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Modelling public attitude towards drone delivery in Germany

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Abstract

Background Last-mile delivery by drone is expected to be a promising innovation for future urban logistics. However, in addition to adoption of services by customers, leveraging this delivery method will depend essentially on a positive public perception of such services in urban airspace.

Objective This article provides novel and comprehensive insights into factors driving or impeding citizens' attitudes towards drone delivery.

Methodology The article develops a structural equation model that derives from a sequential exploratory mixed methods design. In the first step, factors affecting attitudes towards drone delivery were identified within the scope of five focus groups and converted into the development of a questionnaire. In the second step, a German population-representative survey was conducted through telephone interviews, which provided reliable data to test the model (n = 819).

Results Expected risks (particularly stress due to traffic in lower airspace, noise, and visual disturbances), as well as expected benefits (particularly fast and time-flexible delivery), significantly affect attitudes towards drone-based delivery, while the individual level of technological openness (technophilia) does not have a significant association. Moreover, the model reveals that the expected risks of drone deliveries are stronger associated with public attitude than with expected benefits.

Conclusions The provided framework suggests fashioning policies and drone delivery applications that focus on mitigating social, spatial, and visual risks while achieving maximum utility for customers.

Keywords Drone delivery, Urban air mobility, Public attitude, Acceptance, SEM, Modelling, Expected benefits, Expected risks, Technophilia

1 Introduction

1.1 Background

Driven by economic motivations of making processes faster, more flexible, reliable, and paired with the attribution of a "green" transport option, drone delivery has climbed high on industrial and political agendas worldwide [1, 2]. Technically, standard delivery drones, as referred to in this paper, can lift weights of 2–3 kg and fulfil flight missions within a diameter of about 15 km [3]. Thereby, delivery drones generate plenty of applications ranging from medical use [4, 5], intralogistical applications [6] to commercial last mile delivery, e.g. for online retailing or food delivery [7, 8]. Though still in its infancy, drone delivery may form a serious option for innovating future urban and rural transport networks.

From a customer perspective, drone delivery is said to address the demand for ever-faster delivery as well as to open the opportunity for customers to receive their delivery within a narrow or even well-defined timeframe [9]. However, while economic and political actors

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increasingly pursue ambitions to enable deliveries in low-level airspace, the creation of a 'third dimension' for cargo transport may not only become a disruptive moment for customers but may also mark a turning point in people's perception of space and traditional notions of land use. Given the potential of wider diffusion of drone delivery in retail business and the respective possible sizes of drone fleets [10], it remains a relevant question of how citizens position themselves regarding the collective exposure to traffic in low-level airspace as a consequence of using the technology [11]. Thus, the vision of drone delivery not only involves an individual service choice for customers but also entails an inherently public dimension. In current acceptance research, however, this comprehensive understanding appears rather underrepresented, posing a risk to private sector ambitions and the jurisdiction of policymakers alike.

Against this background, this paper presents and tests a structural equation model (SEM) aiming to explain the public's attitude towards the deployment of delivery drones for consumer goods in public space. As citizens are both users and bystanders, the model incorporates relevant aspects of consumer preferences as well as novel societal and spatial dimensions, which are also expected to influence attitudes. The selected factors are subdivided into three latent variables (expected benefits, expected risks, technophilia) and derive from a sequential exploratory mixed methods design. Therefore, in the first step, a set of focus group discussions enabled to qualitatively explore and extract genuine acceptance factors. In a second step, these factors were investigated in a population-representative survey conducted in Germany in early 2020. In the third step, a large sample (n = 819) was tested in our model.

1.2 Literature review

Public support for commercial drone delivery currently appears low. For example, results of a representative population survey in Germany conducted in early 2020 show that only 25% of the respondents support or strongly support the idea of using the technology for the delivery of consumer goods, while 55% of the respondents disagree or strongly disagree [12]. Those results correspond to a cross-European study by EASA [13], in which participants were asked to rank their three most useful drone applications out of fourteen possible. Drone delivery of goods ordered through online shopping was a priority for about 20% of the respondents. Moreover, only 18% of respondents considered drone-based food delivery in urban environments to be one of the three most useful applications [13]. In sharp contrast to medical and emergency applications, the delivery of consumer goods thus doesn't appear to be perceived as a key necessity.

Nevertheless, acceptance research on consumer adoption of drone delivery and the willingness to pay for drone delivery services has grown significantly over the past decade. Drawing on a bibliometric analysis of respective empirical studies [14], results show that the variables' intention to use, 'attitude', 'risk perception', and 'personal innovativeness' are being used most frequently to analyse the acceptance of drone delivery. Moreover, the development of research hypotheses most often derives from modifications of the Technology Acceptance Model [15], the Theory of Reasoned Action [16], and the Diffusion of Innovation model [17]. For example, Yoo et al. [18] presented an acceptance model with a specific focus on delivery drones, which applied the Diffusion of Innovation model [17] and the Technology Acceptance Model to develop their hypotheses. By testing their model, they showed that the delivery speed, the ease of use, as well as individual characteristics such as the personal level of innovativeness, are central in determining the attitude towards the adoption of drone delivery. The latter is also confirmed by Hwang and colleagues, who did extensive research on the adoption of drone-based food delivery in South Korea [19].

Regarding the potential benefits of drone delivery from a customer point of view, the notion of (food) delivery services being "green" have shown a relevant positive association towards the attitude of respondents [20, 21]. Interestingly, lower delivery fees have not been found to significantly influence the attractiveness of drone delivery in general [22] but are suggested to be moderated by the specific context and circumstance, such as the parcel value or the availability of drop-off locations [23]. From a consumer risk perception, the functionality of the service is in question, including risks of technical delivery failures [24], low service reliability [18], unattended deliveries, and theft [25].

