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Modelling public attitude towards air taxis in Germany

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A B S T R A C T

Urban air mobility (UAM) holds great promise as an expansion of the transportation system in cities. Despite the progress in UAM technology, there remains significant uncertainty surrounding how the public will accept and react to these mobility services.

This study employed a structural equation model (SEM) to construct a comprehensive framework that delves into the factors influencing public attitudes toward air taxis. Data for the model is derived from a sequential exploratory mixed methods approach. The initial phase involved identifying acceptance factors towards air taxis through five focus groups, laying the foundation for the subsequent structural model development. A survey involving 819 participants was conducted in Germany in the next phase. The latent variables in this model are the expected benefits, expected risks, and the personal level of technophilia. The results show that rising stress levels through new air traffic flows, noise, and blocking sky views affect negative attitudes toward air taxis in public spaces. In contrast, the user expectation of avoiding traffic jams and achieving time savings contributes positively. Additionally, people who are more technophilic tend to have a more positive attitude toward air taxis.

However, the perceived negative consequences of air taxis exert more substantial and stronger influences on public attitude than the expected benefits. By introducing the acceptance factors and relevant dimensions of a public attitude, this study provides insights to shape the design of UAM in accordance with the common good.

1. Introduction

1.1. Background

In the 1950s, various protagonists had expected helicopters to form a new means of public transport for rapid transit in and between metropolises. However, high costs, lack of infrastructure, safety and security risks, as well as public rejection due to noise emissions prevented this vision from realisation (Dienel, 1997; Cohen et al., 2021). Meanwhile, technological progress has led to the development of new electric vertical take-off and landing (eVTOL) aircrafts (Shamieyeh 2017) that own quieter electric propulsion systems and, at least prospectively, cost-saving automated vehicle control. Considering these developments, the vision of an Urban Air Mobility (UAM) is revived.

In expectation of a relevant market share, investments in the six leading North American and European eVTOL producers and prospected UAM operators (Joby Aviation, Lilium, Paragon, Archer Aviation, Beta Technologies, and Volocopter) accounted for around US$ 4.6 billion between 2020 and 2021 alone (Shaposhnikov et al., 2021). The business models of these companies are primarily aimed at urban and regional passenger transport. Depending on increasing battery capacities, an expansion to inter-city transport is envisaged (Garrow, n.d.). While market analysts predict that air taxis will not become economically viable before 2030 (Grandl et al., 2021) manufactures are pushing for an early market launch in the first half of this decade and are supported by a growing political consensus that air taxis shall play a role in future passenger transit (European Commission, 2020). If recent developments continue to materialize they mark not just a historical turning point in aviation, but the beginning of a new era in which low level airspace may become the ‘third dimension’ of transportation (Kellermann et al., 2020).

Despite optimistic investment forecasts and technological as well as regulatory frameworks for UAM operations advancing steadily, there is a high degree of uncertainty regarding the public response toward such services. Contemporary literature has already provided insights on factors affecting the adoption of air taxi services by potential customers, ranging from target customer definitions (Goyal et al., 2021, Ahmed et al., 2021) to vehicle design considerations (Stolz et al., 2021; Edwards and Price, 2020), to design guidelines for passenger handling and transport service provision (Han et al., 2019; Rice et al., 2022).

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However, the technology also entails an inherently public dimension. It will be a characteristic of UAM that far fewer people will benefit from its services than those who will be exposed to its potential negative externalities (Clothier et al., 2015). As a recent studies for a relatively small European metropolis with 1.5 million inhabitants shows, even an expected market share of 1 % on the overall modal split will account for 45.000 flights per day (Ploetner et al., 2020). Thus, the potential benefits, e.g. of increased mobility and exclusive travelling experiences may stand against the potential impacts of UAM on the urban sound- and landscape, environmental and sustainability concerns, as well as security issues in air or in proximity to ground infrastructure components (Straubinger et al., 2021).

By outlining which dimensions have a significant, positive or negative influence on attitudes towards UAM, social science attitude research can contribute to a better handling of this friction and help policy makers, urban planners and business developer to design services in accordance with the public's expectation. Against this backdrop, this article presents and tests a model to explain the attitude toward air taxis from a societal point of view. The model examines the influence of expected benefits, expected risks, and the individual level of technophilia on the attitude. The relevant data for the model was received using a sequential exploratory mixed methods design. In a first step, factors affecting attitudes toward air taxis were identified within the scope of five focus groups conducted in three German state capitals. In a second step, these qualitative derived factors were converted into the development of a questionnaire and the realization of a population-representative telephone survey in Germany, which provided quantitative data. The measurement model of these variables is tested using a confirmatory factor analysis, and the overall structure of the SEM is assessed on a sample size of 819 entities.

1.2. Literature review

The advancing market maturity for eVTOLs seems to have not reach the awareness of the broader public yet. Drawing on the USA and its ambitions industry, authors surveyed 23 % (Shaheen et al., 2018) and 19 % (Aydin, 2019) awareness towards advanced air mobility concepts in 2018 and 2019 respectively. Still in a 2022 online survey conducted for NASA with a sample size of 1500 citizen from Los Angeles and Ohio, only around 15 % of respondents stated some familiarity with the air taxi concept (MAVEN, 2022). In addition to that, firsthand experiences with the technology are scare as only a very few people have used an eVTOL nor experienced its operation from a resident's point of view. Apart from simulations (Stolz and Laudien, 2022) and ad-hoc surveys at demonstration events (Behme and Planing, 2020), qualitative and quantitative attitude research must therefore draw on the respondent's contemporary knowledge of future air transportation scenarios and results must be understood as time and location specific. However, overarching trends can be outlined. For example, Tepylo et al. (2023) analysed several studies in the USA between 2011 and 2018 and show how the willingness to fly in such an autonomous aircraft increased from almost 10 % to over 50 % (Tepylo et al.). In contrast to that, a German population-representative telephone survey from 2020 shows that only a minority of 18 % of respondents somewhat or fully agree to use air taxis for their personal mobility (Dannenberger et al., 2020), while a representative online study two years later found that 22 % of respondents would be willing to use air taxis for inner-city commuting (Verband Unbemannte Luftfahrt VUL, 2022).

