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Exploring economic feasibility for airport shuttle service of urban air mobility (UAM)

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ABSTRACT

UAM is a new concept of mobility that expands the two-dimensional transportation system to three dimensions using a personal air vehicle (PAV). This study explores the economic feasibility of the UAM airport shuttle service from two perspectives. First, this study estimates the fare of UAM services to attract customers. The UAM service should maintain a competitive price to convert existing transportation users into UAM users. This study used Incheon Airport (ICN) ground transportation data to estimate a competitive fare based on the multinomial logit model. The pricing range at which UAM services can obtain users from Seoul Station to ICN is estimated to be 96 to 108 USD, assuming the new service reduces traveling time by 30–40 min compared to taxi service. The comparison with professional institutions indicates that the 96–108 USD price range is feasible. However, according to a simulation based on the discounted cash flow (DCF) method, other approaches to increase economic feasibility are required. Second, this study reviewed operational policies to improve the economic feasibility of UAM shuttle services from two perspectives. The first is a service perspective that introduces new services or enhances the current service level. The internalization of CNS (communications, navigation, and surveillance) and UTM (unmanned traffic management) services can be a new business area, including premium routing. The second is introducing a dynamic pricing policy. Segmented pricing, time-based pricing, and changing market conditions strategies can practically strengthen the economic feasibility. Operating an airport Vertiport providing a dedicated path for UAM passengers can allow UAM operators to charge more on a premium passenger segment by shortening airport procedure time. Because it can avoid the uncertainty of road congestion, there is plenty of incentive to set higher fares during peak times with severe congestion. In addition, by creating a market environment in which multiple operators participate, the operators can share the burden of infrastructure construction and operation, which account for more than 80% of the total operating costs, increasing the economic feasibility of services.

1. Introduction

According to the Inrix Score Board, as of 2019, Americans wasted an average of 99 h a year on the road in traffic jams. The related costs are estimated at 88 billion USD annually. As a result, social interest in introducing a new transportation concept that can shorten travel time increases. Significantly, there has been a growing need to discuss a new way of transport that expands the two-dimensional

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system into three dimensions.

Since the mid-1990s, research on personal air vehicles (PAVs) has been conducted by NASA in the United States. Based on the results of previous studies, the concept of urban air mobility (UAM) emerged in the mid-2010s. UAM is an air mobility concept that connects several points in the city, including airports, railways, and rooftops of buildings using PAVs. UAM requires smaller investments than other transportation modes because it can utilize the existing infrastructure. In particular, as Uber presented its vision for the UAM market through the Elevate project in October 2016 (Holden & Goel, 2016), many companies, ranging from traditional aircraft manufacturers to automobile manufacturers and start-ups, jumped into this market (Volocopter, 2019).

It is expected that the UAM operation will start from 2025 at the earliest (Porsche Consulting 2018; Roland Berger, 2018). The future of the UAM market is also bright because it can create various new business opportunities such as air taxi service (Goyal et al., 2018). Among them, the airport shuttle service between the airport and downtown is expected to be the fastest commercialized sector (Hasan, 2019; Roland Berger 2020). The most advantageous feature of the UAM is that it is a faster and more convenient transport mode compared to other transportation options. For example, business travelers account for almost 20% of total demand[1] in the aviation industry, and most users have expressed the desire to reduce airport access time. In this regard, several institutes, including NASA, propose an airport shuttle service as the most promising early market for UAM technology.

However, research on the UAM market is in its early stages. In addition, there are various challenges in introducing the UAM service. For example, how can we control the air traffic of UAM? How can we decide on UAM routing? How can we handle passenger's bags when they take UAM? Therefore, academia and industry must proceed with various forms of cooperation to meet these challenges. From this point of view, this study focuses on the economic feasibility of airport shuttle service as a promising early market. For the UAM shuttle service to be successful, it is necessary to change the choice of passengers using other means of transportation as an airport access mode. Several factors can affect passengers' choice of transportation, but many previous studies have suggested the cost of fare as a prominent factor in choosing transportation mode for various travel purposes (Toro-Gonzalez et al., 2020; Liu et al., 2019; Dunkerley et al., 2018; Yang & Zhang, 2012). Thus, this study focuses on identifying the optimal fare that can shift passenger choice from conventional access mode to the UAM service. This study, therefore, aims to answer the following research questions: i). What is the maximum cost of fare per passenger that can change passengers' choice of airport access transportation? ii). What are the operational measures to achieve more economics for the UAM shuttle service?

This study collected Incheon International Airport (ICN) data for an empirical investigation. ICN currently has five types of airport access transportation modes: buses, airport railroads, taxis, private cars, and long-distance limousine buses. This study calculated the share of each transportation mode from ICN's big data platform. Factors such as time and fare using the transportation mode determine the percentage of each transportation method. Thus, how much time the UAM service saves, what quality of services it provides, and how much it charges can affect the share of each transportation mode. Through this, this study aims to answer the above three questions. To the best of our knowledge, this is the first study to use actual airport access transportation data to explore the economic feasibility of the UAM shuttle service.

The rest of the paper is structured as follows. Section 2 reviews the UAM market and technology development status. Next, we discuss the study setting, data, and empirical methods. Section 4 reports the model estimation results and discusses the cost of fare for the UAM shuttle service to obtain initial demand. Managerial implications and suggestions for achieving additional economics are discussed in Section 5. The last section (Section 6) summarizes this study.

2. UAM market forecast and technological progress

2.1. Market forecast

Forecasts for the UAM market size vary widely. Cohen et al. (2021) predict that even if the range is limited to eVTOLs, the US market size will reach 74 billion USD by 2035. According to the Porsche Consulting Group (2018), geographically, Asia Pacific will account for 45% of the market share, emerging as the largest market. Jonas (2018) also presents a similar market forecast result. It predicted the UAM market to 2040 by setting three scenarios. As shown in Fig. 1 (b), the size of the global UAM market in 2040 will reach 1.5 trillion USD under the basic scenario. This is equivalent to about 1% of global GDP.

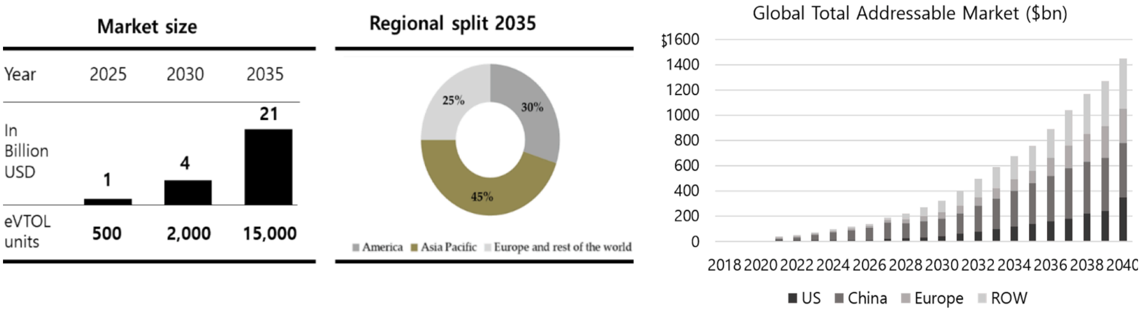
Roland Berger (2020) expects more than 160,000 drones to be be in operation in 2050[2]. These will be split almost equally between the three use cases of city taxis (36%), airport shuttles (35%), and inter-city services (29%). Roland Berger's forecast is more conservative, predicting the UAM market size to be around 90 billion USD by 2050. It also expects the most revenue from airport shuttle and inter-city services, as shown in Fig. 2. Both services will provide 90% of revenues, with city taxis making up the rest. Inter-city services will have fewer overall flights but cover longer distances, generating more revenue per flight and higher utilization. Medium-distance airport shuttle services will be the most appealing business model, enabling operators to charge a premium compared to other services.

2.2. Technologicat progress

Since the Uber Elevate project revealed the required specifications for the UAM aircraft in 2016, many rival companies have

[1] https://www.condorferries.co.uk/business-travel-statistics (retrieved from 2021.9.24).

[2] Global commercial helicopter sales were 657 units in 2019, with a ten-year production volume of around 7,500 units (Source: TEAL group).



(a) Porsche Consulting Group (2018) (b) Morgan Stanley (2018)

Fig. 1. UAM market size forecast.

