Anna Soligo
Dyson School of Design Engineering
Word Count: 2598

The Ethical Impacts of Urban UAV Delivery:

A Value Sensitive Design study to enable a responsible and desirable system design

Abstract

Urban delivery-drones have the potential to greatly improve quality-of-life in cities. However, they also risk worsening it by undermining human-values, such as physical-welfare, privacy, and environmental sustainability. In order to support the design of an ethically responsible and socially-desirable urban drone delivery-system, this study uses two Value-Sensitive-Design (VSD) methods, consequence-scanning workshops and semi-structured interviews, to explore the potential consequences of such a system and the value-tensions it gives rise to. The results identify the need for a gradual implementation of urban drone-services, supported by an extensive education programme, to encourage positive-attitudes and trust around the technology. In addition, a public identification system is proposed, to improve the transparency of drone-operations and further enhance trust. Urban-UAV systems are still in their early stages of development. Therefore, it is suggested that further VSD studies are used to assist the future development of specific features and to enable a holistic evaluation of their impacts.

Introduction

In November 2022, the European commission published their European drone strategy (European Commission, 2022). It envisions that by 2030, drones will be a widespread and accepted part of EU life across civil, security and defence sectors. The development of this new UAV eco-system is identified as a “unique opportunity” to introduce harmonised regulation from the outset, because unlike many other impactful systems within society, UAV-systems are not restricted by historical legal or functional frameworks.

For this same reason, the design of emerging drone-implementations offers a critical opportunity to develop the sector in an ethical and beneficial way. By engaging stakeholders in the early-stages of concept-designs and regulation development, UAV-systems can be shaped in a way that balances the impacts across society, to achieve an overall positive-affect.

This study intends to enable such a beneficial design in the context of urban-delivery drones. Its purpose is to inform the development of a project-at-large: the concept-design for a London delivery-system which integrates small UAVs and public-transport to achieve high-efficiencies.

In 2017, the average UK individual received 22 e-commerce parcels a year. At the time, it was forecast that 1.17 million parcels would be delivered daily in Greater-London by 2025 (Briest et al. 2019). However, this seems likely to be significantly exceeded: the COVID-pandemic accelerated the shift towards e-commerce, causing a 43% growth in online sales in 2020 (Brewster, 2022). This change is expected to become a long-term effect, as online-shopping becomes the “new normal” (Szazs et al. 2022). Unfortunately, the high energy-use, emissions and congestion associated with current last-mile delivery solutions means this growth poses a major threat to quality-of-life and sustainability in urban-areas.

Delivery-drones could mitigate these impacts. UAVs can use as little as 4% of the energy of diesel-vans to deliver the same packages, without occupying road-infrastructure or emitting polluting-gases and particulates. However, the use of UAVs in densely-populated areas gives rise to a broad-range of concerns including safety, security, sustainability, and privacy, and for this reason, it is controversial and currently widely prohibited.

In 2016, the UK Department for Transport commissioned a series of nationwide-workshops to explore public-attitudes to drone-use. Participants were largely found to have little-knowledge of drones and their commercial-applications, but raised concerns around quality, operator-proficiency, and misuse. The increase in public exposure to drone-use since 2016 means that public-attitudes are expected to have changed since then. More recent stakeholder-studies on urban drone-use have used large-scale public surveys (EASA 2021, Mascarenhas 2022) or expert-interviews (Richards 2020, Upadastra 2022) across multiple locations. Therefore, this study differentiates itself by examining the current views of both expert- and non-expert-stakeholders. It uses workshops and interviews, to allow a greater-exploration of personal views and focuses on the London context, to increase its relevance to the project-at-large.

The study was conducted in-two stages. First, consequence-scanning workshops were used to assist the identification of stakeholders and consequences of the project-at-large, and to identify the value-impacts that stakeholders deemed most significant. Then, semi-structured interviews were conducted with members of the public to explore the perception of these impacts in wider society, their causes, and the ways in which they could be supported or mitigated.