The intention to use air taxi services has been attracted broad research interest. Especially the perceived usefulness of service has been outlined of central importance by statistical analysis (Winter et al., 2020). For passenger UAM authors show that this hope is strongly associated to a reduction of travel times (Al Haddad et al., 2020). It is therefore more comprehensible, that a representative study with participants from six European cities commissioned by EASA concludes that an average of 49 percent would try out and pay more for an air taxi if the trip in question can be done in half the time it takes with a roadside taxi service (EASA, 2021). Regarding the risk perception of UAM, Han et al. (2019) outlined that the respondents risks perception to life and limb has a significant negative influence on the attitude to board electric-powered aircrafts, which should be particularly true during early operations and low familiarity with the technology (Han et al., 2019). In addition to these findings, research indicates that participants' feelings of safety about eVTOLs strongly depends on how they are piloted. Chancey and Politovich show that remotely piloted eVTOLs are trusted less compared to services with a pilot on board (Chancey and Politowicz, 2020). What is more, the perceived service reliability of air taxi services, e.g. on-time performance (Al Haddad et al., 2020) and low performance risk (Han et al., 2019) are important for the adoption of air taxis and the desire to use all-electric passenger aircraft respectively.

In addition to the relevance of potentials and risks for forming public attitude, individual dispositions of technological openness or technophilia are shown to play a role in the formation of attitude toward air taxis, as already suggested by the adoption of delivery drones (Yoo et al., 2018), electric vehicles (Schlüter and Weyer, 2019) or driving support systems (Ntasiou et al., 2021). Winter et al. (2020) point out that people have different basic attitudes toward new technologies. Within the framework of their empirical study, they concluded that a greater openness toward new technologies generally also affects the willingness to book an autonomously operating air taxi positively. Al Haddad et al. (2020) have the same assessment for automated air taxis. Furthermore, both groups of authors show that the willingness to fly with a passenger drone decreases the smaller is the understanding of the technology that controls the vehicle (Winter et al., 2020; Al Haddad et al., 2020).

While the willingness to use air taxi services has a direct impact on the economic feasibility of UAM business models, the development of urban airspace as a new transport level is also a societal and political decision. After all, traffic externalities and questions of social equality may hamper the technologies' expansion into the public realm (Biehle, 2022). Thus, research should contribute to understanding the central factors influencing public attitudes towards passenger UAM. Aiming to illuminate public acceptance levels of UAM services, survey data revealed air taxis to be perceived rather critically. The mentioned cross-European study conducted by EASA (2021) shows that among various application scenarios of drone technologies, the use of air taxis in urban areas for inner city point to point travel was considered among the least useful application. In contrast, the perceived benefits of automated drones are primarily seen in deployment scenarios with clear added value for society. These include, in particular, the rapid delivery of medicines or the use of eVTOLs to transport patients. In general, commercial applications are considered to be of secondary importance (EASA, 2021).

Regarding the impact of passenger UAM on public space, the aforementioned population representative study from Germany shows that 43 % of respondents believe that air taxis would make urban areas less liveable, while only 22 % of respondents are sure that passenger transport with air taxis would have a positive impact on the quality of life in cities. When asked about a future in which many people would use air taxis, 61 % of respondents rated it as very or fairly bad if air taxis blocked the currently unobstructed view of the sky (Dannenberger et al., 2020). In a statistical model, authors already confirmed the significance of these both factors for the formation of public attitudes towards delivery drones in urban areas (Kellermann et al., 2023). Further concerns from various surveys in the field of passenger UAM are summarized in Çetin et al. (2022) whereby possible negative environmental impacts form a large thematic cluster. Especially, noise emissions of air taxis are identified as an overarching obstacle to community acceptance (Çetin et al., 2022). Regarding the necessary ground infrastructure for air taxis, so-called vertiports, the mentioned EASA study asked respondents to identify their top three concerns related to a potential vertiport in vicinity to their place of living. Noise (48 %) and safety concerns (41 %) were feared most. In addition, concerns about visual pollution (32 %), increasing inbound and outbound traffic (29 %) and taking up land better used for living or recreation (28 %) rank highest (EASA, 2021) In a survey from the UAM model region Ingolstadt, Germany, the authors show that air taxis can also affect citizens' sense of security in the vicinity of vertiport infrastructures or along flight routes. Risks of misuse, for example, through attacks on weak points in the IT infrastructure, are considered even more relevant than the threat of technical faults or the danger of collisions and wildlife strikes (Janotta et al., 2021).

Concluding this brief review on attitude and acceptance research in the field of UAM, a broad body of studies engages into forecasting customer adoption by investigating factors that increase the willingness of defined customer segments to use air taxi services. In contrast, only a few studies tried to analyse the societal perception of air taxis' deployment in public airspace and the factors that influence public attitudes. Within this field, survey data prevails over more robust modelling approaches that aim to outline, which acceptance factors have a statistical significance on attitudes. This article addresses this research gap, providing orientation for design option for passenger UAM in accordance with public norms and expectations.

2. Methodology & data

2.1. Sequential exploratory mixed methods

Basis for this research forms a sequential exploratory mixed methods design (Tashakkori & Teddlie, 2009; Leech & Onwuegbuzie, 2009). In this methodological approach, qualitative data on the attitude towards air taxis was collected first, which was seen highly relevant because, as shown above, the awareness and knowledge towards the technology is still limited. Thus, instead of drawing on acceptance factors from the literature and conducting a survey, in a first step, focus groups were conducted to deliberate on the topic of air taxis. Second, to develop a model structure, results of the focus groups were evaluated using content analysis within the theoretical framework of technology acceptance research. Quantitative data for the variables was than gathered in a second step by conducting a telephone survey with a standardized questionnaire, allowing to build and test the structural equation model (Fig. 1).

2.2. Structural equation model (SEM)

This paper applies SEM (structural equation model) to analyze different attitudinal factors related to air taxis, including latent and observable variables. SEM contains different statistical approaches: analysis of variance, multiple regression, factor analysis, and path analysis (Bowen and Guo, 2011). SEM measures and estimates the associations among observed and latent variables. The integrated analytical methods in SEM enclose between-group and within-group variance comparisons through the ANOVA method. Therefore, SEM analyzes linear associations among variables while, at the same time, it accounts for measurement errors, which is one of the most splendid limitations of other statistical methods. Hence, SEM includes Path analysis and factor analysis together. Path analysis examines the hypothesized associations among variables. Factor analysis studies how latent variables are calculated from observed variables (measurables). These analyses are usually performed by using data in the form of means or correlations and covariances (i.e., unstandardized correlations). The maximum likelihood function is applied to estimate coefficients and parameters.

Factor analysis (measurement model) evaluates how well sets of observed variables measure latent variables. These latent constructs cannot be measured directly and are related to psychological concepts such as attitudes and emotions (Bowen and Guo, 2011). The Cronbach test was applied to examine the reliability of the measurements. A higher alpha suggests that correlation among observed variables is acceptable to be representative of a latent variable. Many studies indicated that the values of Cronbach's alpha should be above 0.70 to assure the reliability of the constructs (Netemeyer et al., 2003).

