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Article

'We Need Time…': An Expert Survey on Societal Acceptance of Urban Drones

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Drones are rapidly becoming integral components of urban air mobility. Their integration into urban environments hinges not just on broader public sentiments but also on the perceptions of experts who drive their development, deployment, and management. This study delves into experts' perspectives on urban drones to supplement existing knowledge by improving the understanding of acceptance factors and associated challenges. The results indicate that themes of privacy, safety, and regulation are recurring. Notably, trust towards different institutions deploying drones varies, while the need for dedicated awareness and education efforts to inform public understanding is an emergent theme. Overall, the insights gained accentuate the importance of governance strategies that consider all stakeholders' viewpoints and the intertwined nature of challenges they are faced with. This calls for the scientific community to support the development of effective framework conditions alongside enhanced stakeholder collaborations towards a smooth integration of urban drones in society.

Keywords: societal acceptance; urban air mobility; public perception; expert opinion; governance strategy; value-sensitive innovation.

1. Introduction

Unmanned aerial vehicles (UAVs), commonly referred to as drones have considerably transformed urban air mobility and its related services, reshaping different sectors and segments of society through their versatile applications. [Within the scope of this contribution, we use the terms 'drones' and 'unmanned aerial vehicles' interchangeably. We also explicitly focus on civil applications of drones used in the urban environment, excluding any applications related to military or weaponized use. For further details regarding this scope of inquiry, see Wang, Christen, and Hunt (2021) and Wang, Mutzner, and Blanchet (2023).] As these aerial robotic devices become more prevalent in urban settings—deployed for a wide scope of applications ranging from humanitarian work to search and rescue missions, to package deliveries, and to aerial surveillance—their smooth integration into urban life becomes critical (Wang, Mutzner, and Blanchet 2023). Recently, interest in the public perception of drones has been on the rise, and a multitude of scholarly works using surveys or interviews have examined it in different contexts and through various use cases (Kellermann and Fischer 2020; Miethe et al. 2020; Komasova 2021; Lin Tan et al. 2021; Cetin et al. 2022; Sabino et al. 2022; Smith et al. 2022). Yet, urban drone integration hinges, on the one hand, on acceptance by the general public and, on the other hand, on involved stakeholders who are situated at the forefront of drone technology, including its design, development, operation, implementation, and management. Hence, insights provided by experts who are closely involved in urban drone implementation, such as roboticists, engineers, aviation authorities, smart city planners, innovation managers, regulators, and policymakers, are essential to help construct a comprehensive scenario around their societal acceptance.

Unlike existing studies, our research adopts a broader lens by tapping into the perspectives of experts, i.e. key stakeholders around drone project implementation, through a variety of survey questions, with the aim of providing a distinct angle that has been largely under-represented in the existing body of knowledge. By focusing on experts' experiences with drone acceptance and the challenges they are faced with, we offer a nuanced understanding of factors and dynamics shaping the urban drone acceptance landscape. This methodology enables us to provide a more contextualized framing of societal acceptance, highlighting complexities that may have been overlooked, such as the interconnectedness of different acceptance factors at a deeper structural level. In doing so, our study contributes to filling an epistemological lacuna by enhancing the understanding of divergent viewpoints from both the expert and the public perspectives, thereby supporting the development of condition frameworks and actionable guidance to foster informed public policy in the urban mobility context.

2. Background

Understanding the role of technology acceptance is essential for the effective adoption of digital innovations in society. The case of drone technology offers a poignant example of how public sentiments evolve with technological advancements. According to Sabino et al. (2022), *public perception* of drones was shaped by the potential transformative and beneficial effects of their usage, as well as critical concerns regarding their negative impacts. Yet, this shaping of public perception is also influenced by speculative visualizations of drones, crafted by commercial interests to promote particular visions of drone futures that can fuel both fascination and apprehension (Jackman and Jablonowski 2021; Jackman 2022). These critical perspectives highlight how drones are anticipated as transformative technologies that not only reconfigure urban airspaces but also shape public perceptions, social relations, and regulatory approaches. This is especially insightful when looking at the utility versus invasion paradigm (Lidynia, Philipsen, and Ziefle 2017; Gevaert et al. 2018; Lin Tan et al. 2021), where public views on drones are shaped by a balance between perceived benefits and concerns over privacy intrusions. An example was the public recognizing the economic and efficiency benefits of drone delivery (Kellermann and Fischer 2020; Osakwe et al. 2022; Leon, Chen, and Ratcliffe 2023), while being critical about privacy intrusion through the collection of aerial data (Rao, Gopi, and Maione 2016). The convenience and benefits of drones seemed to be further overtaken by concerns of safety, which were shown in examples such as property damage caused by drones (Gevaert et al. 2018; Rosenfeld 2019), cargo safety in drone transportation (Alluhaidan 2021; Ganjipour and Edrisi 2023), personal safety theft due to drone crash (Ivosevic et al. 2021), drone misuse and hacking (Kellermann and Fischer 2020), and data safety and security (Wang, Christen, and Hunt 2021).

While public concerns have traditionally centred on privacy and safety, recent geopolitical conflicts have intensified the security focus within regulatory frameworks governing drone technology. This shift reflects a broader trend towards the securitization of digital technologies, where regulatory policies previously focused on commercial and safety aspects are increasingly infused with security imperatives (Mügge 2023). This evolving regulatory landscape may further shape public perception about drones, potentially amplifying concerns around privacy, safety, surveillance, and even militarization, thereby reshaping public trust in drone technology. The trust aspect is also closely connected to emotional responses, which play a significant role in public acceptance. For instance, a drone's presence in the sky could evoke feelings of marvel in some, while causing discomfort or annoyance to others due to noise or the thought of being watched (Lidynia, Philipsen, and Ziefle 2018; Rosenfeld 2019; Kellermann and Fischer 2020; Wang 2020a, Wang, 2021). Additionally, the aspects of public awareness and education have been increasingly identified as key in improving technological literacy and acceptance of drone applications (Sakiyama et al. 2017; Heen, Lieberman, and Miethe 2018; Martin et al. 2018; Zhu, Pasch, and Bergstrom 2020; Lin Tan et al. 2021; Annan et al. 2022). For instance, Eißfeldt et al. (2020) reported that well-informed individuals within their German sample expressed more positive attitudes towards drones than their less-informed counterparts. Nelson and Gorichanaz (2019) further established that participants with hands-on drone experience exhibited a deeper understanding of the technology and its related infrastructure and expressed fewer privacy concerns. Numerous other factors that shape public perceptions were explored in-depth in our earlier review of the academic literature on this topic (Wang, Mutzner, and Blanchet 2023).

In contrast to knowledgeable users, who offer valuable but limited viewpoints, stakeholders from industry, regulatory bodies, and civil society can bring a deeper layer of specialized *expert opinion* that often differs from public perception. For example, Reddy and DeLaurentis (2016) included both the general public and stakeholder groups in an opinion survey, finding that stakeholders felt better informed about public concerns and were more conditionally supportive of drone technology. Aydin (2019) validated these findings by noting higher drone support among stakeholder groups compared to the general public. Finn and Wright (2012) conducted a survey that included industry experts, regulators, and civil society watchdogs, revealing that these specialized groups held nuanced views on privacy, data protection, and ethical risks, particularly emphasizing risks associated with private recreational drone use. Similarly, Cetin et al. (2022) observed that experts were disproportionately concerned about safety aspects, diverging from the more generalized concerns of the public. Macias et al. (2019) analysed experts' evolving perspectives on drone acceptance in the context of U-Space implementation. Their study revealed that experts became more critical of factors related to safety, economic growth, and political considerations when faced with more complex operational environments. Yet, they simultaneously believed that U-Space would enhance safety and engender economic and societal trust. Yedavalli (2019) incorporated expert interviews to develop a survey on public perceptions of urban air mobility and identified five key factors: safety, noise, inequity, visual pollution, and privacy. Edwards and Price (2020) took a similar approach to examine experts' perceptions of passenger concerns, which included not just safety but also factors like noise, availability, and environmental impact. This body of work suggests that experts' insights offer thicker and richer perspectives, underlining the necessity for their inclusion in discourses on the topic of societal acceptance of drones.

3. Objectives

This study is situated in a larger research project composed of three main components: a scoping literature review (Wang, Mutzner, and Blanchet 2023), an expert survey, and semi-structured interviews with domain experts (all completed). By gathering responses from experts, this survey study seeks to answer two key questions: (1) how do experts evaluate the acceptance of drones in different contexts and applications? (2) What do these experts identify as key challenges for successful drone implementation from the societal acceptance perspective? Through these inquiries, we aim to reveal the dynamics underlying societal acceptance of urban drones to inform implementation and governance strategies more broadly.

In particular, the objective of this study is to bridge potential knowledge gaps by focusing on the insights derived from a cohort of drone experts active in Switzerland. Critically, we aim to not just supplement existing knowledge

about societal acceptance but also disentangle and highlight the multifaceted nature of drone acceptance factors across diverse application contexts. Furthermore, we intend to understand how societal acceptance varies depending on who uses the drone and how different levels of automation in drone technology might affect the level of acceptance. Based on these insights, we seek to identify the key factors that either improve or hinder drone acceptance, by gathering what experts believed to be the most significant challenges and potential solutions in terms of drone acceptance. In doing so, we expect to provide stakeholders with a roadmap for action which, in turn, will help pave the way for a more informed, structured, and harmonious integration of drones into the societal fabric.

4. Methodology

4.1 Survey design

The survey was designed by the first author in January 2023. It was then circulated among a small group of experts for methodological feedback. Based on the feedback received, it was revised, set up on the online survey platform Qualtrics (www.qualtrics.com), and pretested by invited colleagues during February 2023. The survey language was set in English, as it was the common language that all participants could understand. The estimated time for answering the survey was 20–40 min on average. The survey was officially launched on 14 March 2023 and closed on 16 May 2023.

4.2 Participants

Participants were recruited through a two-step snowballing method via email, involving the first author's network and subsequent referral. [Participants were recruited via e-mail invitation with a link to the Qualtrics survey following a two-step strategy: (1) personalized invitations to existing networks of the first author and (2) forwarded invitations from the initially invited participants to their professional networks.] Out of 126 participants who responded, 117 completed at least one survey question and were, therefore, included in the subsequent analyses.

4.3 Procedure

The survey consisted of two main parts, alongside two additional sections including Introduction and Demographic Information, respectively, at the beginning and the end of the survey. [Participants were given the choice of responding to Part I only, followed by an interview instead of answering questions in Part II. After answering Part I, participants were given the option to discontinue the survey. In this case, they were invited to answer a few demographic questions, to which they could again choose to opt out and to conclude their participation thereof.] In the Introduction section, participants were informed of the data protection policy and survey procedure, with a consent to participation. Part I of the survey focused on the general acceptance of drones, including their acceptance in different scenarios and applications. Part II of the survey had two subsections. Section A focused on the participants' personal involvement with drone projects, establishing the participants' expertise and experience with drones in practical settings. Section B focused on the experts' opinions regarding urban drone acceptance, including their understanding of related concepts, and what they deemed to be key challenges and solutions. Finally, before concluding the survey, participants were given the opportunity to send an automated email to the first author to indicate their interest in participating in the subsequent expert interviews (which took place during September–October 2023).

