Transport Policy 171 (2025) 1025–1040

Contents lists available at ScienceDirect

Transport Policy

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

Urban air mobility for airport access: Mode choice preferences and pricing considerations

Filippos Adamidis [a], Chiara Caterina Ditta [b], Hao Wu [a,*], Maria Nadia Postorino [b], Constantinos Antoniou [a]

[a] Chair of Transportation Systems Engineering, Technical University of Munich, Arcisstrasse 21, 80333 Munich, Germany
[b] Department of Civil, Chemical, Environmental and Materials Engineering (DICAM), University of Bologna, Viale del Risorgimento 2, 40136 Bologna, Italy

ARTICLE INFO

Keywords:
Airport shuttle service
Stated preference
Discrete choice
Willingness to pay
Case study

ABSTRACT

The increasing use of commercial aviation in the last decades has urged us to reconsider landside airport accessibility to meet the evolving demand. At the same time, the third (vertical) dimension in urban and suburban areas – i.e. the lower airspace up to 500 m above the ground – has yet to be substantially exploited for transportation. Soon, technological advances in electric vertical take-off and landing (eVTOL) aircraft could enable the commercial use of Urban Air Mobility (UAM) for airport access. Through a case study in Bavaria, Germany, and Austria, this research aims to investigate the potential users' willingness to pay for a novel UAM AirShuttle service, which could connect the airport of Munich with important points in its catchment area, and to analyse their transportation mode choices when accessing the airport. A stated preference mode choice survey was disseminated through an online panel during March 2023 in the catchment area of the airport to assess the current travel behaviour of the population, including the ownership of mobility instruments, the current state of airport accessibility and the satisfaction of the respondents (N=218) with the currently available modes. Furthermore, the survey investigated directly how much the respondents were willing to pay to use the AirShuttle and their sociodemographic background. The results were evaluated using descriptive statistical analyses and discrete choice modelling. The findings reveal that most respondents were satisfied with the current access modes and found their pricing reasonable. On the other hand, their willingness to pay for UAM services was lower than expected. This study yields important implications for the industrial stakeholders of UAM and for policymakers; by analysing the results, it was concluded that the expectations of the industry and potential customers regarding UAM pricing in the short term could be different and that its benefits and implications for society should be carefully weighed by policymakers.

1. Introduction

Over the years, demand for mobility has steadily evolved, requiring new infrastructure development that enables safe, efficient and comfortable transportation, be it within urban areas, agglomerations, regions or between different countries (Noussan et al., 2020). However, demand for transportation can be distinguished between demand for short and demand for long-distance trips. For the latter, integrating air transport with overground and underground transport modes has successfully satisfied mobility needs; according to the International Civil Aviation Organization (ICAO), around 4.5 billion passengers were carried on scheduled flights in 2019 (International Civil Aviation Organization). Meanwhile, the third spatial dimension above the ground remains largely unused for short-range trips within an urban area or between neighbouring urban locations – in such cases, air transport was not considered given the high time losses due to security checks, boarding and disembarking procedures, including baggage claim (Sun et al., 2018). In this context, recent technological advances have enabled flights with electric vehicles, which can hover and navigate above urban areas (Park et al., 2018). Urban Air Mobility (UAM), and more generally Advanced Air Mobility (AAM), is a low-altitude aerial transportation system designed to carry passengers and cargo on urban and suburban routes on demand (Hill et al., 2020; Wu and Zhang, 2021). Although traditional helicopters are currently used in urban aerial transportation,

* Corresponding author.
E-mail addresses: filippos.adamidis@tum.de (F. Adamidis), chiaracaterina.ditt2@unibo.it (C.C. Ditta), wu.hao@tum.de (H. Wu), marianadia.postorino@unibo.it (M.N. Postorino), c.antoniou@tum.de (C. Antoniou).

https://doi.org/10.1016/j.tranpol.2025.07.027
Received 15 May 2024; Received in revised form 24 May 2025; Accepted 17 July 2025
Available online 19 July 2025

UAM aims to utilise electric vertical take-off and landing (eVTOL) vehicles, colloquially known also as flying taxis, with less noise emitted than conventional helicopters. According to the European Union Aviation Safety Agency (EASA, n.d.), those aerial vehicles are planned to take off and land on vertiports, which are infrastructures dedicated to the transportation of passengers or cargo by eVTOLs, and will enable an almost vertical flight trajectory during take-off and landing. According to the European aircraft manufacturer Airbus, which has recently introduced the CityAirbus NextGen, a fully electric prototype eVTOL, those vehicles will be manually piloted in the beginning until the UAM market is mature enough for autonomous operations (Airbus, n.d.). In this context and while focusing on passenger transport, several air services have been defined in the literature with specific characteristics of the UAM system (e.g. air taxis and airport shuttles) (Schuchardt et al., 2021; NASA, 2018b).

Emerging transportation technologies pose numerous potential challenges to policymakers (National Academies of Sciences Engineering, and Medicine, 2024). Even though UAM as a holistic concept has recently gained notable interest from numerous researchers and stakeholders, system development is still constrained by the lack of existing regulations, air traffic control procedures, uncertainty about its environmental impact and the absence of suitable infrastructure and coordination with ground transportation (Wang and Qu, 2023; Cohen and Shaheen, 2021; Bauranov and Rakas, 2021; Vascik and Hansman, 2017). In addition to significant constraints, public acceptance represents a key factor in being able to include UAM among the existing transportation systems (Karami et al., 2024; Al Haddad et al., 2020; Shaheen et al., 2018; Vascik, 2017). In this regard, EASA has conducted a comprehensive analysis of the societal acceptance of UAM operations, where safety issues and noise disturbance emerged as main concerns. Also, it emerged that airport shuttle services could be the most valuable UAM passenger service (EASA, 2021). Airport shuttle services could provide scheduled or on-demand flights between airports and strategic sites in urban and metropolitan areas (Cohen et al., 2021; Roland Berger, 2020) and could reach up to a range of 200 km, depending on the features of the eVTOL (Airbus, n.d.). Furthermore, considering that air travel speeds have stagnated in the last decades (Rothfeld et al., 2019), aerial airport shuttle services could contribute to achieving the European Commission's challenge of 4-h door-to-door intra-European air travel. Currently, this kind of service is the most probable application among UAM systems, also due to the interest of airport operators to inaugurate new facilities that could fulfil the demand during major events, i.e. the Milan-Cortina Winter Olympic Games in 2026 (SEA Milano, 2022). Following this trend, the following research aims to explore the determinants of demand for a UAM AirShuttle concept in the metropolitan area of Munich, which could connect the wider metropolitan region with Munich International Airport (MUC), and to estimate the willingness of potential passengers to pay for this novel service.

Thus, the objective of this study can be summarised into the following two research questions: can UAM operators meet the expectations of individuals concerning aerial airport shuttles, by focusing on the pricing considerations of potential customers, and how can the future demand for an airport shuttle be estimated? To the best of our knowledge, a study that focuses on transportation mode choices including UAM to and from airports in Central Europe, while placing an emphasis on the pricing of this new mode, does not exist. Focusing on a test case for the airport of Munich, we consider not only mode-specific attributes but also the established travel behaviour and the sociodemographic background of the respondents.

The remainder of this paper is structured as follows. A literature review is first presented, concentrating on the main aspects that are being discussed in this study. After that, the methods, including the mathematical background of the estimated models, the data collection and the subsequent data analysis are described. Particularly, to analyse the preferences of potential users and their willingness to pay, a stated preference (SP) survey has been realised, followed by extensive data analyses and discrete choice modelling aiming to identify relevant factors associated with the currently used transportation modes and the UAM AirShuttle in the near future. After collecting data, a methodology to analyse the data and develop suitable models that can generalise the patterns that emerged is applied, aiming to formulate recommendations for public policymakers and stakeholders in the aviation industry. The former could benefit from this analysis by preparing better for the introduction of UAM, while the latter could observe the current study as a first analysis of the potential benefits of UAM as an airport shuttle and as an evaluation of the potential gains they should expect in return. Finally, conclusions are drawn, and recommendations about the future steps of this work are briefly presented.

Although the study provides interesting insights, it also has limitations. Firstly, the survey is developed based on assumptions about the operational scheme of the UAM AirShuttle, and different assumptions could have resulted in contrasting results. Moreover, this study relies on an SP survey, and respondent bias can influence the accuracy of the answers, either due to survey design or the selection of participants. Finally, as with every study in the field of travel behaviour, it is impossible to capture the heterogeneous behaviour of the population in its entirety. As a result, the decisions of the participants may have been influenced by factors not captured by this work.

2. Literature review

To conduct a suitable analysis of the potential transport demand for an aerial airport shuttle, it is essential to understand the current background and the stages of development in terms of operations, market analysis and pricing. Due to the uncertainty related to the operational characteristics of this service, an investigation of the published literature assists in defining the main assumptions of this study.

2.1. Operational characteristics and assumptions

As the literature suggests, the process of using UAM could be similar to commercial aviation. For example, Porsche Consulting (2018) described the process in five steps; access to the vertiport (first mile), boarding, flying route, disembarking and, eventually, egress to the final destination (last mile). Those steps could represent five degrees of freedom regarding any operational assumptions in the studies that require presuming some critical characteristics of the service in question. According to Rothfeld et al. (2021), the processing time and the number of vertiports (within the geographical area of operations) significantly influence the total travel time savings when UAM is compared to ground transport modes. In that matter, different studies have made diverse assumptions; Porsche Consulting (2018) assumed 3 min. each for boarding and disembarking, and 5 min. each for the first and last miles. Further, Bulusu et al. (2021) assumed a processing time of 5–15 min., which does not include access or egress time to the vertiport, while Fu et al. (2019) included 5–10 min. indicating the total walking and waiting time. Al Haddad et al. (2020) assumed a boarding and de-boarding time of 5 min. in total, i.e. including the landside part of the trip in each direction. Furthermore, Pukhova et al. (2021) associated the increase in boarding time with waning demand, as expected.

Also, to investigate the service feasibility, Shamiyeh et al. (2018) provided a summary of UAM vehicle concepts regarding cruise speed, capacity and range. Regarding the cruising speed of aerial vehicles, which primarily influences the in-vehicle travel time, the spectrum of assumptions is wide even within the same studies. Porsche Consulting (2018) assumed speeds ranging between 70 and 120 km/h for multirotor intracity aircraft to 150–300 km/h for tiltrotor and tilt-wing intercity vehicles. Several companies, such as Lilium Aviation, Volocopter and Airbus, displayed eVTOL vehicle concepts with different features depending on the use case. The Lilium tilting-wing (lift and cruise) aircraft could achieve speeds up to 300 km/h (Hawkins, 2017), which could be suitable for long-range services; meanwhile, the Volocity rotary-wing by Volocopter and the CityAirbus lift and cruise aircraft by Airbus could achieve speeds up to 110 km/h and 120 km/h respectively, appearing suitable in urban environments and short-range services. In the context of Germany and central Europe, Ploetner et al. (2020) based their results on a reference vehicle (100 km/h) but noted only slight differences in demand with slower (50 km/h) or faster (350 km/h) vehicles, stressing the importance of pricing and processing times for short-distance missions. Similarly, Fu et al. (2019) studied different scenarios with speeds ranging from 50 to 300 km/h but stated that higher speeds cannot compensate for higher processing times. In their study in Zurich, Switzerland, Balac et al. (2019a,b) applied speeds between 60 and 240 km/h but also identified the relatively higher importance of processing time compared to the cruising speed. Moreover, Binder et al. (2018) described a vehicle that can travel above urban areas at cruise speeds of 150 mph (240 km/h), while Rimjha et al. (2021a) calculated UAM travel times in Northern California at speeds of 120 mph (190 km/h).

Another relevant issue highlighted in the literature is the range of eVTOL vehicles. As UAM is conceived to be operated mainly by fully electric aerial vehicles to minimise noise disruption over densely inhabited areas, its limited battery range is potentially seen as an operational constraint (Vascik et al., 2018). The whitepaper of Uber (2016) assumed that a possible configuration could provide up to 120 miles (222 km) of range, although clearly stating that vehicles with lower speed and range could be more suitable for efficient short-distance operations. Similarly, the CityAirbus NextGen will provide a range of 80 km at a maximum speed of 120 km/h (Airbus, n.d.). According to Ploetner et al. (2020), a comprehensive UAM network in Bavaria, Germany, would require a vehicle range of 180 km – nevertheless, reducing the available range to 110 km still enables 95 % of all connections. Moreover, it is argued by other authors that (hybrid) fuel cells complemented by batteries are the only viable source of energy for multi-rotor eVTOLs when operations exceed 60 miles (110 km) in urban scenarios (Ahluwalia et al., 2021).