Consequence Scanning Workshops

Participants

In total, six individuals participated in two workshops. Initially, five participants were planned per workshop, to represent five different stakeholder-categories. However, during recruitment, it proved difficult to schedule sessions suiting multiple individuals. It was also found that several individuals could represent multiple categories. Therefore, workshops were run with three-participants each. The participants of workshop-one (W1-W3) represented four categories, and the participants of workshop-two (W4-W6) represented all five. Figure 1 shows the participant categories, and detail on their experience is given in Appendix A. Due to the limited-time available for recruitment, four participants were previously known to the researcher, but they were grouped to ensure that they did not know one-another, to reduce any bias in the discussions. The remaining two participants were recruited from relevant online-groups.

Figure 1 - The stakeholder categories of the workshop participants.

Procedures

The workshop structure (Figure 2) was based on Brown (2019). The workshops were hosted on Google-Meet, and a Miro-whiteboard (Figure 3) was used for participants to collaboratively record ideas.

Figure 3 - The consequence-scanning workshop structure and timings

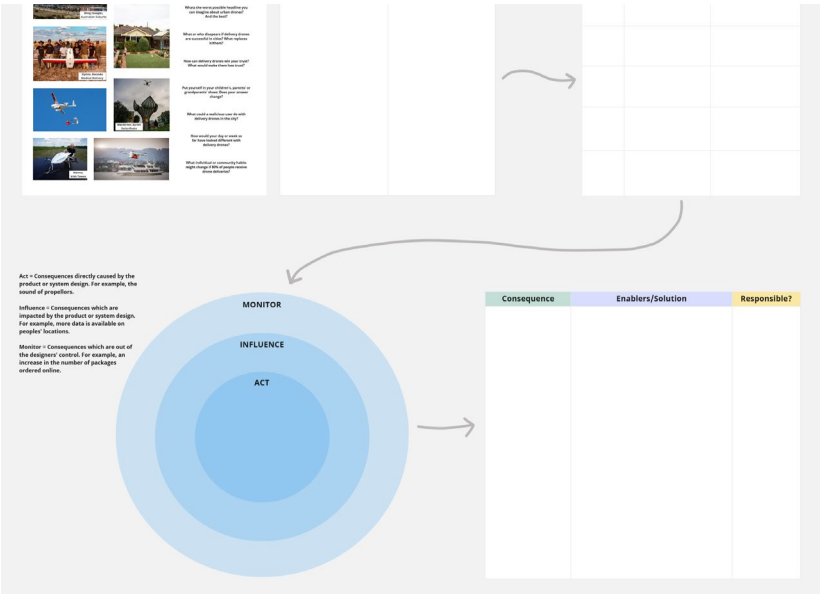

Figure 2 - The consequence-scanning workshop template, used for collaborative idea-sharing on Miro

A set of images and questions were provided as prompts (Figure 4). The images display emerging delivery-drone systems to help realistic-visualisation and the questions were selected to inspire thoughts about pervasiveness, long-term effects, and alternative-perspectives.