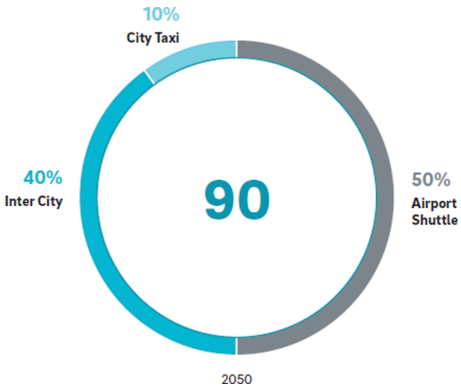


Fig. 2. Revenues from UAM operations (billion USD, Roland Berger, 2020).

entered the UAM field (Hwang, 2018). Since the Uber Elevate project revealed the required specifications for the UAM aircraft in 2016, many rival companies have entered the UAM field (Hwang, 2018). The first and most commonly proposed vehicle configuration is an electric vertical take-off and landing (eVTOL). It is also expected to reduce noise problems and air pollution from existing fossil fuels (Vertiflite, 2017; Fu et al., 2019). Manufacturers of UAM vehicles promise reduced noise and carbon emission footprint by adopting electric-powered vertical take-off and landing (eVTOL) technology (Rothfeld et al., 2021). Recently, the industry has been advancing to develop electric conventional take-off and landing (eCTOL), electric short take-off and landing (eSTOL), and even electric sea gliders (ground effect aircraft) for advanced air mobility (AAM) applications[3].

In October 2019, Volocopter succeeded in flying a passenger boarding from Singapore Seleta Airport to downtown using an eVTOL vehicle for the first time[4]. Recently, there has been growing interest in UAM infrastructure construction, including network design of stations. Lim and Hwang (2019) found that location is more important than the number of stations by employing a k-means clustering algorithm and traffic data in the Seoul metropolitan area. Syed et al. (2017) suggested that higher efficiency can be achieved using census data such as high population and income when designing station networks. The environmental value and efficient network design using air traffic routes can significantly contribute to achieving the marketability of the UAM service. According to Daskilewicz et al. (2018), based on the study using UAM commuter networks in the San Francisco Bay and Los Angeles metro area, the appropriate trip distance at which the UAM service can be efficiently provided is evaluated to be around 30 miles (approximately 50 km).

2.3. Airport shuttle service

Currently, the fastest-growing sector is the airport shuttle service. Since airport accessibility is a crucial factor in airport choice (Reichmuth et al., 2010), UAM is an emerging transport mode for fast travel between the airport and downtown (Porsche Consulting, 2018). Also, because airports are generally located far from cities, it is easy to acquire initial demand (Shaheen et al., 2020).

Meanwhile, some airports seek to introduce the UAM airport shuttle service for special events such as an Olympic game. For example, Paris Charles de Gaulle Airport (CDG) contracted a strategic partnership with Airbus to introduce the shuttle service during the 2024 Paris Olympics, as shown in Table 1. In addition, as shown in Fig. 3, Europe is one of the most active regions in developing the

[3] https://evtol.news/news/category/ectol-estol (retrieved from 2022.1.26).

[4] https://press.volocopter.com/index.php/volocopter-air-taxi-flies-over-singapore-s-marina-bay (retrieved from 2021.6.7).

UAM service along with North America and the Asia-pacific region.

Korea is also promoting UAM service. One of the biggest reasons is that Hyundai, the largest automaker in Korea, where the automobile industry accounts for 13% of GDP, has started manufacturing the UAM aircraft[5]. The Seoul metropolitan area seems ideal for introducing the UAM airport shuttle service. It has a population of 20 million and has two major airports. Incheon International Airport (ICN) is a hub airport that handles 85% of Korean international passengers, and Gimpo Airport (GMP) is in charge of transporting about 70% of domestic passengers. Local passengers who do not live in the Seoul metropolitan area mainly use the high-speed railway (KTX) to Seoul and Gwangmyeong stations and then to ICN via public transportation. As shown in Fig. 4, the straight-line distances from GMP to ICN and downtown Seoul to GMP or ICN are all located within 50 km, which is suitable for UAM service provision[6]. Gwangmyeong Station, which can be used by KTX (Korea express railway) passengers, is also located approximately 40 km from ICN. In addition, it can be easier to secure stability by using the Han River and the Ara Waterway as the movement route of the aircraft.

3. Research design, data, and methodology

3.1. Research design

This study explored the economic feasibility of the UAM airport shuttle service from two perspectives. First, this study estimates the cost of fare of UAM services to attract customers. One of the most prominent features of this study in calculating the cost of fare is that it collected actual ground access transportation data from Incheon International Airport (ICN) for empirical investigation. The most critical driver for passengers to use the UAM airport shuttle service is time-saving compared to current means of transportation (Fu et al., 2019). Thus, among the access transportation methods at ICN, the UAM shuttle service can substitute for taxi service (Straubinger et al., 2021) because taxi service charges much more than other public transportation options[7]. Especially considering that the average time required to access ICN by taxi exceeds over 45 min, it is reasonable to assume that UAM is an alternative transport mode for taxis (Goyal et al., 2021). Likewise, if the UAM service can reduce traveling time compared with taxis, passengers may be willing to pay higher fares for the UAM shuttle service.

This study employs the multinomial logit model (MNL) to determine the optimal fare. The MNL model enables us to identify how the passengers react to the traveling time and cost when choosing a means of airport access. Therefore, it can derive the pricing range of UAM services for obtaining customer demand, given that they provide faster traveling time than other means of transportation.

The second is the review of an operational policy to improve economic feasibility. The pricing range derived from the MNL model is the maximum fare to transfer a taxi user to a UAM passenger, leading to the minimum level of economic feasibility. Because the converting effect of taxi users to UAM passengers decreases when charging higher fares, this results in lower economic feasibility. Thus, to improve the economic feasibility of UAM services, it is necessary to improve the value provided by UAM services. For example, besides travel time reduction, introducing a premium service perspective by changing operational procedures could lead to such a value increase. The value increase can allow operators to raise a cost of fare suggested by the MNL model, leading to higher economic feasibility.

3.2. Data analysis

This study utilized the ground access transportation data for arrivals at ICN Terminal 1 from April 29 to June 1, 2019. The data set includes the share of transportation modes used by passengers arriving at ICN on a daily basis. Therefore, we can determine what percentage of passengers took a taxi or boarded a bus on a specific date. The data was extracted from the operation database of ICN's big data platform. Since March 2020, when the Covid-19 pandemic began in earnest, airport passengers plummeted by more than 95%. Thus, it is reasonable to utilize the data before the onset of the Covid-19 pandemic. There are five types of ground access transportation modes in our data set; long-distance bus (for long-distance passengers), short-distance bus (for short-distance passengers), airport railroad, private car, and taxi. Because the UAM shuttle service targets passengers to move between the airport and downtown, this study excluded long-distance bus data from empirical analysis. Table 2 shows the summary statistics of the daily share of each transportation mode[8].

The MNL model is an econometric model that can examine how customers' choices change according to changes in product characteristics. If the market share, shown in Table 2, results from the customer's choice, we need statistics of influencing factors to analyze the consumer's choice. Travel time, service level, and the cost of fare provided by each mode of transportation are such factors. Table 3 displays travel time and fare level calculated based on each transportation mode's route between ICN and Seoul Station. As of the end of 2019, there were 82 short-distance bus routes in the Seoul metropolitan area[9]. The airport railroad departs from Seoul Station and arrives at ICN Terminal 1 after 12 stations. The travel distance is about 50 km by private car or taxi. The travel time and

[5] https://www.hyundai.com/au/en/why-hyundai/concept-cars/urban-air-mobility (retrieved from 2021.9.26).

[6] There are two major airports, Gimpo (GMP) and Incheon (ICN), in the Seoul metropolitan area of Korea.

[7] According to Table 3, taxi fares are about eight times that of buses and fourteen times that of railroads.

[8] Excluding the share rate of long-distance buses, we recalculated the share rates for each of the four modes: short-distance bus, airport railroad, taxi, and private car.

[9] The route consists of 35 routes in Seoul, 31 routes in Gyeonggi province, and 16 routes in Incheon.

Table 1
European airport case.

Airport	Airport shuttle development status
Paris Charles de Gaulle Airport (CDG)	Promotion of shuttle service between the airport and the city center during the 2024 Paris Olympics - Strategic partnership with ADP-Airbus, scheduled to select a site in 2022
Frankfurt Airport (FRA)	In collaboration with Volocopter, a local manufacturer, a shuttle service connecting the airport and the city center is being promoted (schedule not disclosed)
Düsseldorf International Airport (DUS), Cologne/Bonn Airport (CGN)	Signed a joint promotion agreement with Germany's Lilium to start UAM shuttle service between airports from 2025

Source: Airport website, press release.