The performance and attractiveness of UAM as a transport system can be influenced by eVTOLs' features and operational factors. The former includes all constraints that limit the scope of application due to vehicle design, e.g. the number of passengers per flight, the possibility to transport luggage on board and whether the vehicle can navigate autonomously or not. For example, Asmer et al. (2021) developed their study about UAM as airport shuttles by considering four-seat flying vehicles including luggage, while Fu et al. (2019) also envisioned an autonomous flying taxi with four passengers at once, however, without providing further information about their capability to transport luggage. Still, Brunelli et al. (2023) analysed the passengers' willingness to use aerial airport shuttle services in Italy by exploring shared or unshared UAM alternatives that included a small suitcase and investigated the influence of automation acceptance on passengers' choices. Other important operational factors include the properties of the service that can be configured independently by each operator or can even get adjusted dynamically to adapt to the demand. Among them are trip-sharing, e.g. to reduce the cost per passenger (Ahmed et al., 2021; Al Haddad et al., 2020), the provision of pre-departure amenities such as lounges and workplaces, the possibility of in-flight entertainment, internet connectivity and mobile network coverage, which could enable an almost seamless workflow for business passengers.

2.2. Market demand for UAM

The idea of airport access with flying taxis, either as scheduled services or on-demand mobility, is not new. According to NASA (2018a), shuttle services to and from major airports could take over a significant part of the travel demand for UAM in the near term. In 2019, Blade launched on-demand urban flying using helicopters from Manhattan in New York City to John F. Kennedy Airport (JFK) and later to Newark Liberty International Airport in New Jersey, promising a travel time of 5 min with starting fees of 195 $ (179 €) (Blade, n.d.). Uber proposed a similar on-demand helicopter shuttle service between Manhattan and JFK, which could be booked as a regular Uber ride (Introducing Uber Copter, 2019). The main advantages of those services according to their providers are the possibility to skip road traffic (since New York City is the second most congested city in North America (TomTom, 2022)), to enjoy the views over the city and enhanced amenities (e.g. a lounge) while waiting for a ride and, finally, the seamless booking procedure (Blade, n.d.).

Current research shows that eVTOLs may broaden the potential market for flying airport shuttles (Roy et al., 2020). California, especially Los Angeles and the Silicon Valley region, is often seen as a suitable scenario for flying taxi operations due to the high-income and high-density population, the notable percentage of long-distance commuters and the ensuing road traffic congestion (Antcliff et al., 2016). Rimjha et al. (2021b) estimated that UAM could capture 2.4–3.6 % of the market share in airport access trips to and from Los Angeles International Airport and around 1750 one-way passenger trips daily to Dallas-Fort Worth International Airport (Rimjha et al., 2021c). Goyal et al. (2021) projected that aerial airport shuttles and flying taxis will transport around 82,000 passengers per day in the US in their early years of adoption – 98 % of that demand will stem from trips longer than 30 min by ground transport.

Nonetheless, the demand for UAM has been studied more extensively also in a wider context, focusing on intraurban and interurban passenger services. Binder et al. (2018) found that individuals in the US were generally interested in using flying taxi services, especially for time-sensitive business trips and commuting from rural areas. Using a simulation-based assessment of UAM in Munich, Rothfeld et al. (2021) found that the service could provide travel time savings for 3–13 % of urban trips, especially over travel times of 50–55 min. On a global scale, Mayakonda et al. (2020) performed a sensitivity analysis in 31 major cities worldwide that underlined the importance of the supply, i.e. vertiport density and UAM ticket cost, on the demand; in all study cases, the demand for UAM fell under 1 % of the total passenger-km if prices rise above 1.2 $/km[1] (1.1 €/km).

As urban air mobility is not yet a reality, researchers have largely resorted to models to predict its future demand. Fu et al. (2019) developed discrete mode choice models based on a stated preference survey from Munich, Germany, which included automated flying taxis among other modes. Based on their models, Fu et al. (2022) implemented agent-based simulations to investigate the impact of UAM on urban trips and concluded that it is not probable to notice a sufficient reduction in ground traffic levels after the introduction of flying taxis in the metropolitan region of Munich; instead, they named the premium airport passenger demand as a potential market. Similarly, Ploetner et al. (2020) found that UAM could account for just 1 % of the modal split in the Munich Metropolitan Region in the long term, while demand may increase to 3–4 % on distances over 40 km, despite the vast majority of those trips being under 40 km. In summary, Straubinger et al. (2021) concluded that none of the different studies exceeded a maximum share of 4 % in overall traffic. Also, the results from Rimjha et al. (2021a) indicated that sufficient demand can only be achieved with low fares and a dense network of vertiports, which is consistent with the findings of Rothfeld et al. (2021).

2.3. Pricing

In general, the total trip cost can be split into two components according to the bibliography: the fixed and the variable component, which may vary by the number of passengers, the trip length, the origin and the destination nodes and the time of day. In 2018, Booz Allen Hamilton

[1] 1 US Dollar ($) = 0.92 Euro (€) on April 3, 2023. All currency conversions are approximate.

Table 1
Assumed monetary cost structure of UAM operations from selected publications.

Reference	Fixed cost	Variable cost	Temporal horizon	Country
All trip purposes				
Uber (2016)	–	1.5 €/pkm	Short term	USA
		0.2 €/pkm	Long term	
NASA (2018a)	–	3.2–5.5 €/pkm	Short term	USA
		1.2 €/pkm	Long term	
NASA (2018b)	–	0.9 €/pkm	Long term	USA
Balac et al. (2019a)	6.1 €	0.6–4.2 €/km	–	Switzerland
Mayakonda et al. (2020)	–	0.3–6.6 €/pkm	Long term	USA
Ploetner et al. (2020)	–	4.94 €/km	–	Germany
Goyal et al. (2021)	–	3.58 €/pkm ± 50 %	–	USA
Straubinger et al. (2021)	30 €	0.2–2.4 €/km	–	Germany
Wu and Zhang (2021)	9.2–27.6 €	0.5–1.0 €/km	–	USA
Coppola et al. (2024)	–	3.5 €/km	–	Italy
Airport access				
Porsche Consulting (2018)	100 € for 34 km	–	Long term	Germany
Choi and Park (2022)	88-99 € for 47 km	–	–	South Korea
Rimjha et al. (2021c)	13.8 € base fee and 18.4 € landing fee	1 €/km	–	USA

pkm = passenger-kilometre.
1 mile = 1.852 km.

submitted to the National Aeronautics and Space Administration (NASA) the final report of their UAM market study, which assumed a price of 6.25–11 $ per passenger-mile (3.2–5.5 €/passenger-km) (NASA, 2018a). Also, Balac et al. (2019a) assumed a base fare of 6 SFr.[2] (6.1 €) in Zurich, Switzerland, along with a variable cost between 0.6 and 4.2 SFr./km (0.6–4.2 €/km), stating that charges under 0.6 SFr./km are not attainable because they fall even below the cost of car ownership. In their study in Bavaria, Germany, Ploetner et al. (2020) found that a price of 4.94 €/km, including taxes, is enough to achieve a profit margin of 5 % on operation with two passengers per vehicle. The authors considered that a decrease in vertiport landing fees, combined with the carriage of four passengers, may result in a feasible price of 1.75 € per passenger-km (pkm). In roughly the same geographic area, Straubinger et al. (2021) based their analysis on a fixed price of 30 € to which variable costs of 0.2–2.4 €/km were added. Also, Wu and Zhang (2021) applied a base charge of 10–30 $ per trip (9.2–27.6 €) and a variable unit cost of 1–2 $ (around 0.5–1 €/km) elsewhere. Still, the analysis conducted by Goyal et al. (2021) in the near term expects that a five-seat air taxi trip could cost around 6.25 $/passenger-mile (3.58 €/passenger-km) with an uncertainty of ±50 %. Focusing on accessibility to airports through flying taxi services, the trip cost between the city centre of Munich and the airport (MUC) was estimated at 100 € (for 34 km) by Porsche Consulting (2018), while in Rimjha et al. (2021c) trips to Dallas-Fort Worth International Airport were priced as 2–4 $/mile (1–2 €/km) plus a 15 $ (13.8 €) base fee and a 20 $ (18.4 €) landing fee. In the study of Choi and Park (2022), the economic feasibility of an aerial airport shuttle to connect Seoul Station and Incheon International Airport was investigated. Existing taxi users were considered as initial conversion targets to evaluate a UAM service fare range, with the authors assuming that UAM passengers could be high-income customers. The fare range of UAM in Seoul was set at 96–108 $ (88–99 €) for 47 km, assuming that it can reduce travel time by 30–40 min compared to taxi services. This price range was considered appropriate to overcome the investment in infrastructures, cover operating costs for the aerial airport shuttle and obtain an appropriate rate of return. Recently, Coppola et al. (2024) performed a stated preference UAM experiment where they assumed a unit service fare of 3.5 €/km in Milan, Italy.

Eventually, it is expected that UAM services may become more affordable. Thus, in the long term, this technology is expected to make progress and demand may increase, leading to economies of scale (Balac et al., 2019a,b), which in turn may reduce the cost of operations even further (Thipphavong et al., 2018). Crown Consulting (NASA, 2018b) presumed that the price could be as low as 0.93 $/passenger-km (0.9 €/passenger-km) by 2030, NASA (2018) 2.5 $/passenger-mile (1.2 €/passenger-km) in the long-term and Mayakonda et al. (2020) 0.3–7.2 $/passenger-km (0.3–6.6 €/passenger-km) by 2035. Uber (2016) has predicted a passenger price of 2.97 $/mile (1.5 €/km) initially, 0.98 $/mile (0.5 €/km) in the near-term and finally, 0.47 $/mile (0.2 €/km) in the long-term. In Table 1, the UAM service price assumptions have been summarised, which later helped to hypothesise a suitable fare for the UAM AirShuttle in this study.

Therefore, by reviewing the existing literature, two gaps could be identified, which also shape the methodology and the case study in the next sections. First, although most studies focused on the effects of the introduction of a UAM system in the long term, the present research investigates a short-term introduction, specialising on an aerial airport shuttle as a use case. Second, this study attempts to estimate how much potential passengers are willing to pay by asking direct questions about their pricing preferences. This allows us to assume realistic pricing conditions during analysis and to compare the determinants of UAM demand with the existing modes in the near future.

3. Methodology

3.1. Methodological framework

Based on the existing background, this research aims to analyse the prospective use of a UAM AirShuttle to connect major urban areas with airports. This section presents the methodological approach (Fig. 1) that was used to analyse the aspects of pricing of the service in question and to estimate a discrete choice model for airport access and egress based on a stated preference (SP) survey. The results of this survey were used to explore the users' transport mode preferences, also in terms of willingness to pay. Thus, section 3.2 introduces the general structure of the SP survey with different distance segments, section 3.3 describes the stated preference scenarios with details about the attributes and the levels of the alternatives in question and, finally, section 3.4 introduces the theoretical background employed to develop suitable models and perform the relevant analysis.

3.2. General specification of the survey

As stated, UAM services and particularly an aerial airport shuttle could supplement existing ground transport modes to improve airport accessibility; however, this system has never been tested on a large scale. In order to explore the determinants of the potential demand for this

[2] 1 Swiss Franc (SFr.) = 1.01 Euro (€) on April 3, 2023. All currency conversions are approximate.

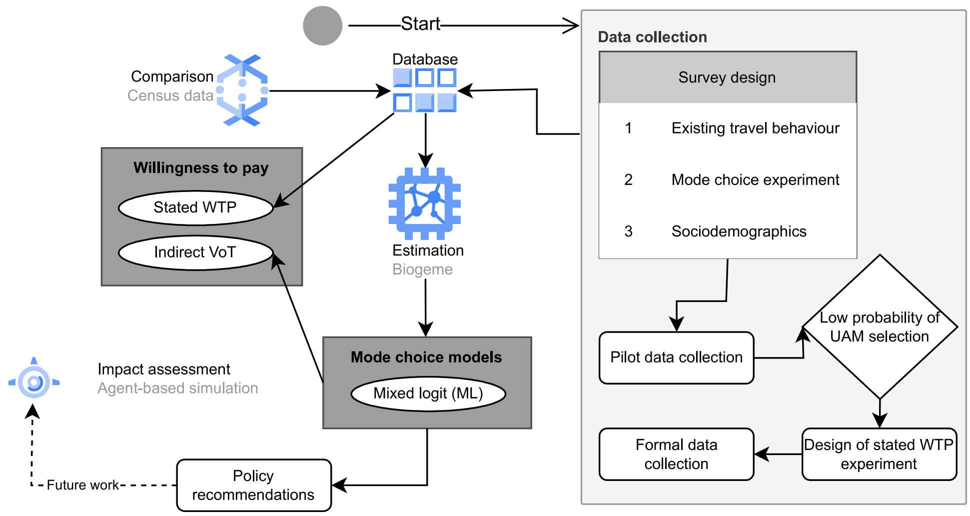


Fig. 1. Schematic methodological framework of this research (own elaboration).

new transport system, a stated preference (SP) experiment has been defined according to the methodology found in the literature (Hensher et al., 2008; de Dios Ortúzar and Willumsen, 2011). The SP experiment was included in a survey that consisted of three parts; part one explored current travel behaviour to and from the airport, such as identifying the journey's origin/destination, investigating which means are usually chosen and the reasons behind, and the frequency of access to the airport. Furthermore, depending on the availability of transport means given by the respondent (e.g. a private car, a business car or a public transport subscription), this part followed an adaptive design in order to reduce the number of redundant questions. Part two included the stated preference experiment, where each respondent received six questions, two of which related to choosing an airport access mode (stated preference), while the remaining asked the respondents to insert a suitable price for the AirShuttle according to the levels of the attributes of other modes (contingent valuation). In the case of MUC, to ensure that all respondents were placed in realistic conditions regarding their origin/destination points, three travel scenarios were approximately defined, covering the airport catchment area with distances of 30, 60 and 120 km. Before proceeding with this, the UAM concept and the airport shuttle service were introduced, showing an eVTOL prototype (CityAirbus NextGen, although not explicitly named) with the relevant technical characteristics. The respondents were informed that eVTOLs can only take off and land on vertiports, while it would also be probable that they share their ride with other passengers and that they can only take their hand luggage on board due to weight restrictions (heavy luggage can be transported on the ground). In addition, the introductory paragraph stated that the same safety levels as traditional aviation will be guaranteed. In part three, the respondents' sociodemographic background and their attitudes towards flight safety and automation in transportation were surveyed (not part of this investigation); flight safety has been examined based on six statements concerning the propensity to fly, the perception of risk in flight, and how safety is perceived in flight compared to ground transport modes (Clothier et al., 2015; Seriwatana, 2018). The same approach, i.e. with six statements, was used to evaluate the respondents' knowledge and inclination towards new automation technologies, electric vehicles and their perception (Stilgoe, 2021; Ziefle et al., 2014; Thiel et al., 2012). In addition, two questions investigated the satisfaction rates with current transport modes and prices. The questionnaire concluded with sociodemographic queries about gender, age, income, education, employment, household status and country of residence.