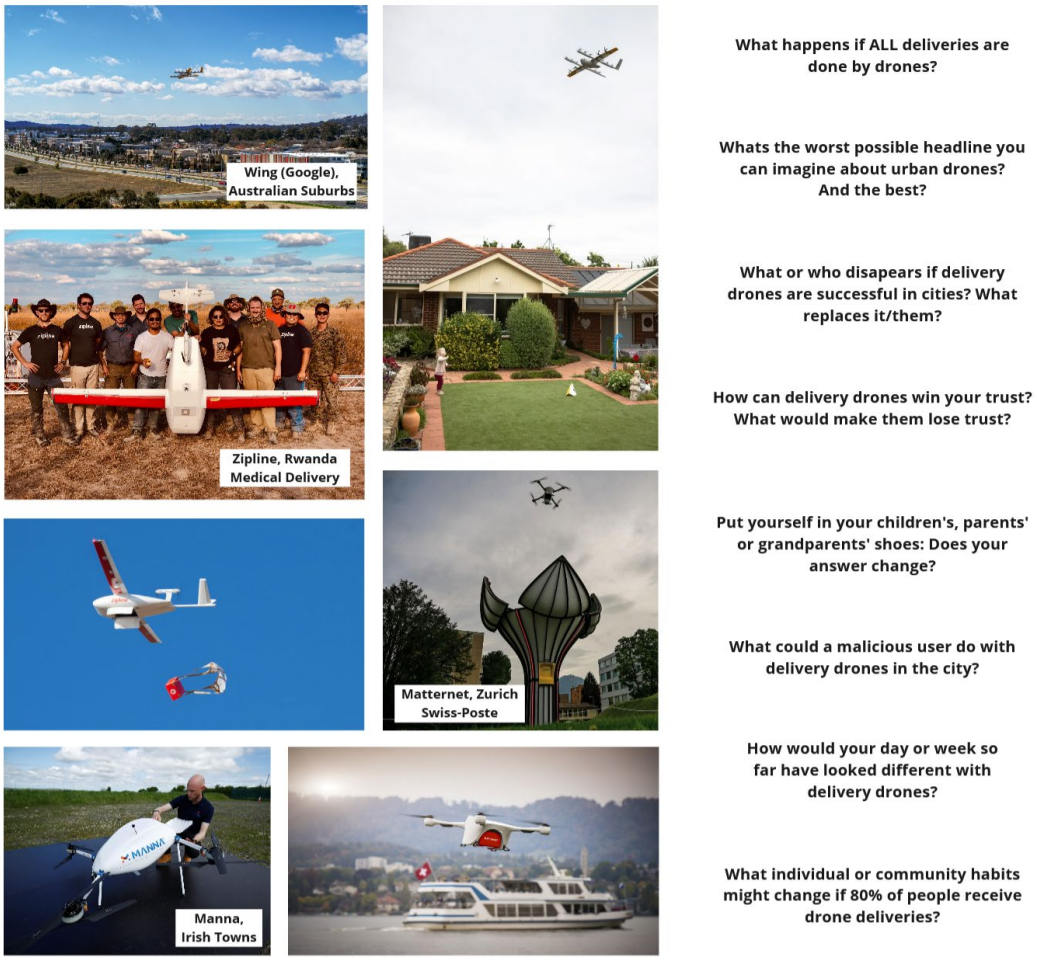

Figure 4 - The images and questions provided as consequence-scanning prompts

These workshops aimed to gather views from different perspectives, and to hear how individuals justified or changed their views in response to the input of others. Specific measures were taken to enable this:

- The participants were told that the group had varied experience, but specific expertise was not introduced. This was to avoid individuals feeling that their views were less valuable than others', which was a concern expressed during recruitment.

- During the initial consequence-ideation, participants were instructed not to read the contributions of others. This enabled contrasting trains-of-thought to emerge. In addition, repeated consequences between participants helped identify impactful areas.

- After this, collaboration was encouraged. The researcher aimed not to influence the discussions, so did not contribute other than to give instructions and answer direct questions.

Results

To analyse the workshop-results, the researcher first sorted the consequences by theme, guided by the participants' affinity-sorting. This enabled the 83 consequences to be compiled into 32 unique consequences, which were grouped based on the value or values with ethical-import they implicated. A

numerical ranking system, explained in Table 1, was used to score the consequences based on their importance and relevance to the design of the project-at-large.

Table 1 - The points system used to score the consequences, in order to rank the significance and impact of the implicated values in the context of the project-at-large

		Meaning	Assigned Points
Repeated Consequences		Shows the consequence was identified as significant by multiple participants.	+1 per additional mention
Affinity Sorting	**Act**	Measure of the relevance of the consequence to the design of the project at large.	+2
	Influence		+1
	Monitor		+0
Priority Voting		Shows participants considered the consequence to be important and impactful.	+1 per vote

The value-categories, consequences and scores are shown in Figure 6. The scoring clearly identified human welfare, environmental sustainability, and calmness as the most significant values. Figure 7 shows the total impact score of each value, plotted against its positivity. This is calculated as the positive minus the negative impact scores, divided by total impact score.