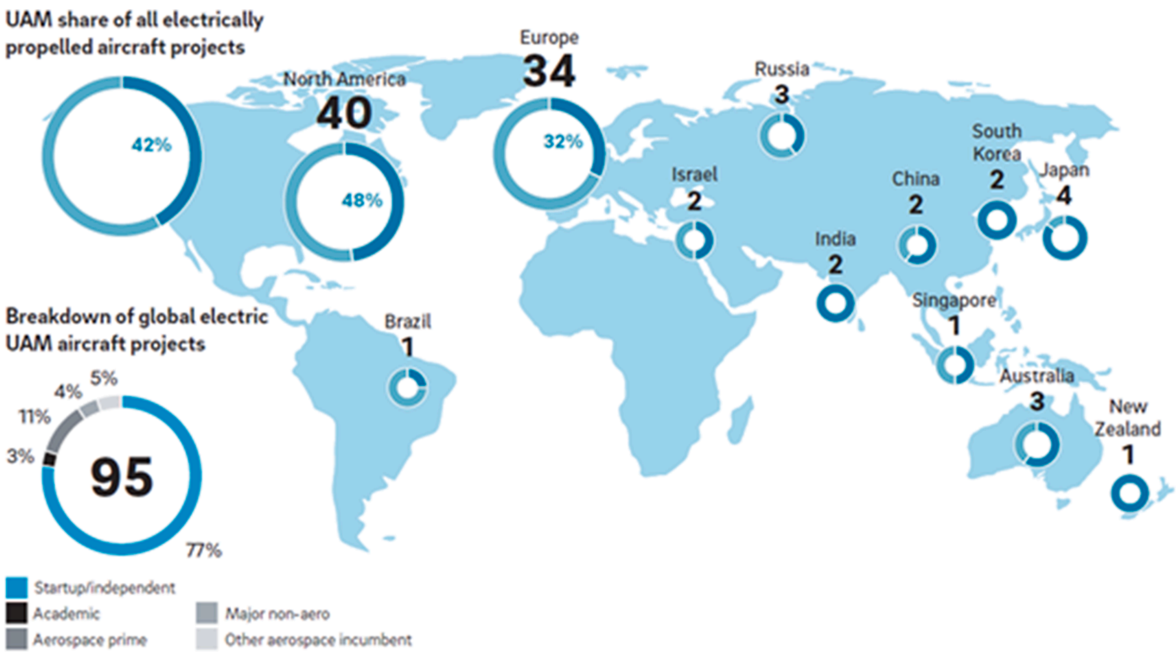


Fig. 3. Distribution of the UAM aircraft projects (Roland Berger, 2020).

cost of each means of transportation vary depending on the departure point of the user. However, since it is not available to find data showing transportation use by passengers by departure point, this study set Seoul Station as the reference point. Seoul Station as the reference point can provide average travel time and cost because it is located in the center of the Seoul metropolitan area. Table 3 shows the travel time and fare for each transportation method used in this study.

Calculating the statistics in Table 3 was the most time-consuming and complex task in this study. This is because the travel time can vary depending on the time and situation. To obtain robust results, this study employed reasonable assumptions. To calculate travel times, we adopted the average value of the time measured by the navigation application from May 25 to May 31, 2021. This is because our data period was May 2019, and during this time, there was no significant change in roads or traffic network conditions. For the airport railroad, we needed to consider that the airport railroad has a significantly smaller number of stations than that of other transportation modes. Thus, when calculating the traveling time of the airport railroad, this study assumes that a one-time transfer from other transportation modes to the airport railroad occurs[10]. For a private car, we considered the time required for parking and moving to the passenger terminal[11].

This study calculated the cost of fare depending on the characteristics of each means of transportation. A one-way bus fare from Seoul Station to ICN was applied to calculate the fare of short-distance buses, and we added the city bus fare to the airport railroad fare. Total costs, including fuel, toll gate, and parking, were considered for passengers using their vehicle[12]. The taxi fare was calculated on average by the navigation application. The amount expressed in Korean Won was converted into USD using the average exchange rate

[10] Approximately 9 min, which is the average transfer time between train stations in the navigation application, was added.
[11] Taking into account about 5 min for parking and 5 min from the transportation center to the terminal, 10 min are added to the required time when using a taxi.
[12] 50% of the average travel period of ICN passengers, 4 nights and 5 days, and a long-term parking fee were applied.

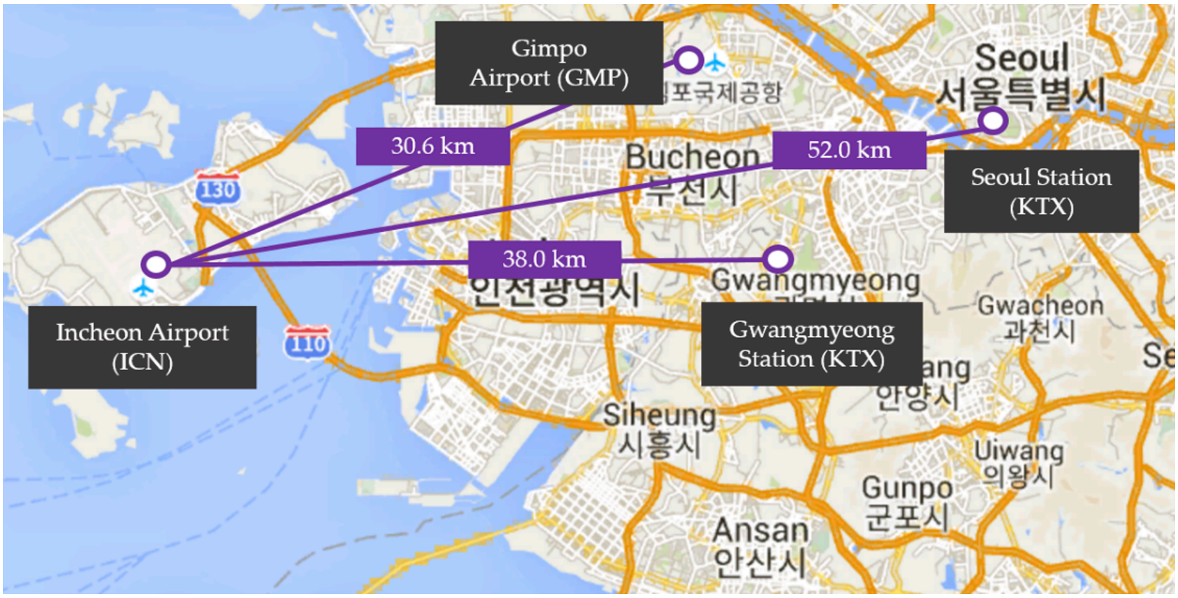


Fig. 4. Distance between airport shuttle service points in Korea.

Table 2
Summary statistics.

Data	Statistics				
	Avg.	Std.	Max	Min.	Obv.
share of short-distance bus	0.359	0.053	0.449	0.210	34
share of airport railroad	0.343	0.080	0.564	0.211	34
share of private car	0.174	0.076	0.354	0.077	34
share of taxi	0.124	0.052	0.198	0.028	34

Source: ICN big data platform.

Table 3
Transport mode statistics.

Data	Statistics	
	The required time (min)	The required cost (USD)
short-distance bus	78.1	7.6
airport railroad	72.0	4.5
private car	64.8	44.4
taxi	54.8	61.7

Source: Opinet (https://www.opinet.co.kr), ICN website (https://www.airport.kr), airport railroad website (https://www.arex.or.kr), navigation application (map.kakao.com).

of 1,183.3 KRW/USD during the data analysis period.

3.3. Model specification

The MNL model started from a discrete choice model for estimating consumer choice drivers when there are several products (McFadden, 1973). The discrete choice model was expanded to discuss consumers' transportation choices and developed into the MNL model through previous studies (Windle and Dresner, 1995; Pels et al., 2003; Berry and Jia, 2010). According to the MNL model, the probability that a user chooses a specific means of transportation k is shown in Eq. (1).

$$Pr(k) = \frac{e^{U_k}}{\sum_{i=1}^{n} e^{U_i}} \tag{1}$$

where *Pr(k)* is the probability that the means of transportation k will be selected, U_k is the utility of the means of transportation k, U_i is the utility of the means of transportation *i*, and *n* is the number of means of transportation.