However, Zhu et al. [26] in particular, have shown that such delivery-related risks are not adequately reflecting the overall risk belief systems of the public towards drone delivery. Lateral and public risk dimensions, such as the risks of drones making the sky less pleasant to look at or causing property damage, can be strongly intervened to those believes [26]. Regarding the public dimension of drone delivery, especially safety and security concerns are broadly anticipated issues [27, 28]. Researchers also show that respondents perceive privacy risks as a significant concern in relation to the public application of drone delivery [21, 29]. In addition to that, noise has predominantly been surveyed as a central barrier to public acceptance of drones for transportation [30]. In addition, Kähler et al. [31] conducted an experiment exploring the salience of drones to the observer in various environments and applications, suggesting that the perception

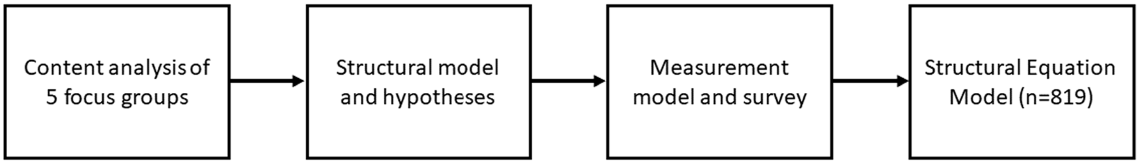

Fig. 1 Sequential mixed-methods approach

and aesthetic evaluation of drones is a relevant acceptance factor. Consequently, concerns regarding visual pollution from drones should be considered more strongly in future research [31]. From an empathetic social perspective, also the potential replacement of post officers generated by automated drone delivery might be a relevant factor to consider, as both Aydin [32] as well as Al Haddad et al. [33] demonstrate a linkage between concerns about possible job losses and lower acceptance of drones.

Reviewing the extensive body of research, we can state that studies currently either focus on consumer adoption or the influence of contextual aspects of drone delivery (environment, aesthetics, and noise). However, acceptance research on drone delivery strongly demands an integrated and applicable approach that incorporates aspects of both individual dimensions of consumer preferences and the various contextual aspects of drone delivery that refer to its public and societal dimensions. Against this background, the article is motivated to achieve an integrated perspective through a model-oriented expansion of current attitudinal research, combining aspects of drone deliveries' consumer and public dimensions. By this, we will provide more comprehensive as well as statistically robust insights on relevant factors driving or impeding attitudes towards drone delivery. Beyond the modeling approach creating conceptual relevance for attitudinal and social science technology acceptance in the field, the results can be of specific relevance for market research, the private sector, and policymakers with respect to future jurisdiction and the development of drone-related transport policies.

2 Methodology and data

2.1 Structural equation model (SEM)

Regarding the research purpose of this paper, we applied the approach of SEM. SEM contains concurrent statistical approaches, such as analysis of variance, covariance, regression, path analysis, and factor analysis [34]. SEM contains the comparisons between-group and within-group variance, generally related to the ANOVA analysis. These analyses are usually performed by applying data in means or correlations and covariances (i.e., unstandardized correlations).

SEM includes the structural model and measurement model. The measurement model (Factor analysis) indicates how observable variables measure the latent variables. The latent variables represent intangible or psychological concepts such as attitudes, behaviors, and emotions, which cannot be directly measured through single items [34]. The structural model (path analysis) indicates the association between the latent variables and examines the hypothesized associations. Regression models test the strength and direction of relationships between predictors and a dependent variable. However, SEM includes regression relationships simultaneously among latent variables and between observed and latent variables. In contrast to most statistical methods, SEM can analyze linear associations among variables at the same time by counting the measurement error.

Factor analysis tests hypotheses on how well sets of observed variables in an existing dataset measure latent construct (i.e., factors). For this reason, in the literature, factor analysis is also known as a measurement model. The constructs' reliability was tested by using the value of Cronbach's alpha for the constructs. Composite reliability (sometimes called construct reliability) is a measure of internal consistency in scale items, much like Cronbach's alpha [35].

$$\alpha = \frac{N \cdot \overline{c}}{\overline{v} + (N-1) \cdot \overline{c}}$$

where, N = the number of items, $\overline{c}$ = average covariance between item pairs, $\overline{v}$ = average variance.

A high level of alpha means that the observed variables are highly correlated and can be representative of a latent variable. Many studies suggest that the value of Cronbach's alpha should be above 0.70 to indicate the reliability of the constructs [35].

2.2 Data set

To develop and test the presented model, a sequential exploratory mixed methods design was applied [36, 37]. In this approach (Fig. 1), genuine qualitative data was collected in the first step using focus groups. To guide the development of a model structure, results