Figure 5 - The unique consequences identified in the workshops, sorted by value and scored according to Table 1. The colours identify the consequences as negative (orange), neutral (yellow) or positive (green)

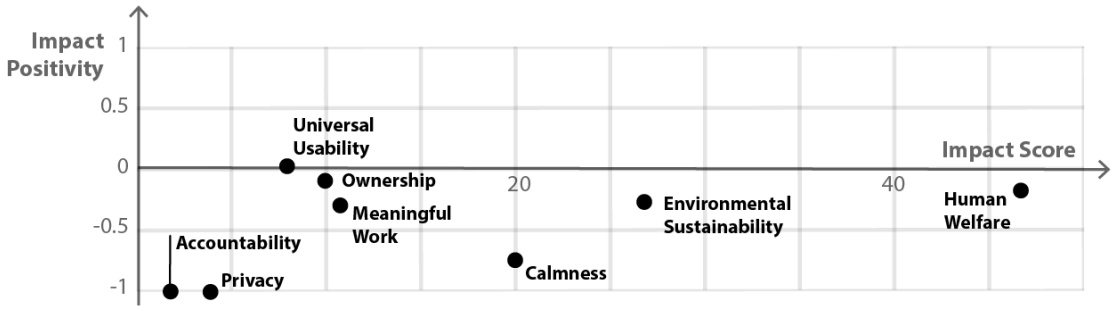

Figure 6 – A graph showing the impact and impact positivity of the implicated values.

Semi-structured Interviews

Participants

Fifteen interviews were conducted (I1-I15). In addition, two individuals gave qualitative comments (C1-C2) but were unable to give a full interview. This far exceeded the five originally planned and was done for two main-reasons: firstly, it was decided that a sample size of five was insufficient to gather reliable quantitative-results, and secondly, the diverse range of people affected by the project-at-large made it valuable to speak to a wide variety of people. Recruitment for this phase was easier, because of the small-time commitment for participants, and the possibility to conduct interviews immediately, rather than having to schedule future-sessions. Six participants were previously known to the researcher, three were introduced by workshop participants, seven were approached at random in a leisure-centre, and one was contacted by calling their workplace. Participants I1, I9, I12 and C1 were recruited because of their relevant experience (detailed in Appendix A) and the remaining participants were recruited as members of the general public based in London. All the participants were classified as bystanders and users, because they live and receive parcels in London, but interestingly, eight of the thirteen generically recruited 'Londoners' also fit into other categories as a result of their profession or hobbies, as shown on Figure 7. This emphasizes the pervasiveness of UAV-system impacts.

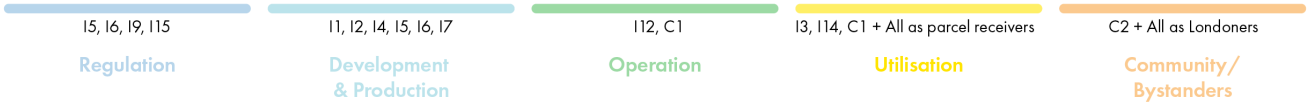

Figure 7 - The stakeholder categories of the workshop participants

Procedures

The interviews were intended to further explore how important the values of calmness, safety and environmental sustainability were among the general public, how and why they could be implicated by the project-at-large, and how they could be better supported. To achieve this a three-part structure was used:

- First participants were asked to rank the values in the context of London-life, to determine their relative importance independent of the project-at-large.
- Then, participants were asked for their age-bracket and professional-background, to divert their attention from these values.
- Next, they were introduced to the project-at-large and asked to give their initial opinions of it, before they were influenced by value-specific questions.
- Finally, they were asked about the impact of the project-at-large on calmness, safety and sustainability. Quantitative questions asked whether the participants felt positively or negatively about the impacts. Then, qualitative follow-up questions identified specific features of the project-at-large which caused these impacts, and how they believed they could be improved. The exact questions are detailed in Appendix B.

All interviews were conducted in person. Eight were recorded using an audio-recording app, but seven were not, either because they were conducted in a loud public-place, or because the interviewee did not wish to be recorded. For this reason, the interviews were not transcribed. Instead, detailed notes were taken during the interviews, and the available recordings were used to expand on them afterwards.

Results

The quantitative results were analysed overall, for males and females, and for under and over 50-year-olds. The overall results are graphed in Figure 8, and where there was a difference of more than 10% of the scale between demographic groups, these are included on the graph. Appendix C contains the full numeric results.