2.3. Data set

First, qualitative data were collected by conducting a set of focus groups to guide the development of a model structure by identifying and classifying relevant variables that could influence perceptions and attitudes toward air taxis. Building on that qualitatively derived set of variables, quantitative data were gathered in a second step by conducting a telephone survey.

2.3.1. Focus groups

The five focus groups took place in the German capital Berlin and in the two state capitals of Stuttgart and Erfurt in autumn 2019. The aim was to qualitatively investigate attitudes but also concerns and expectations toward fully automated, remotely operated air taxis. Participants were chosen according to a pre-screening questionnaire aiming to exclude participants who had never heard about drones before and those who worked in the drone industry.

Since respondents' attitudes toward new technologies are often related to age (Arning and Ziefle, 2007; Jakobs et al., 2008; Niehaves and Plattfaut, 2014) and gender (Gefen and Straub, 1997; Venkatesh and Morris, 2000), two focus groups were conducted with older (45–65) and two with younger (18–44) participants while gender balance was always ensured. In addition, the representation of different levels of education, income, and household sizes were ensured to avoid selection biases (Hollis et al., 2002).

The implementation of the focus groups followed the methodological procedure proposed by Benighaus and Benighaus (2012). First, participants were introduced to different concepts and applications of civilian drones in a ten-minute presentation. Afterward, a commercial video clip[1] was shown, which demonstrated what an automated passenger transport by drone within an urban transport system might look like. Following this, the participants discussed under the guidance of a professional moderator based on a pre-developed discussion guideline about air taxis as a possible new transport mode in the context of their everyday life and living environment (Benighaus and Benighaus, 2012).

All focus groups were recorded, transcribed and analyzed within the theoretical framework of technology acceptance theory (Lucke, 1995; Schäfer and Keppler, n.d) through qualitative content analysis (Mayring, 2012) and the help of the qualitative data analysis software Atlas.ti (Version 8). For coding, first quotations were sorted into the theory-based categories: attitudes, behavioural intentions, object- subject- and context-related acceptance factors (Crabtree and Miller, 1992). The different attitudes and acceptance factors, however, were generated inductively throughout the analysis of the transcripts to assure the identification and contextualization of acceptance factors, which have not been previously investigated by other studies (Boyatzis, 1998). The weighting of the factors was derived from the frequency with which they were coded (Kellermann and Fischer, 2020).

2.3.2. Survey

The survey with 1000 respondents from Germany was conducted in early 2020 using fully structured computer-assisted telephone interviews (CATI). The aim was to investigate attitude, willingness to use quantitatively, and the most frequently discussed concerns and expectations about air taxis based on factors derived from the focus group discussions. The survey sample was representative of the German population older than 18 years.[2]

As an introduction to the survey, respondents were informed that it

[1] The video is available under: https://www.youtube.com/watch?v=44bSw-wPW4c.

[2] The data set is publicly available under: https://data.gesis.org/sharing/#!Detail/doi.org/10.7802/2155.

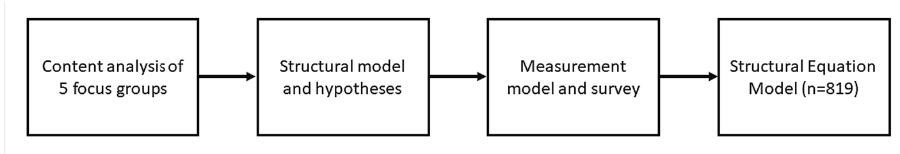

Fig. 1. Sequential mixed-methods approach.

focused on the future of urban transport, in which drone technologies for passenger transportation might play a role. Respondents were then asked to agree or disagree with various statements on a five-point Likert scale for each question. In addition, a "do not know/no answer" response option was offered as a choice. To minimize a response bias due to a fixed order of questions, the corresponding batteries of questions were randomized (Chaudhuri and Mukerjee, 2020). Moreover, to minimize Acquiescence Response Bias (Bogner and Landrock, 2016), the questionnaire followed a query of factors by an alternation of positively and negatively formulated items.

2.3.3. Sample

After removing entries with missing values from the original dataset, the sample size used for the statistical analysis in this paper consisted of 819 respondents. Table 1 indicates the characteristics of the sample, which, despite its reduced size, still corresponded strongly to the socio-demographics of Germany. However, with 54.3 % in the sample, men are slightly overrepresented in the model sample (Statistisches Bundesamt, 2020). About 29 % of respondents were aged 18–39. The age group, 40–59, was represented by about 40 %. Around 31 % of respondents were 60 years or older. Most respondents reported a monthly net household income of 4,500 euros or more (about 27 %). Over two-thirds of respondents stated to be employed. Around 21.1 % of respondents live in major cities of 500,000 or more inhabitants. About 50 % of the respondents originated from smaller towns with a population between 5.000 and 100,000 inhabitants.

Table 1
Socio-demographic distributions of the model sample.

		Count	%
Gender	male	445	54.3 %
	female	373	45.5 %
	divers	1	0.1 %
Age	18–29 years	84	10.3 %
	30–39 years	152	18.6 %
	40–49 years	157	19.2 %
	50–59 years	173	21.1 %
	60 + years	253	30.9 %
Household monthly income	below 500 EUR	4	0.5 %
	500 until below 1.000 EUR	21	2.6 %
	1.000 until below 1.500 EUR	53	6.5 %
	1.500 until below 2.000 EUR	58	7.1 %
	2.000 until below 2.500 EUR	87	10.6 %
	2.500 until below 3.000 EUR	74	9.0 %
	3.000 until below 3.500 EUR	72	8.8 %
	3.500 until below 4.000 EUR	76	9.3 %
	4.000 until below 4.500 EUR	80	9.8 %
	4.500 and more	222	27.1 %
	No indication	72	8.8 %
Employment	employed	519	63.4 %
	unemployed	300	36.6 %
City Size	below 5.000 EW	119	14.5 %
	between 5.000–20.000	177	21.6 %
	between 20.000–100.000	227	27.7 %
	between 100.000–500.000	123	15 %
	more than 500.000	173	21.1 %

2.4. Model and hypotheses

The proposed attitudinal model consists of 16 observed variables that are entirely based on the qualitative results of the five focus group discussions (Kellermann and Fischer, 2020). Based on these results and informed by key concepts from technology acceptance theories, the four latent constructs of expected benefits, expected risks, technophilia, and attitude were defined. Fig. 2 shows the structural model.

