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# Public acceptance of civilian drones and air taxis in Germany: A comprehensive overview

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## Abstract

The technology of unmanned aerial vehicles (i.e., civilian drones) continues to improve and concepts of operations are being developed. Against this background, the importance of public acceptance has grown and the number of studies on the subject has increased in recent years. In this context and as a follow-up to the study by Eißfeldt and colleagues (Eißfeldt et al. in CEAS Aeronaut. J. 11:665–676, 2020), a representative telephone survey on the acceptance of civilian drones in Germany was conducted at the end of 2022. In addition to re-evaluating the attitude towards civilian drones in general, the current study particularly examined the use case of air taxis. It was found that the attitude towards civilian drones tended to be slightly more positive than in the first study. For air taxis, attitudes were revealed to be relatively balanced, with a slight negative tendency. Moreover, extensive inferential statistical analyses showed several factors such as active experience with drones, general sensitivity to noise, and interest in environmental protection to be significantly associated with the attitudes towards civilian drones and air taxis. The application of three different prediction models revealed that a person's attitude towards civilian drones could be predicted with up to 71% accuracy by drone-related concerns. In this context, concerns about the violation of privacy and animal welfare had the highest predictive value. In sum, the current study provides a comprehensive overview on the acceptance of civilian drones and air taxis in Germany. Its findings underline that citizens' opinions and concerns must be considered when designing future air mobility concepts.


**Keywords** Civilian drones · Unmanned aerial vehicles (UAV) · Air taxi · Acceptance · Telephone survey

## Abbreviations

| | |
|---|---|
| AAM | Advanced Air Mobility |
| AAPOR | American Association for Public Opinion Research |
| ACC | Accuracy |
| BIK | BIK ASCHPURWIS + BEHRENS GmbH |
| CART | Classification and regression tree algorithm |
| CATI | Computer-assisted telephone interviews |
| CHAID | Chi-square automated interaction detection |
| cp | Complexity parameter |
| DLR | German Aerospace Center |
| EASA | European Union Aviation Safety Agency |
| $p_{corr}$ | Bonferroni-corrected $p$-value |
| RPAS | Remotely piloted aircraft system |
| TAM | Technology Acceptance Model |
| UAM | Urban Air Mobility |
| UAV | Unmanned Aerial Vehicle |
| UTAUT | Unified Theory of Acceptance and Use of Technology |

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## 1 Introduction

It is widely assumed both within the scientific community and beyond that public acceptance is crucial for the future deployment of civilian unmanned aerial vehicles (i.e., civilian drones). The technology of the vehicles is evolving (for an overview, see e.g., [1]), concepts for ground

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infrastructure for landing and take-off are elaborated (often referred to as vertidromes; e.g., [2]), and necessary legislation is initiated (e.g., [3]). However, without the acceptance of the society in general and potential users in particular, civilian drones will most probably not prevail on a larger scale. Therefore, it is indispensable to examine public acceptance from the very beginning. Although citizens are not used to large-scale civilian drone traffic in everyday life yet, they already have wishes and concerns which need to be considered for the development of the field to be sustainable.

With regard to the acceptance of technologies, several theoretical models have been postulated so far (e.g., [4–7]). Some of these have already been integrated in research on autonomous vehicles (e.g., [8, 9]) and on unmanned aerial vehicles in particular (e.g., [10]). The most prominent theoretical approach is the Technology Acceptance Model (TAM, [4, 5]). In TAM, the behavioral intention to use a technology is defined by the attitude towards using the technology and its perceived usefulness. The attitude, in turn, is postulated to be also decisively determined by the technology's perceived ease of use. Other models such as the Unified Theory of Acceptance and Use of Technology (UTAUT, [6]; see also [7]) postulate a larger number of influential factors on the behavioral intention to use a technology, for instance social aspects and demographic variables. Importantly, these models indicate that research on the public acceptance of civilian drones must not be restricted to exploring current pictures of opinions towards the technology or the willingness to use it. Instead, the same amount of attention needs to be payed to potentially influencing factors.

In recent years, various studies on the acceptance of civilian drones have been published (for a review, see [11]). Some of the studies (e.g., [12]) have considered civilian drones in a general sense, encompassing a variety of use cases (e.g., inspection, photography for commercial purposes, delivery of medical supplies, search and rescue missions). Other research (e.g., [13]) focused on specific use cases such as cargo delivery or passenger transport with so-called air taxis, for instance as an airport shuttle. When both passenger and cargo transport are considered, the terms Urban Air Mobility (UAM) or Advanced Air Mobility (AAM) are often used [14–16].

One study that already provided insights into attitudes towards civilian drones in Germany was the telephone survey by Eißfeldt and colleagues in 2018 [12]. At the time, it showed a fairly balanced pattern of opinion with 53% of citizens reporting to have a rather positive attitude towards civilian drones, 38% stating to have a rather negative attitude, and 9% being undecided or refusing to answer the question. Both the study of Eißfeldt et al. [12] and other surveys (e.g., [13, 14]) have shown that public attitudes vary depending on the purpose of drone flights. For example, in the telephone survey of Dannenberger et al. in Germany in 2020 [13], the use of delivery drones and air taxis only for emergency purposes yielded higher approval than their application for parcel delivery and individual transport in general.

In addition to nationwide surveys, further studies with international scope have been conducted. For instance, the European Union Aviation Safety Agency (EASA) surveyed citizens in six major European cities via online questionnaire between 2020 and 2021 to assess the extent of social acceptance of UAM in regions where UAM might be possible in a reasonable time horizon [14]. Across all participating sites, a majority of 83% of the participants was found to have a rather or very positive attitude towards the deployment of UAM. Furthermore, McKinsey & Company [17] conducted a large-scale survey in 2021 to investigate on a global-scale how potential consumers assess AAM. Respondents were recruited from six different countries (i.e., Brazil, China, Germany, India, Poland, United States). By international comparison, German survey respondents reported the lowest willingness to use passenger AAM as an alternative means of transport. The use case that resulted in the comparably highest approval among German respondents was the airport shuttle [17].

Moreover, several studies have yielded evidence for factors associated with a person's opinion about civilian drones (i.e., potentially influencing factors as mentioned in the context of technology acceptance models above). For example, a Canadian online survey in 2022 showed that individuals who are affiliated with unmanned aerial vehicle technology (e.g., are drone users themselves or personally know a drone user), "are more likely to support the use of RPAS" (i.e., remotely piloted aircraft system) ([18] p. 5). A similar trend appeared for respondents who stated to be strong supporters of other autonomous vehicles such as self-driving cars [18]. Accordingly, Eißfeldt and colleagues [12] revealed that participants who felt more informed about civilian drones more frequently reported to have a rather positive attitude towards these vehicles. Similar patterns were also found for respondents with more pronounced interest in modern technology as well as with respect to certain demographic factors (e.g., age, gender) ([12]; see also e.g., [18, 19]).

Some studies (e.g., [12, 20, 21]) have already taken the approach of building models to predict or explain the attitudes towards civilian drones, the willingness to fly with air taxis, or the presumed individual time horizon for adopting UAM. For example, Eißfeldt et al. [12] used a statistical decision tree approach, which revealed that the presence of concerns about drone noise had the highest potential among all assessed concerns to explain a person's general attitude towards civilian drones. This finding was remarkable as noise was the least common of all concerns in the study [12].

In addition, a start has been made to further investigate potential changes in the pattern of opinion about civilian drones. This is important because unmanned air traffic concepts are evolving and people are increasingly encountering corresponding information in the media. In line with this notion, for example, the federal initiative "Verband Unbemannte Luftfahrt" [22] conducted an online survey on the social acceptance of civilian drones and air taxis among German citizens in 2022. When comparing the results with their previous survey from 2019, an increase in approval of the use of civilian drones and air taxis was revealed [22].

The current study aimed at taking up the recent developments in the research field since the study by Eißfeldt and colleagues from 2018 [12] and implemented them on the dataset of a single study. For this purpose, a large-scale telephone survey was conducted among the German population at the end of 2022, which, in addition to civilian drones in general, also focused on the possible future use case of air taxis. For carrying out the survey, an updated and expanded version of the questionnaire by Eißfeldt et al. [12] was used, which made it possible to discuss the results of the present study in terms of the change in the pattern of opinion in Germany over the past four years (cf. [11]).