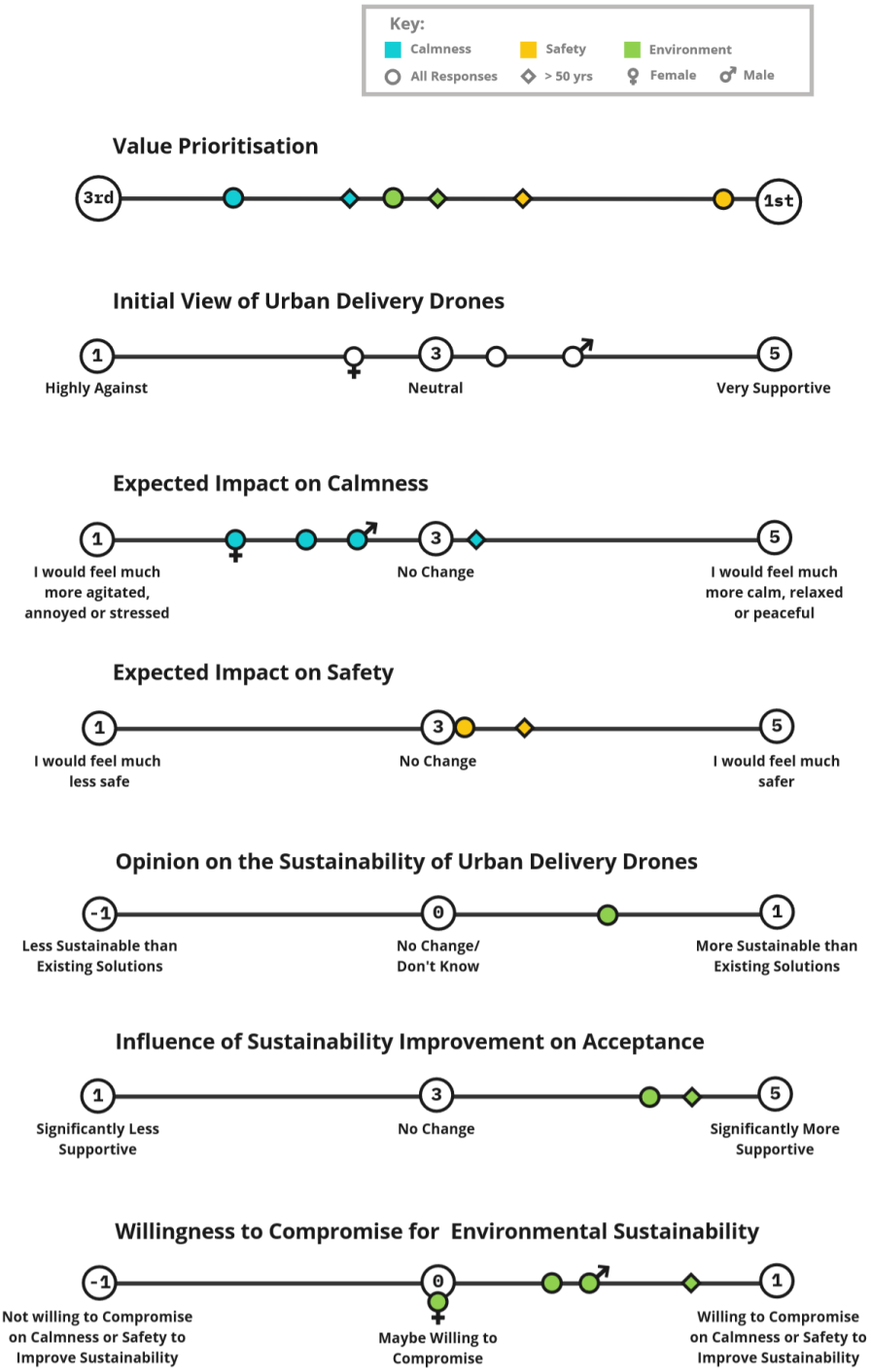

Figure 8 – Graphs showing the results of the quantitative interview questions

There was a strong consensus about the relative importance of the values in city-life: safety was ranked first, with an average of 1.27, followed by sustainability at 2.13, and finally calmness, at 2.60. This separation was reduced among over-50s, who ranked calmness 0.45 higher, at the expense of safety, which was ranked 0.48 lower. These results agree with the value impact-scores from the workshops, which implies that stakeholders' concerns around drone-use align with their priorities in wider city-life.