4.4 Measures

4.4.1 Definition of expert. At the outset of this study, we adopted the definition of 'expert' proposed by Caley et al. (2014): 'someone with comprehensive and authoritative knowledge in a particular area not possessed by most people'. In the context of urban drones, we extended the above definition to also include persons involved with drones on a professional level, including (1) private sector members, such as aviation or robotics industry, (2) public sector institutions, such as governmental and nongovernmental organizations, and (3) academia, such as research institutions and universities of applied sciences. Our rationale is ensuring that the survey participants not only have the required technical and/or social knowledge about drones as an expert, but are also involved in drone operation, implementation, and management in their daily work.

4.4.2 Demographic measures. The demographic questions consisted of gender, age, language, education, location, and political alignment. [Political alignment is generally a less common choice for expert surveys. However, based on our earlier study of the academic literature on this topic, some authors have found that political views could have an influence on drone acceptance (Markowitz et al. 2017; Anania et al. 2019; Milner et al. 2019).] To optimize the use of participants' time, demographic questions were asked just before they exited the survey, with the option of opting out.

4.4.3 Survey content. This expert survey consisted of thirty-two main questions, with some containing follow-up questions for further explanation. Mixed methods were used to prompt responses, including slider measures, numerical ranking, multiple choice, and open texts. A detailed survey design strategy is provided in Appendix 1; a full survey questionnaire can be provided upon request.

4.5 Analytical strategy

To align the specificities of our expert sample with the nascent research context, we adopted a mixed-methods approach in the analyses. Acknowledging the relatively modest size of the expert cohort, and derived from a snowball sampling technique, we used a three-step analytical strategy: (1) we carried out a *descriptive analysis* to elucidate a spectrum of expert perspectives. This approach aims to highlight the heterogeneity within expert opinions and to shed light on the factors influencing drone acceptance. (2) For Likert scale items, we combined the descriptive analysis with an explorative *factor analysis* (FA), restricting our focus to those questions comprising eight or more responses. This statistical method enabled us to discern correlated clusters among the data, offering insights into the interrelatedness of various aspects and aiding in the interpretative process. (3) Finally, we conducted a *thematic analysis* for open-ended responses to carve out distinct categories to illustrate and interpret qualitative data. This approach was informed not only by emergent

patterns within our dataset but also by pre-existing findings in our literature review (Wang, Mutzner, and Blanchet 2023), thereby grounding our results in a broader academic dialogue.

5. Results

The survey was designed with a variety of measures in a comprehensive structure to capture the breadth of expert perspectives. This resulted in the emergence of several key subjects in the subsequent analyses. While the above-described survey measures served as a foundation for data collection, the results presented in this section highlight only the most salient aspects. [For instance, while data concerning the participant's sectoral affiliation and domain expertise were carefully examined to yield important observations, the financial aspects or geographic locations of specific projects they were involved in were considered either confidential or less generalizable, despite insightful, and were excluded from the results presented in this section.] It is important to note here the observed participant dropout rates, primarily attributed to attrition across the survey, starting at 117 responses and narrowing down to 36 by the final item. [Out of the initial 117 participants, 44 completed Part II-A, 41 completed Part II-B (of whom 5 only answered 'n/a', 'none' or '-', making it 36 who actually provided valid answers for the subsequent analyses). This indicates that three participants had dropped out between the two parts, which aligns with conventional response patterns for surveys of this length. Aside from this decrease of participants between Part I and Part II, which served as a natural breakpoint, there was no indication that specific survey questions prompted further dropouts.] To maintain comparability and inclusiveness in the segment, responses from all participants were considered despite the decreasing response rate, which may introduce certain limitations in the interpretative breadth of the outcomes (Section 7).

5.1 Demographic analysis

Of the participants, 117 answered the survey's demographic questions (Table 1). Within this sample, forty-seven answers about gender, age, language, and education were missing, and forty-nine answers about political affiliation were missing, as a result of the aforementioned opting-out option. The sample was disproportionately composed of male participants (sixty, 86 per cent). [The subsequent statistics presented in this section consist of two elements in brackets—number of participants and percentage within the sample, e.g. (sixty, 86 per cent).] While participants' age was more equally distributed, the age group of 30–40 years was most represented (twenty-two, 31 per cent). The most common language spoken by participants was German (forty-three, 61 per cent). The sample showed a skew in education with the majority having attended either the University or the University of Applied Sciences (sixty-five, 93 per cent). [One plausible explanation is that, compared to surveys targeted at the general population, more academics took part in this expert survey. This potentially applies to the gender aspect as well.] Politically, the sample exhibited a significant orientation towards the left end of the spectrum, where thirteen (19 per cent) self-identified as slightly more on the right spectrum, thirty-eight (56 per cent) more on the left spectrum, and sixteen (24 per cent) as neutral. As for the expertise level, the majority indicated either thorough (fifty-one, 44 per cent) or good (forty, 34 per cent) knowledge, while twenty-one (18 per cent) chose basic knowledge and five (4 per cent) showed less confidence in their technical understanding about drone technology.

Table 1. Description of demographic representation.

	Characteristics	Representation ($n = 117$)
Gender	Females	10 (14%)
	Males	60 (86%)
	Missing	47
Age (years)	20–30	9 (13%)
	30–40	22 (31%)
	40–50	16 (23%)
	50–60	15 (21%)
	>60	8 (11%)
	Missing	47
Main language	English	7 (10%)
	French	9 (13%)
	German	43 (61%)
	Italian	4 (5.7%)
	Other (please specify)	7 (10%)
	Missing	47
Education	Higher technical and vocational training	2 (2.9%)
	Other (please specify)	3 (4.3%)
	University of Applied Sciences	16 (23%)
	University, ETH	49 (70%)
	Missing	47
Political affiliation [0 (far left)–10 (far right)]	Mean	3.99
	Standard Deviation	1.63
Expertise	I have no idea what these concepts mean, nor how they can be applied technically.	1 (0.9%)
	I have heard of the concepts in one way or another, but do not really understand what they mean and how they function in a technical system.	4 (3.4%)
	I have basic knowledge on these concepts and can somewhat understand how they may be applied in daily life.	21 (18%)
	I have fairly good knowledge on these concepts and have interacted with their applications in real-world scenarios.	40 (34%)
	I have thorough understandings about these concepts and in-depth knowledge on their operations in a given technical system.	51 (44%)

5.2 Content analysis

Following the research questions set out for this expert survey, our analyses revolved around two dimensions: (1) delineating perceptions about drone acceptability across different application contexts and (2) highlighting expert views on

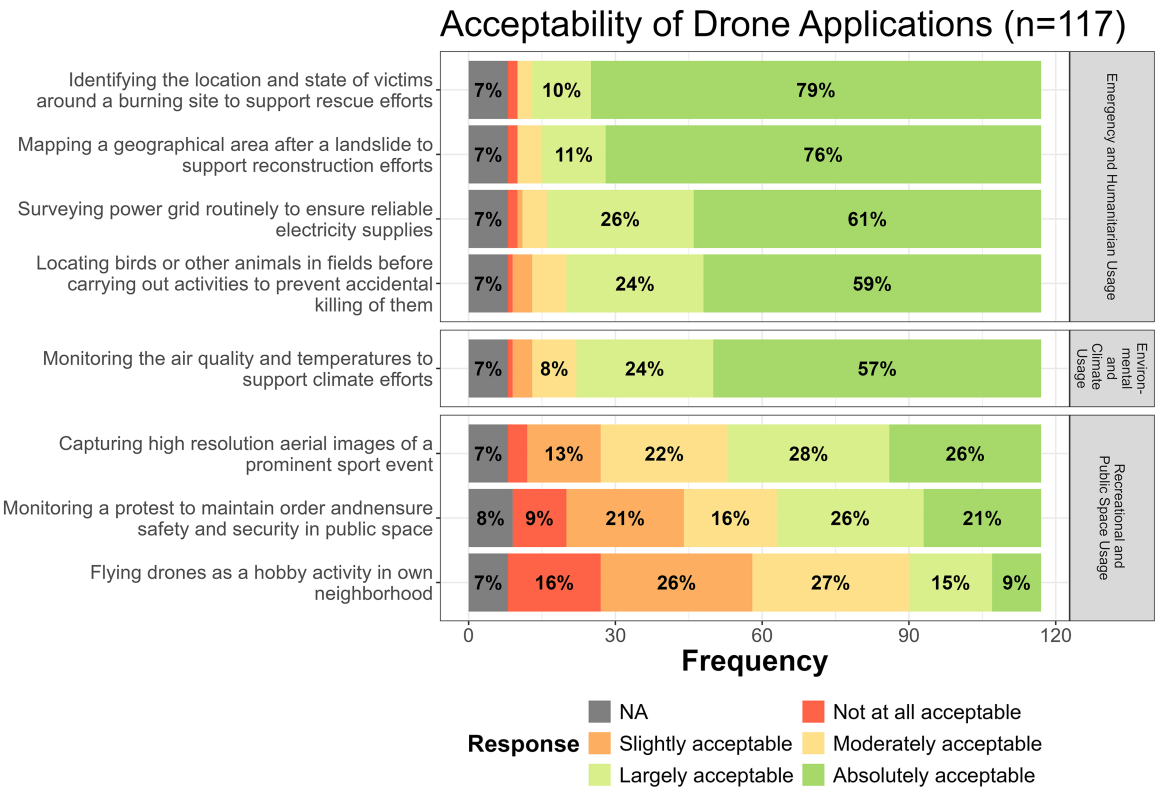

Figure 1. Acceptability of drone applications ($n = 117$).

the most significant challenges and their potential resolutions. This structure offered a comprehensive overview of expert perceptions while elucidating potential shifts in opinions that might be determined by an expert's professional affiliation.

5.2.1 General evaluation of societal acceptance. In this section, we delved into the experts' perspectives through quantitative means. Our objective was to provide a foundational understanding of experts' views on drone acceptance across varying situations and show underlying factors that might influence these views. Additionally, we ran an explorative FA on Likert scale questions containing eight or more items to better understand correlated clusters among the data and derive conceptual insights (for detailed FA loading strength, see Appendix 2).

5.2.1.1 Acceptability of drone applications The context-dependent nature of drone acceptability was found as key when evaluating drone implementation in our survey (Fig. 1). The variability was particularly evident in the acceptance of drones for victim identification at a burning site and geographical mapping post-landslide, which were among the most endorsed use cases. Conversely, drones' utilization in monitoring protests and recreational activities received more critical evaluations. FA results further elucidated this perceptual differentiation, revealing a multifaceted utility of drones that aligns with their acceptance across different use cases (see Fig. A.1 in Appendix 2). Predominantly, the Emergency and Humanitarian Usage cluster, where applications benefit public welfare significantly, received the highest consensus. This cluster shared overlaps with applications such as surveillance of power grids, suggesting a nuanced interplay between public service and societal welfare infrastructure. Intriguingly, tasks in the Environmental and Climate Usage cluster such as air quality monitoring were found to be distinct from the others, underscoring a cognitive distinction between immediate crisis response and broader environmental challenges. Overall, these insights not only reflected the complex landscape of drone acceptance but also underscored the strategic utility of drones in varied operational contexts, resonating with broader research highlighting their diverse applications (Aydin 2019; Eißfeldt et al. 2020; Wang, Mutzner, and Blanchet 2023).