3.3. *Designing the stated preference experiment*

The SP scenarios in the survey's second part include the main alternatives of transportation modes to access the airport in the context of Munich and the new UAM airport shuttle service, i.e. private car, public transport, ride-hailing, car-sharing and AirShuttle. It should be noted that car-sharing was omitted from the 60 and 120 km scenarios, as the service is currently unavailable in cities of the study area other than Munich, while pre-booked car rental was omitted altogether as the SP scenarios aimed to capture the demand from local passengers. For UAM, we assumed an average occupancy of two, halving the travel cost. Special emphasis has been placed on its introduction horizon. According to the description before the survey's second part (SP), the AirShuttle is expected to enter service in less than five years (i.e. before 2029). The main goal is to decrease the travel time between the airport and the main points of interest in the study area. Based on the literature and the industrial stakeholders of the UAM AirShuttle in the metropolitan region of Munich, the service would be provided by an eVTOL with a four-seat capacity, operating at 120 km/h with a range of 80 km. For distances over that range, 5 min were added to the travel time since travellers may be required to transfer into another eVTOL. According to industrial stakeholders, integration of UAM and airport security is not envisaged in the early stages. Recent discussion indicates that regulatory authorities have not yet established standards for vertiport operations and that if a similar approach to helicopter flights gets adopted, UAM passengers and luggage might not require screening at the vertiport (Hoffmann et al., 2023). This would mandate security checks at the airport, and thus, this study does not consider the potential time savings due to integration with airport security.

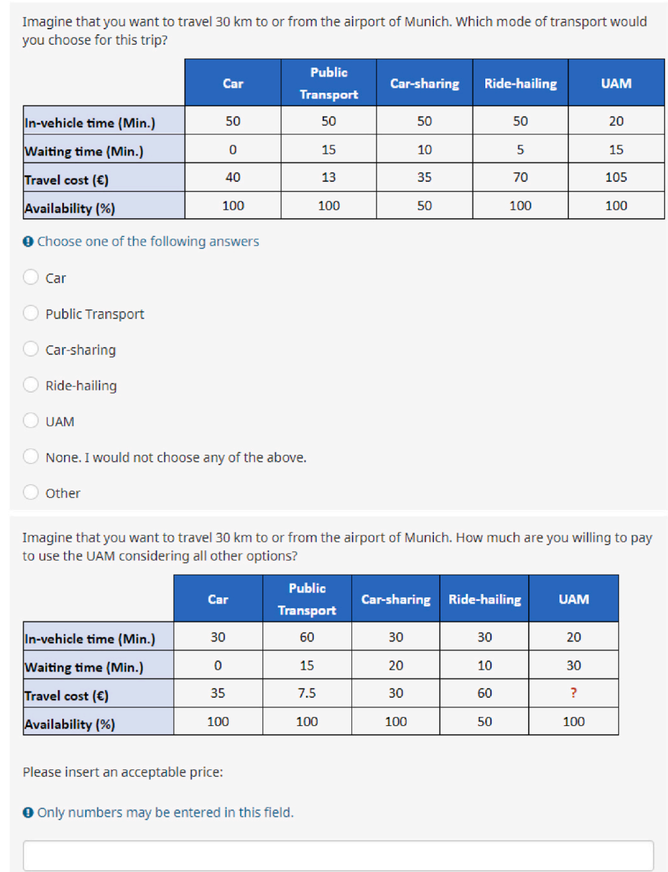
It is generally argued that a random survey design can perform equally well as an efficient design (Walker et al., 2018). Thus, the SP part has been specified by considering a random design, drawing from the full factorial design including four different attributes and one, two or three levels depending on each attribute (Table 2). The attributes of the modes have been defined as follows:

- In-vehicle time (minutes) is the total net time spent in the vehicle without considering any other time spent outside the vehicle.
- Waiting time (minutes) includes the time used to reach a transportation mode, waiting at stops, and any processing time due to check-in, security controls and boarding procedures at the vertiport.
- Travel cost (€) is the total cost incurred by the corresponding mode.

- Availability (%) is the probability that a vehicle (of the means of transportation chosen) is available at the time of a user's departure.

The levels of each attribute were defined based on targeted sampling through popular online tools. For example, we approximated the travel time by private car, car-sharing and ride-hailing through Google Maps, whereas in the case of public transport, the website of the German Railways (www.bahn.de) was utilised to estimate the travel time, the waiting time and the cost. As a consequence of the definition of waiting time, all transportation modes would drop passengers off before airport security, i.e. it was not assumed that security is integrated between the UAM AirShuttle and the airport terminal. The cost of private car use was estimated at about 0.65 €/km - by considering Germany's best-selling car (Volkswagen Golf; ADAC, 2022) – plus a price component related to MUC parking. The car-sharing cost was based on the main sharing operators' fares (i.e. 0.16–0.39 €/min in ShareNow and Sixt share), adding the average airport unlock fee. Ride-hailing was priced around 2–3 €/km in the short scenario (30 km) and 1.8–2.3 €/km in the longer scenarios (60 and 120 km) based on sampling from the Uber and Free-Now mobile applications. Subsequently, the prices were rounded upwards to the nearest 0 or 5 €, where it seemed reasonable, and pivoted around the reference levels based on the magnitude of the values (Table 2). As the survey is referring to the near future, no major deviations from the current levels with regard to the monetary cost are expected, and even then, pivoting around the reference level most likely accounts sufficiently for future price increases. Worth noting is the calculation background for UAM; after consultation with industrial stakeholders, the price was set at 6–10 €/km and was later lowered to 4–10 €/km, while also assuming occupancy of two passengers. This re-evaluation was the result of the first pilot trial of the survey (with 22 respondents), during which none of the respondents selected the AirShuttle.

Generally, each respondent answered six stated preference questions in random order: two questions asked the respondent to choose one mode based on the attribute levels (direct mode choice) and four questions asked about the price that the respondent would be willing to pay in order to use the UAM by taking account the attributes of all other modes, as seen in Fig. 2. The latter question group is termed the contingent valuation (CV) technique with open-ended questions, where the respondents are asked to state how much they are willing to pay for UAM. Despite the fact that CV has often come under criticism for not measuring accurately the preferences of the respondents, it has been used in several studies in transportation (de Dios Ortúzar and Willumsen, 2011), especially to investigate trade-offs (between time and cost, safety and cost, etc.). All six responses per respondent were considered in model development. It is important to mention that each respondent viewed a unique random combination of selected scenarios. A screening question was utilised to test the suitability of the responses.


Imagine that you want to travel 30 km to or from the airport of Munich. Which mode of transport would you choose for this trip?

	Car	Public Transport	Car-sharing	Ride-hailing	UAM
In-vehicle time (Min.)	50	50	50	50	20
Waiting time (Min.)	0	15	10	5	15
Travel cost (€)	40	13	35	70	105
Availability (%)	100	100	50	100	100

Choose one of the following answers

Car

Public Transport

Car-sharing

Ride-hailing

UAM

None. I would not choose any of the above.

Other

Imagine that you want to travel 30 km to or from the airport of Munich. How much are you willing to pay to use the UAM considering all other options?

	Car	Public Transport	Car-sharing	Ride-hailing	UAM
In-vehicle time (Min.)	30	60	30	30	20
Waiting time (Min.)	0	15	20	10	30
Travel cost (€)	35	7.5	30	60	?
Availability (%)	100	100	100	50	100

Please insert an acceptable price:

Only numbers may be entered in this field.

Fig. 2. The stated preference experiment with direct choice (top) and asking the respondent for a suitable price (bottom).

3.4. Discrete choice modelling

In order to properly analyse the survey results and to estimate mode choice models, the random utility theory has been applied. Particularly, we estimated two models by introducing mixed logit (ML) methods:

Table 2
Basic design attributes and levels in the SP experiments.

Attributes 30 km	Private Car	Public Transport	Car-sharing	Ride-hailing	UAM
In-vehicle time (Min.)	30, 40, 50	40, 50, 60	30, 40,50	30, 40, 50	15, 20, 25
Waiting time (Min.)	–	5, 15	10, 20	5, 15	15, 30
Travel cost (€)	35, 40, 45	7.5, 13	30, 35, 40	60, 70, 90	60, 105, 150
Availability (%)	100	100	50, 100	50, 100	50, 100
Attributes 60 km	**Private Car**	**Public Transport**	**Car-sharing**	**Ride-hailing**	**UAM**
In-vehicle time (Min.)	50, 60, 70	60, 75, 90	–	50, 60, 70	30, 35, 40
Waiting time (Min.)	–	10, 20	–	5, 15	15, 30
Travel cost (€)	55, 60, 65	20, 25, 30	–	110, 140, 170	120, 210, 300
Availability (%)	100	100	–	50, 100	50, 100
Attributes 120 km	**Private Car**	**Public Transport**	**Car-sharing**	**Ride-hailing**	**UAM**
In-vehicle time (Min.)	90, 110, 130	105, 120, 135	–	90, 110, 130	60, 65, 70
Waiting time (Min.)	–	10, 20	–	5, 15	20, 35
Travel cost (€)	90, 100, 110	25, 30, 35	–	220, 250, 280	240, 420, 600
Availability (%)	100	100	–	50, 100	50, 100

first, a rich model incorporating travel behaviour and sociodemographic variables and, second, a simple model including only the modes' attributes, which can be used for demand estimation when individual-specific data are not available (in the Appendix). Starting with the standard multinomial logit model, the average utility of each alternative i for an individual n is defined by the random utility model (Cascetta, 2013; Train, 2009):

$$U_{in} = V_{in} + \varepsilon_{in} \text{ with } \quad V_{in} = \beta_i^T x_{in} \tag{1}$$

where U_{in} is the utility associated with each alternative i; V_{in} is the systematic part of the utility; ε_{in} is the random utility component; β_i is a vector of the estimated parameters for alternative i; and x_{in} is a vector of the observable variables considered for each alternative i. Therefore, the probability that alternative i is chosen from a choice set C_n of alternatives by individual n is:

$$P(i|C_n) = \frac{e^{V_{in}}}{\sum_j e^{V_{jn}}}, \forall j \in C_n \tag{2}$$

Moreover, to allow for random taste variation and correlation in unobserved factors over the questions (agent effect as the sample is composed of six observations per respondent), we use ML models. The ML probability takes the following form (Train, 2009):

$$P(i|C_n) = \int \left(\frac{e^{\beta_i^T x_{in}}}{\sum_j e^{\beta_j^T x_{jn}}} \right) f(\beta) d(\beta) \tag{3}$$

where $f(\beta)$ is the mixing distribution of the logit function. In this study, the alternative-specific constant of each alternative is decomposed into one deterministic (ASC_i) and one normally distributed random component with standard deviation σ_{ASC_i}. Monte-Carlo integration with 10,000 draws has been used to estimate the ML models.

