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Acceptance of drone delivery is limited (not only) by noise concerns

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Summary

In recent years, civil drones have become increasingly present in the media and in everyday life. There has been a high level of interest in drone delivery from the very beginning, yet public acceptance of drone delivery still seems limited, with acceptance rates usually ranging from 30 to 40%. The present paper reports findings of a representative national study about the acceptance of civilian drones in Germany. Several factors limiting the support of drone delivery are identified, such as concerns about transport safety, noise, and animal welfare. In addition, effects of drone experience are discussed, showing all areas of concern being reported at higher rates by participants who had no prior experience with civil drones. For noise concerns however, a more detailed look into the kind of experience with drones revealed a significantly higher percentage of noise concern among those who reported having heard a drone compared to those who reported that they had not. Moreover, an effect of NIMBYism is confirmed in the context of drone delivery. Even residents who envision using drones for the delivery of their own parcels frequently report that they would not agree to flights over their own homes. This particular effect is termed NOMOH ('Not Over My Own Home'). Finally, the need for regulation is discussed, as well as potential measures to increase acceptance of drone delivery. Besides defining topographical conditions, urban areas and time restrictions, installing means of noise control or providing residents with tools for participatory

noise sensing can also be viable measures to increase public support. If the acceptance level among residents remains in the range of below one third, drone delivery will not become a successful service in Western cities.

1. Introduction

Drones are becoming increasingly visible in public perception. Applications range from parcel delivery to animal welfare, from the production of live images of major events to law enforcement, and from the inspection of industrial facilities to the design of artificial fireworks. Many drone applications, such as precision farming, are considered to have high potential for conserving resources, and drone technology often is regarded as having a disruptive effect on certain markets and industries. In addition, the use of drones might reduce ground traffic, shorten travel time, and help achieve sustainable transportation. However, when comparing the energy consumption of truck-based and drone-based parcel delivery, these hopes have been called into question for urban areas in particular (Kirschstein 2020). On a global level, the International Transport Forum of the OECD described opportunities and challenges of future drone usage in a recent report (ITF 2018).

Several surveys in different countries have studied public support for drone delivery. A representative national survey (N = 2007) in the United States reported that 44% of respondents liked the idea of drone delivery while 34% disliked this concept, with strong effects of gender, age, region and rurality. Male millennials with an urban background in western regions liked the idea of drone delivery most (Soffronow et al, 2016). In Great Britain, a survey for the Royal Aeronautical Society conducted in 2016 reported support for drone delivery at 32% and opposition at 51% (Comres 2017). Another study reported 44% opposition to drone usage for parcel delivery (Nesta 2017), and in a 2019 study (N = 2010), support for drone delivery in the UK was found to be only 23% (IME 2019).

In Germany, a recent multi-method study found the general support for drone delivery among the public to be 25%, with only 21% indicating they would use it themselves (Dannenberg et al., 2020). A further distinction was made between the usage of drones for delivering one's own consumer goods in general, or exclusively in cases of emergency (e.g. for delivering pharmaceuticals). While only 21% of the sample would use drones for delivering parcels and consumer goods (vs 68% opposing), 60% would use drone delivery for urgently needed pharmaceutical products (vs 28% opposing).

Results for the public perception of drones in Germany based on online surveys for the years 2017 and 2019 have been published by the German Unmanned Aviation Association (VUL 2017, 2019). Here the results for parcel delivery by drones were broken down into three geographical areas of service, with more support for drone delivery in remote areas (small villages in the mountains, or small islands in the sea) and rural areas, and the lowest levels of support in large cities. In the 2017 study, the results from respondents who 'support' vs 'oppose' online delivery were 67 vs 24% for remote areas, 46 vs 44% for rural areas, and 27 vs 64% for large cities. About two years later, the respective results reported were 68 vs 23% for remote areas, 47 vs 43% for rural areas, and 30 vs 60% for large cities, showing a slight increase in support for drone delivery reported in each area over the two-year period.

Differences concerning rurality have also been reported for the United States. As opposed to the German survey, US study participants from urban areas liked the idea of drone delivery better (51% 'like' vs 27% 'dislike') than those from rural or remote locations (37 vs 41%; Soffronow et al, 2016).

