Journal of Air Transport Management 124 (2025) 102719

Contents lists available at ScienceDirect

Journal of Air Transport Management

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

Urban air mobility for airport access: Mode choice preference associated with socioeconomic status and airport usage behavior

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ARTICLE INFO

Keywords:
Urban air mobility
Airport access
Mode choice
Stated preference survey
Mixed multinomial logit model

ABSTRACT

This study examined mode choice preference for airport access given the introduction of Urban Air Mobility (UAM) airport shuttle service and its associations with socioeconomic status and airport usage behavior. We designed the stated preference survey targeting Incheon International Airport in South Korea and collected data from 2604 respondents. We provided six scenarios composed of a combination of experimental attributes (travel time, travel cost, and transfer frequency) for five alternative transport modes (airport train, airport bus, taxi, passenger car, and UAM) to each respondent and asked them to choose one most preferred mode in each scenario. A mixed multinomial logit model was used to consider the underlying characteristics of the collected data. The modeling result confirms that the preference for taking UAM varies by people's socioeconomic status and airport usage behavior. People who have higher incomes, frequently use taxis, and want to arrive at airports quickly before boarding are more likely to take UAM for airport access. The findings imply that UAM may be able to become a kind of taxi service operating in the sky, but its expensive fares may discourage its popularization. The findings extend previous studies of airport-oriented UAM service as one of the first studies to consider airport usage behavior. This study provides policymakers with insight into feasible strategies to make UAM service a practical transportation mode for the public.

1. Introduction

Population growth in urban areas has increased rapidly, and 57 % of the world's population lived in urbanized areas in 2021 (The World Bank, 2018). This rapid urbanization inevitably involves transportation problems such as traffic congestion and air pollution and incurs enormous social and environmental costs in cities. In particular, major metropolitan areas with highly-developed ground transportation systems (e.g., London, New York, and Seoul metropolitan areas) have faced challenges in solving such problems because of land limitations and continually increasing travel volumes.

Urban Air Mobility (UAM) has come to the fore as a future transportation mode, one that is expected to fundamentally solve ground transportation problems. Many global aircraft and traditional automobile equipment manufacturers have participated in developing personal aerial vehicles (Volocopter, 2019), and numerous countries have made short-term plans for building UAM environments (European Union Aviation Safety Agency, 2020; Federal Aviation Administration, 2020; Ministry of Land, Infrastructure and Transport, 2020). For this reason, UAM is expected to be commercialized in the near future, with significant growth of its market to about 1.5 trillion USD by 2040 (Morgan Stanley Research, 2018).

In preparation for the era of UAM, the academic realm has seen many studies exploring the societal acceptability of UAM. Some studies have estimated the potential demand for UAM when it connects major hotspots in cities (Balac et al., 2019; Bulusu et al., 2021; Rimjha et al., 2021a, 2021b, 2021c; Shaheen et al., 2018), and other studies have evaluated its economic feasibility as a new transportation mode (Choi and Park, 2022; Deka and Carnegie, 2021; Rimjha et al., 2021a). The factors influencing the mode choice of UAM have also been examined in several studies (Al Haddad et al., 2020; Cho and Kim, 2022; Deka and Carnegie, 2021; Fu et al., 2019; Ilahi et al., 2021). They discovered its different choices depending on the characteristics of cities, socioeconomic status, and trip purpose.

According to the US National Aeronautics and Space Administration (NASA), the first UAM service will be an airport shuttle with a great possibility in terms of operational efficiency and construction of foundational infrastructure. It will have the form of transporting passengers

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https://doi.org/10.1016/j.jairtraman.2024.102719
Received 21 May 2024; Received in revised form 19 November 2024; Accepted 28 November 2024
Available online 4 December 2024

to, from, or between airports through fixed routes (Goyal et al., 2018). Some experts support NASA's analysis in that, if UAM service begins with airport shuttles, it will be possible to reduce the complexity of supply- and demand-matching in the initial market, and there will be no need to construct additional takeoff and landing infrastructure at least at airports (Goyal et al., 2018).

