User Acceptance of Urban Air Mobility (UAM) for Passenger Transport: A Choice-Based Conjoint Study

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Abstract. Urban air mobility (UAM) has gained increased attention as a promising new solution to tackle issues such as traffic congestion. This study aims to assess users' perception and usage intentions and identify and weigh success-critical acceptance factors against each other. Further, user-related differences in the underlying decision patterns are analyzed. A mixed-methods approach was employed, including a prior interview study with laypeople and experts ($N = 16$), calculations of feasible prices via agent-based símulations, and the main survey study ($N = 135$) – a Choice-Based Conjoint (CBC) with the attributes: environmental impact, costs, placement of take-off and landing stations (vertiports), automation level, and onboard benefits. Results indicated that environmental impact, costs, and vertiport placement were the top three factors influencing user acceptance. The relative importance of these attributes differed, however, depending on the user group. Based on the results, three user segments were identified: automation-skeptical users, environmentally-conscious users, and cost-conscious users. The findings provide valuable insights for UAM providers and policymakers to understand the attitudes and needs of potential users and to design effective strategies for promoting the adoption of UAM.

Keywords: urban air mobility (UAM) · choice based conjoint · acceptance · air taxi

1 Introduction

Mobility is an important research area from several different perspectives. For one, there is the need to reach different places as a person. On the other, ever-increasing numbers of wares need to be transported to and from sometimes remote locations. What used to be provided via cars, delivery vehicles such

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as trucks, and public transit has gained negative attention on many bases. One major challenge of future mobility is avoiding unwanted pollution and emission of greenhouse gases [46]. While alternative fuels are being developed and researched (see, e.g., [34,42]), their active use is still off and therefore uncertain [37]. In addition, individual traffic, meaning the ownership of a car, especially if it is only used by a single person, is sought to be limited or at least decreased as, most of the time, this car is parked somewhere. Especially in cities and urban areas, space is a precious commodity, thus, sharing a vehicle with others might be a better solution [29]. However, car sharing and public transit cannot provide all mobility needs either. For one, pollution is still an issue. As is availability [4]. So, another attempt to reduce the number of cars and vehicles on the streets is to utilize a yet seldomly used area for traffic, namely airspace. Urban air mobility (UAM) could be a possible solution to reduce not only people but also wares transportation on streets [35,45]. This could also be another step toward the electrification of mobility. While other countries are already actively offering, for example, last-mile delivery via drones (e.g., [23]), this is only the first step. Passengers might also profit from short-distance traveling via so-called air taxis. While still in development, several start-ups have already begun to build working drones that are big enough to carry 1 to 6 passengers (e.g., [45]). Testing has also commenced [1]. However, even if such developments and tests are successful, their deployment is doubtful if people are unwilling to use them. Therefore, an early understanding of potential users' acceptance is important, and a first insight will be provided with this paper.

First, some background on the technological aspects of urban air mobility (UAM) is given. This will then be supplemented with insights into the acceptance of technologies, especially in the mobility concept. Based on this, the study design and empirical approach will be provided. The results will be detailed before they are discussed, and a final outlook will be given.

2 Background

This section will provide insight into the current state of research of urban air mobility by giving a short overview of current models in development for passenger air transportation. Afterward, a short synopsis of current acceptance research regarding drones and small aircraft, especially in urban areas, will be given.

2.1 State of the Art UAM

With the development of vertical take-off and landing (VTOL) vehicles, considering future UAM scenarios has gained importance. This potential of UAM systems is mainly based on shorter travel times compared to ground-based mobility, an on-demand service model, lower operating costs compared to complex helicopter systems, and electrically powered vehicles [26,36]. The latter is often defined as eVTOL (electric vertical take-off and landing) vehicles that can operate on vertiports near city centers or in rural areas [33]. In recent research, the overall UAM system is divided into aspects of eVTOL vehicles, infrastructure, social acceptance, certification, safety, and operations [17,18,36,47]. Regarding eVTOL vehicles, different technical configuration approaches are in focus to enable optimal fleet operations, namely wingless multicopters, lift and cruise configurations and tilting systems [3,33]. Firstly, multirotor configurations, such as *Volocopter 2X* and *E-Hang 184*, have a rather short range with mostly intracity implementation potentials due to the missing fixed wing and the resulting lack of aerodynamic lift in cruise flight and higher energy consumption in horizontal flight segments. Secondly, lift and cruise systems, such as *Wisk Cora* and *Boeing Passenger Air Vehicle*, are hybrid systems combining VTOL and longer range properties due to the additional fixed wing. With a travel speed of around 200 km/h, these configurations seem applicable in intracity and city-to-city transportation services, with a rather slow time to market. Thirdly, tilting concepts with tilting wings or rotors allowing VTOL capability are also applicable to both intracity and intercity services, as the cruise speed is relatively high. Disadvantages are the increased system complexity and the later time to market. Tilting air taxi configurations currently regarded in research are the *Airbus Vahana*, and the *Lilium Jet* [3,22,33]. Based on possible UAM scenarios, market potentials of up to 1% of demanded mobility were calculated using agent-based simulation, and fleet operational decisions such as charging approaches, station placement, and pricing were further analyzed [22,36].