First, descriptive statistics were calculated to gain insight into the current pattern of opinion that is representative for the German population with regard to key demographic characteristics. Second, extensive analyses of potentially influencing factors on attitudes towards civilian drones and air taxis were performed using inferential statistics. Third, the approach of previous research (e.g., [12, 20, 21]) to build models for predicting or explaining attitudes using other information assessed in the same survey was extended. Based on the approach by Eißfeldt et al. [12], the degree to which attitudes can be predicted by drone-related concerns was examined. In this context, both the attitude towards civilian drones and the attitude towards air taxis were considered as dependent variables and two different machine learning algorithms and a log-linear model were applied. The use of three different algorithms ensured that the results did not rely on the specifics of a single prediction method.

## 2 Methods

The telephone survey was conducted from September to November 2022. The institute BIK ASCHPURWIS + BEHRENS GmbH (BIK) was commissioned by DLR with conducting computer-assisted telephone interviews (CATI), including pre-tests, sample drawing, and weighting of data. As a member of ADM Arbeitskreis Deutscher Markt- und Sozialforschungsinstitute e.V., BIK was required to fully adhere to the ICC/ESOMAR international code [23] as well as the code of conduct for telephone interviews agreed upon in Germany [24].

### 2.1 Questionnaire

The questionnaire of the telephone survey was divided into four sections (closed and open format). The sections followed the following order: (i) civilian drones in general (11 questions), (ii) air taxis (10 questions), (iii) personal interest in specific other topics (5 questions), and (iv) socio-demographic data (13 questions). At the beginning of sections i and ii, respondents received initial briefings with relevant information about civilian drones and air taxis, respectively (see Appendix A).

### 2.2 Pre-test

Before the survey, the questionnaire was subjected to a qualitative and quantitative pre-test. In this phase, the questionnaire was checked for comprehensibility and potential problems in answering the questions were identified. First, five qualitative interviews were conducted in-person, in which the aim was to test the content from the questionnaire for comprehension using cognitive methods (i.e., paraphrasing, thinking aloud, probing). Any abnormalities were noted in a protocol and incomprehensible phrases or terms were identified in the interview situation. In the second pre-test, 10 computer-assisted interviews (CATI) were realized under field conditions in BIK's telephone laboratory. This served to test the questionnaire with a random sample under the same conditions as the main survey and to identify any difficulties due to the interviews being conducted over the phone. As a result of both pre-tests, the questionnaire was optimized in relevant aspects.

### 2.3 Sample

The German resident population of 18 years of age or older formed the survey population. A total of $N = 1001$ volunteer participants were surveyed. Participants ranged from 18 to 94 years of age ($Mdn = 53$ years). 50.4% were male, 49.5% were female, and 0.1% (1 person) identified as diverse.

The sample was drawn from the telephone selection basis for landline and mobile phone numbers of ADM Arbeitskreis Deutscher Markt- und Sozialforschungsinstitute e.V. 2022, in each case with registered and generated (non-listed) telephone numbers.[1] The study's response rate was 8.4% (7.8% for the landline sample and 9.1% for the mobile sample). The response rate was calculated as the minimum response rate, also called response rate 1, according to the American Association for Public Opinion Research (AAPOR, [25]) using the AAPOR Outcome Rate Calculator (Dual-Frame RDD phone, version 4.1). 57% of respondents were reached via landline and 43% via mobile phones.

### 2.4 Procedure

The interviews were conducted by 42 trained interviewers (73.8% female, 26.2% male). The average duration of interviews carried out in one go ($n = 974$) was $Mdn = 20.7$ min (Min: 12.2; Max: 49.3).[2] For landline numbers, a random selection of the target person in the household was carried out using the last-birthday method. For mobile phone numbers, the interview was conducted directly with the person contacted.

At the beginning of each interview, screening for specific quota statistics was provided. Because male participants became increasingly overrepresented in the field phase, a quota system was activated during the course of the study. According to this quota system, males willing to participate were only interviewed with a probability of 50%; otherwise, the interview did not take place. At the end of the field phase, the quota system was deactivated again and instead specific age and gender group combinations (e.g., males in older age groups) were gradually blocked from further interviews. This ensured that the proportions of people from different age and gender groups in the sample were similar to the corresponding proportions in the population.

### 2.5 Weighting of data

An overall weighting was calculated to ensure that the data was representative of the German population concerning key characteristics. This consisted of both design and adjustment weighting [26, 27]:

Design weighting compensated for the different selection probabilities of individuals in the dual-frame approach: The more numbers a person has, the higher the drawing probability. The more people living in the household, the lower the drawing probability (information collected in the interview). Furthermore, the different sampling frames of landline and mobile numbers as well as the proportion of landline and mobile samples realized in the survey were considered.

Adjustment weighting compensated for distortions caused by differences in the willingness of individuals to participate in the survey. For this purpose, the survey's key demographic characteristic groups were adjusted to the marginal distribution of the Microcensus 2021 data. The characteristics of age, gender, household size, highest general education degree, employment situation, federal state, and BIK community size [28] were used for the weighting.

It needs to be noted that not all of the key characteristics listed above could be collected from 3 of the 1001 participants in the sample. Hence, when weighted results are reported, they are based on a sample of $n = 998$ individuals.

## 3 Results

### 3.1 Attitude towards civilian drones and air taxis

Descriptive statistics on general attitudes toward civilian drones and air taxis, as well as other related central questions of the survey, were calculated on a weighted basis. The use of weighted data made it possible to determine a pattern of opinion that is representative of the German population concerning key characteristics.

#### 3.1.1 Civilian drones (in general)

In total, 93% of respondents had heard of the term "drone" before. It was found that attitudes towards civilian drones varied between very positive and very negative, with a slight positive trend (Fig. 1).

Most respondents had already gathered experience with drones in real life before (85% had seen a drone, 76% had heard a drone, 68% had witnessed someone flying a drone, and 24% had flown a drone themselves). In total, 60% of respondents reported being somewhat (43%) or very well informed (17%) about civilian drones, while the

[1] The size of the sampling frame was determined by the number of assigned telephone number ranges by the German Federal Network Agency (Bundesnetzagentur). The sample of landline numbers was drawn stratified by BIK community size classes (GKBIK10) to avoid regional clustering effects. The sample of mobile numbers was drawn stratified by telephone provider. In preparation for the random drawing from the sampling frame, the distribution of the number of cases in the survey population was determined by an allocation table.

[2] Interviews were conducted Monday through Friday from 4:00 p.m. to 8:00 p.m., Saturday from 11:00 a.m. to 4:00 p.m., and at the end of the field period, also Sunday from 12:00 p.m. to 4:00 p.m. In addition, interviews were conducted with respondents who requested an appointment on weekdays before 4:00 p.m. Four contact attempts were permitted for mobile phone numbers and five for landline numbers. The number was contacted up to 12 times if contact was made by appointment.

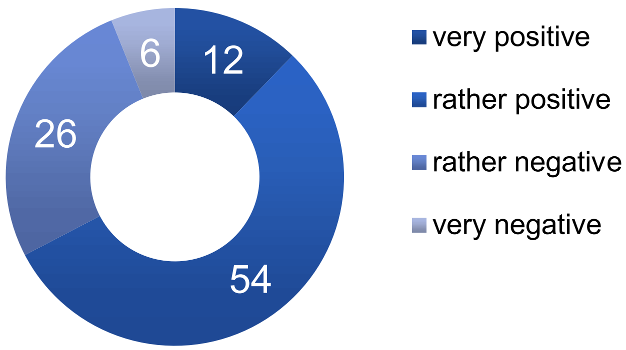


**Fig. 1** Question: Based on what you know about this so far: How would you describe your general attitude towards civilian drones? (Values missing to 100%: "do not know"/"refused"; %)

rest of participants were little (27%) to not at all (13%) informed. The majority of respondents (84%) did not own a drone, 8% owned a drone, and 8% did not own one but would have liked to. The extent to which the use of civilian drones was fully or somewhat supported, depending on the area of operation, is shown in Fig. 2. The highest level of agreement was found for civil protection (e.g., monitoring flood spread), followed by rescue operations (e.g., police, fire brigade), and research (e.g., nature observation). The lowest level of agreement was found for parcel delivery, leisure and hobbies, and taking photos and videos for advertising purposes.