In order for passenger *j* to choose the means of transportation *k*, the utility when using the means of transportation *k* must be greater than the utility when using the other means of transportation, as shown in Eq. (2). In Eq. (2), *r* represents the route in which passenger *j* intends to use the means of transportation. *i* represents a means of transportation other than *k*. Therefore, U_{rkj} represents the utility that passenger *j* experiences for transportation *k* in route *r*, and U_{rij} represents the utility that passenger *j* realizes when using other transportation modes in route *r*.

$$U_{rkj} > U_{rij}, \forall i \neq k \tag{2}$$

The utility when using transport *k* for route *r* can be defined as a function of the time required ($Time_{rk}$) and the cost ($Cost_{rk}$), as shown in Eq. (3).

$$U_{rk} = \beta_0 + \beta_1 Time_{rk} + \beta_2 Cost_{rk} + \beta_3 D_{rk} + \varepsilon_{rk} \tag{3}$$

where D_{rk} means a dummy variable other than the constant term.

Then the choice probability is,

$$\begin{aligned} \Pr(\cap_{k\neq i} U_{rkj} > U_{rij}) &= \Pr\left(\cap_{k\neq i}\beta_1 Time_{rkj} + \beta_2 Cost_{rkj} + \beta_3 D_{rkj} + \varepsilon_{rkj} > \beta_1 Time_{rij} + \beta_2 Cost_{rij} + \beta_3 D_{rij} + \varepsilon_{rij}\right) = \Pr\left(\cap_{k\neq i}\varepsilon_{rij} - \varepsilon_{rkj}\right. \\ &\left.< (\beta_1 Time_{rkj} + \beta_2 Cost_{rkj} + \beta_3 D_{rkj}) - (\beta_1 Time_{rij} + \beta_2 Cost_{rij} + \beta_3 D_{rij})\right) \end{aligned} \tag{4}$$

By assuming that ε_{rkj} is independently and identically distributed (IID) and follows a Type I Extreme Value distribution, the choice probability takes the form of Eq. (5),

$$\Pr(\cap_{k\neq i} U_{rkj} > U_{rij}) = \frac{e^{U_{rkj}}}{\sum_{i=1}^{n} e^{U_{ri}} j} \tag{5}$$

Because there are many customers, we can approximate the individual choice probability with the market share of transport mode *k*, MS_{rk}.

$$MS_{rk} \cong \frac{e^{U_{rk}}}{\sum_{i=1}^{n} e^{U_{ri}}} = \frac{e^{U_{rk}}}{\overline{V_{ri}}} \tag{6}$$

where $\overline{V_{ri}}$ means the mean average of all the alternative modes of transportation other than *k* in route *r*.

By taking the logarithm of both sides of Eq. (6), a semi-log linear regression model can be derived, as shown in Eq. (7). $\overline{V_{ri}}$ can be controlled by introducing a route-level specific dummy into the model (Berry, 1994).

$$\ln(MS_{rk}) = \beta_0 + \beta_1 Time_{rk} + \beta_2 Cost_{rk} + \beta_3 D_{rk} + \varepsilon_{rk} - \overline{V_{ri}} \tag{7}$$

Based on Eq. (6), this study employs a semi-log linear regression model, as shown in Eq. (8), for estimating the fare needed to convert a passenger's existing choice.

$$\ln(MS_k) = \beta_0 + \beta_1 Time_k + \beta_2 Cost_k + \beta_3 Comfort_k + \beta_4 Day + \beta_5 Date + \varepsilon_k \tag{8}$$

MS_k represents the daily share of transportation *k* between Seoul Station and Incheon Airport. $Time_k$ and $Cost_k$ represent the required travel time and cost of transportation *k* for route *r*, respectively. Unobserved product characteristics also affect the selection of transportation mode (Choi et al., 2019). A typical example of the unobserved characteristics is the level of service, such as comfort and kindness felt by passengers when using transportation modes (Gutiérrez et al., 2019). Therefore, this study employs $Comfort_k$, a dummy variable representing the degree of comfort felt by users, and was included in the empirical model. Based on the previous literature (Nicolaidis, 1975; Xu and Cai, 2009; Brown, 2010), this study assumes that more personal space is advantageous to keep passengers' privacy, resulting in greater comfort. As a result, this study assigns 3 for private vehicles, 2 for taxis, 1 for buses, and 0 for airport railroads. These are not precisely consistent with the order of fares, and it means that the feeling of comfort is not just a function of travel time or fare; thus, the comfort variable can have different weights. When interviewing commuters traveling from Seoul Station to ICN, we found that the degree of comfort a commuter feels is generally consistent with the order given by this study. Since the MS_k shows the daily market share, we also introduce dummy variables (*Day* and *Date*) to control the effects of date and day of the week.

4. Estimation results and the economic feasibility analysis for the UAM shuttle service

4.1. Estimation results

Table 4 shows the estimation results of Eq. (7). It indicates that the more time and cost required to use a means of transportation results in a greater decrease in the share of the means of transport. On the other hand, it also suggests that increased comfort increases the use of the transportation mode. However, what is noteworthy is the relationship between coefficients and not the sign of coefficients. According to Table 4, the market share increases when the travel time of a specific means of transportation decreases, but the market share falls when the fare rises. Therefore, we can estimate the value of time for the reduced travel time by using the compensation variation approach. The value of the reduced travel time indicates room for a fare increase. Passengers can feel more considerable utility because their travel time has decreased even if the fare increases. The fare increase does not cause a change in passenger utility If an operator raises the fare exactly corresponding to the reduced travel time. It means the maximum fare increase in this study.

These relationships allow us to estimate a reasonable cost of fare for UAM services to attract passengers from their existing transportation mode choices. If the UAM shuttle service is launched, it will be the top alternative for taxi service. This is because the UAM service can provide most of the advantages of taxis and charge higher rates than other means of transportation. Therefore, in this study, existing taxi users are set as comparison targets to estimate the cost of fares for UAM airport shuttle services. The UAM airport shuttle service can shorten the travel time. However, the fare is likely to be higher than other modes of transportation. Thus, estimating the cost of fare for the UAM service is related to how much UAM services can reduce the travel time. In other words, if the UAM airport shuttle service reduces travel time compared to taxis under the same fare, the UAM service can attract most existing taxi users. However, if the fare for UAM services is too high compared to taxis, the conversion effect will be reduced. Therefore, using the results of Table 4, it is possible to calculate the range of fares in which the UAM service attracts passengers from taxi services according to the degree of travel time reduction. Table 5 shows the maximum fare increase that can convert taxi users into UAM passengers depending on the degree to which UAM services reduce travel time compared to taxi services. Here, the maximum fare increase means that the UAM service cannot switch even a single taxi passenger if the fare increase exceeds the level shown in Table 5. The shorter the travel time, the greater the maximum fare increase. Therefore, if the UAM service providers want to charge a higher fare, they must provide a shorter travel time.

According to Table 5, if the UAM shuttle service shortens the travel time by 20 min compared to taxis, the maximum fare increase that can attract passengers is 22.905 USD. It indicates that the UAM service can charge only 23 USD more than a taxi fare to convert a taxi user to a UAM passenger. However, the shorter travel time leads to a more considerable fare increase. For example, if the traveling time can be shortened by 50 min, the UAM service providers can charge 57 USD more than the taxi fare. It means that even if the UAM service raises its fare by 57 USD more than a taxi fare, it can succeed in converting taxi users to UAM passengers.

According to Table 3, the average taxi fare from Seoul Station to ICN Terminal 1 is about 62 USD, and it takes about 55 min. Therefore, if the UAM airport shuttle service can shorten the travel time by 30 to 40 min[13], the maximum fare level that can attract passengers is 96 USD to 108 USD by adding 34 USD to 46 USD to the existing taxi fare. The 34 USD to 46 USD represents a premium for the UAM service. There are current estimates from various institutions about the cost of UAM services. Therefore, this section compares the 96–108 USD fare to prior estimates by other institutions. In addition, this study employs scenario simulations based on the initial demand estimation from airport premium passengers to identify the feasibility of UAM service cost.

Table 6 shows the comparison results between the pricing range derived from this study and estimates by Uber Elevate, Booz Allen Hamilton (Goyal et al., 2018), and MOLIT (the Ministry of Land, Infrastructure, and Transportation of Korea). Notably, major assumptions applied to the fare estimation by each institution differ, such as the capacity of the UAM vehicle and the level of technology development. In addition, due to the institution's characteristics, some did not disclose precise calculation details. Therefore, this direct comparison may not have much meaning. However, Table 6 suggests that the 96–108 USD presented in this study is comparable to prior estimates. As UAM services are in a very early stage, it also suggests that if technology matures and demand grows, the economic feasibility may not be a long way off.