Exploring factors affecting attitudes to drone delivery, Yoo et al. (2019) report differences when comparing urban and suburban/rural groups in an online survey among US citizens. While speed and ease of delivery were significant factors for both groups, performance risk was an additional negative factor for the urban group, whereas for the suburban/rural group, environmental friendliness and personal innovation both had significant positive effects on their attitude towards drone delivery.

In order to shed further light on people's attitudes towards drone delivery, this paper reports findings of a representative national study about the acceptance of drones in Germany, considering both the attitude toward parcel delivery by drones in general and how respondents anticipate their own usage of drone delivery.

2. Method

The study was conceptualized at DLR and a prototype fielded early in 2018 by infas Institute for Applied Social Sciences as a Computer Assisted Telephone Interview (CATI). Using a dual frame technique with 70% landline and 30% mobile phones, a random digital-dial design was used with the aim of reaching conclusive results representative for the German population.

The questions were asked in a standardized manner by specially trained employees in a telephone interview with a duration of about 20 minutes. The answers were coded according to the appropriate template directly online. For quality assurance, online supervision could be performed occasionally by senior staff listening in on the calls. The study fully adhered to the professional code of conduct for telephone interviews agreed on in Germany (ADM 2016).

832 respondents took part in the study, which was conducted between March and May 2018, and answered all questions. Respondents were 51.8% male and 48.2% female, with ages ranging from 14 to 94 years (M = 51.5 years, SD = 18.2 years), and the average size of household was 2.5 persons (SD = 1.3 persons). The response rate was calculated at 3.8% following statistical procedures published by the American Association for Public Opinion Research (AAPOR 2016). This means that about every 25th eligible phone number led to a full interview. Following the same procedures, the cooperation rate for the study was calculated to be 9.4% (defined as percentage of interviews completed, divided by sum of interviews completed (832), plus sum of partial interviews (5), plus sum of refusals (6.952), and sum of other nonresponses (1.048)).

3. Results

After explaining the purpose of the study and gaining consent for participation, at the beginning of the interview, subjects were asked whether they knew of the term 'drones' in aviation. The 95% of participants who answered 'yes' were subsequently posed an open question that invited them to mention what they associate with a drone. 794 participants gave answers ranging from single-word responses to several complex sentences, all of which were transcribed by the interviewer. Participants mentioned between 1 and 9 different aspects, with a majority mentioning 2 aspects (M = 2.44, SD = 1.26). Terms were automatically translated into English using standard software. A total of 1.926 words underwent translation, of which the term 'parcel delivery' (comprising brand names and service descriptions) was mentioned most frequently (N = 119), followed by 'surveillance/monitoring' (N = 105), 'toy' (N =

98), with the terms 'military' and 'dangerous' being mentioned 89 times each. Seven subjects just responded with the word 'nothing'.

After providing their associations with the term 'drone', study participants were informed that the drones to be discussed in the remainder of interview were unmanned aircraft that look like small helicopters with several rotors, typically four or more, and that only civil applications were relevant for this study. They were then asked how they would describe their general attitude towards civil drones ('rather positive' vs. 'rather negative'). If they could not decide, the answer was coded as 'undecided'. Results (N = 832) revealed an attitude slightly more in favour of drones: 49% of the participants responded 'rather positive', 43% 'rather negative', and about 8% were 'undecided'. (For further information regarding the influence of sociodemographic factors such as gender, age, income, and place of residence in the context of the present study, see Eißfeldt et al., 2020).

During the telephone interview, 7 different areas of concern that had been identified in the literature were asked in randomized order so as to avoid sequence effects. When asked whether they are 'rather concerned' or 'rather unconcerned' about certain aspects of civil drone usage, most of the respondents indicated their concern about misusing drones for criminal purposes (91%), followed by privacy concerns (86%, see also Figure 1). Issues related to accidents (liability and insurance, transport safety, as well as damages and injuries) all raised concerns in the range of 72 to 75%, followed closely by concerns about animal welfare (68%). Concerns about noise were mentioned less frequently (53%). On the whole, a large majority of respondents named at least three or more subjects of concern regarding civil drone usage (91%). However, the number of aspects mentioned varied with the age and gender of the respondent, with women and older respondents being more concerned than younger or male respondents.