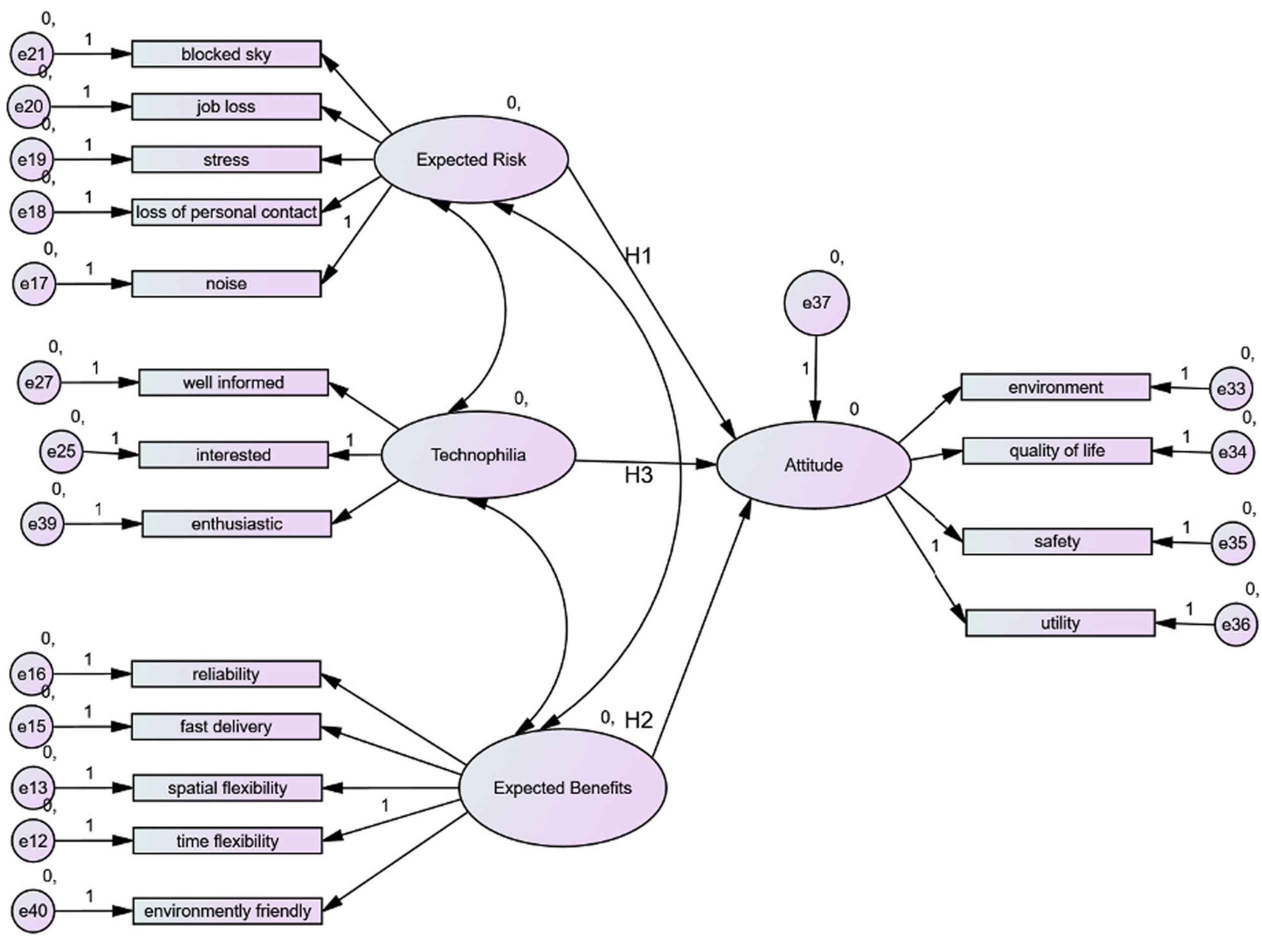

Fig. 2 Structural model and hypotheses

were evaluated using content analysis and interpreted within the theoretical framework of technology acceptance research. Building on this identification and classification of relevant variables that possibly influence the perception and attitudes towards drone delivery, quantitative data was gathered in a second step by conducting a telephone survey. The relevant variables were queried in a standardized questionnaire, allowing to build and test the SEM (Fig. 2).

2.2.1 Focus groups

The variables included in the presented model are derived from the analysis of five focus group discussions, which scrutinized delivery drones from a societal perspective. They were conducted in the German capital Berlin and in the state capitals, Stuttgart and Erfurt, in September and October 2019. The aim of these focus groups was to explore the public's basic perception as well as the associated beneficial expectations and concerns towards automated drone delivery as a possible element of future urban logistics.

Participants were chosen according to a pre-screening questionnaire aiming to exclude participants who worked in the drone industry and those who had never heard about drones before. Given that technology acceptance is often age-related [38–40], four of the five groups were separated into a younger (18–44) and an older (45–65) age-group. Since some studies also demonstrated a relationship between technology acceptance and gender [41, 42], gender balance was assured. In addition, different levels of education, income and household sizes were analyzed to avoid selection effects [43]. Following the methodological procedure proposed by Benighaus and Benighaus [44], eight to ten participants of each group were supplied with information on delivery drones and, in the following, were guided through a group discussion by a professional moderator. Each group discussion was initiated by the moderator providing a 10-min presentation, which was compiled beforehand by the research team. The presentation defined the concept of "drone" and showed different use cases in a neutral and objective manner. In addition, a short video clip was shown, which demonstrated what a parcel delivery by drone might look like in practice. Based on a pre-developed guideline, the participants then discussed the subject of fully automated delivery drones as a possible element of future urban logistics.