2.4.1. Public attitude

Within the classical technology acceptance models of TAM (Davis, 1989) and Theory of Planned Behavior (TPB, Ajzen, 1991), a person's attitude toward an object determines, among other factors, an individual's behavioral intention to use it. Referencing drone related acceptance research, studies have already utilized the concept of attitude as a dependent variable to draw on the usage of drones and related services (Clothier et al., 2015; Chamata and Winterton, 2018; Han et al., 2019; Yoo et al., 2018). As this study tries to shed light on the perception of citizens toward air taxis services, attitude, and not the usage intention represents the target variable. Hence, hypotheses in this research test the formation of attitudes toward air taxis.

In alliance to Lee (2009), attitude can be understood as a person's positive or negative thoughts concerning the performance of a behavior (Lee, 2009). From the focus group discussions, four dimensions of positive and negative concerns regarding air taxis emerged: their implications on the quality of life, the safety of related services, their utility, and their environmental impact. For example participants worried that it would increase the stress level if air taxis "*buzz around all the time*", that they "*can be hacked*", that it would make sense "*to get from one city to the other, when they are not connected through public transportation*" or that they would only be willing to accept the use of the technology if it was "*environmentally sound in any way*" (Kellermann und Fischer 2020).

As these four dimensions mainly reflect broader public interest concerns, the concept of *public attitude* was created. Legitimizing the selection of these qualitatively derived attitudinal dimensions, they also align to basic constructs of behavioral and acceptance research that have been conceptualized across various other domains. While e.g., the construct of environmental attitudes has been prominently used as a predictor to explain behaviors in the context of individual travel patterns (Susilo et al. 2012; Murray et al. 2010), the construct of safety attitudes has been used to explain and predict safety-related issues in road traffic (Ram & Chand 2016) or public health sector (Lee et al. 2010).

Accordingly, in order to receive quantitative data, the four qualitatively derived attitudinal dimensions were measured in the survey by asking respondents how much they would agree to the statements of air taxis (1) bringing advantages in the respondents' everyday life, (2) being safe, (3) having a positive effect on the quality of life in cities, and (4) being more environmentally friendly than a regular taxi.

2.4.2. Expected risks

In the body of acceptance theory, the concept of risk was introduced as a variable to influence attitude formation or decision making when the consequences of an action or the circumstances surrounding it cause uncertainty or anxiety (Bauer, 1960). In drone-related research, the

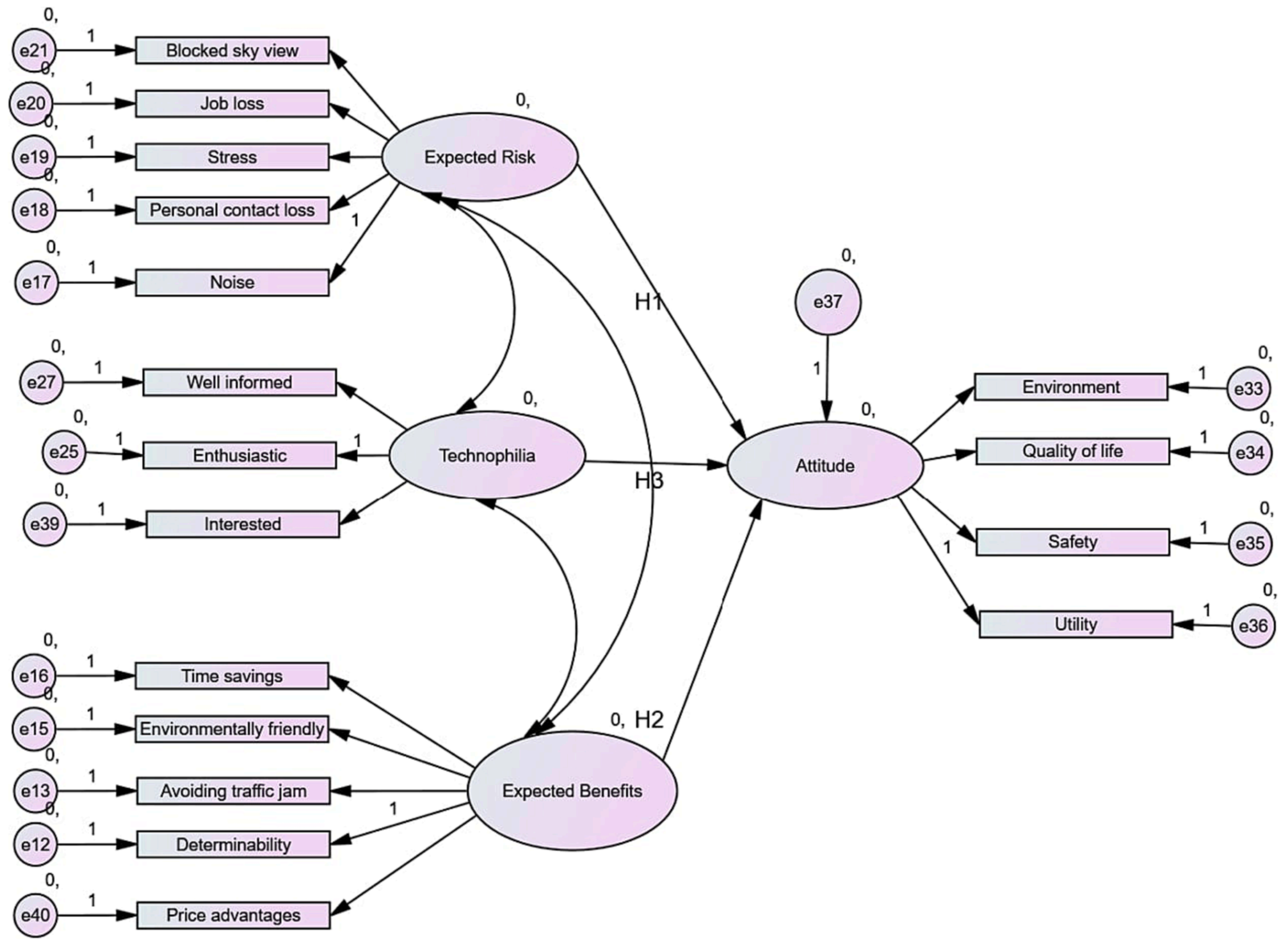

Fig. 2. Structural Model and Hypotheses.

variable of (perceived) risk has already been conceptualized (Clothier et al., 2015) and served as a relevant factor on attitude research on in empirical models (Han et al., 2019). In this research, expected risks are understood as concerns in respect to a future introduction of air taxis in urban areas.