2.2 Acceptance of UAM

Technology acceptance has been established as an important part of the future use of technologies [48]. While different technology acceptance models have been developed over the years, e.g., the Technology Acceptance Model (TAM) by Davies [14], or the Unified Theory of Acceptance and Use of Technology (UTAUT) by Venkatesh et al. [49], they have always had to be adapted to new technologies as those include aspects or intricacies that had not been present in the original acceptance models' technology [48]. However, the basic idea of central aspects such as *intention to use* or *perceived usefulness* can be translated well into new technologies and use cases.

In the context of mobility, especially with the addition of autonomous properties, factors influencing acceptance can stem from multiple sources. For one, there is trust [6], which goes hand in hand with safety [7]. This is also likely to hold true for air traffic as well [21,27].

Other aspects that might impact the acceptance of these small aircraft can be environmental factors. Here, not only gas emissions [13] but also noise emissions can lower the acceptance [17,41]. Perceived barriers to acceptance can also be found in the routes such aircraft are allowed to use and the locations they are allowed to land [24], as bystanders might perceive a loss of privacy or fear injury by a malfunctioning aircraft. Further, the willingness to share a flight, ticket pricing [44], and travel time in comparison to other modes of transportation affect the user acceptance [36,41,45]. For a more detailed overview of potential factors influencing the successful deployment of passenger drones, see, e.g., [1, 17,45].

While various factors affecting the acceptance of UAM have been identified by prior studies, little is known about which factors are ultimately decisive for (user) adoption when weighed against each other. Thus, the present study aimed to fill this gap by employing a holistic investigation of potential users' decisions for or against using urban air mobility and the underlying decision patterns. The research was guided by open-ended questions:

RQ1 Which acceptance attribute is most relevant for acceptance: costs, environmental impact, onboard benefits, automation level, or vertiport placement?
RQ2 Which attribute levels impact acceptance positively or negatively?
RQ3 Are there any differences in the decision patterns between different user profiles, and how do they differ?

3 Empirical Approach

In this section, the empirical approach is explained, starting with the overall research concept, followed by an explanation of the conjoint methodology. Subsequently, the selection of acceptance relevant attributes, levels, and the empirical study design are described. Finally, data preparation, analysis, and the sample are summarized.

3.1 Research Concept and Study Input Parameters

For this study, a three-step approach, combining a qualitative interview prestudy, an already conducted UAM cost optimization based on agent-based simulation [22], and the main study, an online survey – including a choice-based conjoint experiment, was used.

Simulations. Considering the UAM costs and scenario parameters, the results of Husemann et al. are used [22]. Here, the authors used the Multi-Agent Transport Simulation (MATSim) extended with UAM simulations (see Rothfeld et al. [36]) to determine the UAM demand in relation to both ground-based transportation and the time of day. As a simulation scenario, Husemann et al. considered the metropolitan region Rhine-Ruhr with a distribution of 100 vertiports. Further, input values in the base case were a horizontal cruise speed of 150 km/h for the air taxis, a hovering time of the vehicles for take-off and landing of 60 s, a minimum turnaround time of 3 min, a complete linkage of the UAM station network and a passenger capacity of up to 2 passengers per vehicle [22]. The simulated UAM trips were then applied in an optimization model using a total cost of ownership approach and other input data such as charging infrastructure, battery technology, and several cost-specific parameters. Including sensitivity studies for uncertainties in technological developments and UAM system design, resulting costs per passenger kilometer has been calculated to be around 1.50 euros [22].

Interview Pre-study. Guided interviews with laypeople ($N = 13$) and experts ($N = 3$) were conducted to identify UAM acceptance factors. The interview contained an introductory part about the reasons people use their current transport modes and a part about the requirements for air taxis (autonomous and piloted). For analysis, qualitative content analysis was used [25]. The identified topics and statements informed the development of the main studies' conjoint design.

3.2 Conjoint Analysis Method

A choice-based conjoint methodology was used to quantify and weigh the relevance of different decision factors against each other. Conjoint analysis is commonly used in technology acceptance research as it allows for examining individual preferences, decision patterns, trade-offs between decision-relevant attributes, and segmenting groups with distinct decision patterns [2]. Compared to traditional survey methods, choice-based conjoint (CBC) offers a more holistic view of complex decision patterns by mimicking real-world decision trade-offs. In CBC, participants are asked to make trade-off decisions between different product configurations, simulating realistic decision processes. This enables a calculation of how respondents' decisions are influenced by different product attributes and their corresponding levels. The choices are then decomposed into relative importance and part-worth utilities of attribute levels, providing insights into the overall impact of attributes on decisions and identifying tipping points of acceptance [30] [5,12]. For the present study, we included a dual response "none" query to assess the likelihood of participants opting for none of the offered product configurations [38].

3.3 Conjoint Attributes and Levels

The selection of relevant attributes was based on an initial literature review and a qualitative pre-study with laypeople ($N = 13$) and experts ($N = 3$). In total, five attributes (price, environmental impact, automation level, vertiport placement, and onboard benefits; cf. Table 1), were selected.

Table 1. Overview of attributes and levels for the CBC.