The previous studies have provided helpful information to introduce UAM from the perspective of societal acceptability, but only a few studies have addressed UAM as a mode for airport access (Choi and Park, 2022; Kotwicz Herniczek and German, 2022; Rimjha et al., 2021b, 2021c). Moreover, they did not consider the characteristics of airport-oriented trips, which can be quite different from general intra-city trips. According to the National Academies of Sciences, Engineering, and Medicine (2008), the analysis of mode choice for airport access should include the characteristics of airport-oriented trips, such as the purpose of airport visits and the time arriving at an airport. The consideration of such characteristics helps provide more precise insight for successfully introducing the initial UAM service in cities.

In this context, this study aims to examine mode choice preference for airport access when airport shuttle service by UAM was introduced and its associations with socioeconomic status and airport usage behavior. To find such information, we conducted a Stated Preference (SP) survey targeting the Incheon International Airport in South Korea, which is located in the Seoul Capital Area and handles 85% of Korea's international passengers. Seoul is regarded as an extremely promising market (KPMG, 2018) because of its population, economic growth, and severe road congestion. The methodology of the survey's experimental design is elaborated in Section 2 with the Mixed Multinomial Logit (MMNL) model used for analyzing the survey data. The results obtained from the survey and modeling are described in Section 3. Section 4 discusses the findings and suggests policy implications. The final section concludes this study with future study direction.

2. Methods

2.1. Stated preference survey design

Since UAM has not yet been introduced as a realistic transportation mode, a SP survey was designed to collect data for analysis in this study. The SP survey is conventionally used to investigate people's preferences by asking for their most preferred choice among multiple alternatives in virtual scenarios with diverse combinations of experimental attributes.

The questionnaire for this study is comprised of three sections: i) stated preferences of mode choice for airport access; ii) socioeconomic attributes; and iii) airport usage behaviors. To investigate the stated preference of mode choice for airport access, it was assumed that people start their trips at locations 50–60 km away from Incheon International Airport, as shown in Fig. 1, which is the initial operable UAM distance suggested by Daskilewicz et al. (2018). This distance range is similar to the distance for the initial demonstration route in South Korea: Gangnam in Seoul to Incheon International Airport (Ministry of Land, Infrastructure and Transport, 2020).

For choice alternatives, five transportation modes were offered for airport access: UAM, private car, taxi, airport train, and airport bus. The last four modes are popular ground modes for people who want to go to Incheon International Airport in South Korea. UAM was explained to the survey respondents as the concept of a flying electric vehicle that is an air transportation mode smaller than a helicopter.

The respondents were requested to choose the most preferred mode among the five types of transportation modes based on their attributes for an airport access trip. The experimental attributes consist of four variables: In-Vehicle Travel Time (IVTT), Out-Vehicle Travel Time (OVTT), travel cost, and transfer frequency. IVTT refers to the duration of staying in a mode, representing the time between boarding and alighting from a mode. OVTT represents the rest time excluding IVTT from total travel time, which consists of access time to or from stations, waiting time at stations, transfer time between modes, and parking time in the case of using private cars. Travel cost is the total amount required to use each mode. Transfer frequency was decided based on the average number of transfers when using airport trains or airport buses, which includes transfers when using shuttle buses inside the Incheon International Airport.

The base values of experimental attributes for ground modes were measured based on information obtained from an online map, and its attributes for UAM were measured based on the specifications of UAM service (speed and price) suggested in the initial stage of the Korean Urban Air Traffic (K-UAM) technology roadmap (Ministry of Land, Infrastructure and Transport, 2020) presented in Table 1. IVTT for UAM was calculated as the sum of flight time (distance (55 km)/speed (150 km/h)) and times for boarding and alighting (4 min for each). The

Table 1
Estimated market size outlined in the K-UAM technology roadmap.