4.2. The economic feasibility analysis

This section examines whether the fare range of the UAM shuttle service proposed in this study is economically feasible. The feasibility means that infrastructure invested for UAM shuttle services and the operating cost can be recovered within a certain period at an appropriate rate of return (Goyal et al., 2021). This study applies the discounted cash flow (DCF[14]) method to examine economic feasibility (Carmichael & Balatbat, 2008). The DCF method is the most commonly used technique to estimate the period and return on initial investment costs through operating cash flow.

This study estimates initial demand to calculate operating cash flow and initial investment cost. Because a universal view is that low-income consumers are more sensitive to prices (Jones and Mustiful, 1996), this study assumes that UAM passengers are high-income customers, targeting premium passengers traveling in first and business class (Straubinger et al., 2021). As of 2019, 8.93 million passengers bought business class or above fares at ICN. Assume that 5% of the above passengers, approximately 400,000 are the initial demand for UAM services. 5% is a reasonable assumption because the market share of taxis among airport access transport modes is 12% to 13%, and the income level of passengers who purchase tickets above the business class will be high. We also assume that passenger growth is conservatively 2% every year.

Table 7 shows the components and calculation formulas of revenue, cost, and investment applied in this study. This study referred to previous studies or analysis reports to find the components and formulas (MOLIT, 2021; Hill et al., 2020; Stouffer et al., 2020; FAA, 2021). For example, according to MOLIT (2021), operating costs consist of vehicle operation, vehicle maintenance, Vertiport operation, Vertistop usage, CNS (communications, navigation, and surveillance) service, and UTM (unmanned traffic management)

[13] Considering the UAM specifications, we calculated the travel time between downtown and ICN is about 10 min, and the time required for getting on and off is 10 to 15 min (Kim and Yee, 2021; Rothfeld et al., 2021).

[14] Discounted cash flow (DCF) is a valuation method used to estimate the value of an investment based on its expected future cash flows. DCF analysis attempts to figure out the value of an investment today, based on projections of how much money it will generate in the future, https://www.investopedia.com/terms/d/dcf.asp (retrieved from 2021.9.24).

Table 4
Estimation results.

Variable	Coef.	Std. Err.	t	p-value
Time	−0.0827***	0.0222	−3.73	0.000
Cost	−0.0722***	0.0150	−4.80	0.000
Comfort	0.7102***	0.2030	3.50	0.001

Note: *** represents 1 per cent significance level.

Table 5
Maximum fare increase that can secure passengers compared to taxi services.

Reduced time (min)	20	30	40	50
maximum fare increase (USD)	22.905	34.363	45.817	57.271

Table 6
The comparison for the cost of fare (UAM services).

Institution	MNL model	Uber Elevate (2016)	Booz Allen Hamilton (Goyal et al., 2018)	MOLIT (2021)
Cost of fare (USD)	96–108	36–109	111–171	103–116

Note: 1. MOLIT stands for the Ministry of Land, Infrastructure and Transportation of Korea.
2. The estimation of Uber Elevate represents the fare per seat, and others are unclear.

service.

We can calculate the initial investment and operating cost for the first year, as shown in Table 8. This study conservatively assumed infrastructure construction costs by applying the airport passenger terminal with the highest construction cost among transportation facilities. We presume that operating expenses increased by 2% every year in line with the passenger growth rate.

Meanwhile, this study assumes that the boarding rate steadily maintains at 70%. Under the 70% boarding rate assumption, 25 UAM vehicles are necessary to meet demand under the condition that a UAM vehicle has two seats, operating twice per hour (one way) and 16 h a day. Since boarding rate changes affect the revenue and cost structure, we can perform sensitivity analysis by changing the boarding rate assumptions. If the number of passengers increases by 2% every year, the number of passengers increases by more than 10% on a five-year basis. Thus, we add a realistic assumption that the operator needs to reinvest in facilities and vehicles every five years.

Whether the UAM shuttle service can achieve economic feasibility is closely related to whether the operator can recover their investment within a certain period (e.g., 20 years) when maintaining a competitive pricing policy. Table 9 shows the 20-year DCF cash flow estimates of the above scenario.

Table 10 represents the simulation results for changes in the economic feasibility of UAM services depending on the cost of the fare. According to this simulation, when the fare per seat is 57.35 USD, the IRR (internal rate of return) that recovers the initial investment in 20 years is 0%. If the fare per seat increases to 60 USD, the IRR becomes 2.25%. When the fare per seat reaches 63.85 USD, the IRR is 5.0%[15]. When applying the price range of 96 to 108 USD per operation with two seats proposed in this study, the IRR for 20 years is less than −3.68%.

If the capital investment payback period extended to 30 years, the IRR with the price range would be −1.5%-2.8%, making it possible to realize a profit. However, it seems a lower value than the average market return. The average US stock market return has been historically around 10%[16]. Thus, this suggests that other approaches to enhance the value of services are required besides the travel time reduction for the success of the UAM shuttle service.

It becomes clear through sensitivity analysis using boarding rates. Table 11 shows the sensitivity analysis results depending on the assumption of boarding rate. The faster the boarding rate increases by up to 90%, the higher the UAM service's economy. Therefore, it is necessary to review policies to increase profitability, such as service improvement or pricing policy. This study conducts such a review in Section 5.

5. Suggestion of operational policies to improve economic feasibility

According to Table 10, the additional fare required to achieve the rate of return following the market average level is 18.35 USD per seat. This section reviews operational policies for creating an additional 18.35 USD. Table 4 shows that as the value of the *Comfort*

[15] In the case of large-scale infrastructure construction projects in Korea, it is recommended that the capital investment payback period is within 30 years, and the appropriate return is around 5%, https://pimac.kdi.re.kr/guide/plaw_list.jsp (retrieved from 2021.9.25).
[16] https://www.nerdwallet.com/article/investing/average-stock-market-return (retrieved 2021.10.20).

Table 7
Revenue, cost and initial investment structure (UAM services).

Revenue	- Operating income = Daily frequency × No. of vehicles Seats × per vehicle × Fare per pax
Cost	- Vehicle operation - Vehicle maintenance - Vertiport operation - Vertistop usage - CNS (Communications, Navigation, and Surveillance) service - UTM (Unmanned Traffic Management) service
Investment	- Airport Vertiport construction - Vehicle purchase

Table 8
The initial investment and operating cost for the first year (UAM services).

Estimation	Investment		Maintenance & Operation				
	Infra	Vehicle[1)]	Vehicle operation	Vehicle maintenance	Vertiport/ Vertistop	CNS service	UTM service
Amount (thousand USD)	101,114	7,500	1,501.8	359.5	12,033	6.1	1.6

Note: 1. The UAM vehicle purchase cost is about 300 thousand USD per seat based on the estimated price average of six manufacturers (Kim and Yee, 2021).

Table 9
Estimated cash flow (UAM services).

Period	0	3	5	10	15	17	20
Cost (thousand USD)	−108,614	−14,463	−44,076	−45,642	−47,371	−19,084	−49,280
Revenue (thousand USD)	–	24,087	25,060	27,668	30,548	31,782	33,727
Net Cash Flow (thousand USD)	−108,614	9,624	−19,016	−17,974	−16,823	12,698	−15,553

Note: 1. The applied fare per seat is 57.35 USD.
2. The 5-year reinvestment ratio is calculated using the annual recommended reinvestment ratios for major.
facilities such as water, electricity, machinery, buildings, etc.
(https://www.cca-acc.com/wp-content/uploads/2016/08/2016CIRC.pdf, Retrieved from 2021.9.25).

Table 10
Scenario simulation (DCF method, for 20 years).

Fare per seat (USD)	~54.00	57.35	60.00	63.85	72.35
IRR (%)	Less than −3.68	0.00	2.25	5.00	10.00

increases, the market share of the transportation means also increases. It implies, if the UAM service can provide additional value to the customer, it can increase passenger's acceptance for raising fares. This study approaches operational policies to improve the economic feasibility of UAM shuttle services from two perspectives. The first is a service perspective that introduces new services or enhances the current service level. The second is the perspective of price policy through dynamic pricing policy.