The focus groups were analyzed within the theoretical framework of technology acceptance theory [45, 46] and by applying a qualitative content analysis [47]. The different attitudinal dimensions and acceptance factors were generated inductively throughout the analysis of the transcripts [48]. Firstly, this assured the invariable identification of all factors that were considered relevant by the discussants. Secondly, this allowed for the identification of factors that had not been identified in previous studies. A comprehensive review of the focus group results is provided in Kellermann and Fischer [49]. More precisely, four key results can be depicted, which informed the subsequent development of a structural model and the formulation of hypotheses:

1. The focus groups unveiled contrasting attitudes regarding the participants' assessments of whether drone delivery would contribute to a higher *quality of life in cities*, if these new services would be *useful* or if they are rather to be seen as a threat to *public safety* and the common vision of *sustainable societies*.
2. The focus groups strongly emphasized the adverse impacts of automated drone delivery. Anticipated were *potential job losses* of delivery personal and intensified trends of *social isolation*, especially of the elderly. The expected impact of drone delivery on *urban sound and landscape* was a key issue in all the focus groups. What is more, there were broad discussions on how the quality of life in cities would change with respect to this new form of urban air traffic.
3. Participants positively assessed the outlook of drones to provide the *possibility to determine a package drop-off by time and location*. Other stated expectations of *potential benefits* were the *high reliability* of drone delivery and the option to receive packages *faster*. Furthermore, the eventuality of drone delivery being *environmentally friendly* was highlighted positively, thus forming a central aspiration.
4. Finally, discussions about drone delivery tended to be strongly influenced by participants' *opinions about technology* in general. On the one hand, some participants expressed enthusiastic technological optimism, often coupled with a fascination for new technologies. In stark contrast to that stood the technological skepticism or even technophobia expressed by other participants.

2.2.2 Model and hypotheses

The proposed attitudinal model consists of 17 observed variables that are entirely based on the qualitative results of the five focus group discussions. Grounded on these results and informed by key concepts from technology acceptance theories, the four latent constructs of expected benefits, expected risks, technophilia, and attitudes were defined. The following sections present the four latent constructs in more detail, while Fig. 2 shows the structural model.

2.2.2.1 Attitude Attitude represents a central construct in the original Technology Acceptance Model (TAM) presented by Davis [15] and describes a person's positive or negative perceptions regarding the performance of an action [50]. In drone-related acceptance research, attitude has already been proposed as a dependent variable, mostly to predict the intention to use drones or drone-related services [18, 51, 52]. In line with that, the construct of attitude was derived from the focus group discussions. Since the discussions were not only related to individual interests in using drone delivery services but primarily to the technology's expected influence on urban societies, the term *public attitude* is used. Consequently, in this research, attitude represents the target variable, and hypotheses are tested to explain the formation of (public) attitudes towards drone delivery.

In the survey, public attitude was measured by asking respondents how much they would agree to the statements of drone delivery (1) bringing advantages in the respondents' everyday life, (2) being generally safe, (3) having a positive effect on the quality of life in cities, and (4) being more environmentally friendly than current transport alternatives.

2.2.2.2 Expected risks The concept of risk was introduced to attitudinal and behavioral research to explain the consequences of an action or the circumstances surrounding it cause uncertainty, uneasiness, or anxiety [53]. In drone-related research, the variable of *(perceived) risk* has been conceptualized early onwards [52] and proved as a significant predictor of attitude formation in prior models on drone delivery [18]. In this research, *expected risks* are understood as concerns with respect to the future introduction of drone delivery in urban areas, directly affecting the attitude.

H1 There is a significant association between a subject's expectation of risks and its attitude to delivery drones.

Expected risks were measured by how problematic respondents considered (1) the noise from parcel deliveries with drones, (2) the potential decrease of personal contacts between recipients and deliverers/drivers, (3) caused stress due to delivery drones flying around, (4) potential job losses of deliverers/drivers due to automation of flights, (5) a potentially blocked view to the sky.

2.2.2.3 Expected benefits Following TAM, the *perceived usefulness* of a new technology has a direct correlation to respondents' attitudes towards the object [15]. The same concept was already adopted in drone-related research [51, 54]. In this research, the variable of *expected benefits* describes a similar concept and refers to personal but also public benefits that a widespread introduction of drone delivery might contribute to. A direct correlation between expected benefits on attitude is proclaimed.

H2 There is a significant association between the subject's expectation of benefits and its attitude to delivery drones.

As potential predictors for the latent variable of expected benefits, in the survey, it was asked how important it would be for the respondent that parcel deliveries with drones would be (1) reliable, (2) fast, (3) environmentally friendly, (4) flexible in delivery time, and how important it would be (5) that drop-off locations can be determined by the customer.

2.2.2.4 Technophilia While external variables, such as demographics, have already been part of TAM [15], later extensions to the model emphasized more strongly on individual dispositions [42]. In this research, a person having a technophile disposition is considered to evaluate and perceive novel technologies in a positive way to improve his or her own life as well as society as a whole [55]. Constructs such as *personal innovativeness* [18] or *cognitively motivated consumer innovativeness* [21] were already emphasized by acceptance research studies in the field [18],Lin [56]. Henceforth, a direct association of *technophilia* with attitude is suggested.

H3 There is a significant association between a subject's technophilia and its attitude to delivery drones.

The latent variable of technophilia was measured by evaluating the respondents' affinity to new technologies. The survey design drew on established questionnaires in the field, which already measured technophilia as a latent variable [57]. Accordingly, to measure technophilia, (1) the respondents' subjective level of information about technologies, (2) their ability to get easily enthusiastic for new technology, and (3) their general interest in technology were surveyed.

2.3 Survey

Based on the focus group findings, the survey questionnaire was designed and administered in a fully structured computer-assisted telephone interview (CATI) with 1000 interviews in January 2020. In the beginning, respondents were informed that the survey thematizes the future of urban transport. All items were then asked with the agreement or disagreement of different statements on a five-point Likert scale. In addition, "don't know/no answer" was included as a response option. To minimize distortion of the response behavior due to fixed item sequences, the corresponding item batteries were randomized [58]. Moreover, to minimize Acquiescence Response Bias [59], the questionnaire followed a query of factors by an alternation of positively and negatively formulated items. The composition of the sample corresponds to the structure of the total German-speaking population in Germany aged 18 and over. This means that the original dataset is representative.