5.2.1.2 Pro-arguments on drone implementation Our survey revealed that experts' opinions on urban drones were largely split between pro- and con-arguments, highlighting key areas for further clarification. Most pro-arguments were found to be convincing, particularly those emphasizing versatility and efficiency, underscoring drones' comparative advantage over conventional methods for urban mobility integration (Fig. 2). However, ecological and economic aspects were less convincing, with technology availability receiving the least support. Experts believed that drones' core merits were their operational capabilities rather than cost-effectiveness or environmental sustainability. FA results of pro-arguments reflected these interpretations, with distinct clusters for efficiency, sustainability, and accessibility (see Fig. A.2 in Appendix 2). The Accessibility and Safety in Challenging Environments cluster highlighted drones' unique ability to navigate difficult terrains, reframing negative perceptions, especially for humanitarian and emergency responses. The Operational Efficiency and Versatility cluster emphasized

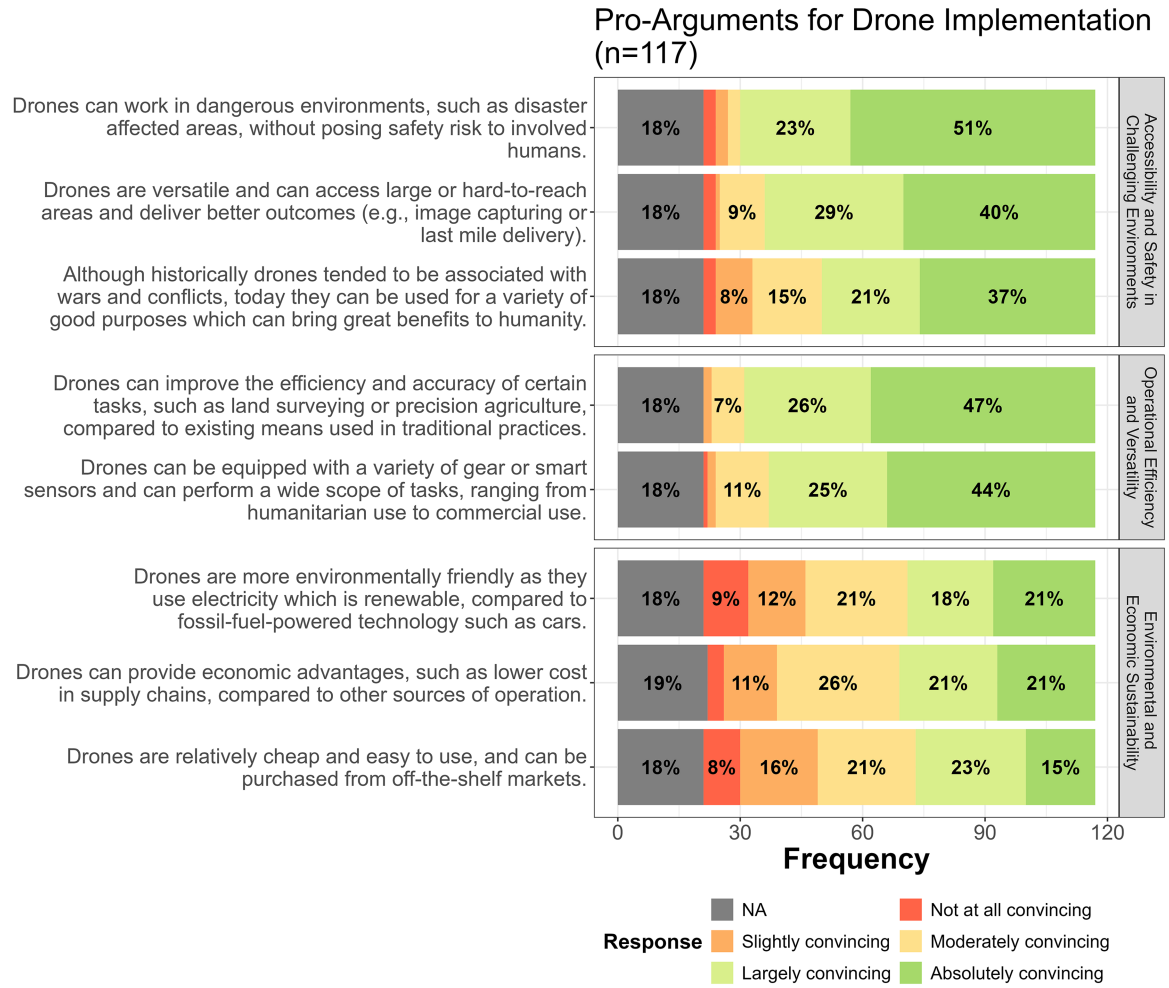

Figure 2. Pro-arguments for drone implementation ($n = 117$).

drones' practical benefits and functional capabilities, particularly reflecting expert perspectives of the drone community. The Environmental and Economic Sustainability cluster correlated with sustainability arguments, such as cost-effectiveness, emerged from both aforementioned clusters. These clusters highlighted nuanced differences in drones' ability to access challenging locations, operational benefits, and functional versatility, with most arguments viewed as convincing.

5.2.1.3 Con-arguments on drone implementation Responses to the con-arguments highlighted experts' main concerns about drone implementation, with the most convincing one centred on the potential malicious use, such as terrorist attacks (Fig. 3). Privacy also emerged as a convincing factor against drone implementation, paired with concerns about human rights infringement. The least convincing arguments were the issues of drone noise and the lack of drone regulation. FA results of con-arguments revealed three thematic clusters (see Fig. A.3 in Appendix 2). The Safety Risks and Misuse Concerns cluster underscored fears of illicit drone use, misuse, and physical dangers from drone accidents, reflecting immediate safety risks. The State Control and Privacy Concerns cluster focused on surveillance worries and harmful state control. The Environmental and Airspace Concerns cluster, while deemed overall less convincing, addressed the environmental and visual impact of drones, emphasizing secondary effects on public spaces and living environments. While visual and noise pollution were found to be less convincing, the overall consensus suggested direct safety and privacy risks as the strongest arguments against drone use. These clusters encapsulated expert apprehensions about the wider scope of drone applications, mirroring public concerns about drone implementation (Khan, Tausif, and Malik 2019; Kähler et al. 2022), thus highlighting key areas requiring further attention and governance improvements.

5.2.1.4 Institutional trust in drone use The variance in urban drone acceptance pivoted not only over the application context but also the identity of the operators, highlighting the critical role of institutional trust in shaping expert perceptions (Fig. 4). Experts expressed the highest trust in rescue operators, scientific organizations, and nongovernmental organizations (NGOs), with firefighters using drones for emergency rescues garnering exceptionally high support. Conversely, government agencies using drones for urban monitoring or postal services, as well as the private sector, received less trust, with private hobbyists being the least trusted. FA results indicated a conceptual framework of how institutional players were grouped (see Fig. A.4 in Appendix 2). The Public Service and Research Institutions cluster, including firefighters, scientific organizations, andnature conserva-

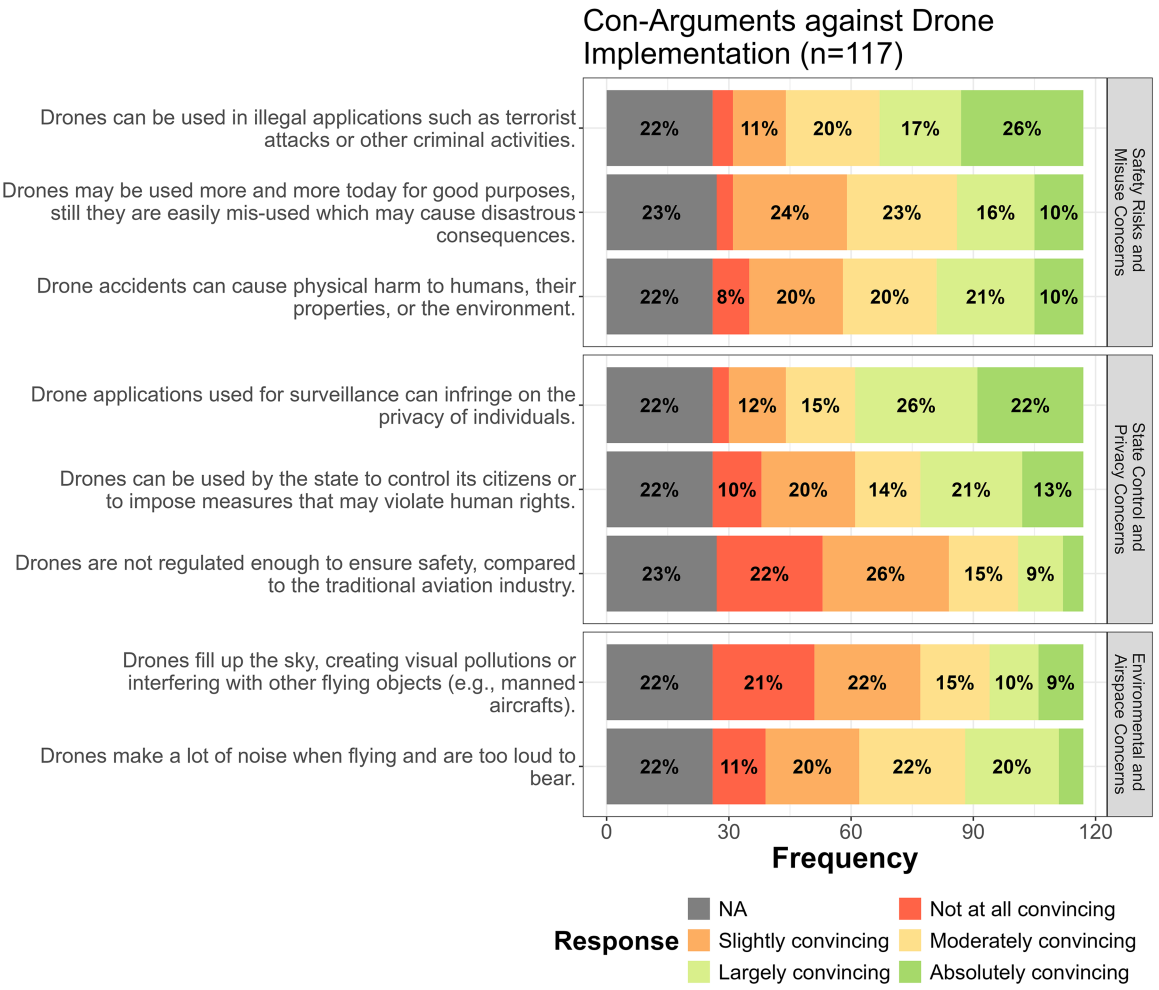

Figure 3. Con-arguments against drone implementation ($n = 117$).

tion bodies, received overall high confidence from experts. The Civil and Commercial Service Providers cluster, comprising police, postal, and commercial enterprises, faced nuanced scepticism. The Media and Recreational Entities cluster, encompassing media agencies and private individuals, exhibited a distrust dynamic towards media production and hobbyist activities. Overall, public institutions using drones for humanitarian goals were the most trusted, while civic and commercial institutions faced more critical views due to potential misuse or economic motivations. Interestingly, media agencies appeared to be more aligned with recreational users than commercial institutions, highlighting a potential lack of trust in such use cases from the experts' perspective.