Furthermore, a scaling factor for the travel cost of all modes is introduced, which converts the total trip cost to per kilometre cost and considers the deviation of the given prices from the average stated willingness to pay for UAM. This was an optional normalisation step, which, however, enhanced the interpretability of the results:

$$Cost\ factor_i = \frac{Travel\ cost_i}{\overline{WTP}_{Stated_{UAM}} * Trip\ length} \tag{4}$$

The *stated willingness to pay* $\overline{WTP}_{Stated_{UAM}}$ is the result of the direct measurement of the willingness to pay for the AirShuttle through a contingent valuation approach, after removing any outliers, as explained in section 3.3. Hence, the utility functions of the alternatives $i=1, 2 \ldots, j$ generally take the following form:

$$\begin{aligned} U_i = {} & ASC_i + \beta_{Travel\ cost_i} * Cost\ factor_i + \beta_{In-vehicle\ time_i} * In-vehicle\ time_i \\ & + \beta_{Waiting\ time_i} * Waiting\ time_i + \beta_{Availability_i} * Availability_i \\ & + \beta_{Trip\ length_i} * Trip\ length + \beta_{Travel\ behaviour_i} * Travel\ behaviour \\ & + \beta_{Sociodemographics_i} * Sociodemographics + \ldots + \sigma_{ASC_i} \end{aligned} \tag{5}$$

Finally, an important trade-off in transportation mode choice models is the value of time (VoT), i.e. the amount of money a traveller is willing to spend to save a unit of time. In this study, it is designated as the *indirect value of time*, in order to distinguish it from the direct measurement of the stated willingness to pay, and is given by the following equation (in €/hour) for linear-in-parameter model specifications:

$$VoT_i = \frac{\partial U_i / \partial InVehicle\ time_i}{\partial U_i / \partial Travel\ cost_i} * 60 = \frac{\beta_{In-vehicle\ time_i}}{\beta_{Travel\ cost_i}} * 60 \tag{6}$$

Please note that it is necessary to utilise equation (4) for the (indirect) VoT, as the utility functions of the alternatives *(5)* include a cost factor, rather than the cost directly. In this study, 'indirect' is used to distinguish the value of time (VoT) calculated through the model coefficients from the 'stated' willingness to pay (WTP) estimated directly through the answers of the respondents in the contingent valuation experiments.

4. Data collection and analysis

4.1. Case study setup and data collection

In order to explore airport passengers' preferences, Munich International Airport (MUC) and its catchment area offer an excellent case study. With 41.6 million passengers in 2024, MUC is the main international gateway of Bavaria and the second busiest airport in Germany by passenger traffic (Munich Airport, n.d.). Bavaria is the second most populous state in Germany, with over 13 million inhabitants (Statistik Bayern, n.d.). Within Bavaria, the city of Munich has 1.56 million inhabitants, whereas, in the vicinity (metropolitan region) of Munich, around six million people live, a number that is projected to rise to 6.3 million by 2030 (Stadt München, n.d.). Furthermore, seven out of the top ten communities with the highest purchasing power in Germany are concentrated in this area (Ploetner et al., 2020).

The catchment area of MUC expands southwards to the Austrian states of Salzburg and Tyrol. The former has a population of around 560 thousand (Land Salzburg, 2022) and the latter around 760 thousand (Land Tirol, n.d.). Both areas are important destinations for tourism due to their location near the Alps. Although the capital cities (Salzburg and Innsbruck, respectively) of those Austrian states have their own airports, they are less connected than MUC, with fewer destinations and highly affected by winter seasonality. On the other hand, Lufthansa, a major player in the European civil aviation market, has established a hub at MUC with many continental and intercontinental destinations. Furthermore, more than 33 thousand employees work at the premises of MUC (Munich Airport, 2022).

Currently, MUC can be reached by a multitude of different modes depending on the origin or destination (as shown in Table 2). According to the airport's latest statistical annual report (Munich Airport, 2025, p. 12), the most popular modes of access are car (as driver or passenger), public transport (rail, urban-suburban rail, city bus, and regional buses), ride-hailing services (taxi, Uber, etc.), rental cars and car-sharing (pay-per-minute and pay-per-kilometre). The main railway station and the city centre are served by two urban-suburban rail lines (S-Bahn) within 40–50 min, while the same trip can be covered within 30–60 min using road transport. For trips outside the city of Munich, car-sharing services are not available – instead, private car, public transport or ride-hailing must be used. Although public transport connections usually require a transfer at the main railway station of Munich, a regional railway service to the northeast connects the airport directly with the cities of Freising, Landshut and Regensburg. It isn't easy to estimate the travel time by road transport, as this depends heavily on the destination. For distances well over 60 km by rail, a change either in the main railway station, the east railway station of Munich or at one of the stations along the northeast railway line is required; especially from Salzburg and Innsbruck, intercity (IC and EC) services terminate at the main railway station or the east railway station of Munich and thus require a transfer to the urban-suburban trains (S-Bahn) to MUC.

An overview of the study area with the planned origins or destinations of the AirShuttle is shown in Fig. 3. As the objective of this paper is neither to study the optimal positioning of vertiports within each city nor to produce exact calculations of travel times or travel costs, only approximate locations are depicted. For the sake of simplification, we categorise roughly the origins or destinations in three travel distance groups: 30, 60 and 120 km, as mentioned in section 3.3. The survey followed an adaptive design depending on each respondent's landside trip origin or destination to the airport, with each participant seeing the questionnaire that corresponds to their distance group (30, 60 or 120 km) based on their answer to the initial question about the usual start or destination for their trips to MUC.

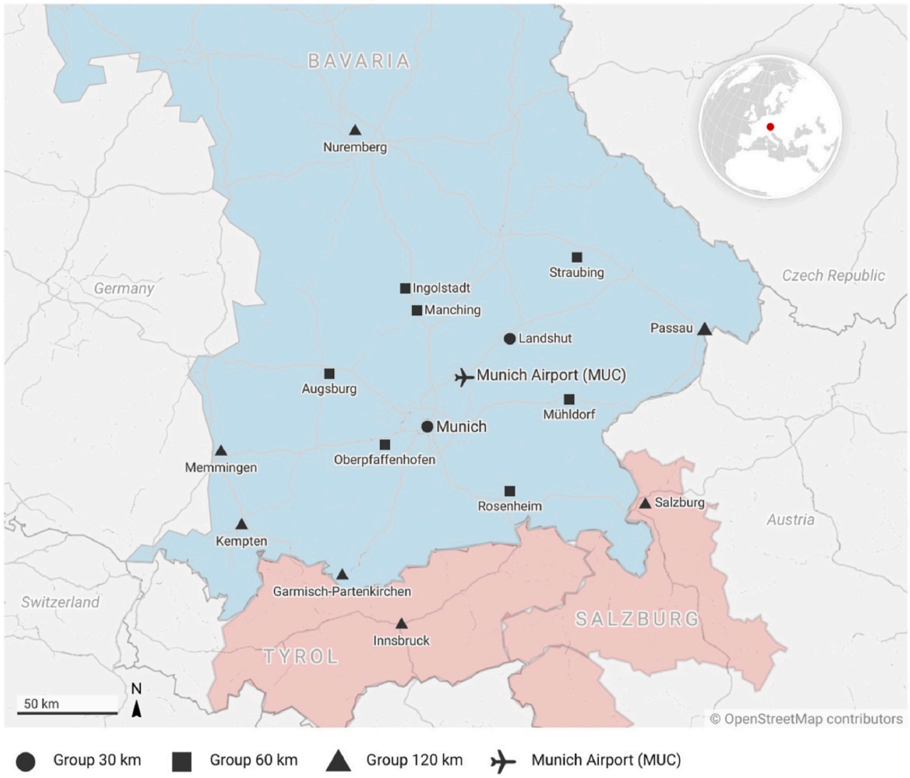


Fig. 3. Bavaria, Salzburg and Tyrol: the study area includes the clustering of cities in three distance groups (own elaboration).

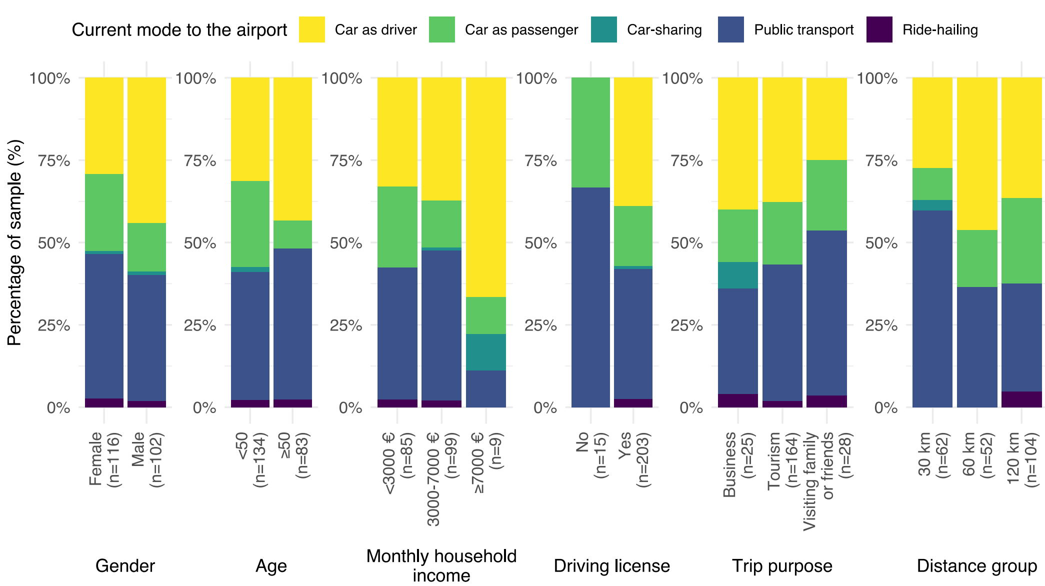


Fig. 4. Descriptive analysis of the factors influencing the current mode choice to the airport.

Responses were collected through an online panel (Bilendi GmbH) in March 2023. The survey generated 218 complete responses in total, with 148 of the respondents residing in Germany (67.9 % of the sample), 69 in Austria (31.7 % of the sample) and one in another country. The average completion time was 8.5 min, while all responses with a completion time of less than 3.3 min (one-third of the initially planned 10 min) were discarded from the sample. It is important to note that the German subsample includes respondents exclusively from Upper Bavaria, whereas the Austrian subsample comprises responses from the states of Salzburg and Tyrol. All respondents were selected by the field institute as they indicated that they use MUC for at least one roundtrip per year.

Overall, as seen in Table 3, a satisfactory representation of gender, principal occupation, place of residence (urban area or countryside), car ownership and driving license was achieved. Shortcomings in the sample can be observed with regard to the absence of respondents younger than 18 years old, who were excluded from data collection, the overrepresentation of employed people (full-time and part-time) and the overrepresentation of households with two members in comparison to the census data. The summary statistics of the collected sample are

Table 3
Sociodemographic characteristics of the total sample (Bavaria and Austria).

Indicator	Value	Sample (%) *N=218*	Bavaria (%) (2011)	Austria (%) (2022)
Sample size	Bavaria	67.9		
	Austria	31.7	–	–
	Other	0.5		
Gender	Female	53.2	51.1	50.7
	Male	46.8	48.9	49.3
Age	≤17	0	17.0	17.3
	18–29	17.0	14.5	14.0
	30–39	26.1	12.3	13.8
	40–49	18.3	16.9	13.1
	50–59	17.0	14.0	15.2
	60–69	16.5	10.8	12.4
	70–79	4.6	9.5	8.2
	≥80	0	5.0	5.9
	N/A	0.5	–	–
Occupation	Full-time employed	58.7	53.4	48.6
	Part-time employed	17.0	4.4	3.9
	Pupil, student or apprentice	4.6	3.5	–
	Housewife/ Househusband	3.2	1.8	3.9
	Unemployed	0	20.3	22.0
	Retired	15.1	16.6	7.1
	Other	0.9	–	–
	N/A	0.5		
Size of household (no. of members)	1	25.7	36.0	40.2
	2	53.7	31.4	31.7
	3	11.5	14.8	13.3
	≥4	6.0	17.8	14.7
	N/A	3.2	–	–
Monthly net household income (€)	0	0.5		
	<1000	5.0		
	1000–2000	15.6		
	2000–3000	17.9		
	3000–4000	18.8	2313.7[a]	2320.3
	4000–5000	12.8	per person	per person
	5000–6000	9.6		
	6000–7000	4.1		
	>7000	4.1		
	No answer	11.5		
Area of residence	Urban	66.5	53.0[b]	59.0[c]
	Countryside	33.0	47.0[b]	41.0[c]
	N/A	0.5	–	–
Driving license	Yes	93.1	90.0[b]	–
	No	6.9	9.0[b]	
Car ownership (per household)	0	16.1	19.0[b]	–
	1	48.6	55.0[b]	
	2	27.1	22.0[b]	
	≥3	8.3	5.0[b]	

[a] Statistik Bayern (n.d.)
[b] infas, DLR, IVT & infas 360 (2018).
[c] The World Bank (2021)

presented in Table 3 next to the latest available census data from Bavaria (Statistische Ämter des Bundes und der Länder, 2014) and Austria (Statistics Austria, 2022) unless indicated– in the cases of Salzburg and Tyrol, regional data were not readily available, and therefore, statistics on the federal level (Austria) are shown instead. This is not expected to impact the outcome of this study, as the social structure is consistent across Austria.

4.2. Data analysis

4.2.1. Current mode choices to or from the airport by sampled indicators

Among the 218 respondents, 93.1 % stated that they hold a driving license. As expected, the main mode of non-drivers (6.9 % of the sample) when accessing MUC was public transport (PT), followed by car as a passenger, meaning that a large percentage of the respondents were driven by others to the airport (Fig. 4). Furthermore, drivers considered private car alternatives first (38.9 % as a driver and 18.2 % as a passenger) before public transport (39.4 %), while the numbers of responses for ride-hailing and car-sharing were low (2.5 % and 1.0 % respectively). From data analysis by gender, it emerged that female users preferred public transport to reach the airport (44.0 %), whereas male respondents were mostly inclined to use the car as drivers (44.1 %). Based on the household income, respondents of lower (less than 3000 €/month) and middle (3000–7000 €/month) income tend to prefer PT instead of driving to the airport, although road-based modes still come first when summed. On the contrary, members of high-income households showed a clear preference towards driving (car as driver 66.7 %), although the presence of high-income respondents in the sample was rather low (n = 9). With regard to the age of the respondents, it seems that younger respondents preferred road-based modes (61.2 % car as driver, car as passenger, car-sharing and ride-hailing), while older participants were almost equally split between road-based modes (54.2 %) and PT (45.8 %).