In total, 75% of the respondents fully (32%) or somewhat (43%) agreed that civilian drones should be allowed to fly over their homes for the purposes they agreed on. Regulations or restrictions were asked most for night time and residential areas (Fig. 3).

Among all assessed concerns (Fig. 4), misuse for criminal purposes and violation of privacy were most common among given answers, while noise concerns were least common.

At the end of section i of the telephone survey, attitudes towards civilian drones tended to be more positive than at the beginning (Fig. 5).

### 3.1.2 Air taxis

In total, 68% of respondents stated that they had heard about the term "air taxi" before. Attitudes towards air taxis were relatively balanced, with more very negative than very positive responses (Fig. 6).

Similarly, the extent to which respondents expected air taxis to bring benefits for the population was relatively balanced (18% great benefit, 33% some benefit, 27% little benefit, 21% no benefit at all). However, most respondents anticipated air taxis to bring at least some risk for the population (Fig. 7).

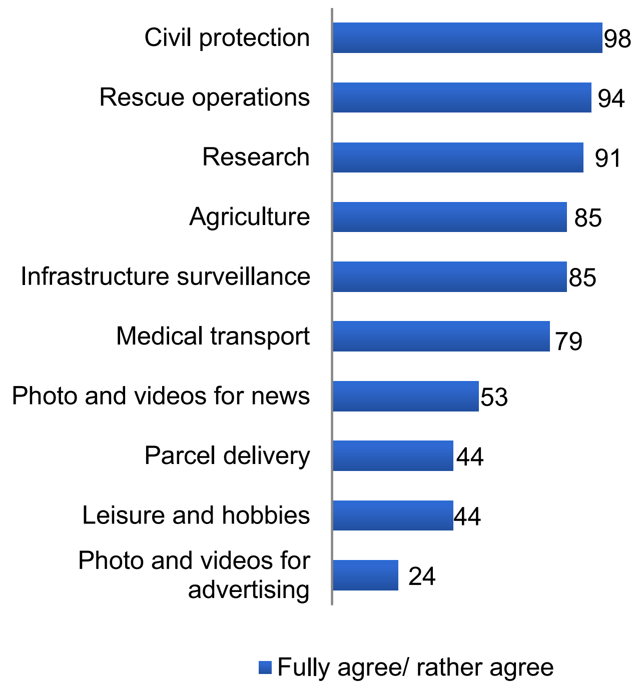


**Fig. 2** Question: To what extent would you agree with the use of civilian drones in the following areas? (Fully agree/rather agree/rather disagree/fully disagree; %)

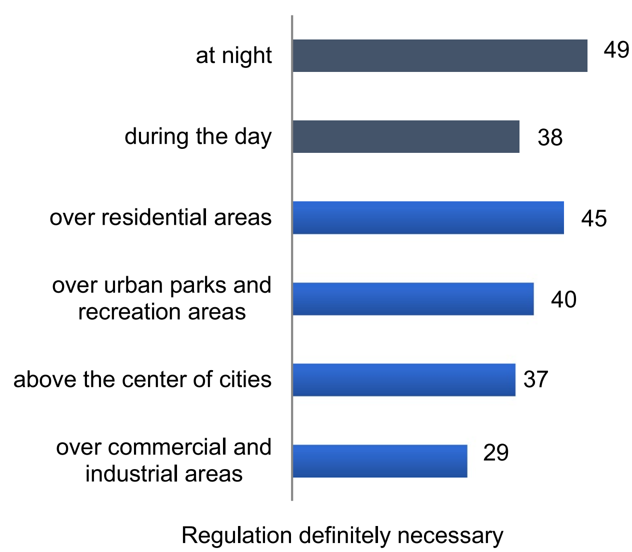


**Fig. 3** Question: Please tell me on the following aspects to what extent it would be necessary in your view to regulate or restrict the use of civilian drones? (Regulation definitely necessary/rather necessary/rather not necessary/definitely not necessary; %)

Willingness to use an air taxi was most widespread for use cases within a rural area and between a rural area and a big city (Fig. 8).

While the majority of respondents (67%) indicated that their attitude towards air taxis had not changed as a result of

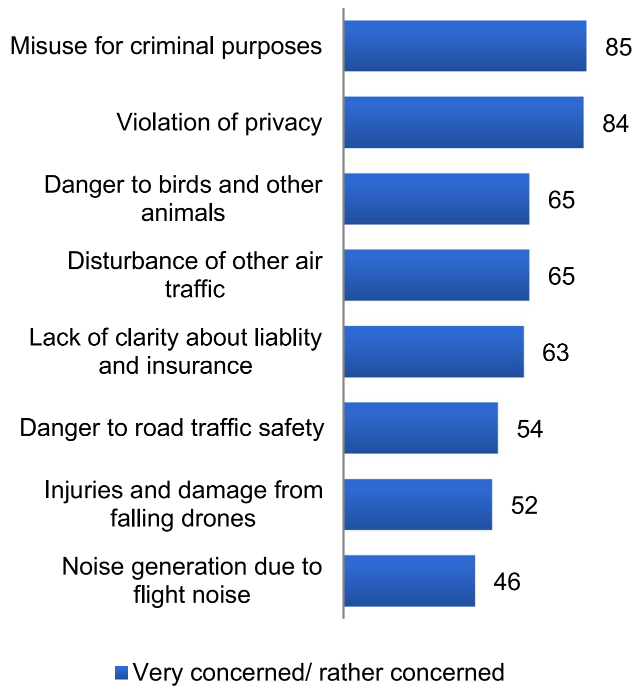


**Fig. 4** Question: Please tell me to what extent you are personally concerned about the following aspects. (Very concerned/rather concerned/rather not concerned/not concerned at all; %)

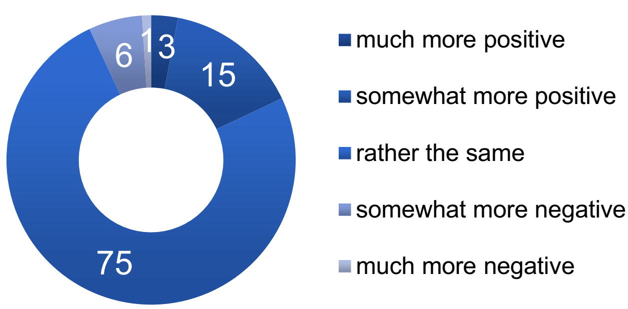


**Fig. 5** Question: Having just talked about drones in detail in the interview: How would you now describe your general attitude towards civilian drones? Is it now … (%)

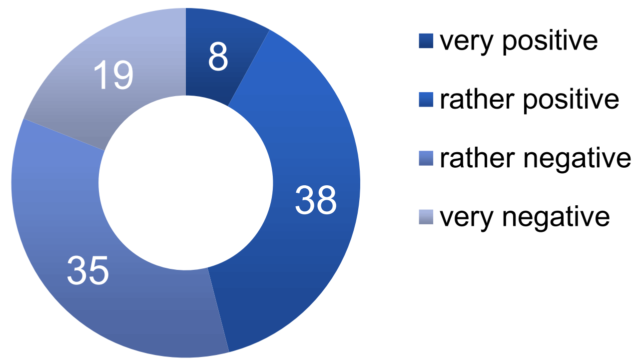


**Fig. 6** Question: Based on what you know about it so far: How would you describe your general attitude towards air taxis? (%)