During the focus groups, risks related to a growing number of air taxis in the sky were discussed mainly from the perspective of being a passively exposed resident rather than being a passenger. Concerns of noise emissions ("*We already have such a massive noise pollution in the city, mostly through traffic and then that on top. That would be really loud for sure*") of cognitive stress from the movement of many vehicles and a blocked view to the sky have been stated most persistently as expected negative consequences (Kellermann and Fischer, 2020). Interesting to note is that the participants associated automation as a relevant risk, e. g., for taxi drivers to lose their job. In contrast to studies on user acceptance, the way in which air taxis are controlled was not treated as a relevant criterion for safety in the focus groups (e.g., Winter et al., 2020; Al Haddad et al., 2020). Accordingly, the following hypothesis is proposed:

- H1: There is a significant association between a subject's expectation of risks and its attitude to air taxis.

The latent variable of expected risks was measured in the survey by asking how bad for the respondent were (1) the noise from passenger drones, (2) that automation would bring job losses to taxi drivers, (3) the stress caused by air taxis flying around to passively exposed persons, (4) that passenger drones would block the free view toward the sky.

2.4.2. *Expected benefits*

As a fundamental assumption of the TAM, the perceived usefulness of a new technology has a direct correlation to respondents' attitudes toward it. In its original understanding, the perceived usefulness concerns actual users and the benefits that information systems might bring them personally (Davis, 1989). In this research, however, expected benefits describe attributes of passenger UAM, that are deliberately recognized by the public to address common issues and enhance welfare, nevertheless individuals might or might not intend to personally use such services. This is in line with attitude research, e.g. on mobility policy preferences, suggesting that general support for investments traffic-reducing measures is strongly predicted by environmental and air pollution perception variables (Schmitz et al. 2019) Thus, a correlation between expected benefits and the formation of the public attitude towards air taxis is suggested. In drone-related attitude research this conceptual approach is novel as prior research aimed to explain the adoption of the technology from a user or consumer perspective only (Clarke, 2014; Chamata and Winterton, 2018; Al Haddad et al., 2020).

In the focus groups, the expected benefits of air taxis were seen by some participants as alleviating common transport problems and, for example, relieving road traffic for all. Other participants were sceptical, pointing to the large number of vehicles in the air that would be needed to achieve such an effect ("*Maybe we would no longer have congestion on the ground but then it would really be crowded in the air. I am not sure that would improve the situation*"). The question of whether electric automated air taxis would become a more sustainable and possibly even cheaper alternative to existing modes of transport was also discussed controversially but partly seen as possible. More agreement was found on potential individual benefits of air taxis. The idea of escaping congested streets and saving travel time seemed highly attractive to many ("*That really is an enormous time saving, especially at rush hour through the inner-city here, you need half an hour or 45 min from one place to the other and with [air taxi] it would be over within 5 min*"). Finally, the participants felt that it would be a great advantage if passengers in the future could determine the drop-off area of an air taxi (Kellermann and Fischer, 2020). Accordingly, we propose the following hypothesis:

- H2: There is a significant association between a subject's expectation of benefits and its attitude to air taxis.

As predictors for the latent variable of expected benefits in the survey, it was asked how important it would be for the respondent that passenger drones would (1) take one exactly to a place of one's choice, (2) be environmentally friendly, (3) be inexpensive, (4) that one would not have to stand in a traffic jam with the air taxi and that (5) one would save time with an air taxi.

2.4.3. Technophilia

The Diffusion of Innovation Theory (DOI) proposed by Rogers (1962) provides a theoretical explanation for explaining why people do or do not embrace new technologies. DOI suggests an innovation to slowly move through different social groups, which also represent differing levels of personal innovativeness. In drone-related research the openness toward air taxis has already been shown to impact the willingness to use an autonomously (Winter et al., 2020) or automated air taxi (Al Haddad et al., 2020). In this research, the perceived individual affinity toward new technologies, as we define technophilia, is introduced as a predictor for the public attitude of air taxis.

This decision draws foremost from the focus groups. As limited experiences and a rather high contingency on the expected effects of air taxis prevailed among participants, their general disposition towards novel technologies was emphasised for the deployment of air taxis in urban space. As the content analysis shows, this was often independently of individuals intending to personally use such services in future nor not. On the one hand, participants expressed an intrinsic interest in new technologies and argued positively for passenger drones ("*I mean I just really love it and it would be fine if it came true*"). In stark contrast to this was the scepticism ("*Somehow this is all very strange to me. I'm already afraid of this little helicopter and the cat is too*") or even hostility by other participants to this and other technology (Kellermann and Fischer, 2020). Accordingly, we propose a third hypothesis:

- H3: There is a significant association between a subject's technophilia and its attitude to air taxis.

The survey design drew on established questionnaires in the field, which already measured technophilia as a latent variable (acatech and Körber-Stiftung, 2018). Accordingly, to measure technophilia, (1) the respondents' subjective level of information about technologies, (2) their ability to get easily enthusiastic for new technology, and (3) their general interest in technology were surveyed.

3. Data analysis and results

The sample size of the survey was 819. All the values of Cronbach's alpha were above the threshold (0.7), which confirmed the high reliability of the measurement model. The result of the Cronbach test is indicated in Table 2. The multicollinearity assumption by using the value of the variance inflation factor (VIF). All the constructs were considered as predictors of one of the constructs and calculated the VIF scores. The VIF scores are less than 2.00, which are less than the recommended value of 10, indicating there is no high risk of multicollinearity (Hair et al., 1998). Structural equation modelling (SEM) was utilized to estimate the hypothesized relationships. The analyses provided acceptable fit indices for the structural model.

Table 2
Results of Cronbach Test.

Latent Variable	Observed Variable	Variable names	Cronbach alpha
Technophilia	**How much would you agree to the following statement:**		
	In general, I am well informed about new technologies.	Well informed	0.798
	I get easily enthusiastic about new technologies.	Enthusiastic	
	I am always interested in new technologies.	Interested	
Expected Risks	How bad would be for you…		
	…the noise from air taxis.	Noise	0.821
	…the stress caused by air taxis.	Stress	
	…job losses of taxi drivers because of air taxis.	Job loss	
	…blocked free view of the sky by air taxis.	Blocked sky view	
Expected Benefits	How important would be for you…		
	…that air taxis generate time savings.	Time saving	0.846
	…that air taxis avoid traffic jams.	Avoiding traffic jams	
	…that air taxis are environmentally friendly.	Environmentally friendly	
	…that air taxis take you exactly to a place of your choice.	Determinability	
	…that air taxis create price advantages.	Price Advantage	
Attitude	How much would you agree to the following statement:		
	…that passenger transport with air taxis is more environmentally friendly than a regular taxi.	Environment	0.851
	…that air taxis are safe.	Safety	
	…that passenger transport with air taxis would have a positive effect on the quality of life in cities.	Quality of life	
	…that passenger transport with air taxis would bring me advantages in my everyday life.	Utility	

3.1. Fitness of model

The comparative fit index (CFI), the Tucker–Lewis index (TLI), and the root mean square error of approximation (RMSEA) are used to check the fitness of the model.