Based on the distance classification, travellers in the vicinity of the airport, i.e. 30 km, used primarily PT (59.7 %), whereas travellers residing at longer distances from the airport, i.e. about 60 or 120 km, were more dependent on private cars as drivers or passengers (62.8 %) (Fig. 4). Further, the interviewees gave different answers regarding their mode choice depending on their trip purpose: business travellers were more inclined towards road transport (car as driver 40.0 %; car as passenger 16.0 %; car-sharing 8.0 %, ride-hailing 4.0 %), whereas tourists and travellers visiting family or friends were almost split between road modes and public transport (42.7 %). Overall, the most prominent transport modes of access to MUC were private car (as driver 36.2 %, as passenger 19.3 %) and PT (41.3 %), and a dominant alternative was apparent in most cases; only people that have no driving license were clearly inclined in favour of PT (captive riders) and respondents from high-income households decided in favour of private cars. It is important to mention that those comparisons are potentially restricted by a lack of statistical significance.

4.2.2. Satisfaction with current modes to or from the airport

The exploration of respondents' current mode choices from/to the airport of Munich showed that the differences between the various demographic segments are minor, with only very few indicators resulting in noteworthy differences (driving license, monthly household income). In the next step, the satisfaction levels of current transport modes and their pricing to reach the airport have been investigated (Fig. 5). Regarding the former, only 4.1 % and 8.7 % of interviewees were "very dissatisfied" or "dissatisfied" with their current mode choice. Almost 22.5 % of the respondents stated to be "neither dissatisfied nor satisfied", while the rest had a positive or very positive impression about that matter (64.6 % car as driver, 69.1 % car as passenger and 62.2 % PT). With respect to the cost of accessing the airport, the level of satisfaction seemed to reduce slightly. Dissatisfaction with the pricing was somewhat higher than before, with 17.0 % (total) being either "very dissatisfied" or "dissatisfied" (car as driver 20.3 %) The users of public transport seemed to be the most satisfied group (67.8 % "very satisfied" or "satisfied"), followed by passengers driven to the airport and drivers. In all cases, at least half of the respondents were either "very satisfied" or just "satisfied" with the cost of accessing the airport. In the cases of ride-hailing and car-sharing, the number of responses was very low (n = 2 and n = 5, respectively), and therefore, commenting may lead to unrobust conclusions. Generally, the existing ground access modes to Munich Airport seem to be well perceived by their passengers, which is an expected result considering the multitude of transport options (see section 4.1).

The existing high levels of satisfaction with ground access to MUC, including the high satisfaction with current prices, could impose negative implications on the success of aerial airport shuttle services. This

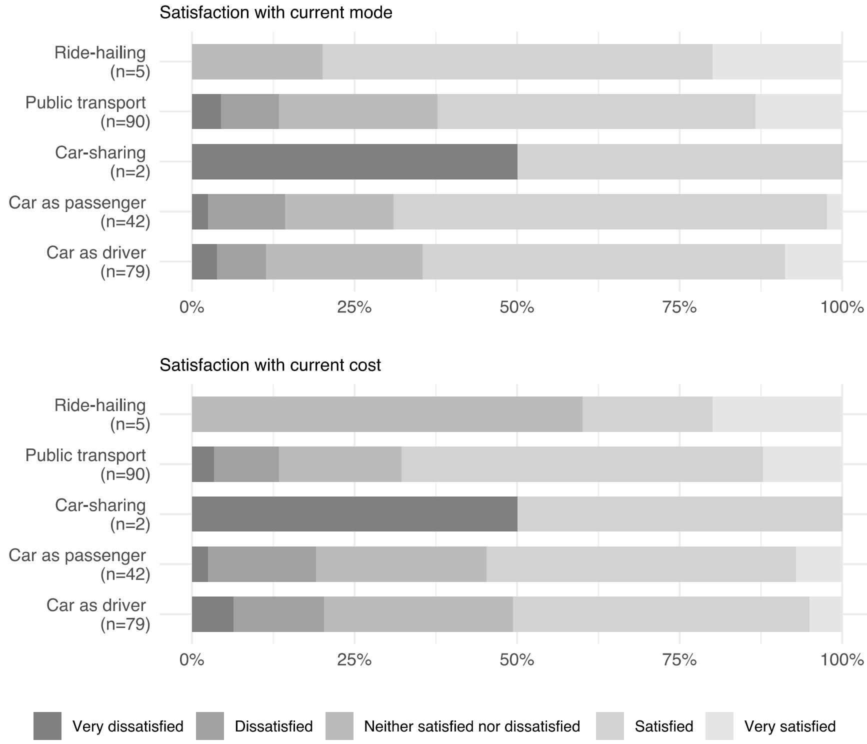


Fig. 5. Satisfaction levels with current access modes and their prices to MUC.

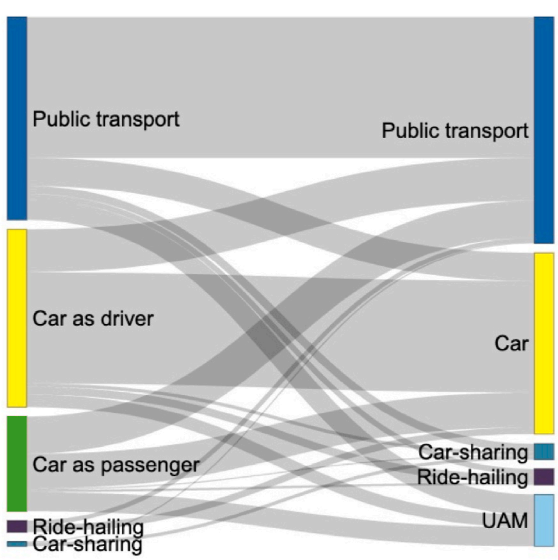


Fig. 6. Mode shift after UAM introduction.

hypothesis is supported by the early findings on potential modal shift after UAM implementation. Particularly, just 11 % of the sample decided to switch modes and exploit UAM services to reach the airport, assuming no major differences among alternative ground modes with regard to the calculated attribute levels and to the values of the attributes in reality. As can be seen in Fig. 6, the largest number of UAM users (right column) would switch from public transport or car as passenger (left column).

4.3. Stated willingness to pay for UAM

Furthermore, this study also aims to investigate the stated willingness to pay (stated WTP) for UAM, i.e. how much the respondents are ready to pay to use the aerial airport shuttle, studying the prices inserted by the respondents. A quantitative analysis of the stated WTP is displayed in Fig. 7; in order to conduct this investigation, the outliers were first systematically removed by employing the interquartile range method. Despite the low stated value of WTP for the airport shuttle (mean $\overline{WTP}_{Stated_{UAM}} = 0.84$ €/km, standard deviation 0.47 €/km), the overall observed data are almost consistent among different socio-demographic segments. Particularly, it emerged that the following segments of the sample showed a slightly higher willingness to pay: female respondents (0.86 €/km), those not in possession of a driving license (0.93 €/km), travelling for business (0.85 €/km) and in shorter distances (0.95 €/km for distances less than 30 km). Also, as it turned out, respondents with high household income (≥7000 €/month) were willing to pay a considerably higher price (1.16 €/km) than respondents with middle (3000–7000 €/month, 0.87 €/km) and lower (<3000 €/month, 0.73 €/km) household income. However, it is worth noting that the stated prices were consistently lower than those of regular taxi services (currently around 2 €/km in Munich) – this finding could have serious implications for the short-term success of UAM as an airport shuttle, assuming a cost of 4–10 €/km upon introduction and imposes questions about the positioning of this new service in the current transport market. Finally, to make the stated WTP comparable with the results of the discrete choice model, the average value was multiplied by the assumed eVTOL speed of 120 km/h, thus resulting in an average hourly stated willingness to pay of 100.8 €/h.

5. Model specification and estimation

The survey results have been used to estimate two panel-data mixed logit (ML) mode choice models using the open-source package Biogeme (Bierlaire, 2023). The models were estimated after removing the alternatives ride-hailing and car-sharing, as the frequency of their occurrence in the sample was low (14 observations each, i.e. 1.1 % of the sample each). Similarly, the ‘None. I would not choose any of the above.’ and ‘Other’ alternatives were excluded because they were not selected by any of the respondents. In particular, the three mode alternatives (Car,

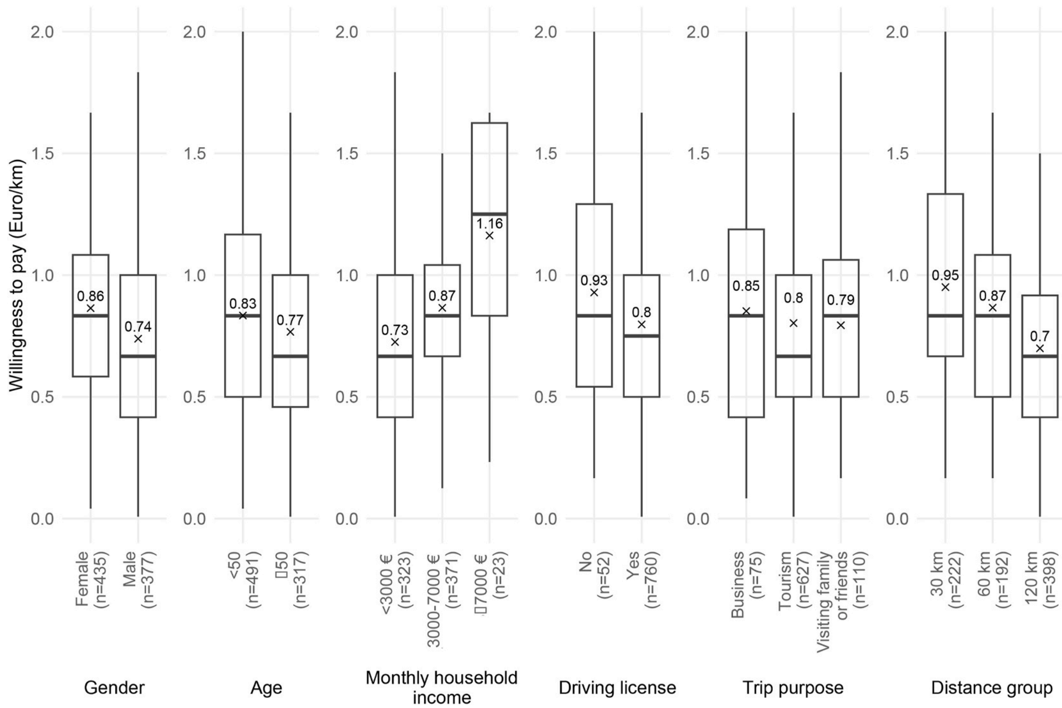


Fig. 7. Sample stated willingness to pay (€/km) for an aerial airport shuttle.

PT and UAM) have been explored through an ML model explaining attributes that are specific to each transport mode (i.e. travel cost, in-vehicle time, waiting time, trip length and availability), introducing individual-specific variables that describe the established travel behaviour to and from the airport of Munich and associating the sociodemographic attributes of the respondents with the available modes. A reduced version of the model is included in the Appendix, which omits the variables related to the current travel behaviour of the respondents and their sociodemographic characteristics, thus making it easier to apply in data scarcity. The ML models consider the serial correlation due to the panel structure of the data during model estimation. All reported estimation results include statistically significant coefficients at a 10 % significance level, with the alternative-specific attributes having been scaled (reduced) by a factor of 100. The following section interprets and explains the values of the parameters in the first ML model in relative terms.

To account for the repeated choices from each individual (serial correlation) in the stated preference experiment, we developed a panel data mixed logit (ML) model. Such models estimate random taste variation and correlation in unobserved factors across individuals by introducing normally distributed alternative-specific error components that explore how the perceptions of the same options may vary across individuals, i.e. by

Table 4
Panel-data mixed logit mode choice model (ML model).