Concerns about civil drones

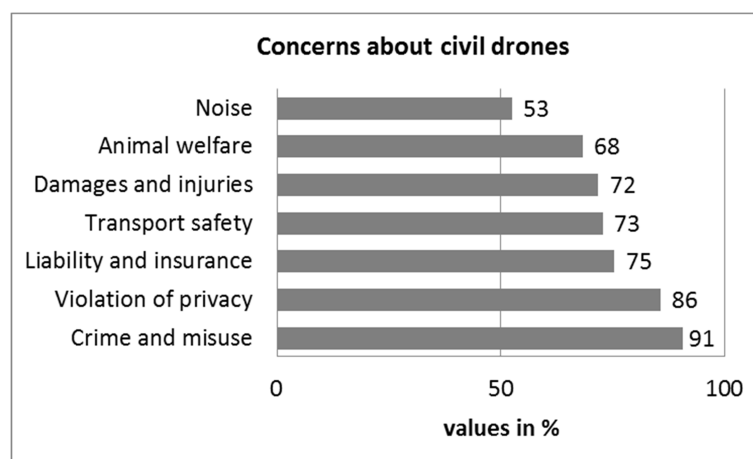| Category	Value
Noise	53
Animal welfare	68
Damages and injuries	72
Transport safety	73
Liability and insurance	75
Violation of privacy	86
Crime and misuse	91

values in %

FIG. 1: Concerns about civil drones (%)

About half of the participants (47%) reported having prior experience with drones in their personal lives (37%), on the job (4%), or in both contexts (6%). All areas of concern were reported at higher rates by participants who had no experience with civil drones. Chi-square tests at the 10% level revealed significant differences for concerns about damages and injuries, $\chi^2 (1) = 3.09$, $p = .08$, OR = .76, animal welfare, $\chi^2 (1) = 4.29$, $p = .04$, OR = .73, and traffic safety, $\chi^2 (1) = 3.39$, $p = .07$, OR = .75.

It is somewhat remarkable that the level of concern about drone noise was rather low (53%), as this had been discussed in previous literature as being a potential barrier to drone proliferation (ITF 2018). However, the relatively low level of noise concern in the results of present study might be due to a lack of acoustic experience among participants. Among those reporting having experience with drones (N = 387), a more detailed look into the kind of experience with drones revealed a significantly higher percentage of noise concern among those who reported having heard a drone compared to those who reported that they had not, χ^2 (1) = 3.29, p = .07, OR = 1.45.

During the interview, the respondents were also asked to what extent they would accept various drone applications in general. Answers were given on a 4-point Likert scale ranging from 1 (totally agree) to 4 (totally disagree). The questions regarding acceptance of the various purposes were asked in a randomized order so as to avoid sequence effects. Acceptance was the highest for official uses such as 'catastrophe response' (M = 1.43), 'life-saving efforts and rescue operations' (M = 1.56), and 'science and research' (M = 1.59). Medium acceptance levels were reported for 'monitoring of infrastructure' (M = 1.82), 'transporting medicine or medical samples' (M = 1.83), and 'agriculture' (M = 2.07). There were low acceptance levels for 'photo and video recordings for news media' (M = 2.40), 'leisure time activities' (M = 2.62), and surprisingly for 'parcel delivery' (M = 2.73) as well. 'Photo and video recordings for advertisement' (M = 3.09) received the least acceptance (see also Figure 2).
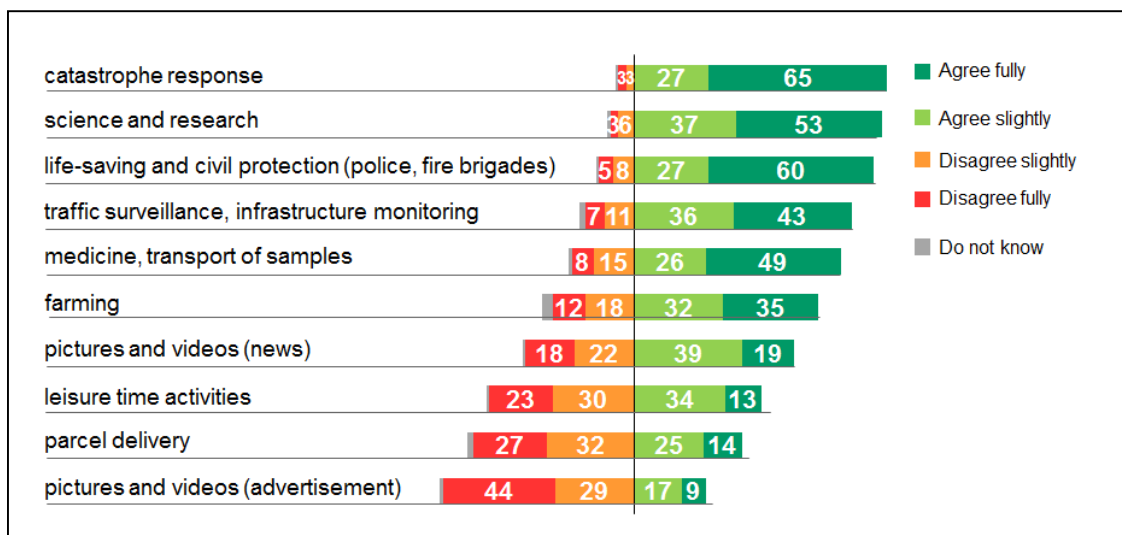