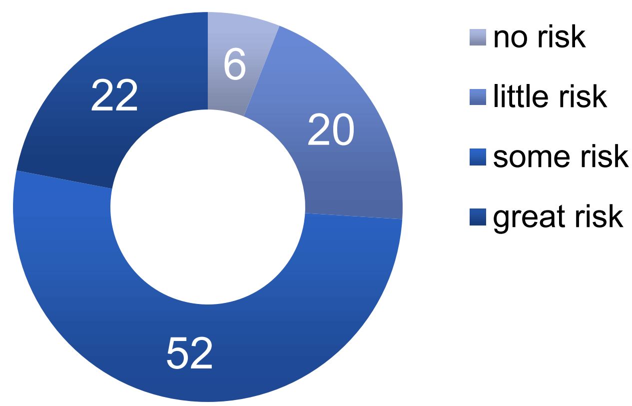


**Fig. 7** Question: In your opinion, to what extent would air taxis pose a risk to the population in Germany? (%)

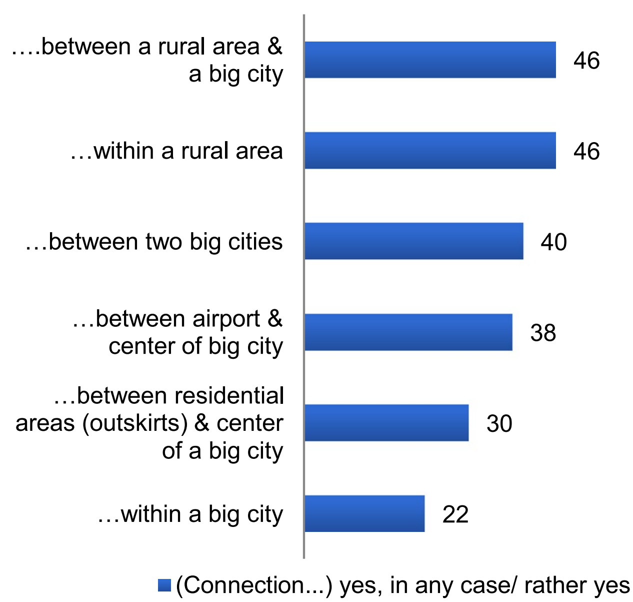


**Fig. 8** Question: Would you use an air taxi for the following purposes? (Yes, in any case/rather yes/rather no/no, absolutely not; %)

the survey across the interview, positive changes (20%) were slightly more common than negative changes (14%; Fig. 9).

## 3.2 Influential factors on attitude

In the telephone survey, personal interest and attitudes towards specific other topics, as well as sociodemographic information were asked. It was analyzed inferentially to what degree these factors might have been associated with the attitudes towards civilian drones (in general) and air taxis. For analyses, unweighted data was used. Mann–Whitney U tests and Kruskal–Wallis H tests were calculated, depending on the type of data and number of response categories of

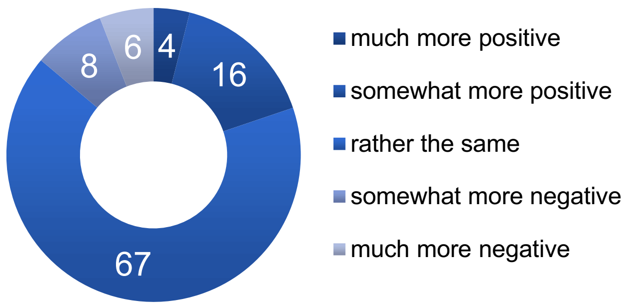


**Fig. 9** Question: Having just talked about air taxis in detail in the interview: How would you now describe your general attitude towards air taxis? Is it now … (%)

the considered variables. Appendix B gives a detailed list of the factors (and their corresponding questions) used for analyses.

### 3.2.1 Data preparation

Before calculating statistical analyses, the factors' response categories were grouped by content or median split. This served to carry out calculations on differences, to facilitate the interpretation of the results, and ultimately to be able to make valid statements. Since a few people were undecided ("don't know") about their attitudes towards (a) civilian drones ($n = 12$) and (b) air taxis ($n = 6$), data from these people was excluded from statistical analyses. This resulted in a total of $n = 989$ for question (a) and $n = 995$ for question (b).

For gender, only the groups of males ($n_{1a} = 498$, $n_{1b} = 502$) and females ($n_{2a} = 490$, $n_{2b} = 492$) were used due to the small sample size of respondents who identified as diverse ($n = 1$). With regard to age, five groups were formed according to the theory of generations [29] and related considerations [30, 31]: generation Z (18–26 yrs; $n_{1a} = 87$, $n_{1b} = 89$), Y (27–42 yrs; $n_{2ab} = 260$), X (43–58 yrs; $n_{3a} = 266$, $n_{3b} = 268$), baby boomers (59–77 yrs; $n_{4a} = 292$, $n_{4b} = 290$), and silent generation (78 + yrs; $n_{5a} = 84$, $n_{5b} = 88$). In terms of subjective income, responses were summarized for participants rating to earn "less than needed" ($n_{1a} = 137$, $n_{1b} = 140$), "approximately as needed" ($n_{2a} = 302$, $n_{2b}$ 303), and "more than needed" ($n_{3a} = 520$, $n_{3b} = 523$). In the context of this question, the rest of the participants did either not know how to rate their income ($n = 4$) or did not want to make a statement on this question ($n = 26$).

With regard to their experience, participants were categorized into having "no experience" with civilian drones at all (not seen a drone *and* not heard a drone *and* not flown a drone by themselves *and* not witnessed someone flying a drone; $n_{1a} = 113$; $n_{1b} = 116$), "passive experience" (seen a drone *and/or* heard a drone *and/or* witnessed someone flying a drone; $n_{1a} = 654$; $n_{1a} = 656$), and "active experience" (had flown a drone; $n_{1a} = 222$; $n_{1b} = 223$). In terms of knowledge on civilian drones, participants were categorized into being "less informed" (not informed, slightly informed; $n_{1a} = 433$; $n_{1b} = 439$) or "more informed" (somewhat informed, very informed; $n_{1ab} = 556$).

In terms of noise sensitivity, responses (not sensitive at all, little sensitive) were summarized into "lower sensitivity" ($n_{1ab} = 409$) and responses (somewhat sensitive, very sensitive) were grouped into "higher sensitivity" ($n_{2a} = 580$; $n_{2b}$ 586). The responses on general noise annoyance were summarized into three categories: "not annoyed" ($n_{1a} = 300$, $n_{1b} = 301$), "somewhat annoyed" (slightly annoyed, moderately annoyed; $n_{2a} = 573$, $n_{2b} = 576$), and "highly annoyed" (very annoyed, extremely annoyed; $n_{3a} = 116$, $n_{3b} = 118$). The questions about noise sensitivity and noise annoyance were adapted from [32, 33]. It was differentiated between residents who were exposed to "no dense traffic" at their place of residence ($n_{1a} = 663$, $n_{1b} = 669$) and those who were exposed to "dense traffic" ($n_{2ab} = 326$). In terms of audibility of air traffic, it was differentiated between residents who were exposed to "no audible air traffic" ($n_{1a} = 377$) compared to residents who were exposed to some "audible air traffic" ($n_{2a} = 612$, $n_{2b} = 618$).

Median splits were performed to group answers on the interest questions (scale from 0 to 10). Concerning personal interest in modern technology, this resulted in either being "strongly interested" ($\geq 8$; $n_{1a} = 512$, $n_{1b} = 516$) or "not strongly interested" ($< 8$; $n_{2a} = 477$, $n_{2b} = 479$). The same accounted for interest in environmental protection with either being "strongly interested" ($> 8$; $n_{1ab} = 407$) or "not strongly interested ($\leq 8$; $n_{2a} = 582$, $n_{2b} = 588$). For interest in aviation, participants could either be "rather interested" ($> 5$; $n_{1a} = 485$, $n_{1b} = 487$) or "rather not interested" ($\leq 5$; $n_{2a} = 504$, $n_{2b} = 508$).

### 3.2.2 Statistical analyses (civilian drones)

*Gender.* A Mann–Whitney $U$ test was performed to evaluate whether the attitude towards civilian drones differed in terms of gender (male vs. female). Women had a significantly less positive attitude towards civilian drones compared to men, $U = 94{,}358.50$, $z = -6.929$, $p < 0.001$, $r = 0.22$.