5.2.1.5 Optimal automation levels of drone applications The degree of automation in drone operations, from complete human oversight to full autonomy, played a crucial role in shaping acceptance and fostering public trust across diverse use contexts. Expert opinions revealed distinct automation preferences contingent upon the specific applications (Fig. 5). In scenarios where drones were deployed for monitoring protests and ensuring public safety, there was a marked inclination towards human oversight. Experts advocated for either direct control by a human pilot, preferably within the visual line of sight of a human pilot, or at minimum with the presence of external observers monitoring the operation. This underscored the criticality of human judgment and accountability in scenarios with potential privacy and ethical implications. In contrast, for missions like victim location, experts were more amenable to the idea of operating beyond the visual line of sight (BVLOS), although the need for human control was still emphasized. This suggested a nuanced balance between leveraging drone capabilities for expansive search areas and maintaining human oversight for decision-making. For tasks like locating fawns and mapping geographical locations, there was a noticeable shift towards automation. Experts perceived these applications as less intrusive and risky, thereby diminishing the necessity for direct human control or oversight. The monitoring of air quality and temperature emerged as the domain where experts predominantly endorsed full automation. This delineation of automation levels provided insightful implications for drone deployment, indicating a recognition of balancing operational efficiency with privacy and safety considerations in less sensitive tasks.

5.2.1.6 Predefined acceptance factors In our earlier study of academic literature, several key factors related to urban drone acceptance emerged, including Safety, Privacy, Noise, Human Control, Environmental Impact, Design, Regulation, and Application (Wang, Mutzner, and Blanchet 2023). Inthis

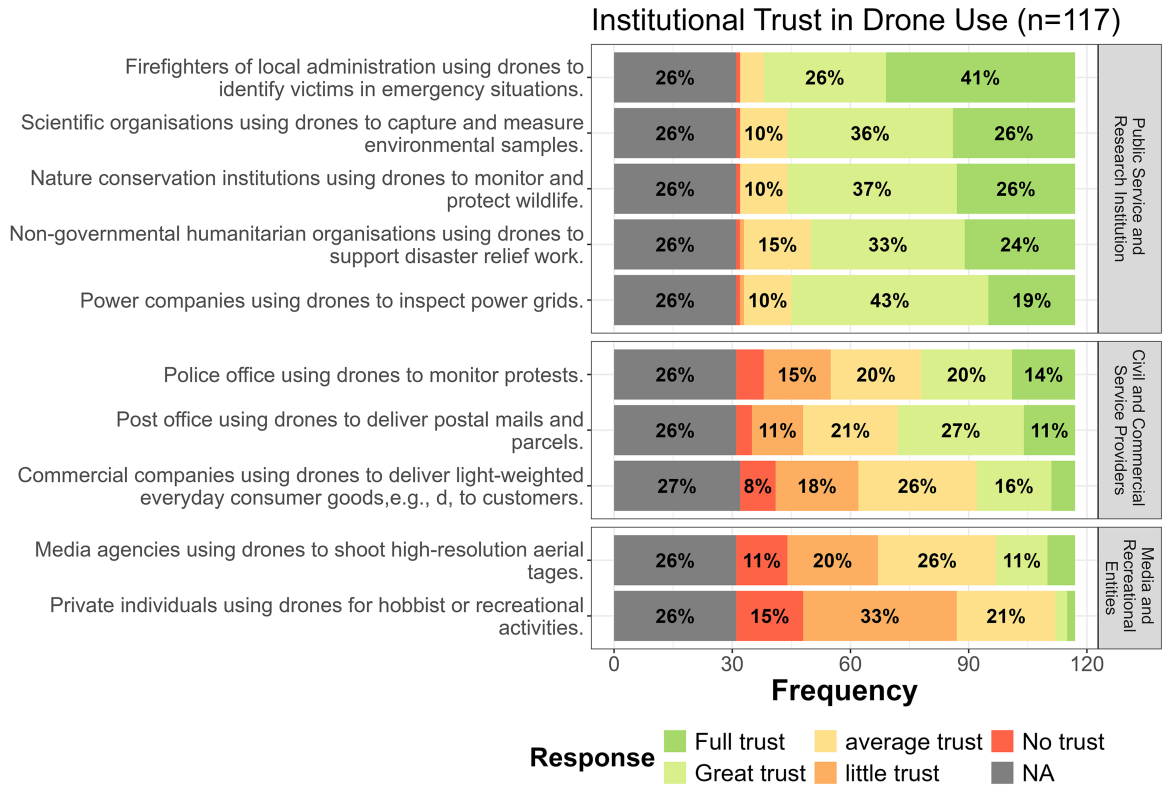

Figure 4. Institutional trust in drone use ($n = 117$).

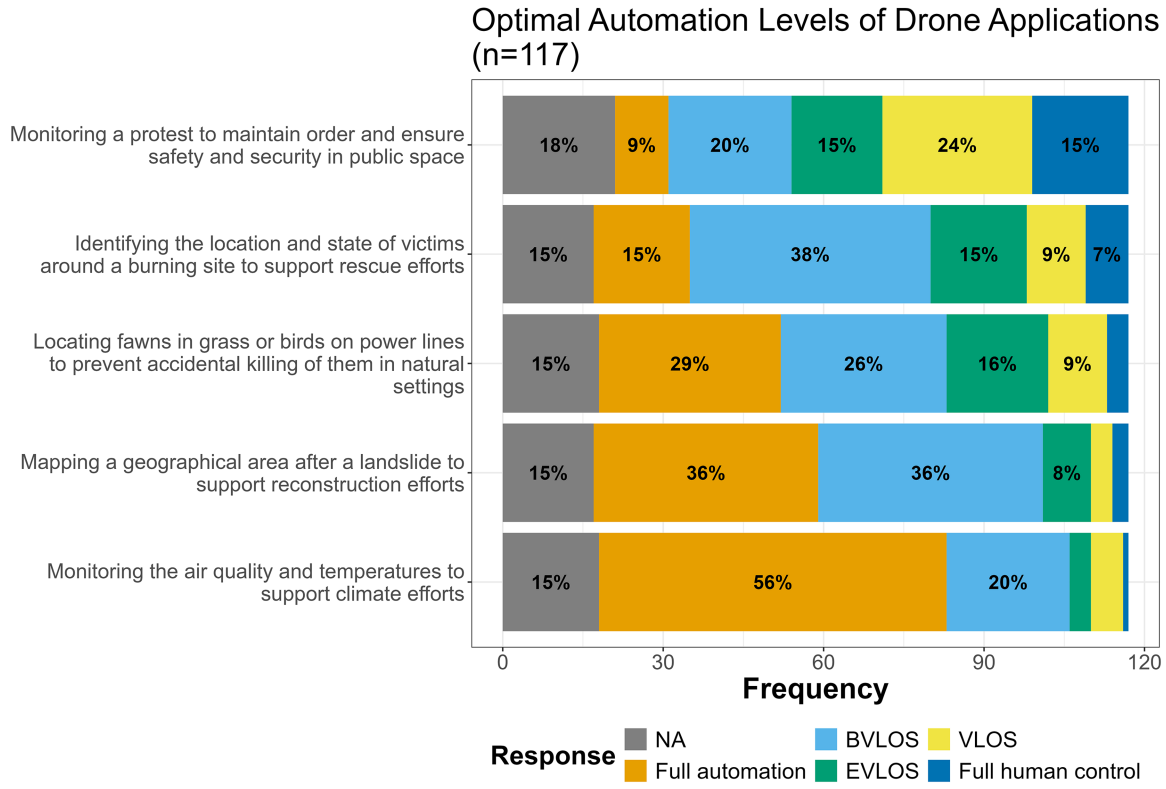

Figure 5. Optimal automation levels of drone applications ($n = 117$).

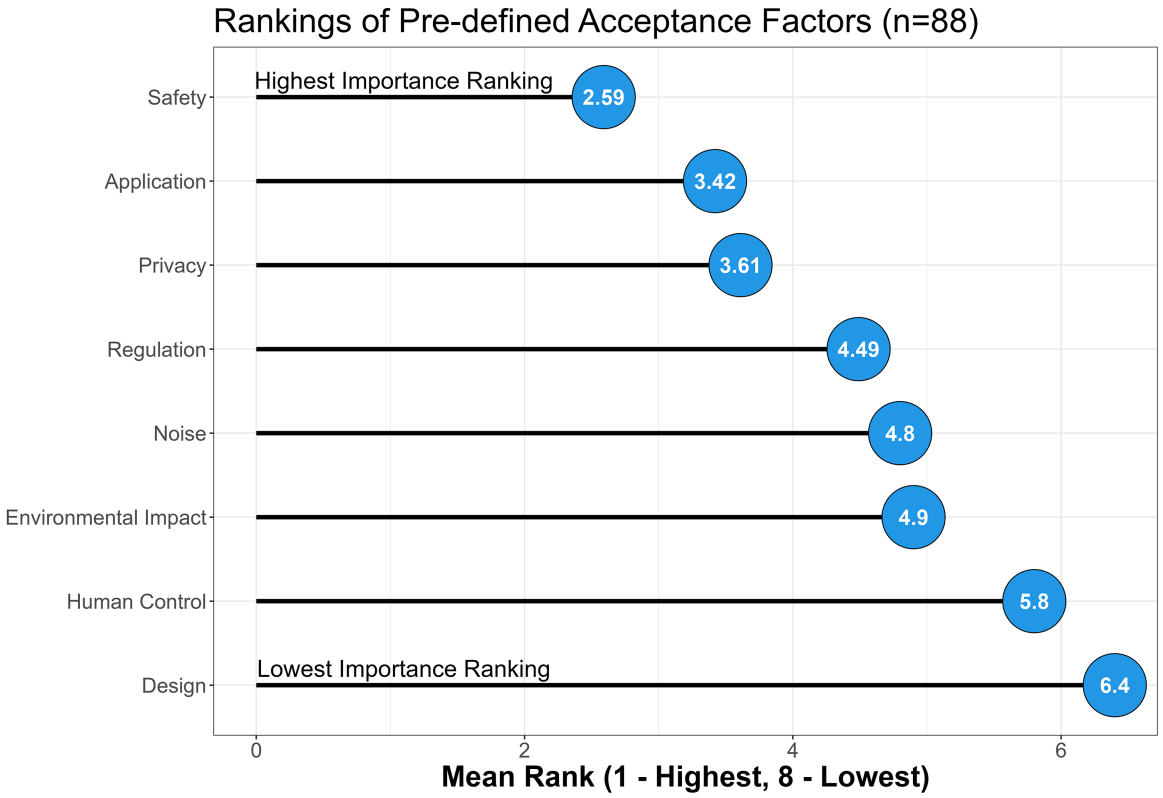

Figure 6. Rankings of pre-defined acceptance factors ($n = 88$).

survey, we employed these categories as the conceptual basis to gauge the perceived importance of them by the experts. The average mean ranking score for each category was computed to ascertain its relative significance (Fig. 6). Safety was an overriding factor, receiving the highest average ranking score of 2.59. This was closely followed by the intended Application of drone use, which scored an average of 3.42. Privacy concerns ranked next with a score of 3.61, followed by Regulation at 4.49. Noise as well as Environmental Impact were also considered important but to a lesser degree, with average scores of 4.8 and 4.9, respectively. Human Control over drone operations and the Design of drones were deemed least critical, with average scores of 5.8 and 6.4, respectively. These insights highlighted the multidimensional challenges of navigating public opinion over urban drone use, emphasizing the need for well-defined operation strategies to foster a more informed societal stance towards drone technology.