FIG. 2: Acceptance of various drone applications (%)

For 9 out of these 10 applications, the agreement varies according to gender, with females being substantially less supportive of drone applications; only for the purpose of 'transporting medicine or medical samples' was the acceptance slightly higher among female respondents.

A subsequent question asked respondents for which purposes they would accept drone usage for their own benefit: for 'leisure time activities', 'first aid', 'parcel delivery', 'police and fire services', or as an 'unmanned taxi'. Answers were given on the same 4-point scale mentioned above. Again, the purposes were asked in randomized order.
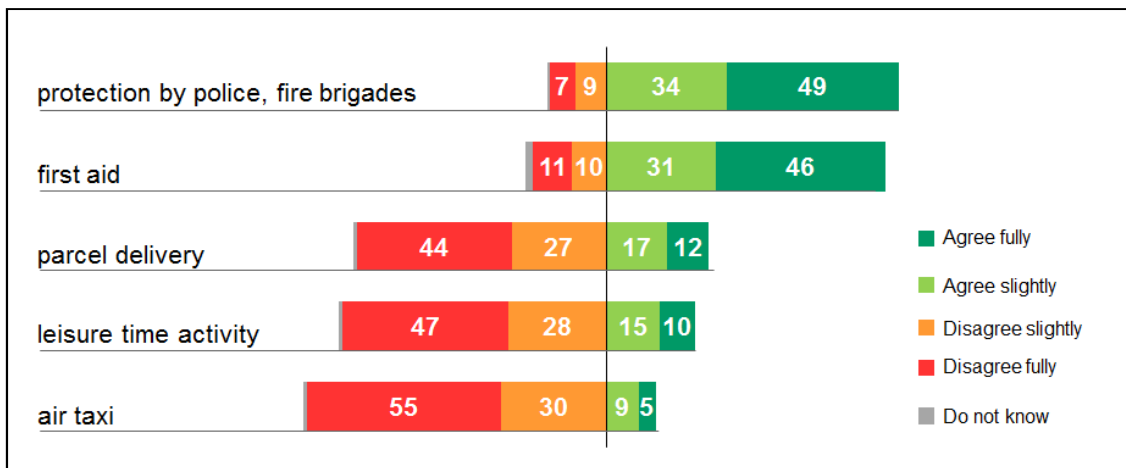
FIG. 3: Acceptance of drone use for own purposes (%)

Interestingly, the willingness to use a drone personally is low for the applications that have the highest economic interest ('parcel delivery', $M = 3.03$) and are featured most prominently in the news ('air taxi', $M = 3.37$, see also Figure 3). The two applications that receive the highest acceptance levels are 'protection by police and fire brigades' ($M = 1.74$) and 'first aid' ($M = 1.87$), which the urban population is already accustomed to because of helicopter overflight.