Attributes	Levels				
Price	56.25 € [-25 %]	67.50 € [- 10 %]	75 € [baseline]	82.50 € [+ 10 %]	93.50 € [+ 25 %]
Environmental impact	50 % less	identical	50 % more	100 % more	
Automation level	piloted	remote controlled	autonomous		
Vertiport placement	downtown	nearest airport	nearest train station	city centre	next to house or apartment
Onboard benefits	radio	wi-fi	comfortable seats	free carry on luggage	

Attribute levels were based on the interview insights and the results from the MATSim simulation with the aim to display realistic choices. In the following, the included levels are explained.

The `Price` per trip was included, as it was seen as a key requirement and exclusion criterion if too high [31] [44]. The base price was set at 1.50 euros per km, resulting in a ticket price of 75 €[22]. To limit complexity, the respondents only saw the total cost of the trip. The lowest price point was estimated, taking optimization potential into account. Based on the calculations, we included two low price points, which were 10 % and 25 % cheaper than the base price. Additionally, two price premiums (+ 10 % and + 25 % compared to the base price) were included. All included prices are listed in Table 1.

The `Environmental Impact` was included due to some concerns – voiced in the interviews and reviewed literature – regarding UAM's energy consumption and its impact upon the environment [13]. In light of recent energy crises and climate change, this is a highly relevant attribute when designing new transport solutions. However, operationalizing the impact on the environment is slightly tricky since respondents also indicated that they lack a feeling for judging energy consumption values. The matter becomes even more complex when, apart from the mere extent of power consumption, the power source (e.g., renewable vs. fossil fuels) is considered. For this study, environmental impact was operationalized as a rather abstract increase or decrease of the harmful effect on the environment. More precisely, the environmental impact represents a relative increase or decrease in the consumption of *non-regeneratively sourced* electricity compared to an average electric car.

The `Automation Level` was included since there were some reservations regarding the autonomous option in the interviews. For the CBC study, three automation levels were included: [1] a piloted option, meaning that a trained pilot would be on board; [2] a remote control option, meaning that the air taxi was remotely monitored by trained staff; and [3] a fully automated option where human supervision was no longer necessary and the air taxi was equipped to handle all situation by itself.

The `Vertiport Placement` as interviewees indicated that part appeal of air taxi services was that they might be closer, more easily reachable, and, thus, more flexible than conventional passenger flights. However, there might be concerns about noise [20,41] or visual pollution (visual density) [43] that could hinder acceptance when vertiports are too close to homes or city centers.

The `Onboard Benefits` were included to capture a whole assortment of comfort-related aspects mentioned in literature and interviews. For this study, we chose the most mentioned extras (comfortable seats, WI-FI, radio, and free carry-on luggage) and included them in the study design.

3.4 Online Survey Design

All used survey items were developed according to the interview insights and measured using 5-point likert scales. To avoid misunderstandings, the design was tested for comprehensibility and completion time by four pre-testers before distribution. In total, the survey consisted of four parts. First, an introductory part in which participants were informed about the study's purpose. It was stressed that, first and foremost, their personal opinion mattered. Further, it was explained that participation was [1] voluntary, [2] not compensated, and [3] could be canceled or interrupted at any time during the survey. Additionally, participants were informed that their data would be analyzed anonymously, i.e., none of their answers allowed conclusions about their person.

The second part was a warm-up in which respondents filled in their socio-demographics, such as age or gender. Additionally, we asked about mobility-related habits. Lastly, respondents stated their familiarity (i.e., perceived knowledge) with air taxis on a 5-point likert scale.

The main part contained the CBC experiment. To ensure every respondent had the same knowledge about the topic, information on air taxis and their use was given. Additionally, respondents received a detailed scenario description and descriptions of all attributes and attribute levels. Respondents were asked to imagine they would consider using a new air taxi service for a work or school commute (50 km), which would take 23 min and save about 22 min compared to commuting by car. Thereafter they were asked to choose the air taxi service configuration they would prefer out of a set of three. At the top of each choice task, an abbreviated version of the scenario was displayed. During the choice experiment, participants were offered an info button for the automation level, and benefits attribute levels to re-check their definitions. The choice tasks were a forced response with a dual-response none format. Thereby, we provided the respondents with the option to indicate if they would use their chosen alternative in real-life without limiting the precision of collected choice data [9]. With dual-response "none" the interpretation of utilities for all attributes apart from the "None of these" alternative remains unaffected. In Fig. 1, an example of a decision task is displayed.

Combining all possible profiles would have led to 1.200 ($5 \times 4 \times 4 \times 3 \times 5$) choice tasks. The conjoint analysis software offers a function to reduce the number of choice tasks. For this study, respondents completed 15 random and two fixed tasks (median efficiency = 93.37 %).

Lastly, we queried the respondents' willingness to use air taxi services (3 items, $\alpha = .72$, [13]), their current flight behavior (i.e., frequency, fear of high and flying), their automation concerns (4 items, $\alpha = .76$, adjusted from [10]), and their technology openness (7 items, $\alpha = .92$, based on [13,28]).