2.4 Sample

After having removed entries with missing values from the initial dataset, a sample size of 819 respondents was employed for the statistical analysis of the model. The characteristics of the sample are indicated in Appendix 1. Around 29% were aged 18 to 39. The age group 40 to 59 was represented by about 40% of the respondents, and around 30% of persons were age 60+ years. About 39% of respondents had completed a technical or university degree. About 23% held a secondary school leaving certificate or technical college entrance qualification. Only 37% of respondents were either retired or unemployed while most respondents reported a monthly net household income of 4500 euros or more (about 27%). Spatially, about 21.1% of respondents lived in major cities of 500,000 or more inhabitants, while with 50%, most of the respondents originated from smaller to mid-size towns with a population between 5000 and 100,000 inhabitants.

Despite the removal of entries with missing values having reduced the sample size, the sample of 819 respondents still closely corresponded to the socio-demographics of Germany (Statistisches [60–63]. Larger deviations from the socio-demographics of Germany exist, however, regarding gender distribution, as around 51% of the population in Germany are women [64] while in the survey, they account for only 45.5%.

3 Data analysis and results

For the statistical analysis of the model, we employed the above-mentioned 819 samples. All the values of Cronbach's alpha and CR were above the recommended

Table 1 Reliability of constructs by Cronbach Alpha Test

Latent variable	Observed variable	Variable names	Cronbach alpha
Technophilia	**How much would you agree to the following statement:**		
	In general, I am well informed about new technologies	Well informed	0.798
	I get easily enthusiastic about new technologies	Enthusiastic	
	I am always interested in new technologies	Interested	
Expected risks	**How bad it would be for you…**		
	…the noise from parcel deliveries with drones	Noise	0.778
	…the fact that parcel deliveries with drones would mean the personal contact between recipient and delivery driver would disappear?	Loss of personal contact	
	…the stress caused by drones flying around to deliver packages	Stress	
	…the fact that delivery drivers would lose their jobs as a result of parcel deliveries with drones?	Job loss	
	…that parcel deliveries with drones would block your free view of the sky	Blocked sky	
Expected benefits	**How important would be for you…**		
	…that parcel deliveries with drones would be reliable	Reliability	0.789
	…that you would get your parcels delivered quickly	Fast delivery	
	…that parcel deliveries with drones would be environmentally friendly	Environmentally friendly	
	…that you could use drones to have parcels delivered to a place of your choice, e.g., balcony or garden	Spatial flexibility	
	…that your parcels would be delivered at an exact time of your choice	Time flexibility	
Attitude	**How much would you agree to the following statement:**		
	I think that parcel deliveries with drones are environmentally friendly than package deliveries with a delivery van	Environment	0.834
	I imagine parcel deliveries with drones to be safe	Safety	
	Parcel deliveries with drones would have a positive effect on the quality of life in cities	Quality of life	
	Parcel deliveries with drones would bring me advantages in my everyday life	Utility	

threshold (0.7), which confirmed the high reliability of the constructs. The result of the Cronbach test is indicated in Table 1. Before examining the structural model, we checked the multicollinearity assumption by using the value of the variance inflation factor (VIF). All the constructs were considered predictors of one of the constructs and calculated the VIF scores. The VIF scores are less than 2.00, which is less than the recommended value of 10, suggesting minimal collinearity [65]. SEM was then utilized to estimate the hypothesized relationships. The analyses provided acceptable fit indices for the structural model.

3.1 Fitness of model

The fitness of the model is checked through the comparative fit index (CFI), the Tucker–Lewis index (TLI), and the root mean square error of approximation (RMSEA). As the chi-square statistic is sensitive to the large sample size [66], it is recommended to use the normed chi-square, that the chi-square is divided by the degrees of freedom (χ^2/df) as a measure of model fit, with the acceptance-value of 5 or less [67]. The chi-square of this model is 458.389 with df = 113, therefore the normed chi-square is 4.05.

The comparative fit index (CFI) analyses the model fit by evaluating the discrepancy between the data and the hypothesized model, and its value is in the range from 0 to 1, and the larger values indicate better fit. A CFI value of 0.90 or larger is considered to indicate an acceptable model fit. The calculated CFI in this model is 0.936. Tucker–Lewis index (TLI), also known as the non-normed fit index, is an incremental fit index. Bentler and Bonett [68] recommended that TLI > 0.90 indicates an acceptable fit. In this model TLI is 0.923. RMSEA (root mean square error of approximation) is one of the most applied measures to check structural equation models. RMSEA is the root mean square error of approximation, indicating how well the model, with unknown but optimally chosen parameters, would fit the populations' covariance matrix [69]. It is "one of the most informative fit indicators because of its sensitivity to the number of estimators in the model" [70]: 85). The values of 0.01, 0.05 and 0.08 indicate excellent, good, and mediocre fit respectively. In this model, RMSEA is around 0.05 which indicates good fit.

Table 2 Results of the measurements and constructs (****P* ≤ 0.001)

	Estimate	S.E	Standardized estimates	*P*
Attitude				
Environment	.856	.045	.666	***
Quality of life	.991	.042	.798	***
Safety	.872	.041	.737	***
Utility	1.000		.789	
Expected risks				
Noise	1.000		.678	
Loss of personal contact	.917	.072	.503	***
Stress	1.345	.069	.838	***
Job loss	.722	.061	.465	***
Blocked sky	1.299	.074	.718	***
Expected benefits				
Time flexibility	1.000		.737	
Spatial flexibility	.993	.054	.708	***
Fast delivery	.968	.050	.760	***
Reliability	.853	.051	.646	***
Environmentally friendly	.456	.043	.401	***
Technophilia				
Well informed	.743	.045	.612	***
Enthusiasm	1.086	.056	.844	***
Interested	1.000		.811	

3.2 Factor loadings

Each of the four constructs in the model is measured by at least three observed variables. The load factors are indicated in Table 2 and visualized in Fig. 3. Results suggest which observed variables most reliably measure the respective construct.