The comparative fit index (CFI) indicates the model fit by checking the discrepancy between the data and the hypothesized model. The CFI value is in the range from 0 to 1, and if its value is close to 1, it indicates better fit. The calculated CFI in this model is 0.984, which is larger than 0.9, indicating an acceptable model fit. Tucker–Lewis index (TLI) is an incremental fit index, that TLI >0.90 indicates an acceptable fit (Bentler and Bonett, 1980). In this model TLI is 0.980.

The root mean square error of approximation (RMSEA) is one of the most widely used measures of misfit/fit of structural equation modelling. RMSEA indicates how well the model, with unknown but optimally chosen parameter would fit the populations covariance matrix (Byrne, 2013). It is 'one of the most informative fit indices' (Diamantopoulos and Siguaw, n.d.) due to its sensitivity to the number of estimated parameters in the model. The values of 0.01, 0.05 and 0.08 indicate excellent, good and mediocre fit respectively. In this model, RMSEA is around 0.035 which indicates a good fit.

3.2. Factor loadings

The measurement model indicates how latent variables are measured by observed variables. The Results are the measurement model are shown in Table 3 and also in Fig. 3.

The latent variable of "expected risk" in this model is measured by the five observable variables implying significantly different load factors. While the concern of *stress* through movement in the sky and *noise* from air taxis have the highest load factor by (0.86) and (0.81), respectively, *Job loss* is still significant but has the lowest factor load by 0.49.

The latent variable "expected benefits" was defined by 5 observed variables. While the observed variable *avoiding traffic jams* has the highest load factor by 0.85, *environmentally friendly* has the lowest load factor by 0.5. The variables of time *saving,* and *determinability* have close load factors by 0.79 and 0.77, respectively.

The measurement model of technophilia includes three observed variables. The variable of easily feeling *enthusiastic* has the highest load factor by 0.86 and the variable of usually *well informed* about new technologies has the lowest load factor by 0.61.

The standardized estimates between the latent variable public attitude and its measurement show that the observed variable of *quality of life*, meaning that Passenger transport with air taxis would have a positive effect on the quality of life in cities, has the highest load factors by 0.85. *Environment,* meaning that transporting people by air taxi is less environmentally friendly than driving a normal taxi, has the lowest standardized estimates (0.49).

3.3. Structural model & hypothesis testing

Table 4 indicates the results of the associations between "Attitude" and the other three latent variables. The model suggests significant associations of attitude with expected risks (H1) by ($\beta = -0.52$, $p < 0.001$) and expected benefits (H2) by ($\beta = 0.38$, $p < 0.001$). Moreover, the standardized estimates of technophilia is 0.11 with the p-value < 0.001, indicating a significant association with attitude. Therefore, all three latent variables have significant associations with attitude (see Fig. 3).

4. Discussion

The relevance of all 16 observed variables that were derived from qualitative research and applied in the SEM model via the four latent variables (expected risks, expected benefits, technophilia, and attitude) is confirmed by significant factor loadings. An overall acceptable fitness of the structural equation model is given as per the relevant indices CFI (0.984), TLI (0.980), and root mean square error of approximation RMSEA (0.035). Furthermore, the presented structural model supports a significant association between expected risks (-0,52), expected benefits (0.38) from air taxis as well as of respondents' level of technophilia (0.11) on the attitude in the dataset (n = 819).

The public attitude toward air taxis was considered as the latent dependent variable in this model. It is reliably represented by a composition of the following four observed variables that were extracted from the focus group discussions and reflect central attitudinal dimensions of broader public interest: i) concerns about *safety*, ii) impacts on the *quality of life* in cities, iii) the *environmental* dimension, and iv) general *utility* of air taxis. In the measurement model of "attitude", the *estimator "quality life"* has the highest load factor of 0.846, which means this factor extracts a high variance of the variable "attitude".

Regarding the research hypotheses, the model confirms a significant negative association of attitude with expected risks (H1). This finding is consistent with previous technology acceptance studies from other domains (Lee, 2009; Im et al., 2008; Vijayasarathy, 2004). Regarding the varying influence of risk factors, our findings demonstrate that particularly people with a more negative attitude toward air taxis who expect them to be a source for cognitive *stress* (0.863) and *noise* (0.814). While *stress* generated by movements in the sky has not yet been considered as a factor in previous studies, the central relevance of *noise* for the acceptance of drones in urban spaces has been anticipated persistently (Kellermann et al., 2020, Çetin et al., 2022). As the relevance of noise concerns has already been confirmed for the case of delivery drones (Kellermann et al., 2023), the present work now confirms this assumption for the case of air taxis. Furthermore, the SEM revealed a negative implication on the attitude of individuals expecting the extensive implementation of air taxi services to create an impression of a *blocked sky* (0.786), which has been suggested for drones, using psychological experiments conducted by Kähler et al. (2022). The study also identifies the risk of *job losses* of taxi drivers as a controversial phenomenon of automated air taxis with the lowest load factor of (0.49) among other observed variables. This hints at the relevance of social implications representing a previously untried dimension of UAM-related acceptance studies, which could inform future research on innovative transportation technologies.

Furthermore, the presented model reveals a significant positive association of attitude with expected benefits (H2). This result aligns with findings from technology acceptance research in various domains, which have illustrated the relevance of beneficial factors in positively affecting attitudes toward technology adoption (Davis, 1989, Lee, 2009, Vijayasarathy, 2004). In relation to attitudes toward the specific case of air taxis, our study provides evidence that particularly people form a more positive attitude toward air taxis who expect them to be a transport mode for *avoiding traffic congest*ion (0.846), and to be a *time sav*er (0.793). This finding is consistent with a similar study by Al Haddad et al. (2020) that showed reduced travel time to affect the willingness to use air taxi services positively. Moreover, our results suggest that people form more positive attitudes if they associate air taxis with the *determinability of mobility* (0.774), and *price advantages* (0.691). However, the observed variable *of "environmentally friendly"* has the lowest load factor in this measurement model (0.497), indicating that this factor has a low contribution on the measurement of the variable "expected benefits". The latter finding correspond to a study on attitudes toward delivery drones, which also found the relative advantage of a more environmentally friendly delivery to be a comparably weak but yet significant predictor of creating a positive attitude or an intention to use delivery drones (Kellermann et al., 2023). Moreover, Yoo et al. (2018) and Mathew et al. (2021) also found the relative advantage of faster delivery to be a significant predictor.