Category		Initial period (2025~)	Progress period (2030~)	Advanced period (2035~)
Specification of UAM	Speed	150 km/h (80 kts)	240 km/h (130 kts)	300 km/h (161 kts)
	Flight distance	100 km (62 miles)	200 km (124 miles)	300 km (186 miles)
	Control system	Pilot	Remote control	Autonomous flight
Method of management		Human-based	Mixed (human-based, automated)	Fully automated
Number of lines/vertiports/airfields/aprons		2/4/4/16	22/24/24/120	203/52/104/624
Fare (KRW per person per km)		3000 (≈$ 2.36)	2000 (≈$ 1.57)	1300 (≈$ 1.02)

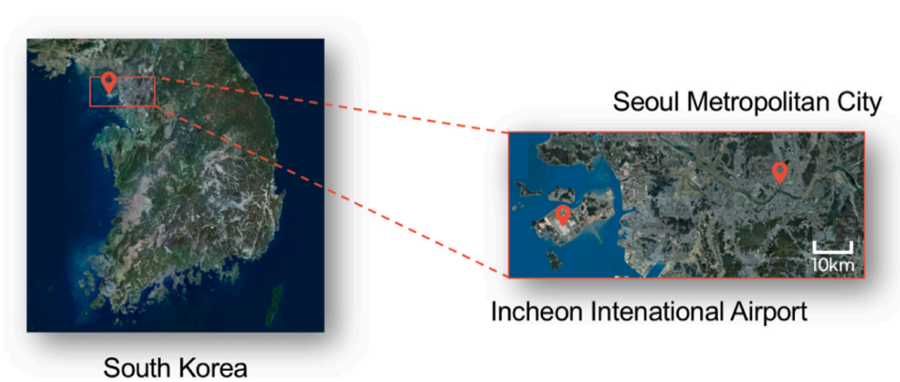

Fig. 1. Location of Incheon International Airport.

attribute levels were defined as the values of the base valueadding and subtracting its 20–25 % values (Sanko, 2001). The levels used for each attribute are presented in Table 2. Scenarios were created based on an L^{MA} method, which is a partial factorial design technique that removes correlations among attributes (Johnson et al., 2006) and efficiently reduces the number of scenarios. We asked respondents to answer questions on a total of six scenarios (see Fig. 2).

Additionally, to verify the assumptions held in the present study, the survey collected information about the socioeconomic status of respondents and their airport usage behavior. As for the socioeconomic status, information regarding their gender, age, educational level, marriage status, household income level, and transportation mode generally used in their daily lives were collected. For airport usage behavior, the respondents were asked about how many hours prior to takeoff they usually arrive at the airport, what the general purpose of going to the airport is, how many times per year they travel abroad, whether they had experience using prestige seats, and which airlines they most frequently use. As for the sampling, only respondents who had experience visiting Incheon International Airport were considered for this study. This was to ensure the reliability of the sample by collecting data from people with a better understanding of the subject.

2.2. Mixed multinomial logit model

A logit model is a conventional probabilistic choice model based on utility maximization (Ben-Akiva and Lerman, 1985; McFadden, 1973). We adopted the *MMNL* model to address multiple alternatives in each decision and to assume that coefficients of certain explanatory variables follow a specific probability distribution (e.g., normal distribution). This approach can consider heterogeneity in the choices of decision-makers with similar characteristics. In addition, decision-makers make multiple choices—one choice for each scenario—in the SP survey, and therefore, the choices made by one decision-maker can be inter-correlated (Hensher and Greene, 2003; Louviere et al., 2000; Revelt and Train, 1998). The *MMNL* model can address such underlying inter-correlation in the survey data by allowing for random taste variation across respondents and correlation among choices of a single decision-maker (Train, 2009).

In a discrete choice model, a decision-maker, q, chooses one alternative, i, from a set of multiple alternatives $(i = 1, 2, 3, \cdots, I, \forall\, i \neq j)$ in a single choice scenario t, aiming to maximize their utility $(U_{itq} > U_{jtq}\ \forall\, i \neq j)$ based on the attribute levels of each alternative. The utility function, U_{itq}, consists of both observable and unobservable parts (Hensher and Greene, 2003). It is expressed as:

$$U_{itq} = V_{itq} + e_{itq}$$

$$V_{itq} = \acute{\beta} X_{itq} \tag{1}$$

$$e_{itq} = \eta_{itq} + \varepsilon_{itq}$$

$$\eta_{itq} = \mu_{iq}^{t} z_{itq}$$

The observable part, V_{itq}, is a deterministic component that depends on a vector of fixed coefficients, $\acute{\beta}$, and a vector of explanatory variables, X_{itq}, that includes socioeconomic status and airport usage behavior. The error term, e_{itq}, expresses unobserved variations in utility and is partitioned into two subparts: η_{itq} and ε_{itq}. η_{itq} is a random term representing preference heterogeneity among decision-makers and is assumed to follow a normal distribution based on the central limit theorem (Washington et al., 2020). μ_{iq}^{t} denotes the estimated coefficients of experimental attributes, z_{itq} (i.e., IVTT, OVTT, travel cost, and transfer frequency); it is assumed that they have linear relationships. ε_{itq} is an error term that follows the Independently and Identically Distributed (IID) extreme value type 1.

Let $f(\eta|\Omega)$ denote the probability density function of the random term η, where Ω represents the fixed parameters (mean and deviation) of the normal distribution. The unconditional probability, P_i, is obtained by integrating the conditional probability over the distribution of η, weighted by its probability density function. It is expressed as equation (2):

$$P_i = \int \frac{\exp\left(\acute{\beta} X_i + \eta_i\right)}{\sum_j \exp\left(\acute{\beta} X_i + \eta_j\right)} f(\eta|\Omega) d\eta \tag{2}$$

In order to estimate the coefficient, we used the Simulated Log-Likelihood (*SLL*) function to maximize the approximate value of the choice probability (Hensher and Greene, 2003; Train, 2009). In the simulation, the process of a draw of β from $f(\eta|\Omega)$ and then its logit formulation is repeated several times. The results are then averaged to obtain the simulated probability, $\frac{1}{R}\sum_{r=1}^{R} L_i(\eta^r)$, where r denotes the draw sequence number and R is the total number of draws. The *SLL* is derived by the sum of the logarithm of the simulated probability as follows:

$$SLL = \sum_{q=1}^{Q} \sum_{i=1}^{J} d_{qi}\, ln\left(\frac{1}{R}\sum_{r=1}^{R} L_i(\eta^r)\right) \tag{3}$$

where d_{qi} equals one if the decision-maker, q, chooses alternative i and zero otherwise. For the simulation, we used 2000 draws generated by the Halton Sequence (Halton, 1960); this is regarded as a sufficient number for the random parameter estimation (Hess et al., 2003).

The *MMNL* model was developed using the 'gmnl' package (Sarrias and Daziano, 2017) in R (version 4.2.1), which estimates outcomes based on the Broyden–Fletcher–Goldfarb–Shanno (BFGS) algorithm (Avriel, 2003; Fletcher, 2013).

3. Results

3.1. SP survey result

The survey data was collected online from May 12 to 17, 2022, with a total of 2604 respondents. The distribution of respondents was designated based on the demographic distribution of airport passengers according to the statistics of the Korea Tourism Organization (Data Lab, 2018). Each respondent answered questions regarding six scenarios. Therefore, we collected a total of 15,624 choice samples. The choice proportions of each transportation mode were 49% for the airport bus, 24% for the airport train, 6% for the taxi, 16% for the private car, and 4% for the UAM. Table 3 shows the distribution of respondents depending on the attributes of socioeconomic status and airport travel behavior.

3.2. Modeling result

The log-likelihood ratio test result between the *MMNL* model and Multinomial Logit (MNL) model shows that the MMNL model outperforms the MNL model by considering randomness across respondents (see Table 4).

In the model, the airport train was set as the reference mode for

Table 2
Experimental attributes for SP survey.

Attributes	Unit	Airport train	Airport bus	Taxi	Private car	UAM
IVTT	10 min	1.5/2/2.5	1.5/2/2.5	0.5/1/1.5	0.5/1/1.5	1.5/2/2.5
OVTT	10 min	7/8/9	7/8/9	5/6/7	5/6/7	2/3/4
Travel cost	10,000 KRW	1/1.25/1.5	0.5/0.75/1	6/7.5/9	4.5/6/7.5	9/12/15
Transfer frequency	Time (s)	0/1/2	0/1/2	0	0/1	0/1/2

Q. Assume that you are in a situation in which you need to choose a mode to visit Incheon International Airport. Please choose your preferred mode of transportation.