The standardized estimates between the latent variable attitude and its measurement indicate that the observed variable of the environment has the least standardized estimates (0.67), while the other three measurements have almost similar load factors, which are quality of life (0.8), Safety (0.74), utility (0.79).

Among the measurements for the latent variable expected benefits, the observed variables of fast delivery and flexibility in time show the highest standardized load factor by 0.76 and 0.74, respectively. The influence of delivery drones' relative advantage of environmental friendliness (0.40) is considerably weaker, nevertheless significant.

In the construct of expected risks and its measurement, the observed variables of stress and blocked sky view show the highest standardized estimates, which are 0.84 and 0.72, respectively, while the variable of Job loss has the lowest impact factor (0.46) on the latent variable.

Finally, technophilia is measured most reliably by interest and enthusiasm in new technologies with standardized estimates of 0.81 and 0.844, respectively, while the level of being informed shows a weaker yet significant influence on technophilia (0.61).

3.3 Structural model and hypothesis

Table 3 shows the results of the relationships. The model reveals significant associations of attitude with expected benefits (H2) by ($\beta = 0.439$, $p < 0.001$) and expected risks (H1) by ($\beta = -0.738$, $p < 0.001$). Hence, H1 and H2 are confirmed. In contrast, the *p*-value of H3 is 0.111, which means that the model does not suggest a significant association between technophilia and attitude.

4 Discussion

The aim of this study was to identify significant factors and their direction of influence on the formation of attitudes towards drone delivery. For this purpose, a SEM was tested on a sample of 819 respondents and showed reliable results. The Comparative Fit Index (CFI), the Tucker-Lewis Index (TLI), and the Root Mean Square Error of Approximation (RMSEA) indicate an acceptable model fit of 0.936, 0.923 and 0.05, respectively. The composition of the four latent constructs of *public attitude, expected risks, expected benefits,* and *technophilia* from the total of 17 observed variables derived from qualitative research can be confirmed.

Therefore, the first relevant result of our research is the robust composition of attitude as a target variable. In addition to individual aspects (personal utility of drone delivery), the composition includes a strong community-oriented character (positive environmental effects, quality of urban life, public safety), which is why the here-used term "public" attitude seems appropriate. The standardized estimates show that especially the impact of drone delivery on the urban quality of life (0.798) serves as a good predictor for public attitude.

Testing of the research hypotheses showed mixed results.

i. The model reveals a significant association of attitude with expected risks (H1). These results are generally consistent with previous risk studies [50, 71, 72], which illustrate a negative effect of potential risk factors on attitude and technology adoption. The more the movement of delivery drones in urban space is expected to be stressful (0.838) and noisy (0.678), would generate the impression of blocked skies (0.718), the more respondents create a negative attitude towards the technology. While