5.1. Service perspecitive

The internalization of CNS (communications, navigation, and surveillance) service and UTM (unmanned traffic management) service can be a business area that can enhance the economic feasibility (Cohen et al., 2021). If an uncrewed aerial vehicle is an unauthorized one, an anti-drone system should be used to monitor, track, and evaluate its risk. However, in the case of licensed uncrewed aerial vehicles, the CNS and UTM system can control hazards to aviation safety. In other words, CNS and UTM services are also essential for securing safety. According to Fig. 5, air traffic control zones are designated around two Seoul Metropolitan airports in Korea. The empty area between the air traffic control zones can be a target area of these services. It is required to designate and monitor the route of the aerial vehicles in the target area by using the two services.

Time-saving is the biggest motivation for introducing the UAM airport shuttle service (Thipphavong et al., 2018). Thus, it is a significant advantage to provide premium routing services, ensuring faster services. Due to the complexity of air traffic areas, big data accumulated through CNS and UTM service operation becomes an asset for premium routing design. UAM operators can collect surcharges from passengers using premium routes or increase operational efficiency through using premium routing. For example, customers with high time value are willing to bear a 10%-20% rate increase for premium routing use. Therefore, the UTM service can

Table 11
Sensitivity analysis on IRR (DCF method, for 20 years).

Fare per seat (USD)	54.57	57.35	60.00
The boarding rate increases from 60% in the first year to 90% by 2 %p every year.	0.00%	2.02%	3.62%
The boarding rate increases from 60% in the first year to 90% by 3 %p every year.	5.15%	6.61%	7.97%

increase the economic feasibility of the UAM shuttle service.

5.2. Price policy perspecitive

Dynamic pricing is a pricing strategy that applies variable prices instead of fixed prices, taking both external and internal influences to control the price of products (Black, 1999). Because dynamic pricing is the concept of selling the same product at different prices based on the changing market demand, it is advantageous in supplier surplus increase and revenue growth (Berman, 2005). Dynamic pricing strategy is widely applied to various industries, including the airline industry, e-commerce businesses, public transportation, retail, and entertainment, and has the following five types; segmented pricing, time-based pricing, changing market conditions, peak pricing, and penetration pricing (Victor et al., 2018; Bertulli, 2019). Among them, the strategies for strengthening the economic feasibility of the UAM airport shuttle service are segmented pricing, time-based pricing, and changing market conditions.

5.2.1. Segmented pricing

Segmented pricing offers different prices to different consumer segments (e.g., high-value customers charged high prices). In this regard, providing premium service of shortening airport procedures, including the airport Custom-Immigration-Quarantine (CIQ) process, provides room for a fare increase for premium passengers of the UAM shuttle. Holden & Goel (2016) presented the concept of enhanced infrastructure divided into Vertiport and Vertistop. Because Vertiport has support facilities such as fuel, hangars, and attendants, it generally requires a larger area than Vertistop, which utilizes the rooftop space of buildings. Since the airport is a critical origin and destination for the UAM shuttle service, it can need more equipped facilities to accommodate many passengers. In particular, it is necessary to build a facility in conjunction with the airport's passenger terminal, effectively linking to the functions of a passenger terminal, such as immigration, security checks, and baggage drop. In addition, building a Vertiport adjacent to the airport can be beneficial from the efficiency perspective because the airport has the infrastructure necessary for the maintenance and repair of air vehicles and is located on the route.

Fig. 6 shows a proposal for the UAM shuttle operation concept. According to this, UAM users take a dedicated vehicle through a passenger boarding bridge (PBB) and proceed to the airport Vertiport. At this time, users go through immigration screening on the dedicated CIQ channel of the airport Vertiport, reducing CIQ time compared to ordinary passengers using the conventional passenger terminal. After completing the CIQ procedure, the UAM shuttle service brings passengers to the downtown Vertistop adjacent to the residence or accommodation. Conversely, a passenger can move from a nearby Vertistop to the airport Vertiport using the shuttle service when leaving the country. Like the arrival case, passengers can save airport check-in time through quick and convenient security checks and departure screening on the UAM service's dedicated CIQ channel. In addition, after the CIQ procedure, passengers move to the duty-free commercial area more conveniently through the entrance located in the airside area. Time-saving through these improved processes enables the UAM service operators to charge more on premium passengers, whose time value is higher[17].

Close partnerships between UAM service operators, airport operators, and airlines are essential for introducing such premium services. The airport operators have enough incentives to introduce this premium service. The larger airports with more premium passengers usually have more severe congestion problems caused by ground access transportation, and more disputes arise due to parking problems. Launching the operation of dedicated CIQ facilities for UAM passengers can effectively distribute peak demand. Airlines generate significant profits from passengers who purchase premium flight tickets for the airline side[18]. Therefore, they constantly consider improving the quality of service for premium passengers (Reichmuth et al., 2010; Kluge et al., 2019), triggering airlines' interest in such a system[19]. Based on airlines' recognition of UAM shuttle services as premium services, market participants can develop cooperation opportunities.

Lufthansa's air-rail service is a representative example[20](Porsche Consulting, 2018). Passengers have traveled conveniently throughout Europe by rail after flying to Lufthansa's hub airport, such as Munich airport (MUC) or Frankfurt airport (FRA). Lufthansa has linked the schedule of air and rail, and passengers can purchase the air-rail transfer tickets on the airline's website or rail operator's ticket offices. Airport-airline cooperation can develop similar models in the UAM shuttle service.

[17] For example, several airports and enterprises, such as London Heathrow Airport and Manchester Airport, sell paid fast-track services. A passenger spends 100 to 300 USD for the paid services to shorten the airport process time. https://www.bloomberg.com/news/articles/2018–11-13/these-airport-vip-services-make-flying-a-breeze (retrieved 2021.10.26).

[18] https://www.globaltravelerusa.com/premium-economy-soars-in-popularity-and-profitability-for-airlines/ (retrieved 2021.9.26).

[19] According to the interview with the senior manager at the Korean Air passenger service division, this is one of the reasons why Korean Air is interested in the UAM business recently, https://www.koreanair.com/br/en/footer/about-us/newsroom/list/210805-korean-air-to-pioneer-uam-with-incheon-international-airp (retrieved 2022.1.24).

[20] https://www.lufthansa.com/ve/en/lufthansa-express-rail (retrieved 2021.10.20).

Fig. 5. Air traffic control zones around two Seoul Metropolitan airports in Korea.

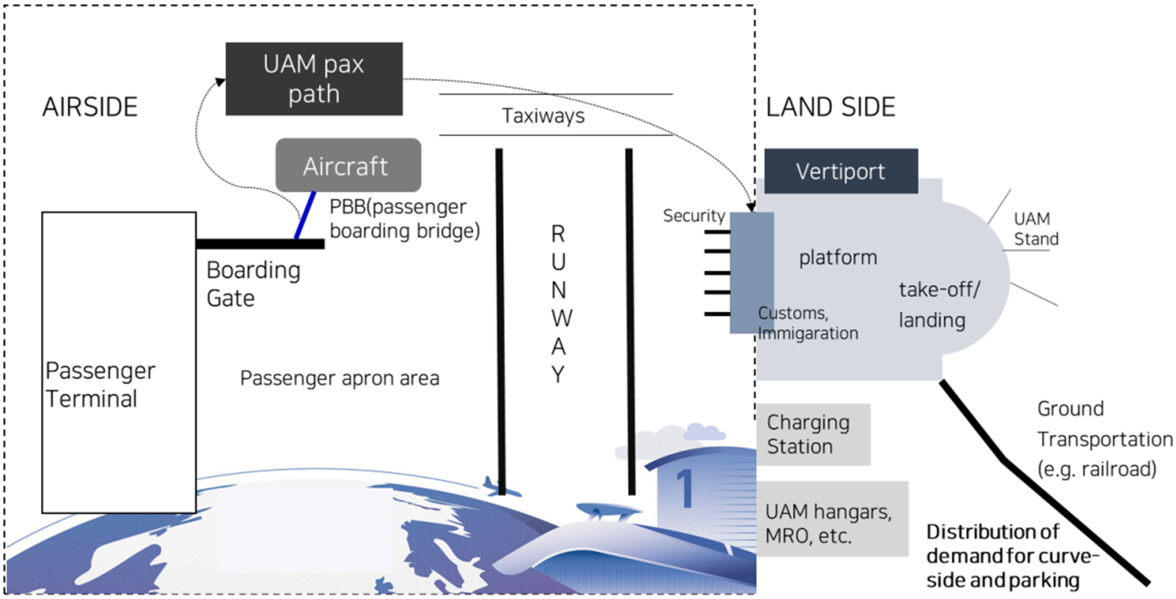


Fig. 6. Airport use procedures for UAM passengers.