Attribute \ Mode		Airport train	Airport bus	Taxi	Private car	UAM
IVTT	10 min	1.5	1.5	0.5	0.5	1.5
OVTT	10 min	7	7	5	5	2
Travel cost	KRW 10,000	10	0.5	6	4.5	9.0
Transfer frequency	Time(s)	0	0	0	0	0
Choice (√)		☐	☐	☐	☐	☐

Fig. 2. Example of experimental scenario.

Table 3
Distributions of respondents.

Attributes		Number of samples (people)	Proportion (%)
Total number of respondents		2,604	100.00
Socioeconomic attributes			
Gender	Male	1,318	50.61
	Female	1,286	49.39
Age	20–30s	1,022	39.25
	40–50s	1,056	40.55
	≥ 60s	526	20.20
Education level	High school	572	21.97
	Bachelor's degree	1,789	68.70
	Over master's degree	243	9.33
Marriage	Single	940	36.10
	Married	1,545	59.33
	Others	119	4.57
Monthly household income (KRW)	< 5 millions	1,376	52.84
	≥ 5 millions	1,228	47.16
Usual mode for daily life	Private car	1,108	42.55
	Public transport	1,113	42.74
	Taxi	27	1.04
	Micromobility	38	1.46
	Walk	263	10.10
	Others	55	2.11
Airport usage behavior			
Time to arrive at airport before flight	< 1 h	117	4.49
	1–2 h	1,112	42.70
	2–3 h	984	37.79
	> 3 h	391	15.02
Purpose of using airport	Travels	1,802	69.20
	Business trips	288	11.06
	Others	514	19.74
Yearly averaged number of taking international flights	≤ 1 time	1,625	62.40
	> 1 time	979	37.60
Experience of business or first-class seats	Only business class	759	29.15
	Both business and first class	286	10.98
	No experience	1,559	59.87
Most-utilized airline type	Full-service airlines	1,770	67.97
	Low-cost airlines	675	25.92
	Foreign airlines	159	6.11

analysis. The estimated coefficients were tabulated and are presented in Tables 5, 6, and 7. The estimated coefficients (β) are log odds; therefore, the form of e^{β} indicates the odds ratio of choices.

Table 4
Goodness of fit measures of *MMNL* modeling.

Measure	Value
Number of observations	15,624
Number of iterations	492
Log-likelihood of *MMNL* (df)	−19,075 (104)
Log-likelihood of MNL (df)	−19,135 (100)
Log-likelihood ratio test	Chi-squared = 119.040, p-value = 0.000

Notes: df denotes degrees of freedom.

3.2.1. *Experimental attributes of travel time, travel cost, and transfer frequency*

The estimated coefficients of all experimental attributes were specified as random parameters that assume them to follow a normal distribution. The result shows that they are negative, with statistical significance (see Table 5). This means that people are less likely to take a transportation mode when travel time, travel cost, and transfer frequency increase, regardless of the type of mode. The estimated coefficients for travel times indicate that people are about 1.2 times more sensitive to OVTT than to IVTT, which is consistent with the finding in the study of Salomon and Ben-Akiva (1983). Travel cost and transfer frequency also have significant effects on mode choice: as travel cost increases by 10,000 KRW or when transfer frequency increases by one, the probability of mode choice decreases by 38%.

3.2.2. *Socioeconomic attributes*

Gender differences cannot be verified for UAM choices for airport access, but, compared to males, females tend to prefer cars (taxis or private cars) by about 45% over the airport train (see Table 6). Some previous studies have confirmed this tendency (Gardner and Abraham, 2007; Maat and Timmermans, 2009; Rosenbloom and Burns, 1994). Females generally prefer private cars over other modes of transportation because of safety and comfort.

As for the age groups, the result shows that younger people are more likely to choose UAM for airport access than people aged 60 and over. People in their 20s and 30s choose UAM about twice as often as people in their 60s and older. This may be because the young-age group generally has a greater willingness to try new mobility (Ye et al., 2020). The interesting result is different preferences for transportation modes between the younger and middle-aged groups. In the 20s and 30s age groups, the probability of taking cars over airport trains is higher than the probability of taking UAM. However, the 40s and 50s groups have a higher probability of taking UAM over airport trains than the probability of taking cars. This may be because the middle-aged group generally has better economic status (Perrotta, 2017).