*Age.* A Kruskal–Wallis H test showed that there was a statistically significant difference in attitude towards civilian drones in terms of generations, $\chi^2(4) = 16.64$, $p = 0.002$, with a mean rank attitude score of 400.62 for generation Z, 489.30 for generation Y, 527.88 for generation X, 498.84 for the boomer generation, and 492.92 for the silent generation. Bonferroni-corrected post-hoc tests showed that the youngest generation Z had a significantly more positive attitude towards civilian drones than generation Y ($p_{corr} = 0.049$), X ($p_{corr} = 0.001$), and the baby boomer generation ($p_{corr} = 0.016$).

*Subjective Income.* A Kruskal–Wallis H test showed that there was a statistically significant difference in attitude towards civilian drones in terms of subjectively rated income, $\chi^2(2) = 19.18$, $p < 0.001$, with a mean rank attitude score of 503.27 for participants who rated their income to be less than needed, 523.64 for approximately as needed, and 448.53 for more than needed. Post-hoc tests showed that people who rated their income to be more than needed had a significantly more positive attitude towards drones than those who rated their income to be approximately as needed ($p_{corr} < 0.001$).

*Experience with civilian drones.* A Kruskal–Wallis H test showed that there was a statistically significant difference in attitude towards civilian drones in terms of level of experience, $\chi^2(2) = 28.56$, $p < 0.001$, with a mean rank attitude score of 491.81 for no experience, 522.15 for passive experience, and 416.63 for active experience. Post-hoc tests showed that people who had active experience with drones (had flown a drone) had a significantly more positive attitude towards civilian drones than those with passive ($p_{corr} <$ 0.001) or no experience ($p_{corr} = 0.032$).

*Knowledge on civilian drones.* A Mann–Whitney U test was performed to evaluate whether the attitude towards civilian drones differed in terms of level of knowledge on civilian drones (less informed vs. more informed). Participants who were more informed had a significantly more positive attitude towards civilian drones, $U =$ 98,464.50, $z = -5.523$, $p < 0.001$, $r = 0.18$.

*Noise sensitivity.* A Mann–Whitney $U$ test was performed to evaluate whether the attitude towards civilian drones differed in terms of general noise sensitivity (lower vs. higher). Participants with a higher sensitivity had a significantly less positive attitude compared to those with a lower sensitivity, $U = 99{,}198.50$, $z = -4.929$ $p < 0.001$, $r = 0.16$.

*Noise annoyance.* A Kruskal–Wallis $H$ test showed that there was a statistically significant difference in attitude towards civilian drones in relation to the level of general noise annoyance, $\chi^2(2) = 25.92$, $p < 0.001$, with a mean rank attitude score of 444.43 for being not annoyed at all, 504.03 for being somewhat annoyed, and 581.18 for highly annoyed participants. Post-hoc tests showed that all groups differed significantly ($p_{corr} < 0.01$). The more people felt annoyed by noise in general the less positive was their attitude towards civilian drones.

*Residential location and traffic.* A Mann–Whitney $U$ test was performed to evaluate whether the attitude towards civilian drones differed in terms of living at a location exposed to dense traffic (no dense traffic vs. dense traffic). No significant differences could be found, $U = 102{,}550.50$, $z = -1.468$, $p = 0.142$.

*Audible air traffic.* A Mann–Whitney $U$ test was performed to evaluate whether the attitude towards civilian drones differed in terms of exposure to audible air traffic (no audible traffic vs. audible air traffic). No significant differences could be found, $U = 112{,}616.00$, $z = -0.707$, $p =$ 0.480.

*Interest in modern technology.* A Mann–Whitney $U$ test was performed to evaluate whether the attitude towards civilian drones differed in terms of level of interest in modern technology (strongly interested vs. not strongly interested). People with a strong interest had a significantly more positive attitude compared to those who were not strongly interested, $U = 99{,}482.00$, $z = -5.664$, $p < 0.001$, $r = 0.18$.

*Interest in environmental protection.* A Mann–Whitney $U$ test was performed to evaluate whether the attitude towards civilian drones differed in terms of level of interest in environmental protection (strongly interested vs. not strongly interested). People with a strong interest in environmental protection had a significantly less positive attitude compared to those who were not strongly interested, $U = 106{,}587.50$, $z = -2.943$, $p = 0.003$, $r = 0.09$.

*Interest in aviation.* A Mann–Whitney $U$ test was performed to evaluate whether the attitude towards civilian drones differed in terms of level of interest in aviation in general (rather interested vs. rather not interested). People who were rather interested in aviation had a significantly more positive attitude compared to those who were rather not interested, $U = 103{,}444.00$, $z = -4.697$, $p < 0.001$, $r =$ 0.15.

#### 3.2.3 Statistical analyses (air taxis)

*Gender.* A Mann–Whitney $U$ test was performed to evaluate whether the attitude towards air taxis differed in terms of gender (male vs. female). Women had a significantly more negative attitude towards air taxis compared to men, $U =$ 102,596.00, $z = -4.883$, $p < 0.001$, $r = 0.16$.

*Age.* A Kruskal–Wallis $H$ test showed that there was a statistically significant difference in attitude towards air taxis in terms of generations, $\chi^2(4) = 21.04$, $p < 0.001$, with a mean rank attitude score of 454.92 for generation Z, 452.47 for generation Y, 504.64 for generation X, 518.53 for the boomer generation, and 588.20 for the silent generation. Post-hoc tests showed that generation Z had a significantly more positive attitude towards air taxis than the silent generation ($p_{corr} = 0.011$) and generation Y had a significantly more positive attitude towards air taxis than the silent generation ($p_{corr} = 0.001$) and the baby boomer generation ($p_{corr} = 0.044$).

*Subjective income.* A Kruskal–Wallis $H$ test showed that there was a statistically significant difference in attitude towards air taxis in terms of subjectively rated income, $\chi^2(2) = 7.81$, $p = 0.020$, with a mean rank attitude score of 462.86 for participants who rated their income to be less than needed, 518.48 for approximately as needed, and 468.76 for more than needed. Post-hoc tests showed the participants who rated their income to be more than needed had a significantly more positive attitude towards air taxis than those who rated their income to be approximately as needed ($p_{corr} = 0.027$).

*Experience with civilian drones.* A Kruskal–Wallis $H$ test showed that there was a statistically significant difference in attitude towards air taxis in terms of level of experience, $\chi^2(2) = 19.57$, $p < 0.001$, with a mean rank attitude score of 524.81 for no experience with civilian drones, 517.32 for passive experience, and 427.23 for active experience. Post-hoc tests showed that participants who had active experience with civilian drones (had flown a drone) had a significantly more positive attitude towards air taxis than those with passive ($p_{corr} < 0.001$) or no experience ($p_{corr} = 0.005$).

*Knowledge on civilian drones.* A Mann–Whitney $U$ test was performed to evaluate whether the attitude towards air taxis differed in terms of level of knowledge on civilian drones (less informed vs. more informed). Participants who were more informed had a significantly more positive attitude towards air taxis, $U = 105{,}379.00$, $z = -3.915$, $p < 0.001$, $r = 0.12$.

*Noise sensitivity.* A Mann–Whitney $U$ test was performed to evaluate whether the attitude towards air taxis differed in terms of general noise sensitivity (lower vs. higher). People with a higher sensitivity had a significantly more negative attitude compared to people with a lower sensitivity, $U = 107{,}937.50$, $z = -2.821$, $p = 0.005$, $r = 0.09$.

*Noise annoyance.* A Kruskal–Wallis $H$ test showed that there was a statistically significant difference in attitude towards air taxis in relation to the level of general noise annoyance, $\chi^2(2) = 9.03$, $p = 0.011$, with a mean rank attitude score of 458.70 for being not annoyed at all, 514.59 for being somewhat annoyed, and 517.25 for highly annoyed participants. Post-hoc tests showed that participants who felt not annoyed at all had a significantly more positive attitude towards air taxis than people who felt somewhat annoyed by noise in general ($p_{corr} = 0.011$).

*Residential location and traffic.* A Mann–Whitney $U$ test was performed to evaluate whether the attitude towards air taxis differed in terms of living at a location exposed to dense traffic or not (no dense traffic vs. dense traffic). No significant differences could be found, $U = 106{,}562.50$, $z = -0.617$, $p = 0.537$.