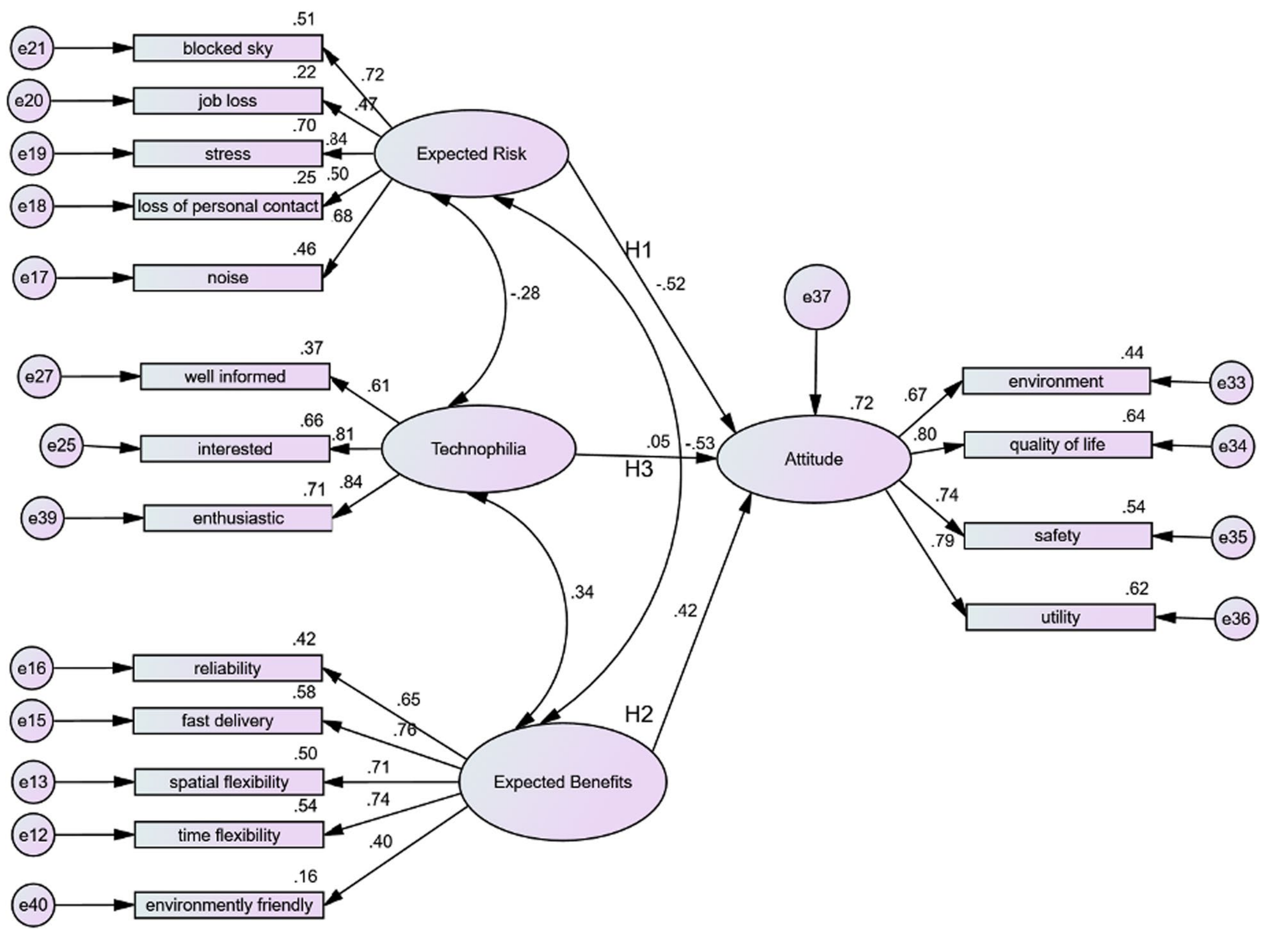

Fig. 3 Structural equation model

noise, in particular, has been addressed in acceptance research and engineering sciences [73, 74], the above-mentioned aesthetic implications of drones and their salient for citizens have yet to receive little attention [31, 75]. Furthermore, our study unveiled the significance of losing personal contact with delivery personnel (0.503) in forming the attitude towards drone delivery. This aspect was previously confirmed in the context of adopting self-service parcel lockers [76], but—apart from general considerations [23]—had not yet been explicitly analyzed in the context of drone delivery. As another social factor, the risk perception of drone delivery generating job losses (0.465) was shown to have a significant negative effect on the public attitude. This outcome appears to be strongly consistent with related works, particularly Aydin [32].

ii. The SEM reveals a significant association of attitude with expected benefits (H2). These results are consistent with findings within technology acceptance research which have repeatedly demonstrated the central relevance of beneficial factors for positively affecting attitudes towards technology adoption in various contexts [15, 50, 72]. Specifically, our study provides evidence that people form a more positive attitude towards the technology who expect the delivery to be faster (0.760) and more flexible regarding delivery date (0.737) and location of parcel drop-off (0.708). Moreover, the expectation of delivery drones providing a reliable service (0.646) and being environmentally friendly (0.401) were also shown to form a more positive attitude.

Table 3 Results of the structural mode (***$P \leq 0.001$)

Hypotheses	Standardized Estimates	*P*	Results
H1: Attitude <–- Expected risks	– 0.520	***	Supported
H2: Attitude <–- Expected benefits	0.424	***	Supported
H3: Attitude <–- Technophilia	0.053	0.111	Not supported

These results are partly consistent with studies focusing on drone deliveries, which also found the relative advantages of speed and environmental friendliness [18], respectively a "green image" [21], to be significant predictors for a positive attitude towards delivery drone usage. In addition, the preceding focus groups have qualitatively revealed the factors of reliability and flexibility (time, location as new and previously uncharted factors influencing attitudes towards drone delivery. In contrast to other studies that rather focused on examining the factor of reliability in the context of a potential "performance risk" [18, 25], the focus groups unveiled that participants actually considered service reliability as a beneficial factor. This conceptual re-interpretation was confirmed in our model and may contribute to a more precise definition of acceptance factors in future studies.

iii. The model does not suggest a significant association between a person's technophilia and attitude (H3) towards drone delivery. The result seems trustworthy, as the latent variable was measured in accordance with an established questionnaire [57] by three separate items that show a good Cronbach alpha (0.8). This suggests that even consumers who have a general interest in learning about new technologies, who consider themselves to know a lot about new technologies and easily feel enthusiastic about using and trying them, don't create significantly more positive attitudes towards drone delivery services. This finding is in contrast to previous studies that highlighted the relevance of concepts such as "personal innovativeness" [18] or "cognitively motivated consumer innovativeness" [21] in significantly influencing attitudes and, thus technology adoption. Our finding of a person's technophilia proving to be neglectable for forming attitudes towards drone delivery appears especially remarkably as technophilia was found to have a significant positive correlation with forming attitudes towards the adoption of electric vehicles [77] or on the attitude towards drone-enabled passenger transport in air taxis [78]. The later may indirectly hint at drone logistics being perceived as less spectacular and rather pragmatic compared to the individual thrill and risk of being transported as a passenger in an automated drone.

Concerning the relationship between expected benefits and risks, we found the latter to have a stronger association with the attitude towards drone delivery (−0.52) than the expected benefits (0.424). On the one hand, this may be explained by the assumption that the benefits of drone delivery might yet appear abstract and hardly imaginable, such as the suggested flexible drop off time and locations for packages, or benefits might be perceived as not sufficiently compelling. This, in turn, may to some extent, be explained by the lack of familiarity and experience with potential beneficial features. Leading behavioral and technology adoption models have demonstrated the relevance of familiarity and experience with a technology [17]. This may particularly apply to drone services, which have just been rarely implemented. Consequently, experience and real-life applications with drone deliveries may become a relevant attitudinal aspect [79]. On the other hand, individuals without real-life experience might more easily imagine obvious threats of drone delivery (physically falling, being misused for criminal purposes, being noisy, or violating privacy) compared to imagining potential benefits.