The groups with better education levels have a lower preference for UAM. This result is comparable to the findings in the previous study (Al

Table 5
Modeling result: alternative specific constants and experimental attributes.

Variables	Airport bus			Taxi			Private car			UAM		
	Coef.	S.E.		Coef.	S.E.		Coef.	S.E.		Coef.	S.E.	
Alternative specific constant	0.4240	0.1334	***	−1.0052	0.307	**	0.1628	0.2423		−0.9599	0.4454	*

Experimental attributes (generic random parameter)

Variables	Mean			Standard deviation		
	Coef.	S.E.		Coef.	S.E.	
IVTT	−0.0145	0.0030	***	0.0482	0.0107	***
OVTT	−0.0179	0.0016	***	0.0245	0.0049	***
Travel cost	−0.4814	0.0495	***	0.3299	0.0357	***
Transfer frequency	−0.4825	0.0238	***	0.3513	0.0974	***

Notes: statistical significance is denoted as follows:***p < 0.001, **p < 0.01, *p < 0.05, .p < 0.1.

Table 6
Modeling results: socioeconomic attributes.

Variables	Airport bus			Taxi			Private car			UAM		
	Coef.	S.E.		Coef.	S.E.		Coef.	S.E.		Coef.	S.E.	
Gender												
Male	Reference											
Female	0.0022	0.0451		0.3705	0.0945	***	0.3572	0.0716	***	0.1171	0.1393	
Age												
20–30s	0.1229	0.0724		1.0858	0.1608	**	0.9343	0.1201	***	0.7195	0.2292	**
40–50s	0.0930	0.0592		0.6079	0.1334	***	0.5133	0.0957	***	0.6889	0.1854	***
≥60s	Reference											
Education level												
High school	Reference											
Bachelor's degree	−0.0672	0.0553		−0.1955	0.1136	.	−0.2513	0.0855	**	−0.6907	0.1671	***
Master's degree or higher	−0.2625	0.0881	**	−0.5867	0.1861	**	−0.4371	0.1360	**	−0.9664	0.2696	***
Marriage												
Single	Reference											
Married	−0.0946	0.0581		0.0873	0.1191		0.4542	0.0918	***	0.7780	0.1880	***
Others	0.0291	0.1147		−0.3463	0.2727		0.1395	0.1877		1.2620	0.3339	***
Monthly household income (KRW)												
<5 millions	Reference											
≥5 millions	0.1485	0.0463	**	0.4098	0.0955	***	0.3261	0.0722	***	0.5011	0.1435	***
Usual mode for daily life												
Private car	Reference											
Public transport	−0.1570	0.0489	**	−0.9989	0.1184	***	−1.4307	0.0956	***	−1.2432	0.1722	***
Taxi	0.4867	0.2723	.	1.3457	0.3845	***	−0.0296	0.3648		1.2901	0.5603	*
Micromobility	0.1758	0.2002		0.5166	0.3411		−0.6394	0.3078	*	1.1772	0.4598	*
Walk	−0.1506	0.0772	.	−0.4492	0.1609	**	−0.9119	0.1240	***	−0.8264	0.2528	**
Others	0.1916	0.1497		−1.5137	0.4078	***	−1.2772	0.2642	***	−2.2763	0.6735	***

Notes: statistical significance notation (***p < 0.001, **p < 0.01, *p < 0.05, .p < 0.1).

Haddad et al., 2020), which means greater uncertainty and less adoption of UAM in the higher-educated group. The estimated coefficients for 'income' variable show a higher preference for UAM in higher-income groups (Al Haddad et al., 2020; Fu et al., 2019; Goyal et al., 2018; Park, 2021). This may be associated with the more expensive travel cost of UAM than those of other modes. In this study, compared to other groups, the probability of taking UAM instead of the airport train is higher, as much as 65% for the group with an income of over 5 million KRW per household per month. This probability of choosing UAM is much higher than that of public transit and even cars. This implies that individual economic status significantly affects the acceptability of UAM.