ML model	Ground Modes				Urban Air Mobility	
	Car		Public Transport		AirShuttle	
Parameters (β_i)	Value	Rob. *t*-stat.	Value	Rob. *t*-stat.	Value	Rob. *t*-stat.
ASC	8.11***	4.45	–	–	8.77***	6.06
Travel cost	−6.36***	−5.44	−6.36***	−5.44	−2.48***	−8.02
In-vehicle time	−7.98***	−6.26	−4.28***	−3.82	−4.28***	−3.82
Waiting time	–	–	–	–	−6.79***	−4.22
Travel behaviour						
Car ownership	–	–	–	–	−1.28*	−1.84
Previous mode$_{Car}$	1.26*	1.85	–	–	–	–
Previous mode$_{PT}$	–	–	4.11***	4.31	1.98**	2.56
Business trip	–	–	–	–	1.83**	2.38
Sociodemographics						
Age$_{\geq 50}$	–	–	–	–	−0.94**	−2.33
Household income$_{<3000\ €}$	–	–	–	–	−0.76*	−1.93
Household income$_{\geq 7000\ €}$	–	–	–	–	3.33**	2.14
σ_{ASC}	2.47***	5.56	2.55***	5.45	–	–
Summary of statistics						
No. of observations		1280				
LL (0)		−1406.22				
LL (final)		−476.53				
Adj. Rho-square (0)		0.65				
AIC		987.05				
BIC		1044.59				

Value of Time (approx.): 51 *€/h* (Car), 27 *€/h* (Public Transport), 70 *€/h* (AirShuttle).
Note that equation (4) from section 3.4 is necessary to estimate the VoT.
Significance levels (Rob. *p*-value): 0 '***' 0.01 '**' 0.05 '*' 0.1.

considering the individuals' tastes (Hensher et al., 2008; Train, 2009). In particular, due to the panel structure of the dataset, ML model treats the coefficient variation over users, even if it is constant over the choice conditions for each person. In the specification of the ML model (Table 4), a normally distributed alternative-specific error component (σ_{ASC}) per alternative tries to capture the serial correlation in the observations from each respondent. There are highly significant distributed error terms for private car and public transport, although in the case of UAM, only the constant component of the error term was found to be significant. Nonetheless, this output reveals that there is indeed heterogeneity between the individuals in the sample, which could not be measured by the survey and is modelled through the error terms.

The model coefficients are mostly reasonable in sign and magnitude and consistent with prior expectations (Table 4). Increases in travel costs are considered more negative in traditional transport modes (−6.36) than the UAM AirShuttle (−2.48). Similarly, the in-vehicle time in public transport and UAM is more enjoyable than the time spent driving a car (−4.28 vs. −7.98) due to the opportunity to use any in-vehicle time productively or with entertainment. Interestingly, the waiting time for UAM is evaluated more negatively (−6.79) than the in-vehicle time (−4.28); the potentially long access time, the mandatory check-in procedures and security checks that occur before boarding the eVTOL could lead to significant time losses and consecutively to a loss in the competitiveness of the AirShuttle. In contrast, the availability of UAM did not prove to be significant, although it is planned as a reliable on-demand service to the airport, thus requiring high levels of availability throughout the day. The trip distance did not prove to be a significant determinant of mode choices in any of the modes.

Regarding the travel behaviour of individuals and their sociodemographic data, the model includes parameters about age (greater than or equal to 50 years), household income of users, car ownership, the previous modes used to reach the airport and the trip purpose. Among the usual trip purposes investigated in this study, business travellers seemed to prefer UAM (1.83) compared to private car and public transport. People who usually drive (or are driven) to the airport were rather willing to continue doing so, as shown by the positive coefficient for car (1.26) and the lack of significance for UAM. Likewise, public transport riders were more likely to adhere to their previous choice (4.11) than to switch to UAM (1.98) to reach the airport of Munich. The respondents' corroboration of their established way of accessing the airport confirms the data in Fig. 5, which shows that the current transport modes are considered satisfactory. Although unexpected, no significant relationship between a subscription to public transport and the use of public transport to access the airport could be established. This could be partially explained by the zonal structure of public transport tariff systems in Germany and Austria, which usually require a high ticket supplement to reach the airport, or by the fact that connections from urban or suburban areas require a special rate. Also, having a driving license did not have a significant impact on any of the modes, although it was expected to positively influence the utility of car. This result could be related to the well-developed railway network around the area of Munich airport, where drivers can potentially choose PT and save the expensive parking fees at the airport (which were not considered extensively in the survey design, as shown in Table 2). Similarly, a significantly negative relationship was found between car ownership and the AirShuttle (−1.28) but not between car ownership and the use of cars, confirming the special nature of airport trips.

Furthermore, the ML model integrated variables that describe the sociodemographic background of the respondents. Respondents aged 50 years old and above were less likely to replace their current mode with UAM (−0.94) than their younger counterparts. The household income was found to be crucial for the choice of UAM, as demonstrated by the highly positive coefficient for monthly net income of 7000 € or more (3.33), in contrast to lower income levels (less than 3000 € per month), which results in higher UAM disutility (−0.76) for this population segment. Thus, respondents of higher income levels are more likely to use the AirShuttle for their airport access and egress trips than respondents with lower income. With regards to gender, no significant effects were observed, confirming the findings of Fu et al. (2019), who identified no difference between male and female respondents in the adoption of an automated flying taxi. In contrast, this result contradicts the findings of Al Haddad et al. (2020), who found that females tend to be more conservative than males in early and long-term adoption of UAM while also being less interested in the new service.

The satisfaction indices from Fig. 5 could also be integrated into the modelling framework. However, as one of our future goals is to apply the mode choice models in demand forecasting for the AirShuttle, only attributes of the population that are usually measured by statistics agencies or by household travel surveys (e.g. car ownership, usual mode choices, trips purpose, age, gender, income) have been considered. The satisfaction with the current mode choices to the airport is usually not captured in those statistics and thus would make the generalisation of the model's findings a difficult task.

A simplified version of the model can be seen in Table 5 (Appendix). This model includes only the attributes of the modes, and any variables related to the travel behaviour of the respondents and their sociodemographic background were omitted. The magnitude of the coefficients is very similar to the previous model, and the model also includes significant panel effects, as expected. Its advantage is that the model can be used even when details about the population are absent.

6. Discussion and policy insights

6.1. Mode choice models and sociodemographic parameters

Interesting results emerged from the analysis of the proposed model. Based on the alternative-specific constants (ASC), the car and the AirShuttle were almost equal, which means that the same person would have almost the same preference for UAM and the private car, all other attributes being equal. However, this finding should be interpreted with caution, as the survey was structured in such a way that biased answers in favour of UAM may have been possible (see the comments about contingent valuation in section 3.2). The experimental design, where respondents were asked how much they were willing to pay to use UAM after considering the attributes of all other modes (Fig. 2), may have led to uncertain answers and unrealistic expectations. Carrying out an SP survey while the UAM alternative has yet to exist requires a detailed description of this new mode, thus devoting space disproportionally between the modes (as the other alternatives were mostly known to the respondents). Despite that, the answers of potential users could still include some bias due to the lack of knowledge about the proposed service. An attention check question was utilised to examine whether the user was paying attention to the experiment.

A common outcome among transportation mode choice models is the influence of the in-vehicle time on mode choice. In particular, UAM was modelled as a mode with characteristics similar to PT, as the travellers will be able to spend their time productively or with entertainment during the trip. As expected, the respondents valued the in-vehicle time of UAM and PT less negatively than the in-vehicle time of the car, which, as a mode, requires the attention of the driver and, therefore, precludes any other activity. Considering that those findings could be related to typical passengers' behaviour who want to avoid missing their scheduled flight (Tam et al., 2008), the AirShuttle could be perceived as a positive travel choice alternative, as its flight time is more predictable (and shorter) than travel time on the ground due to congestion, accidents, or other unpredictable time losses. Still, the coefficient values in favour of PT reflect the statistical analysis, which expressed the respondents' preference for public transport in the study area. On the contrary, the waiting time variable referring to UAM has a strong negative influence on AirShuttle's utility, which could be a bias related to the lack of consistent information about the waiting time before UAM flights. It became apparent that users with higher income are inclined to choose UAM services and, therefore, could be one target sociodemographic segment. Finally, respondents who currently access the airport by car are more likely to continue using the car than shifting to AirShuttle, and accordingly, respondents using PT are more likely to continue using PT than flying in a UAM. Based on the models, it is possible to outline a preliminary profile of users that could utilise the AirShuttle service to/from MUC, close to our expectations: users younger than 50 years, travelling for business reasons, with high household income.

Since one of the main objectives of this study was to estimate the willingness to pay, it was decided to explore the VoT based on the ML model. Thus, using the statistically significant coefficients of in-vehicle time and cost, the Value of Time (VoT) has been approximated for each choice alternative. From the results, it emerges that the VoT of travellers using the car is high (51 €/hour), demonstrating that users are still willing to pay high prices to be able to travel independently and avoid being tied to a schedule. Regarding PT, the VoT obtained (27 €/hour) is more in line with previous results in the same study area (e.g. Fu et al., 2019), also confirming that PT is a competitive choice within the catchment area of MUC due to its coverage and availability. The VoT of UAM – estimated at 70 €/hour– raises expectations that respondents may be more willing to pay higher fares than PT to use innovative and fast air services to reach the airport. This value is comparable to the work of Coppola et al. (2024), who found a median of 69 €/hour for airport access and egress with UAM in Milan, Italy. The high VoT may be justified by the higher temporal importance of airport ground access and by the high income levels of the sample in the Munich metropolitan area. As discussed in section 4.3, each respondent also directly specified their willingness to pay to use UAM (average stated WTP of 100.8 €/hour), with the result being higher than the respective VoT estimated by the ML model. This reveals the bias of the respondents when confronted with direct questions and may also underscore the limitations of our survey design stemming from questions where the exact travel cost of UAM was given by the respondent (contingent valuation).

6.2. Implications for industrial stakeholders

Assuming that the proposed methodology yields a representative approximation of the willingness of potential UAM users to pay, we observe a consistently low stated willingness to pay. The average stated price of 0.84 €/km is lower than the price tag that stakeholders in the UAM ecosystem are expected to charge upon the introduction of the service (4–10 €/km). Additionally, the stated price is lower than that of regular taxi services (currently around 2 €/km in Munich), indicating that the survey respondents could have underestimated the cost of airport access. Still, UAM services in the short term may be overpriced relative to the travel time savings they offer. It is worth mentioning that other studies about the introduction of UAM in Munich and the surrounding areas have consistently assumed a higher price, e.g. 0.2–2.4 €/km plus 30 € in Straubinger et al. (2021) or 3 €/km by Porsche Consulting (2018), whereas Ploetner et al. (2020) have estimated that the service is expected to achieve a small profit at 4.94 €/km. This implies that costs are expected to fall in the long term, potentially capturing higher demand, although those price levels are not likely to approach the average stated value of 0.84 €/km.

Despite the anticipation of industry stakeholders and the local administration that UAM is going to expedite and simplify airport access, this aligns differently from the viewpoint of travellers to and from the airport of Munich. There is a strong indication that the already existing options cater well for most of the respondents in our survey; almost 85 % of the respondents stated that they are 'very satisfied, satisfied or neutral' with the current means of access, while more than 80 % of the respondents were also satisfied (or neutral) with the cost of those modes (Fig. 5). Furthermore, the estimated mode choice model has shown that travellers are likely hold on to their existing mode choices rather than switch to UAM. Additionally, the expected time savings after waiting and boarding time are limited based on the basic design attributes and levels of our experiment (Table 2), designed on rational assumptions and exchange with industrial stakeholders. Therefore, further effort should be invested in discovering a market niche which is not well served by the existing modes and, as a result, could provide higher, unexploited demand. These findings confirm the concluding remarks of Rimjha et al. (2021a) that UAM requires a dense network of vertiports so as to minimise time losses due to access and egress and low fares for sufficient demand, and the conclusions of Ploetner et al. (2020), who underlined that minimising time loss is an important factor for the success of the service.

Although the scope of this study is limited to the factors that contribute to UAM demand forecasting, while at the same time ignoring important aspects of operations, some recommendations can still be formulated. The results have shown that a potential UAM passenger could be younger than fifty years old, with a high household income and travelling on a business trip. As it became apparent in the ML model (Table 4), respondents seemed to decide in favour of their established mode choices even after the introduction of UAM. However, most results were in accordance with our expectations and prior findings. As a consequence of the observations above, stakeholders from the industry should either refer to the aforementioned population segments upon introduction in order to maximise the utilisation of UAM or try to persuade the population segments that seemed to ignore the new service.

6.3. Implications for policymakers

An important finding of this study concerns satisfaction with the current modes. The airport of Munich is seen as an accessible airport in a relatively large geographical area, while this relates not only to the available options per se but also to the current price levels. On the other hand, UAM is introducing a new mode that targets travellers of high income, who are also willing to pay higher prices to save time and avoid the traditional transport modes. However, the observed discrepancy between the stated willingness to pay of the respondents and the price assumed by industrial stakeholders suggests that this system might not introduce significant changes in the status quo of airport access in the short term. Although many hail UAM as a solution to congestion problems in major cities, other researchers have previously shown that only a small percentage of trips could be replaced by UAM (Pukhova et al., 2021) unless a very high number of vertiports is installed. Nonetheless, the technology developed for UAM could be utilised as an environmentally sustainable alternative to conventional helicopters (Rothfeld et al., 2021).

Furthermore, several other factors could prove important for planning and operating UAM services. As Al Haddad et al. (2020) mentioned, important concerns arise about the noise and visual impact of eVTOLs in densely populated areas, as well as about the community acceptance of low-altitude aviation. Moreover, an issue could be integrating UAM into the existing transportation systems to establish effortless transfers and minimise time losses (Wang and Qu, 2023). Similarly, the issue of vertiport siting seems to play a paramount role in the UAM ecosystem (Straubinger et al., 2020), while pricing strategies and land requirements seem to impact social welfare, either positively in highly skilled households or negatively in low-skilled households (Straubinger et al., 2021). Strategic concerns can be associated with managing airspace above inhabited areas (Brunelli et al., 2022) and integrating UAM operations in close proximity to airports (Vascik et al., 2021). Therefore, policymakers may have to face many challenges before the introduction of UAM (Cohen et al., 2024).