The standardized estimate of expected risks is −0.52 and for expected benefits is 0.38. The Wald test is applied to check the significant difference between these two coefficients in the model. The results show the significant difference between two estimates at 95 % confidence level (Wald statistics 17.2, P-value < 0.05). Therefore, the expected risks of air taxis have a stronger association than the expected benefits (It

Table 3
Results are the measurement model.

The measurement model			Estimate
Determinability	<—	Perceived_benefits	**0.774**
Avoiding traffic jams	<—	Perceived_benefits	**0.846**
Environmentally friendly	<—	Perceived_benefits	**0.497**
Time saving	<—	Perceived_benefits	**0.793**
Price advantage	<—	Perceived_benefits	**0.691**
Noise	<—	Perceived_Risk	**0.814**
Stress	<—	Perceived_Risk	**0.863**
Job loss	<—	Perceived_Risk	**0.486**
Blocked sky view	<—	Perceived_Risk	**0.786**
Enthusiastic	<—	Technophilia	**0.845**
Interested	<—	Technophilia	**0.809**
Well informed	<—	Technophilia	**0.613**
Environment	<—	Attitude	**0.698**
Quality of life	<—	Attitude	**0.846**
Safety	<—	Attitude	**0.754**
Utility	<—	Attitude	**0.774**

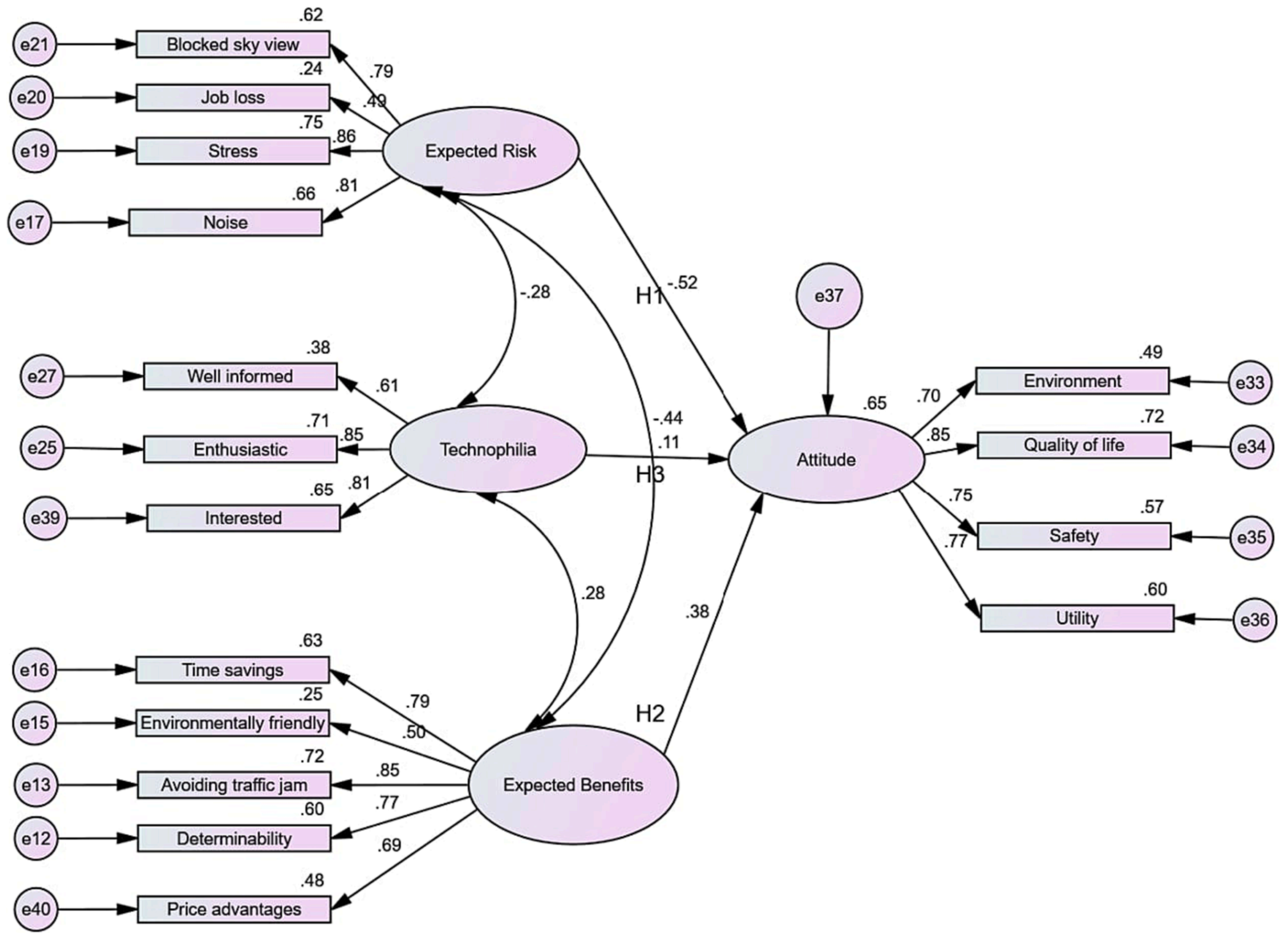

Fig. 3. Structural Equation Model.

Table 4
Results of the structural model.

Hypothesis	Standardized Estimates	P	Results
H1: Attitude <— Expected_Risk	−0.52	<0.001	Supported
H2: Attitude <— Expected benefits	0.38	<0.001	Supported
H3: Attitude <— Technophilia	0.11	<0.001	Supported

means that by one unit increase in expected risks, the value of attitude decreases by 0.52 unit, while by one unit increase in expected benefit, the attitude value increases by 0.38 unit. The relationship might, to some extent, be explained by the lack of familiarity and experience with air taxis. On the one hand, risks in the specific case of flying in urban airspace may be perceived as more intuitive and tangible (e.g., stress, noise). On the other hand, the potential benefits of air taxis might seem unrealistic (e.g., affordability, environmental friendliness) or yet far from reality (e.g., everyday commuting with an eVTOL and determinable drop-off locations). In this respect, behavioral and technology adoption studies have postulated the relevance of factors such as familiarity and experience in forming attitudes (Davis, 1989; Karahanna et al., 1999; Rogers, 2003), which is related to air taxi services that so far have not been implemented.