Beyond that, the comparably lower influence of expected benefits against expected risks strengthens the assumption that in the sample, drone delivery is not considered a prior necessity for improving the delivery system. This may also be explained by respondents' strongly varying environments. Most respondents live in rural areas or smaller towns or cities below 500,000 inhabitants (79% of respondents), where congestion problems affecting last-mile delivery traffic may not be experienced as critical as in bigger urban areas of more than 500,000 inhabitants (21% of respondents). Moreover, respondents may live in heterogeneous housing conditions (single house, multi-story apartment building etc.), thus possibly creating varying perceptions of drone deliveries being practically feasible in their individual environments.

Irrespective of the geographical context, prior studies demonstrated that commercial drone delivery is not considered among the most relevant use cases of drone technology [13]. Furthermore, results from technology assessment show that added values of delivery drones often remain abstract and must be made more plausible to the public in order to sustain a publicly accepted usage of urban airspace as a new transport layer [80]. Strong added values can be created, however when the deployment of the technology is more evidently targeted to serve the common good, e.g. in medical or humanitarian use cases [81]).

This study faces several limitations. First, the transferability of results may be restricted as data were collected in Germany only. However, a cross-national study on the acceptance of drone applications in Europe shows no serious divergences between the examined member countries [13]. Against the background of this finding, the model framework can be considered a relevant research reference for future studies in the European context or regions with comparable socio-demographic features as used in this paper. Secondly, the survey data on drone delivery had the limitation of asking respondents about a technology that is not yet tangible in the daily life of citizens. Future applications of drone delivery should emphasize accompanying social science research to collect alternative data. Third, the database for this study consists of a survey that was conducted in January 2020, so right before the outbreak of the Covid-19 pandemic. As various studies have highlighted that the pandemic induced (long-term) changes in mobility and consumption behaviors [82, 83], our findings may not reflect these changed societal framework conditions. As people confronted with the pandemic might have perceived a bigger value of contact-less delivery methods than before the pandemic, a share of respondents might have slightly reduced their expectation of risks and might have slightly increased their expectation of benefits related to drone delivery [84].

5 Conclusions

The vision of commercial drone delivery in urban environments incorporates not only an individual service choice for potential customers but also entails an inherently public dimension. In current acceptance research, this comprehensive understanding appears rather underrepresented. Therefore, this study aimed to build and test an integrated model to define and explain the public attitude towards drone delivery that includes both relevant aspects of consumer preferences as well as significant societal and public dimensions.

Using a large sample (n = 819) from a representative survey in Germany from 2020, the results of the model reveal insights of practical utility. We confirm that particularly the expectation of a fast and time-flexible delivery are highly valued attributes from a customer perspective. On the other hand, especially the expectation of spatial and visual implications (noise, visual disturbance, and rising stress levels through drone movements) are relevant factors that negatively impact respondents' attitudes from a citizen's perspective. Rather than solely focusing on individual aspects of adopting the use of drone delivery, we, therefore, suggest that the planning of business cases and drone-related policies should give stronger emphasis on the consideration of public dimensions of drone delivery.

What is more, by highlighting the centrality of social risk factors that outweigh individual benefits, the results suggest that the public is currently not willing to accept the risks of large-scale drone delivery of consumer goods. From an acceptance perspective, rather than focusing on business-to-customer solutions, drone delivery service providers may generate more robust business cases by focusing on business to business applications.

In addition, the results of this research show that technophilia, as we framed the individual innovativeness towards technology, has no significant association with the attitude towards drone delivery. This may have general implications for the industry as drone service providers may not easily be able to count on the innovativeness of certain consumer subgroups, e.g., innovators or early adopters.

Finally, the presented model may be of methodological utility as both the qualitative identification of novel acceptance factors and their quantitative transition into a survey and the test in a model highlights the appropriateness of following a mixed methods approach in technology acceptance research.

Appendix 1: Socio-demographic distribution of the sample

Attribute	Value	Count	%
Gender	Male	445	54.3
	Female	373	45.5
	Divers	1	0.1
Age	18–29 years	84	10.3
	30–39 years	152	18.6
	40–49 years	157	19.2
	50–59 years	173	21.1
	60+ years	253	30.9
Education	Without lower secondary/vocational school leaving certificate	3	0.4
	Lower secondary/vocational school leaving certificate	62	7.6
	Secondary school leaving certificate, technical college entrance qualification	199	24.3
	Completion of polytechnic secondary school (8th/10th grade)	20	2.4
	Advanced technical college entrance qualification, completion of a specialized upper secondary school	63	7.7
	High school diploma, general or subject-linked higher education entrance qualification	144	17.6
	Technical/college studies	317	38.7
	Other school-leaving qualification	9	1.1
	No indication	2	0.2
Employment	Employed	519	63.4
	Unemployed	300	36.6
Household monthly income	Below 500 EUR	4	0.5

Attribute	Value	Count	%
	500 until below 1.000 EUR	21	2.6
	1.000 until below 1.500 EUR	53	6.5
	1.500 until below 2.000 EUR	58	7.1
	2.000 until below 2.500 EUR	87	10.6
	2.500 until below 3.000 EUR	74	9.0
	3.000 until below 3.500 EUR	72	8.8
	3.500 until below 4.000 EUR	76	9.3
	4.000 until below 4.500 EUR	80	9.8
	4.500 and more	222	27.1
	No indication	72	8.8
City size	Below 5.000 EW	119	14.5
	Between 5.000 and 20.000	177	21.6
	Between 20.000 and 100.000	227	27.7
	Between 100.000 and 500.000	123	15
	More than 500.000	173	21.1

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