As such, the findings of this study could be further useful when introducing UAM into simulation models that enable an evidence-based evaluation of the aforementioned concerns, thus resulting in policy recommendations. For instance, the developed mode choice models can be incorporated into agent-based simulations, as previously seen in Rothfeld et al. (2021), which allow for capturing interactions not only among UAM passengers but also between passengers of different transport systems. Additionally, a simulation platform can model the long-term behavioural changes of the travellers within the study area, through iterations in learning by the agents, and the impact of introducing UAM on the environment (e.g. greenhouse gas emissions and noise), accessibility, social welfare and other indicators can be assessed (Ditta and Postorino, 2023). Also, the simulation framework can investigate UAM pricing schemes and charging strategies for eVTOLs, thus providing useful insights to local governments regarding technology investment and infrastructure planning.

6.4. Study limitations

The proposed methodology enabled a macroscopic investigation of UAM as an airport shuttle but posed several limitations. In preference surveys where respondents lack experience with the proposed alternatives, as is the case with UAM, bias can influence the accuracy of the responses due to the description of the alternatives, the selection of participants and the uncertainty stemming from the survey's design. We attempted to counterbalance bias by selecting respondents with diverse sociodemographics, using a random design in the survey and placing the sociodemographic questions and the attitudinal statements after the stated preference experiments. Furthermore, we developed a relatively simple design that aimed at ensuring accessibility and transparency for the respondents. It can still be argued that the omitted modes (for example, private transfers) could capture an important share of traffic to and from the airport, or that omitted service attributes (e.g. number of transfers, existence of many co-passengers, delay probability) could have influenced the findings. Additionally, the resulting data was imbalanced with regard to the choice frequency of each mode. It is important to mention that different operational characteristics (such as trespassing of airport security checks for UAM passengers) are expected to impact the demand for AirShuttle. Lastly, an important limitation of SP surveys is the gap between the intentions and the future actions of the respondents, i.e. it is not certain that the actions of travellers will reflect the stated decisions in this survey.

7. Conclusions

In this study, a framework was presented to assess the mode choices of individuals for ground access trips to the airport of Munich and to analyse their preferences after the introduction of an aerial airport shuttle (UAM). The first aspect focuses on satisfaction levels with the currently available transport modes and their respective cost. The second aspect is centred on the stated willingness to pay for an AirShuttle based on the direct responses of the survey participants. In the third and last focal point of this study, we develop mode choice models that consider the short-term introduction of UAM, aiming to find relevant factors that could potentially play a role in the choices of individuals while placing an emphasis on the current travel behaviour and the sociodemographics of the sample. To this aim, we disseminated a stated preference (SP) survey through an online panel in Bavaria (Germany) and the two neighbouring states in Austria, namely Salzburg and Tyrol. The survey included questions about the established travel behaviour of the respondents, their sociodemographic background and their transportation choices when travelling to and from the airport of Munich. As we observed that a very low percentage of individuals selected UAM during the pilot experiments, a part of the SP questions was inverted by asking the respondents directly how much they were willing to pay to travel to the airport in an eVTOL. The collected sample of 218 respondents was first analysed for its representativeness of the population structure with regard to the sociodemographic characteristics of the study area. Thereafter, satisfaction with the existing transport modes to and from the airport of Munich was investigated while also focusing on satisfaction with the current price levels (prior to the introduction of UAM). In the final part of the methodology, mixed logit transportation mode choice models were developed in order to investigate which factors were considered by the respondents during the stated preference experiments.

Overall, the results challenge the idea of an aerial airport shuttle (based on the eVTOL technology) from urban and rural areas surrounding the airport up to a radius of approximately 120 km. First and foremost, the participants of the survey reported high levels of satisfaction with the currently available modes of transport, with the results being consistent across different modes, even when considering the out-of-pocket cost of using those modes. With regard to the direct (stated) measurement of the willingness to pay for UAM, it turns out that there is a difference between the expectations of the industry stakeholders and those of potential users, a fact that could challenge the success of UAM in the early stages of operations. Moreover, the modelling results confirmed that the in-vehicle time, the travel cost and the waiting time are important attributes that determine the mode choice – an observation that is widely shared with existing research. Variables of socio-demographic importance, such as age and income, as well as variables that describe the existing travel behaviour of the respondents, such as the trip purpose, the possession of a driving license and the habitual use of a car or public transport, also explain the choice of mode with UAM.

Based on the findings that were summarised in the previous paragraph, this work delivers valuable insights to industrial stakeholders and policymakers. By considering the direct (stated) measurement of the willingness to pay, the expectations of potential passengers and UAM stakeholders seem to differ as the average value of 0.84 €/km is generally lower than the price assumed in relevant research (Ploetner et al., 2020; Fu et al., 2019) or anticipated by the industrial stakeholders of UAM. As a result, policymakers may not expect significant changes with regard to airport access in the coming years, although it is important to note that this study focused only on the expectations of customers under rational assumptions.

Despite the interesting findings, this work came with important limitations that need to be investigated in subsequent studies. In the future, a more comprehensive study may either confirm or reject the current findings, considering the relatively simple design of the current survey. Emphasis should also be placed on the reasons why most respondents did not select UAM, unless they were forced by survey design, and which features would make the service more compelling. It would also be interesting to study the relationship between the VoT and airport access/egress. Additionally, business travellers' profiles should be investigated further, as they constitute the target sociodemographic of the potential UAM users. Finally, a subsequent iteration could focus on integrating psychometric indicators such as the perceptions and attitudes of respondents about current topics in aviation.

CRediT authorship contribution statement

Filippos Adamidis: Writing – review & editing, Software, Formal analysis, Visualization, Investigation, Conceptualization, Writing – original draft, Methodology, Data curation. **Chiara Caterina Ditta:** Writing – original draft, Investigation, Writing – review & editing, Methodology, Conceptualization, Software, Formal analysis. **Hao Wu:** Visualization, Investigation, Writing – original draft, Methodology, Writing – review & editing, Project administration, Conceptualization. **Maria Nadia Postorino:** Resources, Supervision. **Constantinos Antoniou:** Writing – review & editing, Project administration, Funding acquisition, Resources, Investigation, Supervision, Methodology, Conceptualization.

Declaration of competing interest

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

Acknowledgement

This study has received funding from the Air Mobility Initiative (AMI) project AirShuttle (Grant number HAM-2109-0006), supported by the Bavarian Ministry of Economic Affairs, Regional Development and Energy.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.tranpol.2025.07.027.

Appendix B

Table 5
Panel-data mixed logit model with basic parameters.

Basic ML model	Ground Modes				Urban Air Mobility	
	Car		Public Transport		AirShuttle	
Parameters (βi)	Value	Rob. *t*-stat.	Value	Rob. *t*-stat.	Value	Rob. *t*-stat.
ASC	6.96***	3.83	0	-	6.31***	6.01
Travel cost	−6.82***	−5.53	−6.82***	−5.53	−2.56***	−7.78
In-vehicle time	−8.19***	−6.24	−4.89***	−4.14	−4.89***	−4.14
Waiting time	–	–	–	–	−6.50***	−3.94
σ_{ASC}	3.09***	5.67	3.20***	5.85	–	–
Summary of statistics						
No. of observations	1280					
LL(0)	−1406.22					
LL(final)	−522.19					
Adj. Rho-square (0)	0.62					
AIC	1062.37					
BIC	1092.83					

Significance levels (Rob. *p*-value): 0 '***' 0.01 '**' 0.05 '*' 0.1.

Data availability

Data can be made available on request for reasonable purposes.

References

ADAC, 2022. Autokosten aller Modelle von A bis Z [Car costs for all models from A to Z]. https://www.adac.de/rund-ums-fahrzeug/auto-kaufen-verkaufen/autokosten/uebersicht/.

Ahluwalia, R.K., Peng, J.K., Wang, X., Papadias, D., Kopasz, J., 2021. Performance and cost of fuel cells for urban air mobility. Int. J. Hydrogen Energy 46 (74), 36917–36929.

Ahmed, S.S., Fountas, G., Eker, U., Still, S.E., Anastasopoulos, P.C., 2021. An exploratory empirical analysis of willingness to hire and pay for flying taxis and shared flying car services. J. Air Transport. Manag. 90, 101963.

Airbus. (n.d.). CityAirbus NextGen. Retrieved May 1, 2023, from https://www.airbus.com/en/innovation/low-carbon-aviation/urban-air-mobility/cityairbus-nextgen.

Al Haddad, C., Chaniotakis, E., Straubinger, A., Plötner, K., Antoniou, C., 2020. Factors affecting the adoption and use of urban air mobility. Transport. Res. Pol. Pract. 132, 696–712.

Antcliff, K.R., Moore, M.D., Goodrich, K.H., 2016. Silicon valley as an early adopter for on-demand civil VTOL operations. In: 16th AIAA Aviation Technology, Integration, and Operations Conference, p. 3466.

Asmer, L., Pak, H., Prakasha, P.S., Schuchardt, B.I., Weiand, P., Meller, F., Torens, C., Becker, D., Zhu, C., Schweiger, C., Volkert, A., Jaksche, R., 2021. Urban air mobility use cases, missions and technology scenarios for the HorizonUAM project. In: AIAA Aviation 2021 Forum, p. 3198.

Balac, M., Rothfeld, R.L., Hörl, S., 2019a. The prospects of on-demand urban air mobility in Zurich, Switzerland. In: 2019 IEEE Intelligent Transportation Systems Conference (ITSC), pp. 906–913. IEEE.

Balac, M., Vetrella, A.R., Rothfeld, R., Schmid, B., 2019b. Demand estimation for aerial vehicles in urban settings. IEEE Intel. Trans. Syst. Mag. 11 (3), 105–116.

Bauranov, A., Rakas, J., 2021. Designing airspace for urban air mobility: a review of concepts and approaches. Prog. Aero. Sci. 125, 100726.

Bierlaire, M., 2023. A Short Introduction to Biogeme. EPFL, ENAC. Technical report TRANSP-OR 230620. Transport and Mobility Laboratory.

Binder, R., Garrow, L., German, B., Mokhtarian, P., Daskilewicz, M., Douthat, T., 2018. If you fly it, will commuters come? Predicting demand for eVTOL urban air trips. In: AIAA Conference, pp. 1–41. Atlanta, Georgia.

Blade. (n.d.). Get to the airport in 5 minutes. Retrieved May 08, 2023, from https://www.blade.com/airport.

Brunelli, M., Ditta, C.C., Postorino, M.N., 2023. SP surveys to estimate airport shuttle demand in an urban air mobility context. Transp. Policy 141, 129–139.

Brunelli, M., Ditta, C.C., Postorino, M.N., 2022. A framework to develop urban aerial networks by using a digital twin approach. Drones 6 (12), 387.

Bulusu, V., Onat, E.B., Sengupta, R., Yedavalli, P., Macfarlane, J., 2021. A traffic demand analysis method for urban air mobility. IEEE Trans. Intell. Transport. Syst. 22 (9), 6039–6047.

Cascetta, E., 2013. Transportation Systems Engineering: Theory and Methods, vol. 49. Springer Science & Business Media.

Choi, J.H., Park, Y., 2022. Exploring economic feasibility for airport shuttle service of urban air mobility (UAM). Transport. Res. Pol. Pract. 162, 267–281.

Clothier, R.A., Greer, D.A., Greer, D.G., Mehta, A.M., 2015. Risk perception and the public acceptance of drones. Risk Anal. 35 (6), 1167–1183.

Cohen, A., Shaheen, S., 2021. *Urban air mobility: opportunities and obstacles.* International encyclopedia of transportation. Trans. Sustain. Res. Center. UC Berkeley. https://escholarship.org/uc/item/0r23p1g.

Cohen, A.P., Shaheen, S.A., Farrar, E.M., 2021. Urban air mobility: history, ecosystem, market potential, and challenges. IEEE Trans. Intell. Transport. Syst. 22 (9), 6074–6087.

Cohen, A., Shaheen, S., Wulff, Y., 2024. Planning for advanced air mobility. https://www.planning.org/publications/report/9286262/.

Coppola, P., De Fabiis, F., Silvestri, F., 2024. Urban air mobility (UAM): airport shuttles or city-taxis? Transp. Policy 150, 24–34.

de Dios Ortúzar, J., Willumsen, L.G., 2011. *Modelling Transport* (4th ed.). John Wiley & Sons.

Ditta, C.C., Postorino, M.N., 2023. Three-dimensional urban air networks for future urban air transport systems. Sustainability 15 (18), 13551.

EASA, 2021. Study on the societal acceptance of urban air mobility in Europe. https://www.easa.europa.eu/sites/default/files/dfu/uam-full-report.pdf.

EASA. (n.d.). Vertiports in the urban environment. Retrieved May 08, 2023, from https://www.easa.europa.eu/en/light/topics/vertiports-urban-environment.