Finally, the model suggests a significant positive association between a person’s technophilia and attitude (H3) toward air taxis. Individuals that consider themselves as being *well informed* (0.613), *generally interested* (0.809), or easily *feeling enthusiastic* about learning and trying new technologies (0.845) have significantly more positive attitudes toward air taxis. This finding can be interpreted as consistent with findings in related fields. For example, the significance of technophilia was confirmed by studies examining the user adoption of delivery drone services, using the latent variables “personal innovativeness” (Yoo et al., 2018) and “Cognitively Motivated Consumer Innovativeness” (Mathew et al., 2021). The personal openness to new technologies and the risks related to them were also found to affect the customer willingness to book an autonomous (Winter et al., 2020) or automated (Al Haddad et al., 2020) air taxi. However, Kellermann et al. (2023) did not capture a significant positive association of technophilia and attitude in the case of using delivery drones for commercial purposes. This discrepancy might be explained by generally imagining it more thrilling to be transported personally by an automated drone compared to receiving a drone-delivered package.

Besides being confirmatory in nature, the presented results may inform economic and political decision-makers toward the implementation of air taxis. First, concrete factors influencing public attitudes were presented. Regarding negative impacts, a detailed exploration should be made of how the perception of stress for people on the ground is created by aircraft movements in the sky and how this perception can be moderated, especially through prudent urban mobility planning and stakeholder participation (Biehle 2023). Regarding the noise factor, a similar research focus is already established (Vascik et al., 2018; Bauer, 2021), e.g., on technological means of noise mitigation or legal noise emission limits. Regarding positive factors, fields of application for air taxis should be identified in which traffic relief and time savings can be credibly achieved. As studies show, both claims are not unconditional to fulfil and strongly depend on the operational environment (Pukhova, 2021; BMVI, 2019; Kellermann et al., 2020).

According to the logic of the model, it may be more advantageous in terms of public attitude to effectively mitigate expected risks than aiming to maximise the expected benefits identified in this paper. Moreover, various studies indicate that the greatest public support for small electric aircraft is, at least currently, not to be expected in their deployment as commercial air taxis but in medical or humanitarian applications (Nentwich and Horváth, 2018; Sky Limits, 2021). This suggests that the search for business models with clearer social added values should be intensified (Straubinger et al., 2021). However, a significant positive correlation between people with technophilic tendencies and their attitude toward air taxis was confirmed in this research. Therefore, it can be affirmed that UAM related mobility as a service approach may count on innovators and early adopters as early target group.

This study faces several limitations. First, focus group participants were questioned about a technology that is not yet in service. People's evaluation criteria of air taxis may change after adoption because new and previously unconsidered impacts may become apparent once the technology is introduced. For example, most focus group participants assumed that air taxis would not crash. If, however, critical incidents were to occur in the future, safety concerns would likely affect public attitudes stronger than they do today. Nevertheless, the qualitatively derived attitudinal factors represent relevant factors at this early phase of technology maturation and thus enrich the scientific and political discourse, as their importance for forming public attitudes was confirmed in the presented model.

Secondly, the survey participants were asked to assess possible technology impacts of air taxis on society and urban space. Citizen's perceived risks and benefits of the technology depend on concrete business models, i.e., the intensity of aircraft movements, the actual noise impact of eVTOLs, and environmental impacts. Nevertheless, the present study provides a clear understanding of which acceptance factors are particularly advantageous or disadvantageous features of air taxis.

Thirdly, the data-gathering was conducted before the outbreak of the COVID-19 pandemic. While several studies suggested the pandemic slightly improve public attitudes toward automated drone-delivery services (Thomas et al., 2021; Elavarasan & Pugazhendhi, 2020), the effect of the virus on the perception of air taxis as a form of shared mobility, in which passengers find themselves traveling in closed compartments, cannot be reflected within this study. Moreover, all research data was gathered in Germany. A transferability of the results to other world regions cannot be made without reservation. However, the impacts of new mobility technologies on citizens' perception and mobility behaviors in different cities depend on the urban form, socioeconomic, and cultural parameters (Mostofi, 2022), and sometimes they are contradictory and opposite in different cities (Mostofi, 2021; Mostofi et al., 2020a; Mostofi et al., 2020b). Moreover, a cross-national study on the acceptance of various drone applications in Europe shows no severe divergences between the examined member countries (EASA, 2021). Therefore, validity can be assumed for the European context.

5. Conclusions

The implementation of urban air mobility (UAM) services, e.g., air taxis, can be considered a disruptive development for the transport field. However, apart from a potential opening of new transit and market opportunities, air taxis' disruptive character may become controversial as they will operate in public spaces and represent a transport technology of comparably high perceptibility.

Against this background, this study defines an understanding of public attitudes toward air taxis. The structural equation model results provide evidence of how this attitude is formed. Expected risks (particularly cognitive stress from air traffic, noise emissions, and the expectation of blocked skies) and expected benefits (particularly avoiding traffic jams, saving time, and a location-flexible hop-on drop-off) affect attitudes toward air taxis. The expectation of risks has greater load factors in forming attitudes than the expectations of benefits. In other words, the public attitude toward air taxis is stronger associated with expected risks rather than expected benefits.

The results of this study may be of practical utility. Above all, the currently expected risks from air taxis should be anticipated to be preemptively minimized. From a traffic-psychological perspective, it should be investigated how stress from traffic is formed and whether urban air traffic can also reinforce similar dynamics. On the other hand, aesthetic concerns should be considered regarding air taxi infrastructures, their routing, and route frequency.

What is more, a person's technophile disposition positively affects the formation of attitude. Like other consumer markets, urban air transportation providers may count on the innovativeness of certain consumer groups with high technophilia, e.g., innovators or early adopters. However, based on our findings, we suggest political administrations harvest the benefits of innovative aviation technologies while creating a regulatory framework that ensures the environmentally sustainable, need-oriented, and aesthetic development of UAM, thus responding to the central dimensions of public concerns.

Finally, the mixed methods approach of this study explored attitudinal factors beyond the classical taxonomy of behavioral and acceptance research (e.g., social, environmental, and aesthetic concerns). Consequently, this study advocates for future research to strongly consider methodological approaches, including qualitative research, to gain a more comprehensive understanding of potential users and the passively exposed public.

CRediT authorship contribution statement

Hamid Mostofi: Conceptualization, Data curation, Formal analysis, Methodology, Visualization, Validation, Writing – review & editing. **Tobias Biehle:** Conceptualization, Formal analysis, Methodology, Visualization, Writing – review & editing. **Robin Kellermann:** Project administration, Writing – review & editing. **Hans-Liudger Dienel:** Writing – review & editing.

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.

Data availability

The primary survey dataset (telephone survey) is publicly available under: https://data.gesis.org/sharing/#!Detail/10.7802/2155.

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