Additionally, people who frequently use taxis for their daily lives are more likely to choose UAM than people who usually use private cars. This is understandable since UAM will play a role similar to taxis in the sky (Naser et al., 2021). Furthermore, people who generally use micromobility for daily life are more likely to choose UAM, which can correspond to the finding that a positive relationship exists between the adoption of new mobility systems and people's curiosity about new technologies (Yuerong and Maria, 2022). Meanwhile, people who primarily take public transportation tend to prefer UAM or taxis less. This result may be because people who do not spend much money on their trips tend to perceive the costs of UAM or taxis as significantly higher.

3.2.3. *Airport usage behavior*

The estimated coefficients of 'time to arrive at the airport before flight' variable show that people who tend to arrive early at the airport have a higher preference for UAM (see Table 7). People who plan to arrive at the airport less than 1 h before their flights are 1.8 times more likely to prefer UAM than people who plan to arrive 1–2 h before. This implies that UAM preferences can vary depending on people's value of time. Those who plan to arrive at the airport closer to their flight may place a higher value on time (Ben-Akiva and Bierlaire, 2003). They may want to reduce their travel time to the airport, even if they need to pay a higher price for travel. Moreover, they tend to prefer driving as well as taking UAM, rather than taking public transit. This result implies that people's perception of the value of time beyond cost savings plays a significant role in their travel-related choices (Ben-Akiva and Bierlaire, 2003; Train, 2009). The other three variables in the category of airport usage behavior show that the groups with better economic status are more likely to take UAM, which is in the same line with the result of the income variable. People who take international flights more frequently

Table 7
Modeling results: airport usage behavior.

Variables	Airport bus			Taxi			Private car			UAM		
	Coef.	S.E.		Coef.	S.E.		Coef.	S.E.		Coef.	S.E.	
Time to arrive at airport before flight												
<1 h	−0.0475	0.1116		0.1577	0.2097		0.1621	0.1624		0.6028	0.2906	*
1–2 h	Reference											
2–3 h	0.0774	0.0492		−0.5657	0.1093	***	−0.5043	0.0820	***	−0.9785	0.1666	***
>3 h	0.0604	0.0661		−0.2514	0.1357	.	−0.1057	0.1004		−0.6503	0.2096	**
Purpose of using airport												
Travels	Reference											
Business trips	0.0958	0.0749		0.0487	0.1502		−0.1042	0.1167		−0.1673	0.2198	
Others	0.0221	0.0579		0.5475	0.1150	***	0.5125	0.0885	***	0.2883	0.1716	.
Yearly averaged number of taking international flights												
≤1 time	Reference											
>1 time	−0.1083	0.0479	*	0.2099	0.0969	*	−0.0975	0.0735		0.4258	0.1453	**
Experience of business or first-class seats												
Only business class	0.1575	0.0517	**	0.2910	0.1057	**	0.1051	0.0802		0.4854	0.1591	**
Both business and first class	0.1471	0.0794	.	0.8056	0.1504	***	0.6929	0.1168	***	1.2089	0.2156	***
No experience	Reference											
Most-utilized airline type												
Full-service airlines	0.0263	0.0907		0.3581	0.1934	.	0.3356	0.1476	*	0.0219	0.2866	
Low-cost airlines	0.1535	0.0966		−0.3026	0.2100		−0.0538	0.1577		−0.1583	0.3103	
Foreign airlines	Reference											

Notes: statistical significance notation (***$p < 0.001$, **$p < 0.01$, *$p < 0.05$, .$p < 0.1$).

or have experience with business-class or first-class seats also prefer UAM for airport access. It is an unquestionable fact that higher-income groups have more experience with premium services related to air travel. People with experience taking business-class and first-class seats have much higher probabilities of choosing UAM, 305% and 560%, respectively, than people with no such experience. Those who use premium services are also more likely to select a taxi or private car.