When asked about their own potential use of drones, the agreement among female respondents is significantly lower for all the applications listed in Figure 3. For 'air taxi', 'leisure time activity', 'parcel delivery' and 'protection by police, fire brigades', these differences are significant at $p < 0.01$, whereas for 'first aid' the difference is significant at $p < .05$.

Taking a closer look at the acceptance of drones for delivering one's own parcels, not only does gender produce a significant difference, $\chi^2 (1) = 8.77$, $p = .004$, $OR = 1.58$, but the corresponding distributions (see Figure 4) seem to indicate that male and female distribution in general show the same linear pattern from 'agree fully' to 'disagree fully'. However, the disapproval from the female respondents seems to be more distinctive.
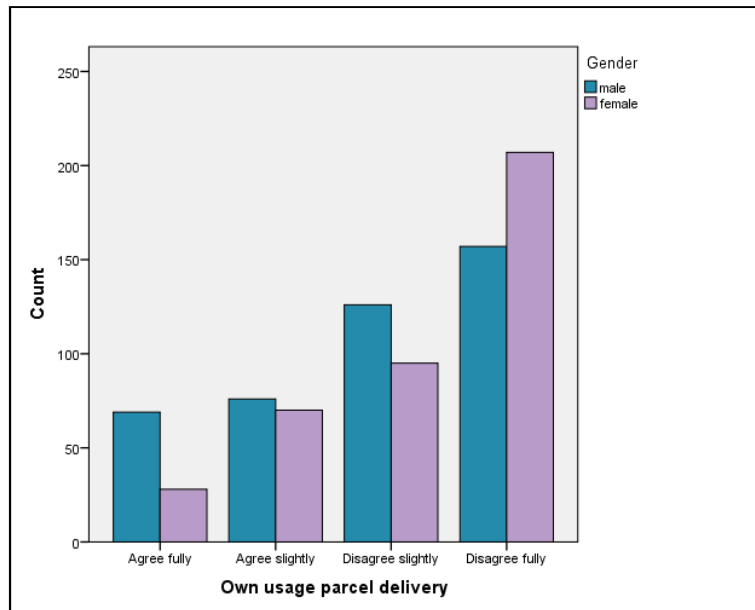
FIG. 4: Acceptance of drone usage for delivery of respondents' own parcels by gender

According to the regulations in Germany, any overflight of people's homes is prohibited unless the owner has provided prior consent. The same is valid for flying over groups of people, industrial facilities or public institutions. However, among the public, there is concern about how such an overflight ban could be enforced. When the respondents of the present study were asked about their general acceptance of flights over their own homes during the daytime using the same 4-point scale, results showed slight disagreement (M = 2.8, SD = 1.0). Overflight at night was even less accepted, with an average rating of 3.1 (SD = 0.9), which reflects clear disapproval. However, for the official functions of rescue and protection, respondents agreed slightly with home overflight of drones (M = 2.2, SD = 0.9).
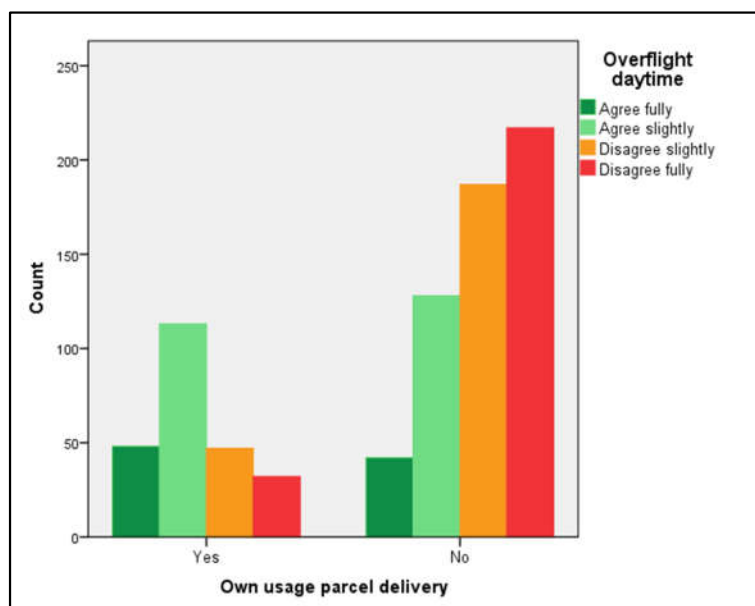

FIG. 5: Own usage of parcel delivery envisioned and acceptance of home overflight at daytime.