3.5 Data Preparation and Analysis

All constructs were checked for internal consistency (Cronbach's α), which was above the critical threshold of 0.7 for all used constructs. Additionally, analyses were performed to check for assumption violations. Participants with completion times under 10 min (below 35 % of the median) were removed. Based on the Hierarchical Bayesian (HB) analysis of the responses, a root-likelihood score (RLH) can be estimated for each participant. This fit statistic is higher the better the model fits the observed data, with the maximum being a value of 1. Random response behavior is generally poorly predictable and results in low RLH scores. Responses with an RLH threshold below 0.44 were removed, in line with the suggestions by Chrzan & Halversen (2020) [11].

Data were analyzed using descriptive (i.e., mean scores (M), Median (Mnd), standard deviations (SD), and interference statistics. The level of significance (p) was set at 0.05. For the analyses of the conjoint experiment, relative importance scores and part-worth utilities of each attribute level were calculated via HB using the Sawtooth Software [39]. The former indicates how important an attribute is for the overall decision in relation to every other included attribute. The part-worth utility scores hold information about the – positive or negative – contribution of each attribute level to the recorded decisions. Part-worth utilities cannot be compared between different attributes. To identify user segments, latent class analysis (LCA) was conducted. For the LCA analysis, information on the respondents' propensity to choose the "none" option was excluded from the calculations.

3.6 Sample Description

The survey was distributed in August 2022 online using snowball sampling and 135 complete responses were obtained. The sample is relatively young and highly educated compared to the German population. Most participants live in cities (71.8%), nearly all (94.1%) hold a driver's license, and most (80.7 %) also own a car. Additionally, just over half the sample own a public transport ticket (cf. Table 2).

The technology openness was, with $M = 3.79$ ($SD = 0.89$, min $= 1$, max $= 5$), higher than the center of the 5-point scale, indicating a rather technophile sam-

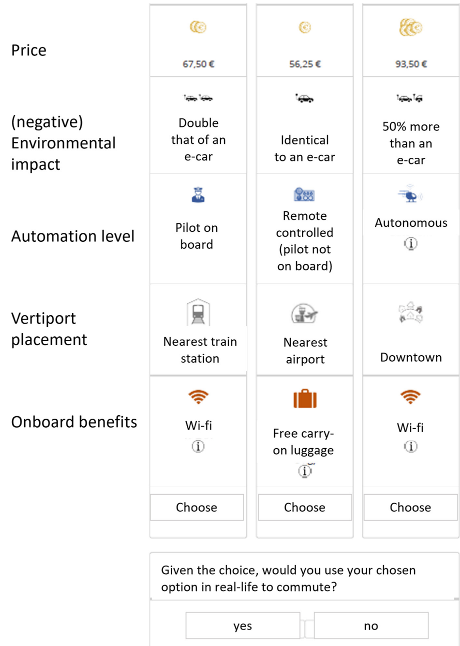

Fig. 1. Examplary choice task of the CBC experiment.

Table 2. Characteristics of the sample (N = 135).

Gender	Male	n = 56 (41.5 %)
	Female	n = 79 (58.5 %)
Age	*M*	31.96
	SD	13.01
Residential area	City center	n = 60 (44.4 %)
	Outskirts city	n = 37 (27.4 %)
	Suburban	n = 24 (17.8 %)
	Rural	n = 14 (10.4 %)
Occupation	Student	n = 67 (49.6 %)
	Vocational training	n = 2 (1.5 %)
	Employed	n = 59 (43.7 %)
	Retired	n = 5 (3.7 %)
	Seeking work	n = 2 (1.5 %)
Drivers license	Yes	n = 127 (94.1 %)
	No	n = 8 (5.9 %)
Car ownership	Yes	n = 109 (80.7 %)
	No	n = 18 (13.3 %)
Public transport ticket ownership	Yes	n = 79 (58.5 %)
	No	n = 56 (41.5 %)
Distance of regular commute	*M*	17.76 km
	SD	28.82
Frequency of flying (trips per year)	*M*	1.96
	SD	2.90

ple. Automation concerns were neutral ($M = 2.94$, $SD = 0.97$), and knowledge of air taxis were relatively low ($M = 2.19$, $SD = 0.90$).

4 Results

In this section, results are presented – starting with a section about the general attitude of participants toward an air taxi service, followed by the results of the conjoint analysis. Lastly, the user group segmentation is presented.

4.1 General Attitude

Overall, participants were somewhat undecided on the question if they would use air taxi services ($M = 3.05$, $SD = 1.15$). This willingness, however, changed depending on the automation level. For air taxis with a pilot on board, 72 % stated they could imagine using such a vehicle. For remote-controlled or autonomous air taxis, this share decreases to 57 % and 58 %, respectively (cf. Fig. 2).

4.2 Preferences for Air Taxi Services

On average, the `environmental impact` (30.04 %, $SD = 15.60$) was most important for participants' decisions, followed by the `price` (24.73 %, $SD = 13.12$), the `placement of vertiports` (20.30 %, $SD = 8.79$), and the `automation level` (16.82 %, $SD = 14.24$) (cf. Fig. 3). Least important were the offered `onboard benefits` (8.11 %, $SD = 5.32$).