4. Discussion and policy implication

The outcome of the *MMNL* model demonstrated that the acceptability of UAM (as an airport access mode) varies depending on socioeconomic status, airport usage behavior, travel time, and travel cost. People who are younger and have higher economic status will be more likely than others to take UAM for airport access. The notable result is that people in their 40s and 50s and those who have higher incomes are more likely to take UAM for airport access than they are to use taxis or private cars. This implies that middle-aged adults who usually have good economic status can be potential passengers for initial UAM service. Another notable result is that people who usually take taxis in their daily lives have similar preference levels for taxis and UAM for airport access. This indicates that UAM service can replace taxi service or become a kind of taxi service in the sky.

The estimated coefficients for the variables related to airport usage behavior provide novel findings that are absent from previous studies. People who want to arrive at the airport with sufficient time to prepare for boarding are less likely to prefer UAM service. This implies that understanding different individual levels of value of time can be a dominant factor in designing UAM services. Meanwhile, a variety of choice probabilities of UAM were observed in the variables closely related to economic status. People who frequently travel internationally and those who have experience with business-class or first-class service will be more likely to take UAM for airport access. This is comparable with the different probabilities according to income level because people with better economic status generally have more experience with premium services related to air travel.

The initial UAM service, due to public and private investment costs and low service supply, has a high possibility of being launched at fares higher than those of other ground transportation modes. The results of this study also show that potential users of UAM service will be higher-income groups. Airport corporations or airlines might gain revenue by launching a UAM-based premium service for airport access, targeting customers who put a high value on their time. However, if UAM service remains a premium service even after its initial launch, serious equity issues in the transportation sector would arise. Lower-income groups may still struggle with road congestion and spend a considerable amount of times on roads. This could connect to a widening rich-poor gap or health issues for lower-income groups because these groups have less time for working or caring for themselves. Therefore, policymakers should make feasible strategies to start the UAM service as a practical transportation mode for the public, even though the introduction of UAM as a premium service in the initial market may be unavoidable.

5. Conclusion

This study aimed to investigate mode choice for airport access when UAM was introduced as an airport shuttle service and its different choices by socioeconomic status and airport usage behavior. The SP survey was designed to target Incheon International Airport, located in South Korea, and was conducted online with 2604 respondents living in the country. We developed an *MMNL* model to examine who prefers UAM for airport access trips. The modeling result shows different choices of UAM depending on people's socioeconomic status and airport usage behaviors. People who are younger, have higher incomes, usually use taxis in their daily lives, want to arrive at airports closer to boarding time, and have experience with premium services of airlines are willing to take UAM more for airport access. The findings imply that UAM can replace ground taxis or become another kind of taxi service operating in the sky but may have barriers to widespread use because of its expensive fare.

Academically, this study contributes to the literature as the first study to consider airport usage behavior by extending the findings in previous studies of airport-oriented UAM service. Given that UAM service is in the initial stages of becoming a part of the transportation service market globally, the results can be used to estimate the potential demand of early UAM service for airport access and formulate operational designs. Furthermore, because the findings suggest recommendations from an equity perspective that policymakers should be aware of, the findings can assist in the creation of future policies to integrate UAM into the current public transportation system.

However, this study has a few limitations. First, this study cannot consider people's unobserved perceptions of UAM (e.g., its safety or reliability). Such perceptions affect people's acceptability of UAM as one of the public transportation modes. Thus, future studies will need to consider psychological factors related to the mechanism related to social acceptance of new UAM services. Second, this study examined people's acceptability of UAM focusing on the initial stage of UAM introduction. There is a need to explore how people's behaviors toward UAM usage vary according to the development of related technology (e.g., operating distance or safety) to prepare for future UAM policies. The combined findings can provide comprehensive insights into the acceptability of UAM and help formulate detailed strategies for each stage of the UAM introduction.

CRediT authorship contribution statement

Hyeokjun Jang: Writing – original draft, Formal analysis, Data curation, Conceptualization. **Yeongmin Kwon:** Writing – original draft, Investigation, Formal analysis, Conceptualization. **Kitae Jang:** Funding acquisition, Data curation, Conceptualization. **Suji Kim:** Writing – review & editing, Supervision, Formal analysis, Data curation, Conceptualization.

Acknowledgements

This work was supported by the Incheon International Airport Corporation and by Korea Institute for Advancement of Technology (KIAT) grant funded by the Korea Government (MOTIE) (Grant number P0020647).

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