5.2.2 Key challenges to societal acceptance. In this section, we aimed to identify generalizable trends across the sample through qualitative means. To maintain the integrity of the dataset, we adopted the strategy of aggregating individual answers to derive insights holding broader applicability. This methodology helped ensure that researchers neither selectively excluded nor included individual responses (Mayring 2000; Kohlbacher 2006; Schreier 2012; Flick 2018). It also aligned with the overall content analysis approach we employed throughout the survey's evaluation.

5.2.2.1 Conceptual understanding of societal acceptance A foundational knowledge of relevant concepts could not only shape expert views on public perception but also guide their approach to navigate the complex landscape of societal integration of drones. In our survey, experts' responses about their 'familiarity with theories or concepts' around public perception, attitude, or acceptance of technology varied. Within this expert cohort, four (10 per cent) answered 'not at all', twenty-one (51 per cent) answered 'not sure', and sixteen (39 per cent) answered 'yes'. While the majority reported familiarity with concepts regarding technology acceptance and public perception, most were not confident in explicitly quoting any. For example, only five (13 per cent) referred to theories such as 'Value Design Method', 'Tech Aversion/Affinity', 'Participation Models', and 'Technology Acceptance Model', while three (7 per cent) cited existing studies on public perception of drones (EASA 2021). Additionally, four (10 per cent) elaborated on the concept of acceptance within their expertise, and two (5 per cent) referred to regulatory themes, offering insight into the different ways in which experts contextualized perception and acceptance when working with drones. Overall, these statistics revealed a multi-dimensional understanding of general concepts about acceptance, underscoring the necessity of raising awareness of the importance of the topic among experts.

The concept of '*social responsibility*' played a pivotal role in public opinion about technology development and its implementation. In our survey, experts offered mixed responses regarding their knowledge. Among them, five (12 per cent) answered that they were 'not at all' familiar with the concept, twenty (49 per cent) answered 'not sure', and sixteen (39 per cent) answered 'yes'. When asked to elaborate on the concept, seven (17 per cent) expanded on prevalent risk factors such as safety, privacy, social impact, moral and

legal, as well as environmental impact. This was followed by four (10 per cent), who highlighted the importance of societal benefits and societal well-being. Additionally, two (5 per cent) pointed out the necessity for stakeholder engagement and participation in drone operations. Apparently, experts viewed the concept from different angles. For instance, one expert advocated for a net positive impact from technological deployments, while another pinpointed explicitly the role of drones in achieving sustainability development goals. Collectively, there was an emphasis on the need for technology developers and policymakers alike to ensure that technological advancements should not only mitigate adverse impacts, but also produce benefits to society at large.

The examination of '*exposure to public sentiments*' also indicated that it influenced experts' perceptions on drone acceptance. In our survey, when experts were asked if they had encountered any public sentiments about drones, thirty (73 per cent) confirmed while nine (22 per cent) remained ambivalent and two (5 per cent) reported negatively. Analysis of the public sentiments revealed a wide spectrum of perspectives, of which eight (20 per cent) were concerned with noise, privacy, and safety. Concerns about privacy included drones intruding privacy through image capturing or flying around private homes. Interestingly, sentiments around noise were not just negative such as feelings of annoyance, but also positive such as technical progress in noise reduction. Overall, general negative sentiments were noted by six (15 per cent), including narratives like 'general distress', 'most people being averse'. Mixed sentiments were observed by three (7 per cent), where the public would weight benefits against risks. Mostly positive and curious sentiments were encountered by twenty-three (58 per cent), including mentions of 'positive societal value', and 'informed about the operation'. On a related note, four (10 per cent) highlighted the necessity to raise public awareness, e.g. on drone capabilities and operational transparency, or through pre-operation engagement. This diverse assortment of public sentiments shared by our expert cohort showed a dynamic interplay between main concerns like noise, privacy, and safety and general apprehensions of drone acceptance, as well as the potential for positive perceptions through enhanced public awareness and education efforts.

5.2.2.2 Key challenges to societal acceptance The operational insights inherent to experts' experiences provided a unique vantage point in understanding their positions and viewpoints, which were instrumental in identifying key barriers that must be addressed to harmonize technology with public sentiment. To this end, we asked our expert cohort to define the three foremost challenges they encountered in relation to urban drone acceptance. Responses were systematically categorized using a thematic content analysis approach (Mayring 2000; Kohlbacher 2006; Flick 2018; Khan, Tausif and Malik 2019), resulting in a range of thematic categories that encapsulated the identified challenges. Illustrative quotes for each identified theme are presented in Table 2.

Figure 7 presents an overview of the identified operational challenges and their reported frequency. [Percentages indicate the frequency of the specific challenge category divided by the total frequency of coded segments ($n = 117$).] The most common challenge according to our expert cohort was *Awareness & Education*, cited twenty-three times (20 per cent). Some noted a lack of efforts to raise awareness on drone capabilities, safety, drone operations, positive and negative impacts, and the general need for public outreach and engagement, while others suggested more specific aspects such as educating the public on drone regulations and on regulatory ranges. *Safety* was a key category named eighteen times (15 per cent), comprising concerns over the maturity of drone technology and the impact of safety regulations. *Regulation* was also mentioned seventeen times (15 per cent), reportedly having both a positive and a negative force in drone implementation. *Privacy* was another major concern, brought up fourteen times (12 per cent), particularly with respect to data protection. Additional challenges included *Public Sentiments* (twelve times, 10 per cent), *Operational Environment* (nine, 8 per cent), *Noise* (nine, 8 per cent), *Drone Application* (six, 5 per cent), *Environmental Impact* (five, 4 per cent), *Drone Misuse* (two, 2 per cent), and *Availability of Operational Data* (two, 2 per cent). This overview underscored the intricate web of operational

Table 2. Description of themes and quotes of operational challenges.

Themes	Example quote
Awareness & education	'Education of the public, for instance safety of drones, ecological impact, etc.' 'Perception—local pops should be aware of our operations and be informed of the nature of the work'
Safety	'Safety—making sure the technology is mature enough' 'Ensuring safety of drone operations, by ensuring the predictability of their behaviour in the aviation system'
Regulation	'More regulations make it harder to use drones near built up areas' 'Regulation and responsibility attribution' 'Unclear regulations'
Privacy	'Data ownership and privacy' 'Skepticism on privacy'
Noise	'Showing that the noise of our UAS is within limits (and that busses and trams create more noise)' 'What is (or will be) the annoyance of people due to drone noise?'
Public sentiments	'Perception of new technology in general' 'No trust in the technology' 'High expectation from tech'
Availability of operational data	'Testing drones in urban environment in order to gain acceptance data of real flying vehicles'
Drone application	'Using drones for environment and avalanche data gathering, which can impact the safety of avalanche environments' 'Understanding the scope of application of drones, either piloted or autonomous, in various contexts'
Environmental impact	'From ecological standpoint, drones are better ecologically than helicopter for the same purpose, but Rules (EASA 2019/947) make a helicopter flight more easy' 'Ecological impact'
Operational environment	'Acceptance of temporarily higher pricing' 'Financing challenges' 'Scalability'
Misuse of drones	'Drones used in military contexts' 'Distinction from military/defence stuff'

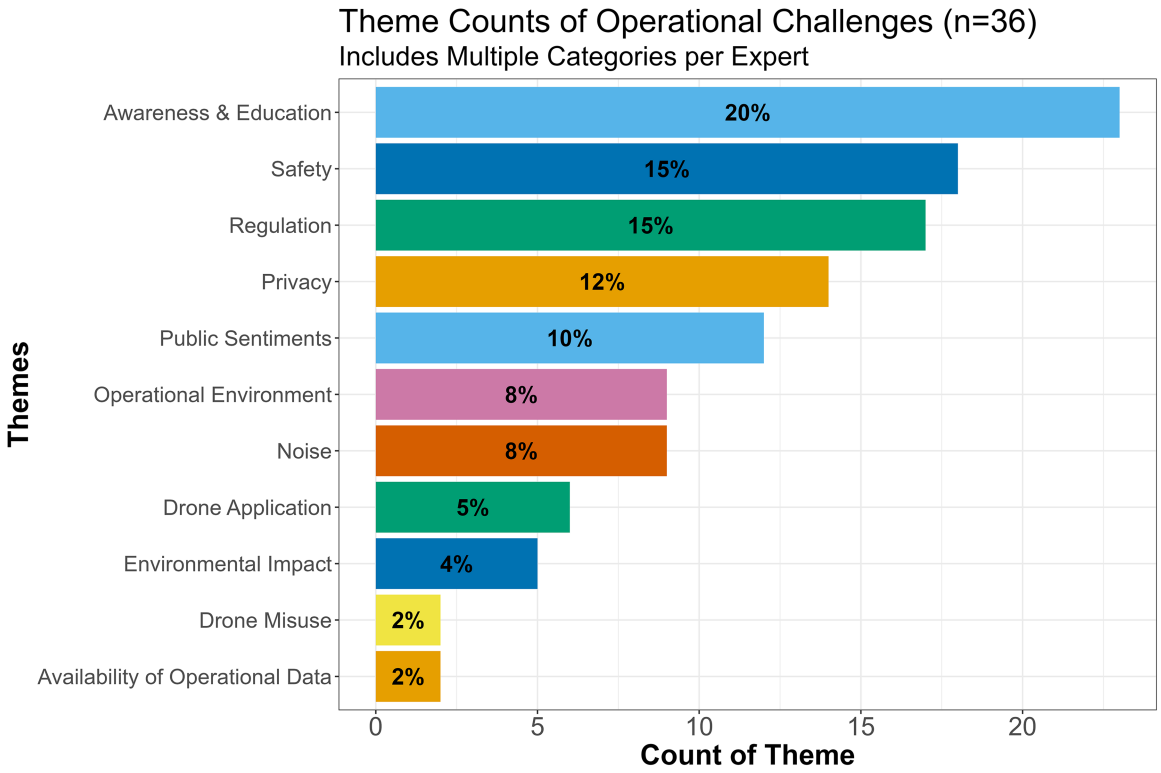

Figure 7. Theme counts of operational challenges ($n = 36$).

challenges as perceived by the experts, with Awareness & Education emerging as a critical concern, alongside emphasis on Safety, Regulation, and Privacy issues.