*Audible air traffic.* A Mann–Whitney $U$ test was performed to evaluate whether the attitude towards air taxis differed in terms of exposure to audible air traffic or not (no audible air traffic vs. audible air traffic). No significant differences could be found, $U = 110{,}718.50$, $z = -1.389$, $p = 0.165$.

*Interest in modern technology.* A Mann–Whitney $U$ test was performed to evaluate whether the attitude towards air taxis differed in terms of level of interest in modern technology (strongly interested vs. not strongly interested). People with a strong interest had a significantly more positive attitude compared to those who were not strongly interested, $U = 99{,}003.00$, $z = -5.738$, $p < 0.001$, $r = 0.18$.

*Interest in environmental protection.* A Mann–Whitney $U$ test was performed to evaluate whether the attitude towards air taxis differed in terms of level of interest in environmental protection (strongly interested vs. not strongly interested). People with a strong interest in environmental protection had a significantly more negative attitude compared to those who were not strongly interested, $U = 108{,}247.00$, $z = -2.707$, $p = 0.007$, $r = 0.09$.

*Interest in aviation.* A Mann–Whitney $U$ test was performed to evaluate whether the attitude towards air taxis differed in terms of level of interest in aviation in general (rather interested vs. rather not interested). People who were rather interested in aviation had a significantly more positive attitude compared to those who were rather not interested, $U = 92{,}547.00$, $z = -7.269$, $p < 0.001$, $r = 0.23$.

## 3.3 Machine learning

To determine the power of the assessed eight concerns about civilian drones (see Fig. 4) to predict the general attitude towards civilian drones as well as the general attitude towards air taxis, a classification and regression tree algorithm (CART, [34]), a naïve Bayes algorithm [35], and a log-linear model [36] were used and compared on the unweighted data. Both the CART and the naïve Bayes algorithm belong to the group of machine learning algorithms. The log-linear model is used for linear regression problems with categorical predictor and outcome variables, calculated using the logarithmic function. The algorithms were chosen to cover different approaches to modelling (i.e., rule-based classification (CART), probabilistic modelling (naïve Bayes), and logarithmic analysis (log-linear model)) adjunct to their capability of handling the scale level of our data. We specifically chose the machine learning algorithms as they handle data in very different ways. While naïve Bayes algorithms are usually known to be efficient [35], CART algorithms are seen as robust and interpretable [34]. The models were calculated in R 4.3.1 [37].[3]

As our log-linear model cannot handle variables with more than two levels, data was first split into two different subsets. Each subset contained all eight predictor variables

[3] The following R packages were used to calculate the models: aod [38], caret [39], Gifi [40], haven [41], ltm [42], MCMCpack [43], mirt [44], mlr [45], parallelMap [46], psych [47], rpart.plot [48], tictoc [49], and tidyverse [50].

and the two dependent variables. The first subset contained all four levels of each variable. For the second subset, all variables were re-coded on a binary scale by combining "very concerned" with "rather concerned" responses as well as "rather not concerned" with "not concerned at all" responses. This was also done with both dependent variables by combining "very positive" and "rather positive" responses as well as "rather negative" and "very negative" responses. The CART algorithm used tuned hyperparameters and fivefold cross-validation to find the best model fit. Tree building stopped once the complexity parameter (cp) reached $<0.01$ [51]. The naïve Bayes algorithm employed tenfold cross-validation repeated 50 times. The described parameters were chosen to attain reliable results while keeping computation times moderate [47]. As the log-linear model's specific use is to handle dichotomous data, it was used solely on the dichotomous dataset and trained on 70% of the data (rule of thumb, [51]).

The accuracies and runtimes of each algorithm are portrayed in Table 1. The CART algorithm on the full-range dataset predicting the general attitude towards civilian drones had an overall accuracy of 60% and identified concerns about the violation of privacy (cp $=0.02$) and concerns about animal welfare (cp $=0.01$) as the most important nodes. For air taxis, the corresponding CART algorithm had an overall accuracy of 38% and found concerns about injuries and damages (cp $=0.04$) and concerns about misuse for criminal purposes (cp $=0.02$) to be the most important predictors. With the dichotomous dataset, the CART algorithm predicting the general attitude towards civilian drones did not include any concerns for prediction, but solely predicted positive attitudes in any case. This resulted in an accuracy of 68%. The corresponding CART algorithm regarding air taxis had an accuracy of 58% and revealed concerns about road safety (cp $=0.09$) as the only important predictor.

The naïve Bayes algorithm predicted the general attitude towards civilian drones with an accuracy of 51% and the general attitude towards air taxis with an accuracy of 40% using the full-range dataset. With the dichotomous dataset, prediction accuracies of 65% and 60% were revealed. The log-linear model predicted the general attitude towards civilian drones with an accuracy of 71% and the general attitude towards air taxis with an accuracy of 56%.

**Table 1** Results of the three algorithms predicting general attitudes by concerns: accuracies and runtimes of each algorithm, separately for both subsets of data and both dependent variables

| Algorithm | Subset | Variable | ACC (%) | Run-time (s) |
|---|---|---|---|---|
| CART | Full | Drones | 60.14 | 132.88 |
| | | Air taxis | 37.87 | 109.14 |
| | Binary | Drones | 68.38 | 101.34 |
| | | Air taxis | 58.14 | 104.56 |
| Naïve Bayes | Full | Drones | 50.88 | 69.99 |
| | | Air taxis | 40.01 | 69.07 |
| | Binary | Drones | 64.87 | 65.74 |
| | | Air taxis | 60.02 | 68.02 |
| Log-linear model | Binary | Drones | 70.99 | < 1 |
| | | Air taxis | 56.27 | < 1 |

Note. ACC = accuracy. As runtimes of algorithms depend on the hardware used for computing, all algorithms were calculated on the same system. The displayed runtimes can therefore only be used for relative comparison.

## 4 Discussion

The current study aimed to provide a comprehensive empirical overview on the pattern of opinion about civilian drones and air taxis in Germany. For this purpose, 1001 citizens were interviewed in a large-scale telephone survey at the end of 2022. Descriptive statistics were calculated on the basis of weighted data to yield results representative of the German population with respect to key demographic characteristics. Moreover, extensive statistical analyses were performed to determine factors associated with attitudes towards civilian drones and air taxis. In addition, two machine learning algorithms and a log-linear model were used to investigate the power of drone-related concerns in predicting attitudes. Importantly, the applied questionnaire was an updated and expanded version of the one used by Eißfeldt et al. in 2018 [12]. Hence, the present findings can be discussed in terms of the change in the pattern of opinion in Germany over the past four years (cf. [11]).

The majority of the German population was found to be familiar with the terms "civilian drone" and "air taxi". For both types of vehicles, attitudes varied from very positive to very negative. With regard to civilian drones, attitudes tended to be slightly positive (66%). This indicates a slight positive shift in the pattern of opinion compared to the telephone survey by Eißfeldt et al. from 2018 (53%) [12] and replicates prior research that also reported an increase in approval of the use of civilian drones in Germany in recent years [22]. This is interesting because in the four years between the current survey and the one by Eißfeldt et al. [12], not only unmanned aerial vehicle technology evolved and the presence of topics related to civilian drones increased in the media, but both studies took place at substantially different times with regard to the political situation and public sentiment. At the end of 2022, the COVID- 19 pandemic was still affecting everyday life in Germany and the war in Ukraine was dominating the news, with repeated reports of attacks with military drones.

Fears and concerns about these world events have most probably had an impact on the public's mood in general as well as on drone-related opinions in particular. For this reason, it was particularly important to explicitly inform all participants in initial briefings at the very beginning of the interview that the survey exclusively dealt with civilian drone usage, not with military applications (see also [12]). In this context, it has to be noted that the initial briefings were slightly updated for the purpose of the current survey compared to the previous one [12]. For example, the present questionnaire explicitly stated that civilian drones typically fly with electric propulsion. Thus, despite the high similarity between the current study and the one by Eißfeldt et al. [12], it cannot fully be excluded that slight methodological changes might have contributed to the reported shift in the pattern of opinion.