5.2.2. *Time-based pricing and changing market conditions*

Time-based pricing means the strategy that charges more on faster services. Transportation businesses often benefit significantly from the time-based pricing strategy (e.g., night tariffs for taxi services). The UAM shuttle service has a significant advantage in that the travel time is shorter than other transportation modes. Mainly because it can avoid the uncertainty of road congestion[21], there is plenty of incentive to set higher fares during peak times with severe congestion. Table 12 shows the distance to downtown from major airports. Uber X service rates are calculated by the following Eq. (9) with multipliers per minute distributing between 0.47 and 1.02, and multipliers per mile showing a distribution of 1.21 and 1.64[22].

[21] This statement is based on the assumption that there is little poor weather or airspace congestion.
[22] Various Uber/Taxi fare estimators were comprehensively used. https://www.ridester.com/uber-rates-cost/, https://taxihowmuch.com/, https://uberfarefinder.com/, https://uberestimator.com/ (retrieved 2022.1.24~25).

$$Final\ \ fare = base\ \ fare + rate\ \ of\ \ total\ \ time\ \ taken\hat{a}\ddot{\overline{m}}ultiplier + rate\ \ of\ \ total\ \ distance\ \ covered\hat{a}\ddot{\overline{m}}ultiplier \tag{9}$$

Assuming that road congestion occurred for 20 min, a passenger should pay an additional fee of 24.2 to 32.8 USD more. It means a 122–165% increase compared to the fare when there is no congestion. At the same time, this suggests that passengers are willing to pay additional fees if the UAM service resolves the congestion problem. Therefore, UAM operators can apply higher prices according to the congestion situation.

Market conditions can change due to numerous reasons. For example, if multiple operators provide the UAM airport shuttle service, fares may fall due to competition. However, there seems more possibility to strengthen the economic feasibility by multiple operators' market participation. Multiple operators' market participation can improve economic feasibility by sharing enormous infrastructure construction costs and operating costs, which account for 87% of the total operating expenses.

6. Conclusion

UAM is a new concept of mobility that expands the two-dimensional transportation system to three dimensions using a personal air vehicle (PAV). There is a growing prospect that UAM services will start from 2025. Many organizations, including NASA, have suggested airport shuttle routes connecting airports and downtown as a promising early market. However, research on the UAM market is in its early stages, and it also seems complicated to research due to the lack of operating data found in the actual market. To fill the research gap, this study approaches the economic feasibility of the UAM airport shuttle service from two perspectives. First, this study estimates the cost of fare of UAM services to attract customers. The UAM service should maintain a competitive pricing policy to convert existing transportation users into UAM users. One of the most prominent features of this study in calculating the appropriate fare is that it collected actual ground access transportation data from Incheon International Airport (ICN) for empirical investigation. This study estimated the competitive fare using ICN ground access transportation data and a multinomial logit model (MNL). This study set the existing taxi users as initial conversion targets and calculated the fare range of the UAM service corresponding to reduced travel time. According to this, the pricing range at which UAM services can obtain users from Seoul Station to ICN is estimated to be 96 USD to 108 USD, assuming that the UAM service can reduce traveling time by 30–40 min compared to taxi service.

In addition, this study compared the fare estimated by the professional institutions to identify whether such a pricing policy is achievable. The comparison results indicate that the 96–108 USD presented in this study is viable. As UAM services are in the very early stages of development, it also suggests that if technology matures and demand grows, economic feasibility may be achieved. However, according to scenario simulations based on the DCF method, other approaches to enhance the value of the service are required besides the travel time reduction for the success of the UAM shuttle service.

In this regard, this study reviewed operational policies to improve the economic feasibility of UAM shuttle services from two perspectives. The first is a service perspective that introduces new services or enhances the current service level. The internalization of CNS (communications, navigation, and surveillance) service and UTM (unmanned traffic management) service can be a business area that can create new added value. Significantly, the premium route business that ensures faster and safer services by using big data from CNS and UTM can be an important business area for the operation of UAM shuttle services.

The second is the perspective of price policy through dynamic pricing policy. Dynamic pricing is a pricing strategy that applies variable prices instead of fixed prices. Segmented pricing, time-based pricing, and changing market conditions strategies can practically strengthen the economic feasibility of the UAM airport shuttle service. Operating an airport Vertiport providing a dedicated path for UAM passengers and shortening airport procedures can allow UAM operators to charge more on premium passengers purchasing the business or first-class tickets. Because it can avoid the uncertainty of road congestion, there is plenty of incentive to set higher fares during peak times with severe congestion. Multiple operators' market participation can improve economic feasibility by sharing enormous infrastructure construction and operating costs, which account for 87% of the total operating expenses.

Meanwhile, this study has several limitations. First, there are many assumptions surrounding many of the costs, travel times, and operational concepts in the analysis. Parametric sensitivity studies of the critical inputs, including operating hours and the number of seats, would present a far more robust and complete picture of the potential opportunity for UAM from a market perspective. Therefore, further research regarding additional parametric sensitivity studies is required to acquire more rigorous results providing practical implications for market participants.

Second, as this study estimates the demand for UAM through the MNL model, it adopts the assumption that UAM users also exhibit behavior patterns similar to those of existing transportation passengers. However, since UAM services feature significant differences in terms of safety, there is a possibility that UAM users will show different behavior patterns than existing transportation users. Therefore, it is necessary to supplement the passengers' willingness to use and preferences through further research using the survey.

Third, despite UAM's goals of providing affordable and accessible mobility, it faces some challenges, including public acceptance regarding noise, safety, and security. For example, in terms of security issues, there remain several operational risks, such as physical security of Vertiport/aircraft, personnel security for a passenger's journey, and cybersecurity for unmanned traffic control, to provide stable services (Cohen et al., 2021). Therefore, the government's effective regulatory measures to secure operational stability can be an important future research task. Further research should also be complemented from the operator's point of view. Especially, travelers' luggage can significantly affect the payload of a UAM vehicle. Therefore, it is necessary to devise a different transportation method. In

Table 12
Simulation of fare difference in case of congestion.

Route (Airport-downtown)	ORD (Chicago)	JFK (New York)	LHR (London)	CDG (Paris)	NRT (Tokyo)
Travel time (without congestion, min[1])	24	30	24	34	62
Travel distance (mile[1])	18	19	17	19	46
Fare range[2] (USD)	37.5–57.7	45.2–68.6	37.0–56.7	50.1–75.1	96.6–148.6
Fare range[3] (USD)	61.7–90.5	69.4–101.4	61.2–89.5	74.3–107.9	120.8–181.4

Note: 1. We derived the distance and travel time from January 24 to January 25, 2022 using the Google Maps service.
2. Estimated fare for Uber X service assuming that there is no congestion.
3. Estimated fare for Uber X service assuming 20 min of congestion.

this regard, baggage pick-up/drop-off services available at some airports can be a good reference[23]. Handling UAM travelers' luggage can be an exciting topic for further research on UAM services.

Nevertheless, this study is meaningful. Although professional institutions presented airport shuttle service as the most promising initial market, little discussion has been made on the economic feasibility and operational concept. In addition, as the UAM airport shuttle service is located at the intersection of ground access transportation, which mainly relies on land transportation, and the existing air transportation system, it is necessary to discuss ways to harmonize the two transportation systems. We hope that this study will serve as a starting point for various discussions, including the commercialization of UAM airport shuttle services.

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.