5.2.2.3 Mechanisms to address key challenges In addressing the operational challenges affecting societal acceptance of drones, our survey identified key strategies for overcoming these barriers. Experts emphasized the need for better Regulation, with fifteen (44 per cent) advocating for clearer national and international guidelines, ranging from minimal rules to more stringent policies. Additionally, six (17 per cent) called for greater Availability of Operational Data, e.g. for testing purposes, to help understand drone functionalities more comprehensively, which, in turn, can improve communication. Awareness & Education was deemed crucial by nine (25 per cent) in bridging knowledge gaps, while eleven (28 per cent) highlighted its critical role in shaping public perceptions. Stakeholder engagement was also noted as essential by six (17 per cent), helping bridge gaps between stakeholders and incorporate perspectives of local community, industry, and research institutions into the discourse around drone acceptance. Other strategies included expanding drone testing and improving media portrayals to separate civilian use from military use. These insights suggested the necessity for a well-informed public dialogue and balanced policy development, integrating regulatory clarity, educational initiatives, and operational flexibility.

Based on the mapping of these key challenges, insights into how the challenges have personally impacted the experts helped provide a deeper understanding about the broader implications for the drone community. Among our expert cohort, ten (40 per cent) reported significant effects on their projects, from compromising safety and efficiency to causing delays in regulatory approval. Academic efforts were also affected, with five (20 per cent) indicating impacts on research pathways, execution, and dissemination. Additionally, four (16 per cent) highlighted potential detriments to technological innovation during testing and development, hindering environmental sustainability initiatives. Furthermore, regulation was seen to affect policy development and the delineation of clear regulatory boundaries, which helped allow for proper drone development. These remarks highlighted the technical, operational, societal, and regulatory aspects of drone technology, emphasizing the need for comprehensive solutions to unlock its full potential.

6. Discussion

In delving into how experts involved with urban drone operations perceived societal acceptance, our survey revealed a landscape rich in its depth and complexity. More specifically, we identified two main clusters of implications—theoretical and practical—to help shed light on the directions for future research.

6.1 Theoretical implications

Generally, we observed a large overlap between key categories identified by the experts participating in this survey, and those within the wider literature that we reviewed in an earlier study (Wang, Mutzner, and Blanchet 2023). Privacy remained a critical factor in relation to urban drone acceptance, echoing previous research findings (Finn and Wright 2012). Experts placed high importance on the factor of safety,

Table 3. Thematic landscape mapping of survey results against literature review findings.

Cluster	Theme identified in literature review	Frequency of citing	Operational implications
Technical factors	Levels of autonomy		
	Technical risk	2	Clarify potential risks from the technical perspective.
	Noise	9	Identify and communicate the acceptable levels of noise, annoyance, and noise pollution.
	Aerodynamics & design		
Operational factors	Application type, purpose, and location	10	Inform the public about applications that benefit society, differentiating beneficial drone applications from the 'toy' uses.
	Dual-use and Misuse	2	Draw distinctions of civilian use of drones from military use.
	Trust, accountability, integrity, and transparency	6	Improve trust in drone operating entities, recognize public expectations, and provide transparency in public engagement and communication.
Regulatory factors	Privacy	14	Clarify procedures and processes regarding data privacy, data handling, data protection, and data ownership.
	Safety and security	14	Ensure safety of the technology, communicate safety measures appropriately, and manage tensions between safety and regulations proactively.
	Aviation	7	Fill the knowledge gap on aviation regulation, address the perceptions about regulations being hindrance of innovation, and promote inter-agency regulatory cooperation.
Economic factors	Technical performance and usefulness		
	Intention to adopt the technology	1	Understand motives of stakeholders with different domain and sector backgrounds.
	Related infrastructure and services		
Impact factors	Environmental impacts	5	Communicate the ecological and environmental impacts of drones openly with the public.
	Health impacts		
	Quality of life impacts	1	Discuss transparently the potential disruptions of drone applications over quality of life for the public.
Personal factors	Socioeconomic status		
	Emotional and psychological readiness	2	Acknowledge the sociopsychological dimensions related to societal acceptance of drones.
	Technical knowledge and competency	2	Improve the public's technology literacy of drones.
External factors	Media appropriation and public communication	10	Inform the public through nonbiased communication outlets and improve public understandings about drone applications and their impacts.
	Peer and social influence		
	Information source and influence	4	Prevent potential misinformation about the drone technology and its applications from occurring.
	Technical terminology	1	Be mindful of the terms used to describe the technology and the narratives associated with its use.

as previously suggested by Cetin et al. (2022). Nonetheless, some differences were identified. For example, noise and visual pollution, a topic widely discussed in the academic literature, appeared to be less of a convincing argument against drone use within our sample. Experts also disagreed with the argument that drones were insufficiently regulated and that safety was a prominent risk. The insights regarding institutional trust offered novel perspectives, revealing a more intricate tapestry of expert attitudes towards institutional embedding, highlighting the link between actors and purposes of drone usage and how that might influence perception and acceptance. Overall, in synthesizing these findings, the analyses largely validated intuitive assumptions about the role of drone technology across different application contexts. These perspectives not only reflected current stances but also suggested the complex interplay of trust, acceptance, and the evolving regulatory landscape that will shape the future of drone integration into societal frameworks.

An essential point of comparison within our own research was to gauge this expert survey results against our previous study encapsulating the core themes around public acceptance of drones as depicted in academic literature (Wang, Mutzner, and Blanchet 2023). By juxtaposing the survey results against the findings of the literature review, a mosaic of shared and divergent themes came to the foreground, from which a thematic table was derived (Table 3). This table helps unravel the intricacies of expert perspectives versus established academic viewpoints. By examining the frequency of themes cited by experts, we discerned that operational and regulatory aspects, as well as external considerations, resonated across the two datasets. Intriguingly, the economic aspects were given less emphasis by our expert cohort; similarly, personal factors and some of the external factors, such as technical terminology used to describe drones, apparently garnered decreased attention. These insights suggested that experts were predominantly tuned into their operational

milieu, emphasizing the importance of stakeholder engagement and knowledge dissemination to inform public understanding of drone technology and its applications in light of broader societal acceptance.

6.2 Practical implications

6.2.1 Operational implications matter to experts. One of the reasons why the experts' perspectives on drone acceptability differed from those of the public was their unique roles in the design, development, and implementation of both drone technology and its operational ecosystems. Our survey revealed several themes that diverged significantly from the core concepts highlighted in our prior study of the academic literature (Wang, Mutzner, and Blanchet 2023). Notably, experts focused more on the operational intricacies of drone deployments, emphasizing that factors such as financial viability, resource allocation, and information dissemination were critical to the success of drone projects and, by extension, their societal acceptance. According to our expert cohort, a scarcity of operational projects not only resulted in limited data for assessing societal acceptance but also restricted them from being exposed to and acquiring insights about public perceptions of drone projects. Moreover, they pointed out a tension between operational considerations and existing regulatory frameworks, suggesting that regulatory measures may at times hinder pilot testing and data collection. Of particular importance was the experts' emphasis on the role of public awareness and education in this context. They argued that well-planned operational projects could serve as vehicles for public engagement, thereby enriching a broader societal understanding of drone technology. Collectively, these operational challenges indicated direct implications regarding acceptance, in particular, empirical data for measuring and assessing acceptance should be collected earlier on in the testing and pilot phase. It is, therefore, plausible that by properly addressing this point, a more informed discourse around urban drone acceptance in society can be fostered.

6.2.2 Public awareness and education are critical. Closely related to the above is a key theme that recurred within this survey, i.e. public awareness and education. This theme also emerged in our literature study, where educational engagement with key stakeholders was suggested as essential for assessing societal acceptance (Wang, Mutzner, and Blanchet 2023). According to the qualitative data gathered in Part II of this survey, our expert cohort held the general view that by educating the public about the actual risks and benefits of drones, their understanding of drone technology and its implementation could increase, leading to more comprehensive perceptions. For example, Expert 2 deemed it important to 'show advantages and disadvantages of the technology in a value-free way'. Additionally, there was a consensus that public communication should not only be informative but also emphasize societal benefits of the technology, aligned somewhat with a sense of social responsibility. Furthermore, it was suggested that educational programmes around drones could aim at providing the public with empirical data on risks and impacts, easing the public's concerns over safety and security. These views resonated with the wider drone acceptance literature, which highlighted the beneficial impact of education and public awareness (Sakiyama et al. 2017; Heen, Lieberman, and Miethe 2018; Martin et al. 2018; Zhu, Pasch, and Bergstrom 2020; Lin Tan et al. 2021; Annan et al. 2022). Nonetheless, while public education was reported as a prominent challenge—and a solution at the same time—experts pointed out that regulation was the key to unlock its power. For instance, Expert 3 advocated 'regulatory bodies limit(ing) drone operations being necessary to educate the public'. These remarks highlighted the need for regulatory bodies to allow for more testing, thereby facilitating data collection that would be essential for informed policymaking including educational efforts. In sum, the interconnected nature of the challenges like public education, regulation, and societal acceptance was recognizable, reinforcing the necessity for developing more responsive and agile governance frameworks. More in-depth studies may, thus, be conducted to assess the effectiveness of different public education strategies in addressing urban drone acceptance, focusing more on methods that can bridge the knowledge gap between experts and the general public.

6.2.3 Acceptance factors are interconnected. The above discussions spelled out the importance of considering acceptance factors not in isolation, but rather in a dynamic relational light. The interconnectedness of the acceptance factors was evident in the experts' responses to our survey, especially regarding the most significant challenges that the experts identified. For example, Expert 7 linked concerns over safety and regulation, stating that there were 'technical challenges of making BVLOS flights safe while also complying with the unclear and dynamic regulations regarding BVLOS operations'. Similarly, Expert 25 observed that there were 'too complex regulation(s) and procedure(s) in the name of safety'. These reflections illustrated how safety, a key factor in affecting drone acceptance, was dynamically connected with the prevailing regulatory environment in both directions. Another aspect worth noting was the role of public education in mitigating other challenges. Expert 5, for instance, quoted the problem of 'showing that the noise of our UAS is within limits (and that buses and trams create more noise)', highlighting the role of awareness-raising in informing the public and increasing their technological literacy. Illuminated by the interconnectedness of acceptance factors around urban drones, it can be discerned that, more robust conceptual frameworks are needed when studying societal acceptance of emerging technology. This calls for scholars working on related topics to develop responsive constructs in their future research, which will allow us to explore how particular factors may be leveraged to better understand other factors in question.

6.2.4 Conceptual understanding about acceptance is missing. With respect to robust conceptual frameworks enabling more comprehensive understandings about societal acceptance, there seemed to be a noticeable level of uncertainty among the experts. While the majority indicated decent knowledge about drone technology and related technical concepts, they lacked a comparable level of expertise in systematic conceptualization of public perception and societal acceptance. For example, only a few experts were able to name specific concepts pertaining to technology or to drone acceptance, while the others were more cursory with their explanations. Similarly, while 'social responsibility' remained an

important and established concept around technology governance, most experts in our cohort seemed to have vague understandings about it. These findings indicated an overlap with the findings of our own literature study (Wang, Mutzner, and Blanchet 2023), where the use of theories or concepts was limited to very specific fields. Echoing the aforementioned calls for action, these findings underscore the need for communication strategies that can bridge gaps in experts' understanding of societal acceptance and social responsibility, particularly within technology governance. Effective strategies might include structured workshops or interdisciplinary collaborations aimed at deepening experts' understanding of these concepts, alongside the development of practical, context-specific guidelines. Such approaches would support expert stakeholders in aligning their work with public values, fostering a more nuanced appreciation of societal concerns and thereby enhancing the integration of social responsibility into drone governance frameworks. Consequently, this highlights a direction for future research on technology acceptance, where both scientists and domain experts can benefit from collaborative exchanges that situate research within real-world contexts and address specific societal needs.