Even though attitudes towards civilian drones tended to be slightly positive in the present study, approval was shown to depend on the specific use case. Use cases that were greatly supported by the public mainly addressed societal needs such as civil protection, rescue operations, or research work. Individual or commercial purposes such as advertising, leisure, and parcel delivery were given much less support. These findings replicate prior results (e.g., [12–14]) and even the ranking of use cases regarding their approval rates was very similar to the findings from 2018 [12]. The notion that the approval of civilian drone usage depends on specific conditions (see also e.g., [19]) was further supported by the finding that regulations and restrictions were demanded especially for night time and residential areas. Taking this into account when designing future urban air mobility, for instance by focussing on certain use cases and implementing the regulations the population asks for, might not only have a positive impact on public acceptance, but might also facilitate a cost-efficient allocation of resources.

In contrast to the positive tendency in the attitude towards civilian drones, the public's opinion on air taxis in particular was relatively balanced and most people anticipated air taxis to imply at least some risk for the population. This finding is in line with previous studies (e.g., [22]). Interestingly, prior research also provided evidence that even when focusing on air taxis, different approval rates were found depending on the air taxi's specific use case: the usage only for emergency purposes yielded higher approval than the application for individual transport in general (e.g., [13]). The present study and its initial briefings for respondents did not address medical use cases of air taxis explicitly. Therefore, respondents might have had air taxis in the context of individual transport in mind when answering the survey. It could be speculated that the pattern of opinion might have been somewhat more positive if medical use cases had been discussed explicitly. Something similar could presumably also be the case if initial briefings were to focus on certain non-medical use cases, provided they are ones that also receive comparatively high approval. In addition to the differences between various use cases, it should also be noted that the current study aimed to provide a comprehensive overview of the prevailing opinions in Germany. Previous research [17] indicated the willingness to use passenger AAM as an alternative means of transport to be higher in several other countries.

Two factors that may have contributed to the difference in attitude towards civilian drones in general versus air taxis could be the level of familiarity and the extent of real-life experience with both types of vehicles. The present study as well as prior research (e.g., [12, 18, 52, 53]) demonstrated attitudes to be associated with existing knowledge as well as previous experience. For example, participants of the current study who were more informed about civilian drones were found to have a significantly more positive attitude towards them (see also e.g., [12]). In the current study, almost all respondents (93%) reported that they had heard of the term "drone" before. In contrast, only 68% stated to have heard of the term "air taxi" before. Furthermore, 85% of respondents stated to have already seen a civilian drone in real life, while air taxis are not yet present in public life in Germany. Therefore, the difference in the pattern of opinion about civilian drones and air taxis could be related to the extent of knowledge and experience. Hence, the reported difference in attitudes might be diminished with more information available about air taxis and the possibility of gaining real-life experience, for example in the context of live flight demonstrations (see e.g., [54]).

In addition to the mentioned association between attitudes and the level of knowledge about civilian drones (see also e.g., [12]), the present study examined a wide variety of potentially influencing factors. This was realized by means of extensive inferential statistical analyses which corroborate and extend prior research (e.g., [12, 18, 19]). In this way, ten of the twelve considered variables were found to be significantly associated with the attitudes towards civilian drones and air taxis: Significantly more positive attitudes were shown for male respondents, younger respondents, participants who rated their income as more than needed for a living, respondents who stated to have already flown a drone, respondents with more self-rated knowledge about civilian drones, participants who rated themselves to be less sensitive regarding noise in general, participants who stated to have been less annoyed by noise in the past year, respondents who rated themselves to be strongly interested in modern technology, respondents who stated to be rather interested in aviation, and respondents who rated themselves to be not strongly interested in environmental protection. In contrast, neither the presence of dense road or railway traffic at the residential location, nor the presence of audible air traffic in daily life were shown to have a significant influence on the attitudes towards civilian drones or air taxis in the current study. Despite the extensive systematic analyses, the current study cannot claim to have examined all potentially relevant influencing factors. For example, in contrast to other studies (see e.g., [14]), we did not ask to what extent certain economic aspects, such as the potential creation of jobs through UAM, are considered a possible benefit. Linking such aspects with the approach of the current study could provide additional insights into the relevance of different factors to the acceptance of civilian drones and air taxis in future research.

In this context, it has to be noted that the reported inferential statistical analyses revealed associations between certain variables and attitudes towards civilian drones and air taxis. Importantly, such associations cannot unambiguously be interpreted as factors influencing the attitude towards civilian drones and air taxis. Instead, they could merely indicate covariations of variables or even influences in the opposite direction, i.e., influences of drone-related attitudes on the considered variables [55]. Obviously, there are variables for which an influence in a certain direction is implausible. For example, the attitude towards drones cannot influence a respondent's age. However, interpretations are less clear when it comes to variables such as the level of knowledge about civilian drones or existing real-life experience. On the one hand, the slight positive trends in attitudes towards civilian drones and air taxis at the end of the corresponding sections in the questionnaire may go back to the knowledge provided throughout the survey and the time just spent on the topic. This effect has already been present in the survey by Eißfeldt et al. [12] and led to the interpretation that education about the technology in question may play a big role in increasing the acceptance among the population ([12]; see also e.g., [56]). A similar notion has also been formulated with respect to real-life experiences in the context of live flight demonstrations (see e.g., [54]). On the other hand, it was found that active (but not passive) experience with civilian drones was significantly associated with more positive attitudes towards civilian drones and air taxis (see also e.g., [12, 18, 52, 53]). It cannot be excluded that this association might have been based on a selection effect: People who were more positive about civilian drones might have been more interested in flying one themselves, i.e., gaining active experience. In contrast, people who were less positive about civilian drones might have occasionally experienced a flying drone, but might have been less interested in flying one themselves. Future research is needed to clarify whether the reported associations are mere covariations of variables or indeed indicate factors influencing attitudes.

Beyond examining influencing factors, the current study extended previous research approaches (e.g., [12, 20, 21]) to build models for predicting or explaining attitudes. Based on the approach by Eißfeldt et al. [12], the degree to which general attitudes towards civilian drones and air taxis could be predicted by drone-related concerns was investigated. By means of concerns, a person's general attitude towards civilian drones could be predicted with up to 71% accuracy. As a specific category of drones, a person's attitude on air taxis could be predicted with up to 60% accuracy. Both prediction accuracies are well above chance level, corroborating the notion that worries on specific drone-related issues are substantially related to overall acceptance [12]. Importantly, the present results were based on using three different approaches, i.e. two different machine learning algorithms and a log-linear model. This substantiates the reliability of the reported findings. Across algorithms, the power of the assessed concerns in predicting attitudes was found to be higher for the attitude on drones than for the attitude on air taxis. This is likely due to the predictor variables being focused on drone usage in general, but not on air taxis in particular. Integrating predictor variables focusing on air taxi specific concerns might result in higher prediction accuracies.

Furthermore, using the algorithms on a dataset with dichotomized variables yielded higher prediction accuracies as compared to using the full-range dataset. It could be speculated that this difference in prediction accuracy became evident because it might have been less complex to predict whether a respondent's attitude was positive or negative than predicting attitude in terms of a variable with four distinct levels. In addition, it has to be mentioned that not only the log-linear model, but also the classification and regression tree algorithm (CART) required dichotomous variables by default. However, the CART algorithm could be run with the full-range dataset yet proceeded by choosing the two answering options with most predictive potential and ignoring the remaining answering options entirely. In contrast, computing the binary dataset took data of all answering options into account and simply combined them in a predefined way. This implied an information gain when using the CART algorithm on the dichotomized as compared to the full-range dataset, which was visible in the current results.