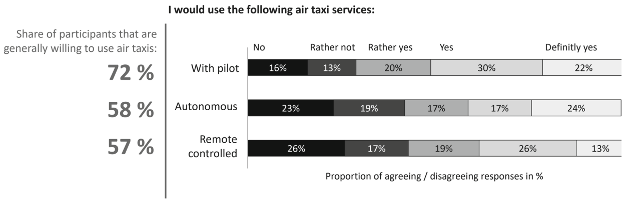

Fig. 2. Participants' willingness to use air taxi services with different levels of automation.

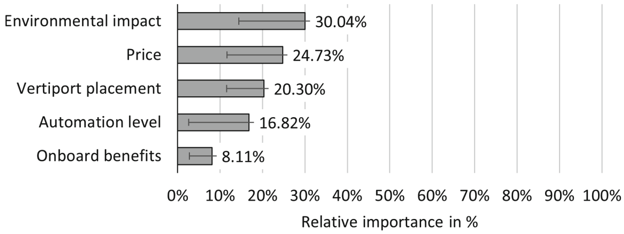

Fig. 3. Relative importance scores (with standard deviation) of the attributes in the CBC study.

Additionally, part-worth utilities were examined (cf. Fig. 4). For the attribute ``` ``environmental impact,'' ``` the "50 % decrease" and the "identical" level were acceptable, contributing both positively to the participants' decision (– 50+%: +65.18, $SD = 49.47$; identical: +40.61, $SD = 27.20$). Overall, the results show that the more the consumption of non-regenerative energy increases, the less likely people are to choose the option. Consequently, an increase of 50 % (–35.03, $SD = 27.48$) and 100 % (–70.76, $SD = 49.11$) both deterred respondents from choosing the air taxi.

For the `price` the results indicate that the more affordable, the more positive the effect on the decision. The two cheapest price levels of 56.25 € (+52.38, $SD = 43.67$) and 67.50 €(+25.47, $SD = 22.53$) had high positive contributions. In comparison, the 75 €price point only slightly positively impacted decisions (+1.37, $SD = 19.25$). Both price premiums showed large negative effects (93.50 €: –59.84, $SD = 37.44$; 82.50 €: -19.38, $SD = 18.72$).

For the ``vertiport placement'' attribute, nearly all levels showed positive effects. The airport placement is the only exception (–58.12, *SD* = 39.77). Most positively contributed the "close to own home"-level (+29.61, *SD* = 20.91), followed by the placement at the closest train station (+14.52, *SD* = 21.21). The effects of the levels "downtown" (+8.58, *SD* = 16.92) and "city center"(+5.41, *SD* = 22.12) were comparably slight.

Within the attribute ``automation level'', both levels without a pilot on board had negative contributions, while the piloted option was deemed acceptable (+37.96, *SD* = 53.26). Here, the autonomous option had the highest negative impact (–21.00, *SD* = 35.51). However, the "remote controlled" option was only slightly less negative in its impact (–16.69, *SD* = 29.31).

In contrast to the other attributes, the utility scores of the benefit levels varied only marginally between the radio option with a slightly negative contribution (–9.2, *SD* = 20.89) and the wi-fi with the highest, but still small, positive contribution (4.31, *SD* = 16.80). The contributions of the carry-on luggage option (+3.25, *SD* = 16.76) and the comfortable seats (+1.64, *SD* = 16.10) were also slightly positive. After each choice task, we asked participants if they would use the selected option to commute. The results show a high positive utility for the ``none'' option, indicating that only an attractive combination of levels represents an air taxi service that would actually be used.

4.3 User Segmentation

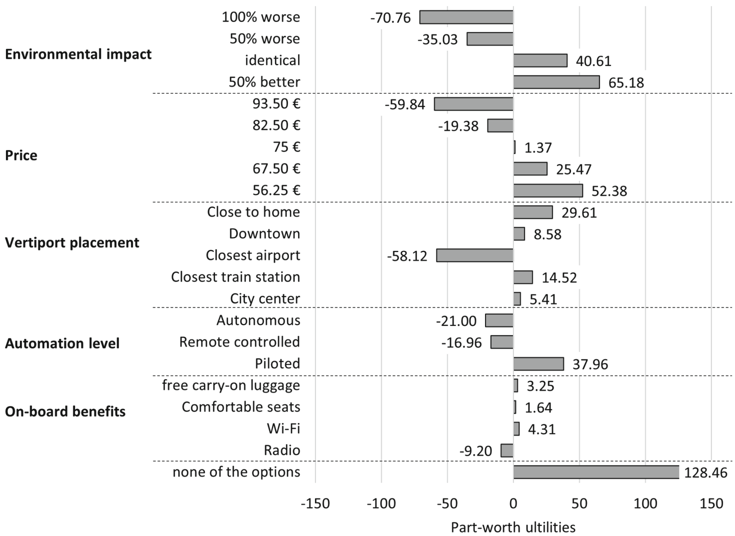

Fig. 4. Part-worth utility scores (zero-centered diffs) for each attribute level included in the CBC study. Note: Levels cannot be compared across attributes.

