of **total given costs** (including housing mortgage or rent, parking fees, property management fees, utility costs, gas fees, heating fees, internet fees, and maintenance fees) **compared to your actual living costs**.

• **Drone delivery docking pad** is a platform specifically designed for the sending and receiving of parcels through drones, allowing recipients to directly send or receive parcels from docking pads outside the window, without the need to visit traditional courier stations.

• **Parking fee at nearby vertiport** refers to the parking fee incurred when driving to the vertiport to park and use urban air taxis (yuan/day).

Fig. C1. A screenshot explaining UAM-friendly neighborhoods and the attributes of the stated choice experiment (translated from Chinese).

Data availability

Data will be made available on request.

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