One major benefit of the CART algorithm compared to the other two methods is its ability to rank predictors by their predictive power: Based on whether a person was worried about the violation of privacy as well as animal welfare, this person's general attitude on civilian drones could be predicted with 60% accuracy in the current study. Importantly, this is different to the survey by Eißfeldt et al. from 2018 [12], who used a chi-square automated interaction detection (CHAID, [57]) tree model and revealed noise concerns as the main predictor. Concerns about the violation of privacy and concerns about traffic safety only served as secondary predictors/nodes [12]. To exclude that this difference in importance of specific concerns between the present survey and the one from 2018 [12] solely arose due to the application of different tree algorithms (i.e., CART vs. CHAID), additional post-hoc CHAID tree models were run on the present data. These models confirmed concerns about the violation of privacy on the first level and concerns about animal welfare on the second level to be the most important predictors of one's attitude towards civilian drones. However, in contrast to the CART algorithm, the CHAID approach revealed additional predictors on the second and third level (e.g., noise concerns), depending on whether the model was run on the full-range or the dichotomized dataset. Hence, even though applying different tree algorithms may have contributed to it, this cannot fully explain the difference in importance of specific concerns found in the current survey and the one from 2018 [12]. It can, therefore, only be speculated about the causes of this difference. One possibility might be changes in the political situation and public sentiment. In addition, small methodological differences between the studies may have had an impact, for instance the small changes in the briefing text on drones mentioned above as well as differences in the total set of questions in the questionnaires. Future research is needed to further investigate the development of the predictive value of certain concerns (e.g., about noise) to understand the underlying factors.

In addition to the aspects discussed, the findings of the present survey have several implications that have to be considered when challenges and opportunities of future UAM are weighed. On one hand, the extent to which air taxis were expected to bring benefits for the population was found to be relatively balanced among respondents, with 51% expecting at least some benefit. One potential benefit of air taxis might be that they are typically assumed to fly with electric propulsion and electric vehicles in general might be viewed as an environmentally-friendly mode of mobility (e.g., [58]). However, respondents who reported to have a strong interest in environmental protection had a significantly less positive attitude towards civilian drones and air taxis in the current study (see also e.g., [14]). One could speculate this effect to be related to discussions about the level of environmental friendliness of large-scale battery cell productions for electrical mobility in general (e.g., [59]). On the other hand, at the same time as benefits were expected by about half of the present study's respondents, also most of the respondents (74%) anticipated air taxis to bring at least some risk for the population. Additionally, even though a slight positive tendency in the attitude towards civilian drones was revealed, a substantial number of citizens tended to evaluate civilian drones negatively. The effect was even more pronounced for the attitude towards air taxis and, for each considered future use case, the willingness to use an air taxi was below 50%. Along with previous research (e.g., [22]), this emphasizes the necessity to consider not only potential passengers and users of UAM for future system design, but to also take the needs and concerns of the vast number of citizens into account, that may not want to choose this mode of transportation, but would still be affected by it. One way to realize this could be to create opportunities for co-design, such as the participatory measurement of noise from overflying unmanned aerial vehicles by pedestrians with smartphone apps and the consideration of this data in traffic management (e.g., [1, 60]).

Although concerns about the noise of civilian drones were the least common of all assessed concerns in the present survey as well as the one by Eißfeldt et al. [12], both studies demonstrated noise-related aspects to be important for the evaluation of civilian drones. For example, in the present study, respondents with a higher general noise sensitivity or higher noise annoyance in the past year were shown to have a less positive attitude towards civilian drones and air taxis. In addition, several prior studies indicated noise concerns to be more common with regard to air taxis compared to delivery drones or civilian drones in general (e.g., [13, 14, 22]). This emphasizes that manufacturers and other stakeholders should invest in reducing UAM's potential noise burden (see also e.g., [12]). Only by taking citizens' concerns seriously, a sustainable UAM that is oriented to the population's needs as well as the public's health could be possible. Moreover, the current study indicates that in particular the population in rural areas could benefit from air taxis as the willingness to use them in the future was most pronounced for use cases involving rural areas (see also e.g., [14]). This suggests that the overall system should not strictly be limited to urban airspace and emphasizes the need to rather use the term Advanced Air Mobility (AAM), instead of Urban Air Mobility (UAM) [14–16].

## 5 Conclusions

In sum, the present study provided recent empirical insights on the pattern of opinion about civilian drones and air taxis among the German population. As the questionnaire used was based on an updated and expanded version of the survey by Eißfeldt et al. [12], direct comparisons could be drawn to the pattern of opinion in Germany in 2018. The current study found a slight positive shift in the general attitude towards civilian drones among German citizens at the end of 2022 compared to 2018. Moreover, the general attitude towards air taxis was shown to be rather balanced, without the positive tendency that was evident in the attitude towards civilian drones. A wide variety of factors influencing the attitudes towards civilian drones and air taxis were revealed, such as gender, subjectively rated income, interest in environmental protection, general noise sensitivity, and active experience with civilian drones. In addition, using three different prediction algorithms, it was possible to predict a person's general attitude towards civilian drones with up to 71% accuracy by drone-related concerns. Taken together, the combination of reporting findings representative of the German population with regard to key demographic characteristics, performing extensive inferential statistical analyses of potentially influencing factors on attitudes, and applying predictive models on a single dataset makes the current study a comprehensive overview on the acceptance of civilian drones and air taxis in Germany.

## Appendix

### Appendix A

The following briefing texts are translated versions of the briefing texts used in the study, which were originally presented in German.

Briefing text on civilian drones (translated version):

"The drones we are going to talk about in the following are unmanned aerial vehicles that usually look like small helicopters with several rotors. They usually fly with electric propulsion and can fulfil various tasks, for example taking measurements, making recordings, or transporting objects. They are also available for hobby use. They can be remote-controlled from the ground or, in some cases, fly autonomously to predefined destinations. This study only deals with the civilian use of drones, not their military use."

Briefing text on air taxis (translated version):

"The air taxis we are going to talk about in the following are aircraft that can typically carry two to five people. Various concepts of such air taxis already exist and are in different stages of development and certification. They either look like smaller helicopters or a type of smaller airplane. Typically, they should be able to take off and land vertically. According to the manufacturers, air taxis will technically be used as standard in just a few years. They will mostly fly with electric propulsion. For safety and licensing reasons, air taxis will probably be flown by a pilot on board for the time being. In the medium to long term, however, it is planned that air taxis will be controlled more or less automatically from the ground, that is without a pilot on board. Air taxis are therefore sometimes also referred to as passenger drones."

### Appendix B

Overview of potentially influencing factors (and corresponding questions) on attitude towards civilian drones and air taxis (translated from German).

*Gender*
You are…?
(male/female/diverse)

*Age*
Please tell me how old you are

*Subjective income*
Would you say the total income of your household is…?
(much less than you need for a living/little less/approximately what you need for a living/little more/much more than you need for a living)

*Experience with civilian drones*
Have you already gathered practical experience with such civilian drones? In reality, have you…
(already seen a drone/already heard a drone/already flown a drone/already witnessed someone flying a drone)

*Knowledge on civilian drones*
Overall, how well informed do you feel about civilian drones and their potential uses? Do you feel…
(very well informed/somewhat informed/little informed/not at all informed)

*Noise sensitivity*
How sensitive to noise are you in general?
(very sensitive/somewhat sensitive/little sensitive/not sensitive at all)

*Noise annoyance*
If you think back over the last 12 months, to what extent have you felt disturbed or annoyed by noise? This entails all noise sources taken together
(extremely annoyed/very annoyed/moderately annoyed/slightly annoyed/not annoyed at all)

*Residential location and traffic*
Is your apartment or house located directly nearby a busy road or railroad line?
(yes, busy road/yes, busy railroad line/yes, both/no)

*Audible air traffic*
Do you hear air traffic from airplanes or helicopters several times a week in your everyday life?
(yes, airplanes/yes, helicopters/yes, both/no)

*Interest in modern technology*
Are you generally interested in modern technology, or is that rather not the case?
(0: not interested in modern technology at all/10: very much interested in modern technology)

*Interest in environmental protection*
Are you generally interested in environmental protection, or is this rather not the case?
(0: not interested in environmental protection at all/10: very much interested in environmental protection)

*Interest in aviation*
Are you generally interested in aviation, or is this rather not the case?
(0: not interested in aviation at all/10: very much interested in aviation)

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**Data availability** The data set of the current study cannot be made publicly accessible for data protection reasons, as it consists to a large extent of highly sensitive information that could potentially make the survey participants identifiable.

## Declarations

**Conflict of interest** The authors have no competing interests to declare that are relevant to the content of this article.



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