To identify clusters of respondents with differing preferences, latent class segmentation (LCA) was used [40]. In this analysis, utility scores for each found cluster and a probability score (i.e., the probability that this respondent belongs to the cluster) are calculated. To identify a suitable number of clusters, the criteria "percentage certainty", "consistent Akaike information criterion" (CAIC), and "relative Chi-square" were examined [40]. For the acquired data, a three-group solution showed the best fit.

Table 3. Overview of attributes and levels for the CBC.

Respondent characteristics	Group 1 "Automation sceptics" ($n = 22$)	Group 2 "Eco-conscious" ($n = 53$)	Group 3 "Price optimizers" ($n = 60$)	level of significance (p)	effect size
Age	$M = 35.68$, $SD = 13.17$	$M = 31.23$, $SD = 14.05$	$M = 31.23$, $SD = 11.95$	n.s	$\eta^2 = .02$
Gender	36.36 % male ($n = 8$)	56.60 % male ($n = 30$)	30.00 % male ($n = 18$)	$p \leq .05$	Cramér's V = .25
Technology openness (min = 1; max = 5)	$M = 3.64$, $SD = 0.75$	$M = 3.93$, $SD = 0.89$	$M = 3.73$, $SD = 0.93$	n.s	$\eta^2 = .02$
Automation concern (min = 1; max = 5)	$M = 3.83$, $SD = 0.82$	$M = 2.58$, $SD = 0.90$	$M = 2.93$, $SD = 0.88$	$p \leq .01$	$\eta^2 = .19$
Willingness to use air taxis (min = 1; max = 5)	$M = 2.36$, $SD = 0.1.03$	$M = 3.23$, $SD = 1.12$	$M = 3.14$, $SD = 1.14$	$p \leq .01$	$\eta^2 = .07$
perceived knowledge (min = 1; max = 5)	$Mdn = 2.00$, $SD = 0.87$	$Mdn = 3.00$, $SD = 0.95$	$Mdn = 2.00$, $SD = 0.83$	$p \leq .05$	Cramér's V = .26

To interpret the characteristics of the found clusters, demographics, and attitudinal characteristics were compared [2] via MANOVA and Chi^2-tests. The results are listed in Table 3. For the MANOVA, Tukey Post Hoc tests were performed.

The one-way MANOVA showed a statistically significant difference between the groups F(8, 258) = 4.51, p $\leq$ .01, partial η^2 = .12, Wilk's λ = .77. Overall, differences were found for *gender*, *automation concerns*, *willingness to use*, and *perceived knowledge* (cf. Table 3). The share of male respondents was significantly lower in groups 1 (automation skeptics) and 3 (price optimizers). Further, group 2 (eco-conscious) showed a higher perceived knowledge. Automation concerns were significantly greater in group 1 (automation skeptics) than in the two remaining groups. Likewise, group 1's (automation skeptics) willingness to use air taxis was significantly lower than the willingness of groups 2 and 3. There were no significant differences regarding age or technology openness.

The relative attribute importance of each group was as follows (cf. Fig. 5): in **group 1**, the automation level was the most decisive decision criterion (55.18 %), followed by the vertiport placement (18.11 %), and the environmental impact (14.60 %). Offered benefits (5.75 %) and price (6.35 %) only played a minor role in group one's decision. For **group 2**, the most important factor was the environmental impact (54.59 %). Vertiport placement (15.70 %), price (16.07 %), and automation level (10.84 %) affected the decision less. Offered benefits only had a relative importance of 2.80 %. For the decisions of **group 3** respondents, the price was most decisive (43.43 %); but the vertiport placement also played a crucial role (27.28 %). Less influential were the environmental impact (16.82 %), the benefits (6.88 %), and the automation level (5.59 %).

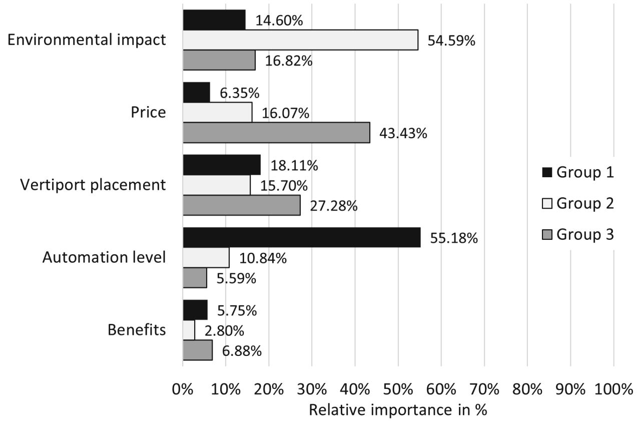

Fig. 5. Relative importance of the attributes for each identified preference group.

In Fig. 6, the average zero-centered diff part-worth utilities for each attribute level and all three groups are visualized. For the `environmental impact` attribute levels, the general preference tendencies are much the same across the three groups, with the "identical" and "50 % better" levels resulting in positive utilities. However, the range between the attribute levels is much more pronounced for group 2 than for both other groups. Especially for group 1, the "50 % worse" (–7.12) condition only had a slightly negative impact.