As shown in Figure 3, 71% of the respondents indicated they would not use drone delivery. However, even having a positive attitude towards using drones for parcel delivery does not necessarily mean accepting drones flying above one's own dwelling. Among the 29% of respondents who agreed either fully (12%) or slightly (17%) with the prospect of using drone delivery themselves, only two out of three (67%) would accept drones flying above their home at daytime (Figure 5), and less than half (44%) would agree to night-time flyovers.

Whereas parcel delivery is the most prominent association when asked about drones, respondents tend to disapprove of this application. In order to further investigate this attitude, the influence of the various concerns about civil drones on the acceptance of drone delivery for oneself was analysed using Chi-square Automatic Interaction Detection (CHAID). This method partitions a contingency table produced from cross-tabulation by using a semi-hierarchical, sequential procedure (Perreault et al. 1980) and has the advantage that it can be used with non-parametric survey data. In this study, it has been used to explain the extent to which each of the concerns explains the public acceptance of civil drones in Germany, finding that, out of all areas of concerns (listed in Figure 1), being or not being concerned about noise best explained the attitude towards civil drones χ^2 (2) = 38,6, p = .000, OR = .41 (Eißfeldt et al., 2020).

With drone delivery under special scrutiny in the present analysis, the acceptance of parcel delivery by drones was defined as a parent group variable that was split according to the different categories of concerns. Out of all areas of concerns that were assessed, being rather concerned or rather unconcerned about transport safety best explained the attitude towards parcel delivery by drones among all respondents, χ^2 (1) = 52.7, p < .001, and entered the analysis first. Concerns about noise among those concerned about transport safety followed on the second level. On the third level of the CHAID model, concerns about animal welfare entered the analysis among those who were concerned about traffic safety and noise. Overall, the analysis yielded groups of 59% approval (node 1) down to 23% approval (node 6) of the use of drones for parcel delivery (see Figure 6).