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References

Berman, B., 2005. Applying yield management pricing to your service business. Bus. Horiz. 48 (2), 169–179.
Berry, S.T., 1994. Estimating discrete-choice models of product differentiation. Rand J. Econ. 25 (2), 242–262.
Berry, S.T., Jia, P., 2010. Tracing the woes: an empirical analysis of the airline industry. Am. Econ. J.: Microecon. 2 (3), 1–43.
Bertulli, M. (2019). Five Dynamic Pricing Strategies for eCommerce Growth, https://www.bounteous.com/insights/2019/05/30/fivedynamic-pricing-strategies-ecommerce-growth (retrieved from 2022.1.24).
Black, T.R., 1999. Doing Quantitative Research in the Social Sciences: An Integrated Approach to Research Design, Measurement and Statistics. Sage.
Brown, R.D., 2010. Design with Microclimate: The Secret to Comfortable Outdoor Space. Island Press.
Carmichael, D.G., Balatbat, M.C.A., 2008. Probabilistic DCF analysis and capital budgeting and investment—a survey. Eng. Econ. 53 (1), 84–102.
Choi, J.H., Wang, K., Xia, W., Zhang, A., 2019. Determining factors of air passengers' transfer airport choice in the Southeast Asia-North America market: Managerial and policy implications. Transport. Res. Part A: Policy Practice 124, 203–216.
Cohen, A.P., Shaheen, S.A., Farrar, E.M., 2021. Urban air mobility: History, ecosystem, market potential, and challenges. IEEE Trans. Intell. Transp. Syst. 22 (9), 6074–6087.
Daskilewicz, M., German, B., Warren, M.M., Garrow, L.A., Boddupalli, S.S., Douthat, T.H., 2018. Progress in vertiport placement and estimating aircraft range requirements for eVTOL daily commuting, in: 2018 Aviation Technology, Integration, and Operations.
Hill, B.P., DeCarme, D., Metcalfe, M., Griffin, C., Wiggins, S., Metts, C., et al., 2020. UAM Vision Concept of Operations (ConOps) UAM Maturity Level (UML) 4.
Dunkerley, F., Wardman, M., Rohr, C., Fearnley, N., 2018. Bus Fare and Journey Time Elasticities and Diversion Factors for all Modes. RAND Corporation.
FAA. https://www.faa.gov/regulations_policies/policy_guidance/benefit_cost/ (retrieved from 2021.3.14).
Fu, M., Rothfeld, R., Antoniou, C., 2019. Exploring preferences for transportation modes in an urban air mobility environment: Munich case study. Transp. Res. Rec. 2673 (10), 427–442.
Goyal, R., Reiche, C., Fernando, C., Serrao, J., Kimmel, S., Cohen, A., Shaheen, S., 2018. Urban Air Mobility (UAM) market study. (No. HQ-E-DAA-TN63717).
Goyal, R., Reiche, C., Fernando, C., Cohen, A., 2021. Advanced air mobility: Demand analysis and market potential of the airport shuttle and air taxi markets. Sustainability 13 (13), 7421.
Gutiérrez, A., Miravet, D., Saladié, Ò., Anton Clavé, S., 2019. Transport mode choice by tourists transferring from a peripheral high-speed rail station to their destinations: Empirical evidence from Costa Daurada. Sustainability 11 (11), 3200.
Hasan, S., 2019. Urban air mobility market study (No. HQ-E-DAA-TN70296).
Hwang, C., 2018. Status and challenges of urban air mobility development. Curr. Ind. Technol. Trends Aeros. 16 (1), 33–41.
Inrix Score Card. https://inrix.com/press-releases/2019-traffic-scorecard-us/ (retrieved from 2021.3.9.).

[23] https://www.hongkongairport.com/en/passenger-guide/airport-facilities-services/baggage-pick-up-and-delivery, https://www.united.com/ual/en/us/fly/products/travel-options/baggage-delivery.html (retrieved 2022.5.15).

Jonas, A., 2018. Flying cars: Investment implications of autonomous UAM. Morgan Stanley.
Jones, E., Mustiful, B.W., 1996. Purchasing behaviour of higher-and lower-income shoppers: a look at breakfast cereals. Appl. Econ. 28 (1), 131–137.
Kim, H., Yee, K., 2021. A Novel Cost Estimation Method for UAM eVTOLs. J. Korean Soc. Aeron. Space Sci. 49 (3), 233–241.
Kluge, U., Paul, A., Urban, M., Ureta, H., 2019. Assessment of Passenger Requirements Along the Door-to-Door Travel Chain. In: Towards user-centric transport in Europe. Springer, Cham, pp. 255–276.
Lim, E., Hwang, H., 2019. The selection of vertiport location for on-demand mobility and its application to Seoul metro area. Int. J. Aeronaut. Space Sci. 20 (1), 260–272.
Liu, Y., Chen, J., Wu, W., Ye, J., 2019. Typical combined travel mode choice utility model in multimodal transportation network. Sustainability 11 (2), 549.
McFadden, D., 1973. Conditional logit analysis of qualitative choice behavior. In: Zarembka, P. (Ed.), Frontiers of Econometrics. Academic Press, New York.
Molit, 2021. Ministry of Land, Infrastructure and Transport of Korea. The Korean Urban Air Traffic (K-UAM). Technology Roadmap.
Nicolaidis, G.C., 1975. Quantification of the comfort variable. Transp. Res. 9 (1), 55–66.
Pels, E., Nijkamp, P., Rietveld, P., 2003. Access to and competition between airports: a case study for the San Francisco Bay area. Transport. Res. Part A: Policy Practice 37 (1), 71–83.
Porsche Consulting, 2018. The Future of vertical mobility. https://www.porsche-consulting.com/fileadmin/docs/04_Medien/Publikationen/TT1371_The_Future_of_Vertical_Mobility/The_Future_of_Vertical_Mobility_A_Porsche_Consulting_study__C_2018.pdf (retrieved from 2022.5.12.).
Reichmuth, J., Grimme, W., Berster, P., Gelhausen, M., 2010. Analyses of the European air transport market, Airport Accessibility in Europe. European Comission, Köln, Germany, Scientific Report.
Roland Berger, 2018. Urban air mobility. https://www.rolandberger.com/publications/publication_pdf/roland_berger_urban_air_mobility_1.pdf (retrieved from 2022.5.12.).
Roland Berger, 2020. Focus, Urban air mobility. https://www.rolandberger.com/publications/publication_pdf/Roland_Berger_Urban_Air_Mobility.pdf (retrieved from 2022.5.12.).
Rothfeld, R., Fu, M., Balać, M., Antoniou, C., 2021. Potential Urban Air Mobility Travel Time Savings: An Exploratory Analysis of Munich, Paris, and San Francisco. Sustainability 13 (4), 2217.
Shaheen, S.A., Cohen, A.P., Broader, J., Davis, R., Brown, L., Neelakantan, R., Gopalakrishna, D., 2020. Mobility on Demand Planning and Implementation: Current Practices, Innovations, and Emerging Mobility Futures (No. FHWA-JPO-20-792). United States. Department of Transportation. Intelligent Transportation Systems Joint Program Office.
Stouffer, V.L., Cotton, W.B., DeAngelis, R.A., Devasirvatham, D.M., Irvine, T.B., Jennings, R.E., et al., 2020. Reliable, Secure, and Scalable Communications, Navigation, and Surveillance (CNS) Options for Urban Air Mobility (UAM).
Straubinger, A., Michelmann, J., Biehle, T., 2021. Business model options for passenger urban air mobility. CEAS Aeron. J. 12 (2), 361–380.
Syed, N., Rye, M., Ade, M., Trani, A., Hinze, N., Swingle, H., Smith, J.C., Marien, T., Dollyhigh, S., 2017. ODM commuter aircraft demand estimation. 17th AIAA Aviation Technology, Integration, and Operations Conference.
Thipphavong, D.P., Apaza, R., Barmore, B., Battiste, V., Burian, B., Dao, Q., Verma, S.A., 2018. Urban air mobility airspace integration concepts and considerations. In: 2018 Aviation Technology, Integration, and Operations Conference, p. (p. 3676)..
Toro-González, D., Cantillo, V., Cantillo-García, V., 2020. Factors influencing demand for public transport in Colombia. Res. Transport. Bus. Manage. 36, 100514. https://doi.org/10.1016/j.rtbm.2020.100514.
Holden, J., Goel, N., 2016. Fast-Forwarding to a future of on-demand urban air transportation. Uber Elevate.
Vertiflite, 2017. https://vtol.org/files/dmfile/eVTOLConcepts-KenSwartz2.pdf (retrieved from 2021.3.20.).
Victor, V., Joy Thoppan, J., Jeyakumar Nathan, R., Farkas Maria, F., 2018. Factors influencing consumer behavior and prospective purchase decisions in a dynamic pricing environment—an exploratory factor analysis approach. Soc. Sci. 7 (9), 153.
Volocopter, 2019. White paper on urban air mobility. https://www.volocopter.com/wp-content/uploads/Volocopter-WhitePaper-1-01.pdf (retrieved from 2022.5.12.).
Windle, R., Dresner, M., 1995. Airport choice in multiple-airport regions. J. Transp. Eng. 121 (4), 332–337.
Xu, T., Cai, Y., 2009. Feeling-based location privacy protection for location-based services. In: Proceedings of the 16th ACM conference on Computer and communications security, pp. 348–357.
Yang, H., Zhang, A., 2012. Effects of high-speed rail and air transport competition on prices, profits and welfare. Transport. Res. Part B: Methodol. 46 (10), 1322–1333.