7. Limitations

A first consideration revolved around our expert cohort. The recruitment strategy, leveraging existing networks and referrals, may have introduced selection bias. Despite efforts made to engage a broad spectrum of experts from different domains and sectors, acknowledging the multistakeholder nature of urban drone use, we cannot confirm that our sample fully represented the drone expertise landscape. Additionally, participation decreased significantly from 117 to 36 by the final survey section, potentially affecting the results' interpretation.

A second consideration concerns the organization and presentation of survey findings. Due to the extensive survey measures and varied responses, we adopted a selective approach to encapsulate the results, which excluded more granular qualitative responses, particularly about experts' personal engagements in specific projects. Thematic coding of open-text answers was streamlined for quantification, potentially overlooking detailed explanations. Although individual perspectives were analysed, they may not be generalizable to their respective domains or sectors, and insights should be approached with caution.

Lastly, our prior work (Wang, Mutzner, and Blanchet 2023) may have conceptually influenced the thematic analysis. Despite rigorous reflexive qualitative practices, our categorization was influenced by previously identified clusters and themes from our own study. However, these categories aligned with broader drone acceptance literature, suggesting that our approach was anchored in prevailing theoretical paradigms. Moreover, the clarity and specificity with which the experts articulated their responses often highlighted distinct themes, thereby reducing interpretative ambiguity during the coding process. Overall, the survey findings should be viewed as a preliminary exploration, with future research benefiting from a more systematic methodology and targeted sampling for a more representative spectrum of expert opinions.

8. Conclusion

This work aimed to provide an informative snapshot of the current state of drone acceptance viewed from the experts' perspective. We employed a mixed-methods approach that synthesizes both qualitative and quantitative data. Given the scarcity of comprehensive analyses on this topic, our strategy was designed to contribute a foundational understanding that can support and guide future scholarly inquiries into technology acceptance studies. Our research shed light on the multifaceted perceptions of drone experts in relation to popular public discourses on drone acceptance. While there existed a considerable overlap between expert opinions and the broader literature, the nuances offered a unique avenue for in-depth exploration. Experts highlighted operational intricacies like financial viability and resource allocation as pivotal to both the success of drone projects and their societal acceptance. The concerns over themes such as noise and visual pollution, or design and human control, which have often been emphasized as crucial in wider public discussions, were not the most notable features in our study. This discrepancy underscored the importance of targeted communication strategies to help bridge the knowledge gaps between different stakeholder groups. It also highlighted the important role of public awareness and education, which was raised as a central strategy to foster more informed public policy on urban drones, and their benefits and potential risks. The intricate web of interrelated challenges, from safety to regulation to privacy, and their influence on public perceptions suggested a need for a holistic approach to future technology governance agenda-setting. As the drone industry continues to evolve, this study could serve as a foundational work to inspire more robust conceptual explorations over the topic, on the one hand, and practically orient awareness-raising efforts and support more responsive regulatory processes, on the other hand.

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Author contributions

Ning Wang (Conceptualization, Methodology, Writing—original draft, Writing—reviewing & editing, Supervision, Project management, Funding acquisition), Nico Mutzner (Investigation, Data curation, Analysis, Validation, Visualization, Writing—original draft, Writing—reviewing & editing), and Karl Blanchet (Supervision, Project management, and Funding acquisition)

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Data availability

All data is availabile.

Appendix 1.

Survey design strategy

Part I of the survey consisted of an initial multiple-choice question about the participants' drone expertise, each response corresponding to a different level of knowledge on drones. Next, four slider-measure questions were introduced to ascertain perceptions on drone acceptance in different contexts. The slider measures ranged from 1 to 4, with 1 indicating 'not at all acceptable' and 4 'absolutely acceptable', as well as an additional option of 'Don't know'. The first measure concerned the acceptability of different drone applications, such as geographical mapping, air quality monitoring, drone surveillance, or hobby flying, among others. The second measure concerned the perceived optimal automation levels of the same drone applications, ranging from full automation to full human control. The third and fourth measures assessed how convincing participants found certain arguments for and against drone use. Pro-drone arguments included benefits, such as operation in dangerous environments, improved efficiency, environmental advantages, and a wide range of use cases. Conversely, counterarguments encompassed issues such as the potential for accidents, privacy infringements, illegal activities, and visual pollution. Following this, participants were asked to rank predefined factors affecting societal acceptance of drones based on their perceived importance. Using a numerical scale, a score of 1 denoted the highest level of importance and a score of 8 represented the lowest. Finally, participants were asked to indicate their level of trust in various institutions to responsibly implement drones in their operations, ranging from NGOs and governmental agencies to scientific organizations and private or commercial entities. The slide scale assessment ranged from 'no trust' to 'full trust'.

Part II of the survey included two subsections: section A on personal involvement in drone projects and section B on understanding about drone acceptance. Regarding personal involvement, participants were asked to describe technical characteristics of a drone, what organization they were affiliated with, what their role or function was in that entity, and how their work related to drones. This was followed by multiple-choice questions concerning their focus areas, and duration and geographical locations of the drone projects they were involved in. Finally, more detailed questions about those projects were asked, including financial aspects, relevance to policies and regulations, coordination with other stakeholders, and the involvement of the general public or local communities within the work. Concerning understanding of societal acceptance, participants were initially prompted to indicate their familiarity with theories or concepts related to public perception, attitude, or acceptance of technology, and those who were familiar were then asked to specify which particular theories or concepts they referred to. Next, participants were asked to indicate their awareness of the concept of 'social responsibility' and to describe their understanding of it in the context of technology governance. Subsequently, participants were invited to share whether they had encountered any specific public opinions or sentiments regarding drones and to detail those observations if possible. Following these inquiries, participants were asked to identify the top three challenges concerning drone acceptance that they faced in their work, with a brief explanation why these challenges mattered to them. Finally, participants were asked to allude to what elements currently lacking in addressing those challenges and to suggest potential mechanisms that could facilitate overcoming them.

Appendix 2.

FA loading strengths

Acceptability of drone applications

The FA on general acceptability of drone use revealed a perceptual distinction among respondents, emphasizing the utility of drones in diverse contexts. The *Emergency and Humanitarian Usage* cluster, explaining 23 per cent of the variance (loadings between 0.46 and 0.83), reflected the correlation between the applications benefitting public welfare including uses such as locating birds and mapping geographical areas post-landslide. Interestingly, the application of surveying power grids using drones showed correlations with both emergency and public space usages, bridging these two contexts. The *Recreational and Public Space Usage* cluster accounted for 20 per cent of the variance (loadings between 0.56 and 0.72), underscoring the correlation between the use of drones in public spaces and by private individuals. Notably, the *Environmental and Climate Usage* cluster, characterized by a single item related to air quality monitoring and representing 14 per cent of the variance (loading of 0.86), emerged as a distinct category. The overall suitability of the analysis was confirmed with a KMO measure of 0.85, with individual item KMO values ranging from 0.83 to 0.91. [The Kaiser–Meyer–Olkin (KMO) test is a statistical measure to determine how suited data is for factor analysis. The test measures sampling adequacy for each variable in the model and the complete model. The statistic is a measure of the proportion of variance among variables that might be common variance. The higher the proportion, the higher the KMO-value, the more suited the data is to factor analysis.]

Pro-arguments for drone implementation

The FA applied to the pro-arguments for drone use revealed three distinct clusters, offering insights into a host of perspectives. The *Operational Efficiency and Versatility* cluster, accounting for 20 per cent of the variance (loadings from 0.73 to 0.72), underscored the practical advantages and operational capabilities of drones. Notably, within the *Environmental and Economic Sustainability* cluster, representing 10 per cent of the variance (loadings from 0.39 to 0.83), the argument emphasizing drones as relatively cheap and easy to use

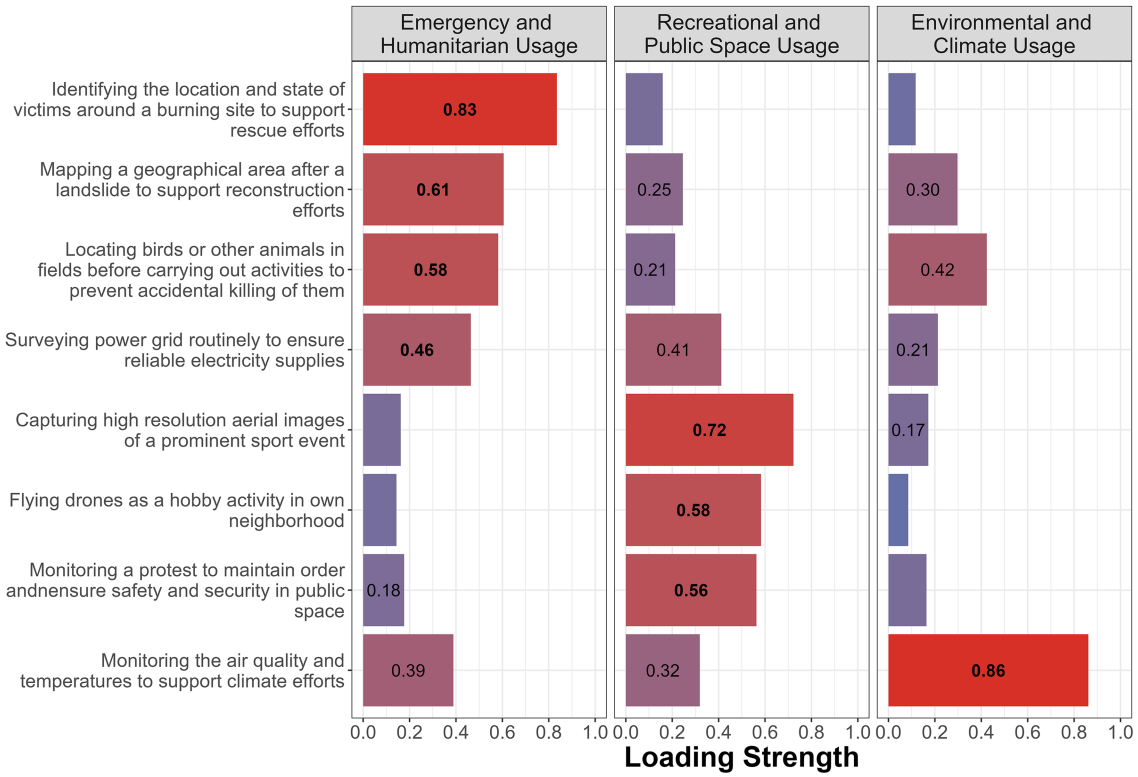

Figure A.1. FA: acceptability of drone applications ($n = 117$).