In comparison, a decision tree for the usage of drones for one's own parcels revealed a nearly identical model, with slightly lower acceptance levels at each node (node 1: 49%; node 5: 14%). Again, traffic safety entered the analysis first, with noise following on the next level for those concerned with traffic safety, and animal welfare further explaining concern among those who were also concerned about noise and about traffic safety. Acceptance of parcel delivery in general and personal usage of parcel delivery were highly correlated (Spearman rho = .76).
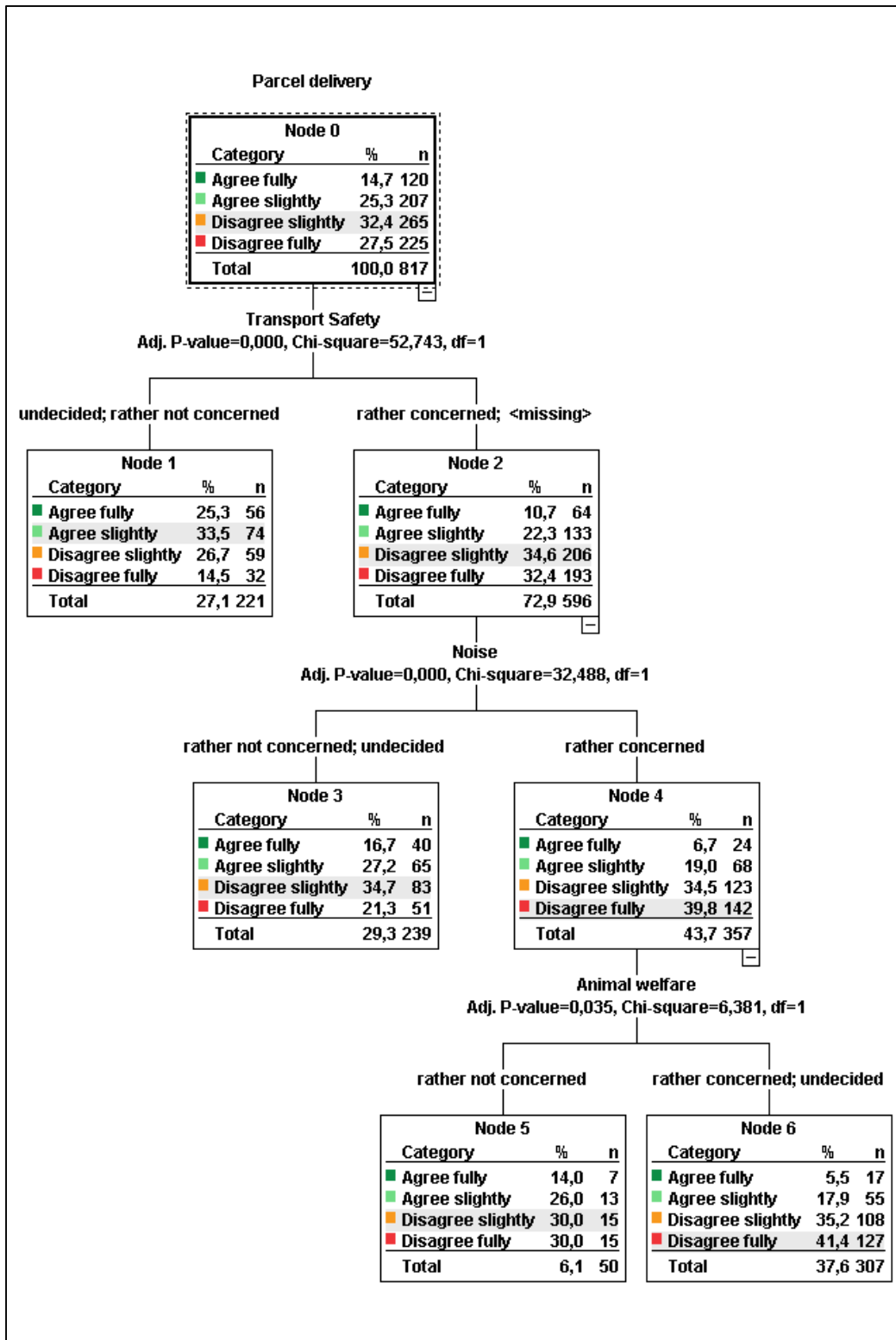
FIG. 6: CHAID decision tree model for agreement with parcel delivery by drones, partitioned by areas of concern.

4. Discussion

The attitude towards drone delivery among the German population is rather critical; about 6 out of 10 respondents disapprove of this application in general, and 7 out of

10 do not envision using it themselves. This is well in line with findings for other Western countries and has been quite stable for several years.

The disapproval rates are higher among females than males, with the gender dimension again being well in line with other countries. An important aspect is that this could be related to women being underrepresented in e-commerce. However, in recent years, females statistically pulled even with men in online shopping, as two thirds of both men and women have ordered products or services online in Germany (Statista 2020). Gender differences can be found throughout nearly all aspects of drone acceptance: Women display lower acceptance levels, have more and higher concerns, are more critical of different applications in general and are critical of home overflight in particular. This attitude might be driven by the technology used and the impacts anticipated, thus also leading to the support for drone delivery being especially weak among women. However, when asked about using drones for transporting medical samples or urgently needed medication, the picture changes. Not only are approval rates in the total sample much better then, with 3 out of 4 approving this usage, but furthermore, in this case women demonstrate even slightly higher approval of drone delivery than men. It might be that women value health-related usages of drones higher than men, an interesting aspect in times of pandemic when special neighbourhood deliveries are being tested (Fuller 2020). In those trials, the noise of the drone used for delivery (a popular consumer model) was measured to be in the range of 47 to 50 dB while hovering at an altitude between 100 and 200 feet, with about 68 dB while landing. The report takes this as proof of concept in terms of not being harmful to hearing and only a little more than the ambient noise level of 42 dB. Ambient noise is sometimes discussed as softening the noise impact of drones, however it underlies certain variation too. When investigating the effects of drone noise from a small multicopter (same model as above) added to various audio-visual scenarios, Torija et al. (2020) found that in soundscapes with reduced traffic noise, subjects in the position of a pedestrian reported higher perceived loudness and annoyance than they did in scenes highly impacted by road traffic noise, although the drone noise was held constant at 65 dBA across all scenarios. Instead of seeing this as proof for the potential of masking drone noise by street traffic, the results rather underlines the impairing aspects of drone noise on residents of such roads: As traffic varies over the day, there will be times with low traffic volume when local residents experience loudness and annoyance of drones much more ("annoyance up to 6.4 times higher than without drone noise" p. 18), e.g. at night. Furthermore, even in psychoacoustic tests comparing different outside noise using the same drone model, subjects rated the sound of drones as more annoying than that of road vehicles, at an equal level of sound pressure (Christian & Cabell, 2017). Other noise issues to be considered with drone delivery include the special aspects of tonality typical for quadcopters (Kloet et al., 2017), special influences of ambient weather conditions on sound levels and quality (Alexander et al., 2019), or the effects of load. In addition, quadcopters are controlled by varying the speed of every rotor individually, inducing pitch and yaw of the vehicle and changing the sound constantly, leading to more content at higher frequencies compared to conventional aircraft (Senzig et al., 2019). Cherney (2018) provides an example of how this led to problems in the neighbourhood of a testing site. While these trials took place in Canberra and even led to parliamentary review in Australia (Gothe-Snape, 2019), it is interesting to note that a follow-up of this drone model has recently been added to the collection at the Smithsonian National Air and Space Museum as being the first drone to make an official U.S. home delivery in Christiansburg VA (Fox 2020).