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.

Fu, M., Straubinger, A., Schaumeier, J., 2022. Scenario-based demand assessment of urban air mobility in the greater munich area. J. Air Transport. 30 (4), 125–136.

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.

Hawkins, A.J., 2017. Watch this all-electric 'flying car' take its first test flight in Germany. https://www.theverge.com/2017/4/20/15369850/lilium-jet-flying-car-first-flight-vtol-aviation-munich.

Hensher, D.A., Rose, J.M., Greene, W.H., 2008. Combining RP and SP data: biases in using the nested logit 'trick'–contrasts with flexible mixed logit incorporating panel and scale effects. J. Transport Geogr. 16 (2), 126–133.
Hill, B.P., DeCarme, D., Metcalfe, M., Griffin, C., Wiggins, S., Metts, C., Bastedo, B., Patterson, M.D., Mendonca, N.L., 2020. UAM vision concept of operations (ConOps) UAM maturity level (UML) 4 – version 1.0. https://ntrs.nasa.gov/api/citations/20205011091/downloads/UAM%20Vision%20Concept%20of%20Operations%20UML-4%20v1.0.pdf.
Hoffmann, R., Pereira, D.P., Nishimura, H., 2023. Security viewpoint and resilient performance in the urban air mobility operation. IEEE Open J. Syst. Eng. 1, 123–138..
infas, DLR, IVT & infas 360. (2018). Mobilität in Deutschland (im Auftrag des BMVI) [Mobility in Germany]. Federal Ministry of Digital and Transport, Bonn, Germany. https://www.mobilitaet-in-deutschland.de/archive/pdf/MiD2017_Ergebnisbericht.pdf.
International Civil Aviation Organization (ICAO). (n.d.). The world of air transport in 2019. https://www.icao.int/annual-report-2019/Pages/the-world-of-air-transport-in-2019.aspx#:~:text=According%20to%20ICAO%27s%20preliminary%20compilation,a%201.7%20per%20cent%20increase.
Introducing Uber Copter, 2019. Uber blog. https://www.uber.com/blog/new-york-city/uber-copter/.
Karami, H., Abbasi, M., Samadzad, M., Karami, A., 2024. Unraveling behavioral factors influencing the adoption of urban air mobility from the end user's perspective in Tehran–A developing country outlook. Transp. Policy 145, 74–84.
Land Salzburg, 2022. Bevölkerung im Land Salzburg [Population in the state of Salzburg]. https://www.salzburg.gv.at/statistik_/Documents/Publikationen%20Statistik/statistik-bevoelkerung_2022.pdf.
Land Tirol. (n.d.). Bevölkerung in Tirol [Population in Tyrol]. Retrieved April 7, 2023, from https://www.tirol.gv.at/statistik-budget/statistik/wohnbevoelkerung/.
Mayakonda, M., Justin, C.Y., Anand, A., Weit, C.J., Wen, J., Zaidi, T., Mavris, D., 2020. A top-down methodology for global urban air mobility demand estimation. In: AIAA AVIATION 2020 FORUM, p. 3255.
Munich Airport, 2025. *Statistischer jahresbericht 2024* [annual statistical report 2024]. Retrieved May 20, 2025, from. https://www.munich-airport.de/_b/0000000000000031396273bb67eb884b/Statistischer-Jahresbericht-2024.pdf.
Munich Airport, 2022. *Campusweite Firmen- und Beschäftigtenerhebung 2021* [Campus-wide company and employee survey 2021]. https://www.munich-airport.de/campusweite-firmen-und-beschaeftigtenerhebung-2021-5684185.
Munich Airport. (n.d.). Traffic figures. Retrieved May 20, 2025, from https://www.munich-airport.com/traffic-figures-263342.
NASA, 2018a. *Urban air mobility (UAM) market study* (NASA document ID 20190001472). Technical Report commissioned to Booz Allen Hamilton. https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20190001472.pdf.
NASA, 2018b. *Urban air mobility (UAM) market study* (NASA document ID 20190002046). Tech. Rep. comm. Crown Consult. McKinsey & Co. https://ntrs.nasa.gov/api/citations/20190002046/downloads/20190002046.pdf.
National Academies of Sciences, Engineering, and Medicine, 2024. Risks related to emerging and disruptive transportation technologies: a guide. https://nap.nationalacademies.org/catalog/27842/risks-related-to-emerging-and-disruptive-transportation-technologies-a-guide.
Noussan, M., Hafner, M., Tagliapietra, S., 2020. The evolution of transport across world regions. The Future of Transport Between Digitalization and Decarbonization: Trends, Strategies and Effects on Energy Consumption, pp. 1–28.
Park, J., Kim, S., Suh, K., 2018. A comparative analysis of the environmental benefits of drone-based delivery services in urban and rural areas. Sustainability 10 (3), 888.
Ploetner, K.O., Al Haddad, C., Antoniou, C., Frank, F., Fu, M., Kabel, S., Llorca, C., Moeckel, R., Moreno, A.T., Pukhova, A., Rothfeld, R., Shamiyeh, M., Straubinger, A., Wagner, R., Zhang, Q., 2020. Long-term application potential of urban air mobility complementing public transport: an upper Bavaria example. CEAS Aero. J. 11, 991–1007.
Porsche Consulting, 2018. The future of vertical mobility: sizing the market for passenger, inspection, and goods services until 2035. Available at: https://www.porsche-consulting.com/en/press/knowledge/the-future-of-vertical-mobility/.
Pukhova, A., Llorca, C., Moreno, A., Staves, C., Zhang, Q., Moeckel, R., 2021. Flying taxis revived: can urban air mobility reduce road congestion? J. Urban Mob. 1, 100002.
Rimjha, M., Hotle, S., Trani, A., Hinze, N., 2021a. Commuter demand estimation and feasibility assessment for urban air mobility in northern California. Transport. Res. Pol. Pract. 148, 506–524.
Rimjha, M., Hotle, S., Trani, A., Hinze, N., Smith, J.C., 2021b. Urban air mobility demand estimation for airport access: a Los Angeles international airport case study. In: 2021 Integrated Communications Navigation and Surveillance Conference (ICNS). IEEE, pp. 1–15.
Rimjha, M., Hotle, S., Trani, A., Hinze, N., Smith, J., Dollyhigh, S., 2021c. Urban air mobility: airport ground access demand estimation. In: AIAA Aviation 2021 Forum, p. 3209.
Roy, S., Kotwicz Herniczek, M.T., German, B., Garrow, L.A., 2020. User base estimation methodology for an evtol business airport shuttle air taxi service. In: AIAA Aviation 2020 Forum, p. 3259.
Roland Berger, 2020. Urban air mobility: the rise of a new mode of transportation. Available at: https://www.rolandberger.com/en/Publications/Passenger-drones-ready-for-take-off.html#:~:text=As%20the%20Roland%20Berger%2Dstudy,ease%20the%20existing%20traffic%20situation.
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.
Rothfeld, R., Straubinger, A., Paul, A., Antoniou, C., 2019. Analysis of European airports' access and egress travel times using google maps. Transp. Policy 81, 148–162.
Schuchardt, B.I., Becker, D., Becker, R.G., End, A., Gerz, T., Meller, F., Metz, I.C., Niklaß, M., Pak, H., Prakasha, P.S., Schier-Morgenthal, S., Schweiger, K., Sülberg, D., Swaid, M., Torens, C., Zhu, C., 2021. Urban air mobility research at the DLR German aerospace center–getting the HorizonUAM project started. In: AIAA Aviation 2021 Forum, p. 3197.
SEA Milano, 2022. Urban air mobility: the city is getting closer. Retrieved. https://seamilano.eu/en/urban-air-mobility. (Accessed 30 June 2023).
Seriwatana, P., 2018. Effect of passenger perception of In-Flight safety and security procedures on their satisfaction: the moderating role of safety knowledge. ABAC Journal 38 (1).
Shaheen, S., Cohen, A., Farrar, E., 2018. The potential societal barriers of urban air mobility (UAM). International Encyclopedia of Transportation. Transportation Sustainability Research Center, UC Berkeley. https://escholarship.org/uc/item/7p69d2bg.
Shamiyeh, M., Rothfeld, R., Hornung, M., 2018. A performance benchmark of recent personal air vehicle concepts for urban air mobility. Proc. 31st Congr. Int. Council Aero. Sci. 14, 10. Belo Horizonte, Brazil.
Stadt München. (n.d.). *Europäische Metropolregion München* [European Metropolitan Region Munich]. Retrieved April 7, 2023, from https://stadt.muenchen.de/infos/kooperationen_ueber_die_euroaeische-metropolregion.html.
Statistics Austria, 2022. Statistics. Retrieved April 07, 2023, from. https://www.statistik.at/en.
Statistik Bayern. (n.d.). *Bevölkerungsstand* [Population Levels]. Retrieved April 7, 2023, from https://www.statistik.bayern.de/statistik/gebiet_bevoelkerung/bevoelkerungsstand/#link_2.
Statistische Ämter des Bundes und der Länder, 2014. Ergebnisse des Zensus 2011 [Results of the census 2011]. https://www.zensus2011.de/DE/Home/Aktuelles/aktuelles_node.html?gtp=559066_list%253D3.
Stilgoe, J., 2021. How can we know a self-driving car is safe? Ethics Inf. Technol. 23 (4), 635–647.
Straubinger, A., Rothfeld, R., Shamiyeh, M., Büchter, K.D., Kaiser, J., Plötner, K.O., 2020. An overview of current research and developments in urban air mobility–setting the scene for UAM introduction. J. Air Transport. Manag. 87, 101852.
Straubinger, A., Michelmann, J., Biehle, T., 2021. Business model options for passenger urban air mobility. CEAS Aero. J. 12 (2), 361–380.
Sun, X., Wandelt, S., Stumpf, E., 2018. Competitiveness of on-demand air taxis regarding door-to-door travel time: a race through Europe. Transport. Res. E Logist. Transport. Rev. 119, 1–18.
Tam, M.L., Lam, W.H., Lo, H.P., 2008. Modeling air passenger travel behavior on airport ground access mode choices. Transportmetrica 4 (2), 135–153.
The World Bank, 2021. Urban population (% of total population) – austria. https://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS?end=2021&locations=AT&start=2021.
Thiel, C., Alemanno, A., Scarcella, G., Zubaryeva, A., Pasaoglu, G., 2012. Attitude of European Car Drivers Towards Electric Vehicles: a Survey. JRC report.
Thipphavong, D.P., Apaza, R., Barmore, B., Battiste, V., Burian, B., Dao, Q., Feary, M., Go, S., Goodrich, K.H., Homola, J., Idris, H.R., Kopardekar, P.H., Lachter, J.B., Neogi, N.A., Kwan Ng, H., Oseguera-Lohr, R.M., Patterson, M.D., Verma, S.A., 2018. Urban air mobility airspace integration concepts and considerations. In: 2018 Aviation Technology, Integration, and Operations Conference, p. 3676.
TomTom, 2022. TomTom traffic index – ranking 2022. Retrieved. https://www.tomtom.com/traffic-index/ranking/?country=CA%2CMX%2CUS. (Accessed 15 June 2023).
Train, K.E., 2009. Discrete Choice Methods with Simulation. Cambridge University Press.
Uber, 2016. *Fast-forwarding to a future of On-Demand urban air transportation* [Whitepaper]. Uber Elevate. https://evtol.news/_media/PDFs/UberElevateWhitePaperOct2016.pdf.
Vascik, P.D., 2017. Systems-Level Analysis of on Demand Mobility for Aviation. Doctoral dissertation, Massachusetts Institute of Technology.
Vascik, P.D., Hansman, R.J., 2017. Evaluation of key operational constraints affecting on-demand mobility for aviation in the Los Angeles basin: ground infrastructure, air traffic control and noise. In: 17th AIAA Aviation Technology, Integration, and Operations Conference, p. 3084.
Vascik, P.D., Hansman, R.J., Dunn, N.S., 2018. Analysis of urban air mobility operational constraints. J. Air Transport. 26 (4), 133–146.
Vascik, P.D., John Hansman, R., 2021. Evaluating the interoperability of urban air mobility systems and airports. Transp. Res. Rec. 2675 (6), 1–14.
Walker, J.L., Wang, Y., Thorhauge, M., Ben-Akiva, M., 2018. D-efficient or deficient? A robustness analysis of stated choice experimental designs. Theor. Decis. 84, 215–238.
Wang, K., Qu, X., 2023. Urban aerial mobility: reshaping the future of urban transportation. Innovation 4 (2).
Wu, Z., Zhang, Y., 2021. Integrated network design and demand forecast for on-demand urban air mobility. Engineering 7 (4), 473–487.
Ziefle, M., Beul-Leusmann, S., Kasugai, K., Schwalm, M., 2014. Public perception and acceptance of electric vehicles: exploring users' perceived benefits and drawbacks. In: *In Design, User Experience, and Usability. User Experience Design for Everyday Life Applications and Services: Third International Conference,* DUXU 2014, Held as Part of HCI International 2014, Heraklion, Crete, Greece, June 22-27, 2014, Proceedings, Part III 3. Springer International Publishing, pp. 628–639.