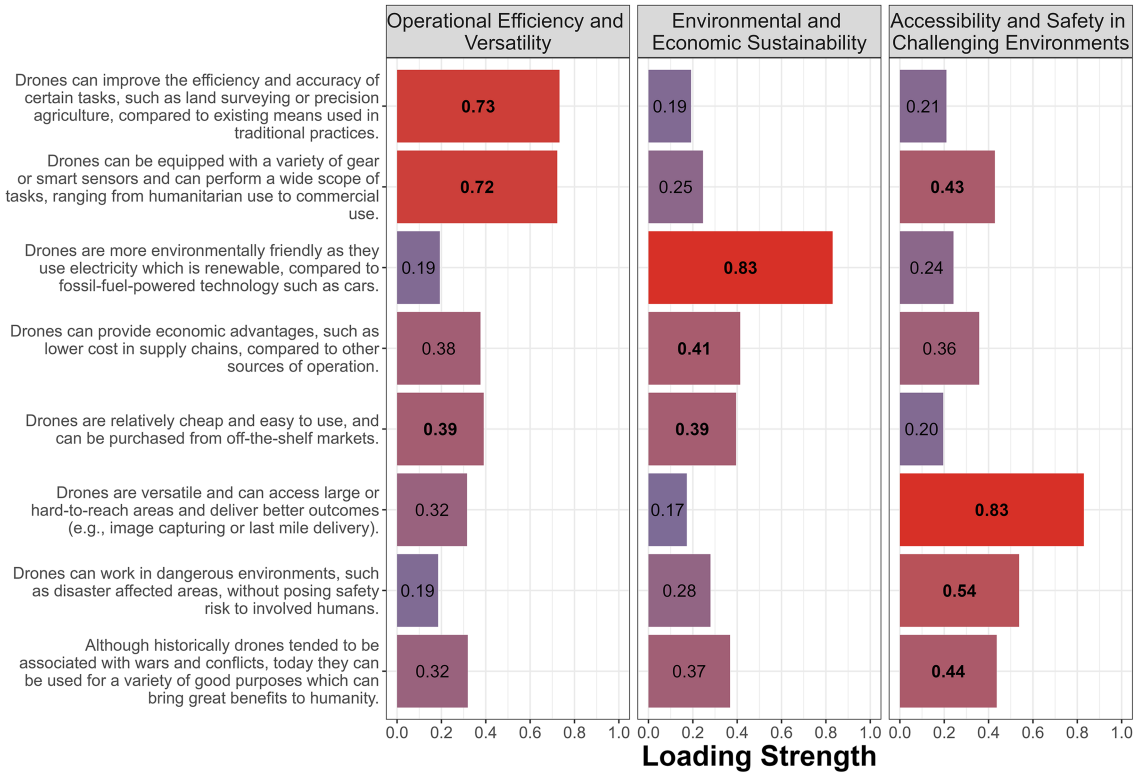

Figure A.2. FA: pro-arguments for drone implementation ($n = 117$).

demonstrated an identical correlation to both this and the previous clusters. However, due to its stronger correlation with the items in the sustainability cluster, it was more sensibly attributed to this cluster. The *Accessibility and Safety in Challenging Environments* cluster, contributing 17 per cent of the variance (loadings from 0.44 to 0.83), highlighted the unique

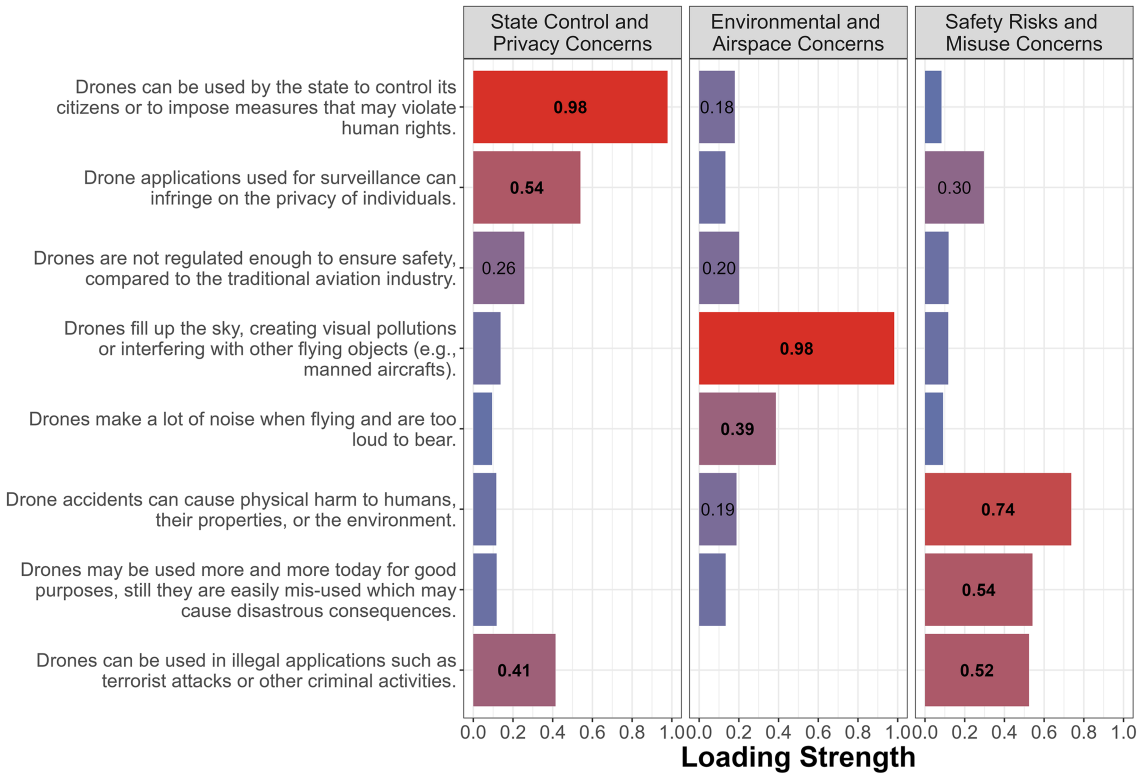

Figure A.3. FA: con-arguments against drone implementation ($n = 117$).

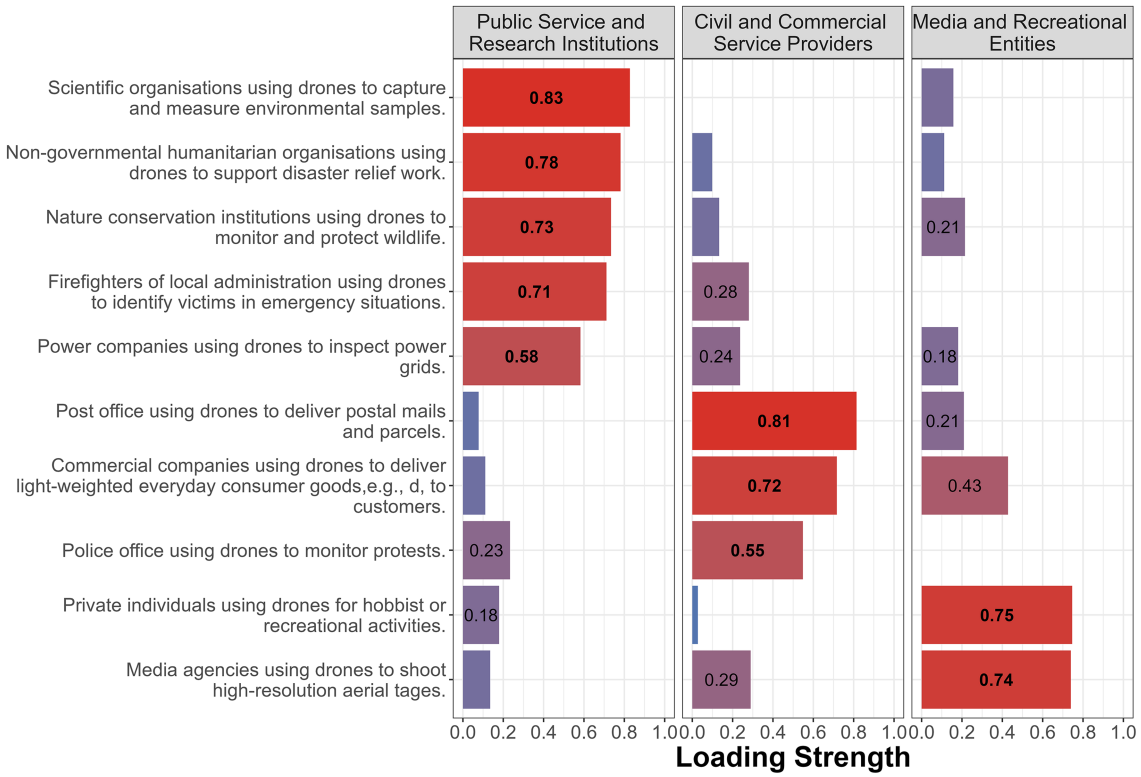

Figure A.4. FA: institutional trust in drone use ($n = 117$).

capability of drones to access and operate in hard-to-reach locations, effectively countering their historically negative associations by a more positive contemporary application. This analysis elucidated a spectrum of pro-drone arguments, ranging from immediate practical benefits to broader societal, economic, and technical considerations, and is further validated by an overall KMO measure of 0.86 and individual item KMO values from 0.82 to 0.92.

Con-arguments against drone implementation

The FA applied to the con-arguments against drone use delineated three thematic clusters encapsulating expert apprehensions. The *Safety Risks and Misuse Concerns* cluster, encompassing risks associated with drone accidents and misuse, contributed to 15.5 per cent of the variance (loading between 0.52 and 0.74). This cluster highlighted fears surrounding potentially illicit use of drones, their proneness to be misused, and the physical dangers from drone accidents, reflecting a consensus on the immediate tangible risks that drones present to society. The *State Control and Privacy Concerns* cluster, accounting for 19.3 per cent of the variance (loading of 0.98), highlighted experts' deep-seated worries about surveillance and potential state control. The *Environmental and Airspace Concerns* cluster, representing 15.7 per cent of the variance (loading of 0.98), signified apprehensions regarding the environmental and visual impacts of drones, e.g. filling up the sky. Despite being rated less convincing overall, it emphasized the secondary effects of drones on public space and the environment. Notably, the issue of insufficient regulation of drones, indicating a need for more appropriate industry standards, was a cross-cutting concern, suggesting a fundamental sense of unease about the current governance of drone applications. The analysis was supported by an overall KMO measure of 0.69, indicating moderate sampling adequacy, with individual item KMO values ranging from 0.64 to 0.74.

Institutional trust in drone use

The FA clusters on institutional trust suggested that experts might view certain institutional uses of drones as distinct. The *Public Service and Research Institution* cluster, capturing 28 per cent of the variance (loadings from 0.58 to 0.83), combined the use of drones by firefighters, scientific organizations, and nature conservation bodies. This cluster indicated a shared confidence in entities associated with public welfare and scientific inquiry. In contrast, the *Civil and Commercial Service Providers* cluster, representing 17 per cent of the variance (loadings from 0.55 to 0.81), encompassed police, postal, and commercial delivery services. This suggested a nuanced scepticism towards drone use in civil operations and commercial enterprises. Finally, the *Media and Recreational Entities* cluster including media agencies and private individuals, accounting for 15 per cent of the variance (loadings from 0.74 to 0.75), reflected a distinct trust dynamic associated with drone use in media production and hobbyist activities. The analysis was substantiated by a KMO measure of 0.78, indicating moderate common variance, with individual item KMO values ranging from 0.67 to 0.88, affirming the validity of these thematic distinctions.

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