The imbalance between a generally supportive attitude towards a new, often technological development and the lack of acceptance of change in one's direct environment connected with it has been described as the NIMBY ('not in my backyard') effect in literature. According to Pol et al. (2006): 'Different factors can generate a NIMBY effect, especially fear of loss of the perceived quality-of-life status and economic value of property' (p.44). This effect is considered to be somewhat 'normal' and seems to be relevant in the context of drone delivery too. Even among those who support drone usage and would consider using drone delivery themselves, the motivation to accept drones as part of their personal environment is limited. As is the case with other new developments that are accepted in general, NIMBYism will be a factor when it comes to the acceptance of drones flying over one's own dwelling. In this special setting however, the term NOMOH ('not over my own home') seems more appropriate. There is hope that providing transparent information and careful communication can limit the influence of such phenomena on the acceptance of civil drones in daily life.

Based on the results of this study, the critical attitude toward drone delivery in general is based on concerns about transport safety, noise, and animal welfare. The same combination of concerns determines the attitude towards using drone delivery for one's own purposes. The special role of noise in shaping the attitude towards drone delivery has been confirmed in a recent study on using drones for parcel transportation in German towns. Asking for positive and negative factors, noise was confirmed as a disadvantage of drone delivery by two-thirds of the respondents. Other important problem areas that were foreseen included 'job-loss effects' (68%), 'stress due to drones flying around' (67%) and 'visual clutter' (57%). On the other hand, 'environmental friendliness' (79%) and 'reliability of service' (73%) were the top-rated benefits anticipated for drone delivery (Dannenberg et al., 2020).

After years of limited trials of drone delivery services, the start of large-scale services authorized by the government is coming. An online survey conducted late in the year 2019 among 528 online shoppers reports that 31% of the respondents are feeling 'excited', 19% are 'anxious', and 50% 'uncertain' about drone delivery (Panko 2020). As another survey has shown, residents do not support a general right to drone deliveries ('agree' 24%, 'disagree' 31%) whether or not people in their area have agreed beforehand. Instead, they largely agree (73% 'agree', 16% 'disagree') that communities should be consulted on drone deliveries (IME 2019).

Therefore, the results of this study attest to the need for regulation. Besides defining favourable topographical conditions and certain urban areas where drone delivery should be allowed, time restrictions can also be a viable measure to increase support. In addition, installing measures of noise control or providing tools for participatory noise sensing to residents could increase general acceptance (Eißfeldt 2020). If the acceptance level among residents remains in the range of below one third, drone delivery of commercial products will not become a successful service in Western cities. Thus, further research should closely monitor drone delivery services and their perception in the public, while taking into account relevant aspects such as the different usages, in order to avoid undesirable developments and to foster community agreement.

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