For group 3, the price level utility scores follow a linear line, following the principle of "the cheaper, the better". Here, acceptance tips into rejection after the 67.50 €price point. In contrast, for group 2, prices of 56.25 €(+24.49), 67.50 €(+17.15), and 75 €(+22.59) were all nearly equally (positively) affecting the decision. Lastly, for group 1, the price did not matter much, as indicated by the small range of utility scores. Still, lower prices were preferred slightly.

The preference pattern for the `vertiport placements` looks similar across groups. Notable is, however, that for group 1, a vertiport placement in the city center (–23.15) was not acceptable, while it was for groups 2 and 3 (group 2: +9.23; group 3: +8.36).

In group 1, the piloted option (+179.20) was highly preferred, and both automated options – remote controlled (–96.72) and fully autonomous (–82.49) – were equally highly rejected. For group 2, the preference pattern reflects the "the less human control, the worse" mindset and views the remote-controlled option (–0.72) rather neutrally while rejecting full automation (–26.74). Group 3 shows positive utility scores for both the piloted (+27.46) and the fully autonomous (+7.84) option but rejects the remote-controlled option (–26.74).

Differences between the preferences regarding the included `benefits` were observable for the "wi-fi" and the "comfortable seat" levels. Here, the wi-fi option was slightly negatively affecting the decision of group 2 (–2.57), while it had a positive impact on the decisions of group 1 (+10.15) and 3 (+8.29). Comfortable seats had a slight positive effect on the decisions of groups 2 (+4.93) and 3 (+8.20) and a slightly negative effect on group 1 (–5.41).

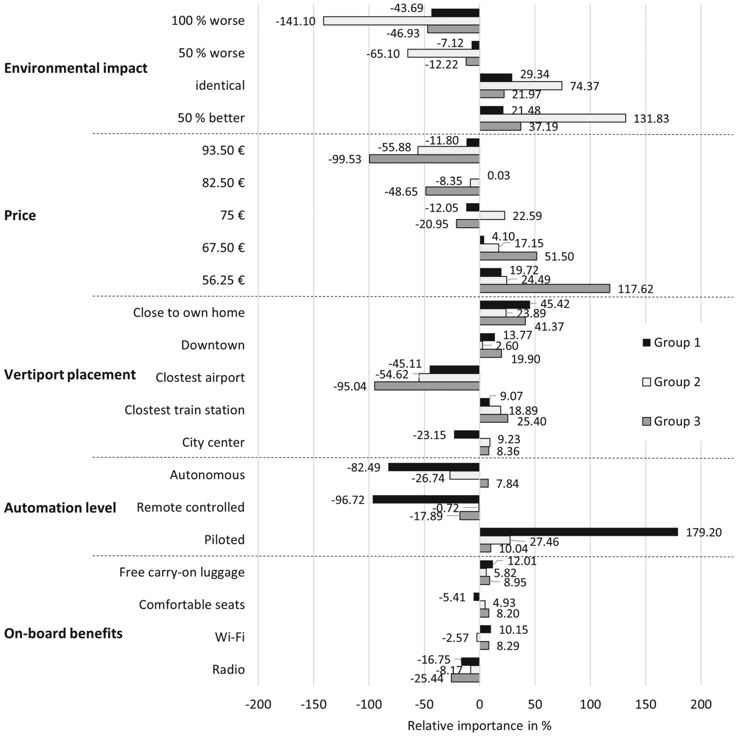

Fig. 6. Part-worth utility scores (zero-centered diffs) for each identified preference group.

5 Discussion

The present study aimed to investigate the user acceptance and acceptance influencing factors of air taxis for regular commute trips in Germany via a conjoint experiment approach. Before conducting the CBC, a literature review, a qualitative interview study, and a MATSim simulation were performed to ensure the relevance and accuracy of included attributes and levels. The obtained results are discussed in the following sections.

5.1 Insights on Decision Behaviors for Air Taxi Use

The present study assessed people's willingness to use UAM services. Results showed that the respondents are still undecided about using air taxis. While 72 % could imagine using air taxis if a pilot was accompanying the flight, this share dropped to only half for the remote and fully autonomous options, which still is a higher willingness than found in comparable recent studies [16, 50]. Additionally, the high share of respondents choosing the "none" option indicated that most people are (as of yet) unwilling to swap from their current transportation choice to UAM. An attractive combination of service features may be needed to change this.

The results also confirm the dependence of acceptance on automation levels, as both options without a pilot onboard had negative utility scores and deterred people from using UAM services. The lacking trust in the automated options poses a challenge for introducing UAM, as staff wages substantially increase operating costs and make it difficult to offer competitive prices, which, however, are crucial for widespread acceptance as underlined by the high relative importance of the price attribute.

One key finding was that the environmental impact was most decisive for people's decisions. Here, little non-renewable energy use was preferred. Acceptance was tipped when environmental impacts became worse than alternative transportation choices. Several aspects might have contributed to the observed high importance of the environmental aspect. Possibly the level descriptions made the issue more tangible to respondents than it would have been in daily life, where people often only have an abstract idea about the environmental impact of their transportation choices. Additionally, the study was conducted during an energy crisis, when the media frequently covered energy shortages and volatile prices. This might have increased people's awareness of the issue.

Regarding the location of vertiports, respondents preferred locations close to their homes or easily reachable locations such as train stations. This finding is somewhat surprising as prior research suggests that concerns about noise and visual pollution caused by UAM are high [20,41,43] and that acceptance of UAM in people's immediate environment is limited [16]. This phenomenon is called NYMBY ("not in my backyard") and is typical for new and large-scale technologies deployed in public spaces [15,32].

One explanation that the NIMBY effect did not play a role in the current study might be that we looked at user acceptance rather than public acceptance. From a customer's point of view, travel time and effort are essential factors when choosing how to travel. Easily reachable locations are, thus, preferred. Especially since one of the perceived advantages of air taxis is their presumed flexibility and time savings, and far away or hard-to-reach locations might negate all expected advantages, as indicated by our pre-study. Lastly, the onboard benefits played only a neglectable role.

5.2 Explaining Divergent Decision Patterns

A high standard deviation could be observed for the level utility scores, which usually indicates diverging decision patterns due to user diversity factors. Indeed, an LCA revealed three preference subgroups differing in gender, automation concerns, willingness to use, and perceived knowledge: the automation skeptics, the eco-conscious, and the price optimizers. One of the major outcomes of the present study is that, even for a more or less homogeneous sample in terms of age and education, trade-off decisions are heterogeneous.

The first identified group, whose decisions were heavily influenced by the automation level, is not very likely to be at the forefront of adoption. Compared to the other user segments – even if they were less price sensitive – they were more unwilling to use it than the other groups. Their high automation concern and low perceived knowledge might explain this finding. Prior research shows the relationship between expertise and risk perception; i.e., higher domain-specific knowledge reduces risk perceptions [8].

In comparison, group 2 was more willing to use air taxis and also more willing to pay slightly higher prices if their environmental impact was better or at least identical to an electric car which makes them an attractive group for early adoption. Concerning the environmental impact, however, the question remains whether this is achievable by optimizing the aircraft or employing measures such as ride-pooling. Compared to the attributes mentioned above, the eco-conscious group placed little importance on the automation level. However, some preference for human-controlled UAM was observed. Remote-controlled aircraft were viewed neutrally, though full automation was rejected.

For the last group (prize optimizers), UAM has to be, above all, affordable and easily accessible. The automation level only played a minor role in their decision. Interestingly, the price optimizer group was the only group where full automation positively affected their task decision. In fact, the utility score of the fully autonomous air taxi was nearly as high as that of a piloted version which underlines how unconcerned this group is about flight automation. Interestingly, the remote-controlled option was rejected. At this point, it is unclear what might have contributed to this finding. Group 3 neither displayed a higher level of knowledge than the automation skeptic group nor were they more unconcerned about automation than the eco-conscious group. Their technology openness was also at the same level as for both other groups.

5.3 Limitations

Although this study provides valuable first insights into perceptions and decision patterns for air taxi use, some methodical limitations should be considered when interpreting the results.

Firstly, due to the early stages of UAM development, a scenario-based approach was adopted. The respondents lacked experience with the technology. Thus, like any social science study that examines attitudes and perceptions, the reported values do not allow an accurate prediction of consumer behavior – even if attitudes and behavior are, in most cases, closely linked, there still is a gap between them, especially for sustainability-related behavior (e.g., [19]).

Secondly, convenience sampling was used. The sample size was relatively small and homogeneous in terms of demographics. Still, even in this relatively homogenous sample, attitudinal and differences in the underlying preference patterns were observable. These might be even more pronounced in a larger and more diverse sample. Thus, further research should validate the findings with a larger census-representative sample.

Moreover, the chosen operationalization of the "environmental impact" attribute might need some adjustments to mimic a real-world scenario more closely, as directly showing a simplified score might have made the issue more salient and, thus, more decision-relevant. In a realistic situation, indications about ecological impacts are rarely tangible and almost always complex to asses. When considering the environmental impact of a transport choice prevailing mental models and consumer (mis-)conceptions play a crucial role. In other words: rather than the actual environmental impact, what people expect the environmental impact of air taxis is, might be more relevant for their transport decisions.

6 Conclusion – What Did We Learn

Overall, there was still a fair amount of skepticism, as indicated by the high share of respondents opting for the "none"-option. However, even if some skepticism about the use of air cabs is prevalent and the concept is still unfamiliar to most, most respondents were generally willing to use them if the price and environmental impact are right and vertiport locations are easily accessible. In other words: The new mobility option has to offer the user a tangible economic, time, or ecological advantage. In the present study particularly, the environmental impact played the most critical role in influencing usage intentions. This suggests that people increasingly consider the environmental impact of their transport mode choice. Recent developments, such as the uncertain energy supply in Germany and the increased salience of environmental issues, might fuel this finding. Especially for one group, the eco-conscious, the environmental factor plays a crucial role in their decision. Since this group is promising as an early adopter due to their general openness towards UAM and slightly larger price range acceptance, the environmental impact of new UAM technologies should be considered when designing such technologies. Furthermore, our results show that autonomy is still met with apprehension and skepticism by most user groups, especially so by automation skeptics, which after all, made up 16 % of this study's sample. Human-piloted air cabs are preferred overall. The observed apprehension most likely stems from missing trust in the system and has to be considered, especially during the early implementation phase.

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