Despite it being secondary to safety, the results did show a concern for sustainability: 87% of participants said an improvement in environmental sustainability would make them more supportive of UAV-use, and 47% would be willing to compromise on safety and calmness for the sake of sustainability, compared to only 20% who would not.

Although in the workshop stage, all three values had negative impact-totals, only calmness was perceived to be overall negatively impacted in the interviews, with an average rating of 2.27 on the scale shown in Figure 7. Delivery drones were seen to be marginally safer than existing delivery solutions, with a score of 3.13, and were also believed to be more sustainable by 60% of the participants.

Two possible reasons were identified for this. Firstly, the workshop asked about consequences across society, whereas the interviewees were asked about the impacts on themselves. This means the workshop participants were more likely to consider negative but improbable impacts. Secondly, the interview questions compared drones to existing solutions. The responses show that this encouraged comments about reducing the negative consequences of current delivery-methods, which were less present in the workshops.

The responses to the qualitative follow-up questions were sorted into two categories: consequences and solutions. As in the workshop-stage, the consequences were sorted by theme to identify unique-comments, then by value. The results are shown in Figure 9, and the consequences are scored on the number of individuals who mentioned them before the value-specific questions (left) and the number who mentioned them after(right). Human-welfare, calmness and sustainability were once-again identified as the most significant values. They were the most frequently implicated in the comments made both before and after the value-specific questions, which shows that this result was not biased by the explicit mention of these values.

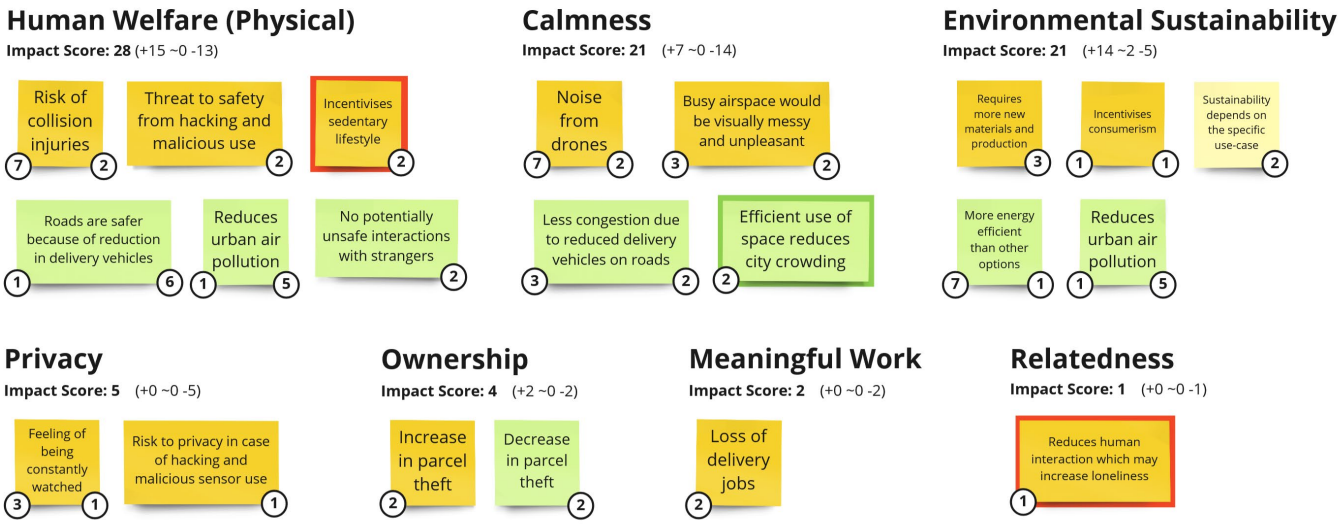

Figure 9 - The unique consequence comments made in response to the qualitative interview questions

Themes were also apparent in the solution comments, and the most common are graphed in Figure 10 with example comments shown in Figure 11.

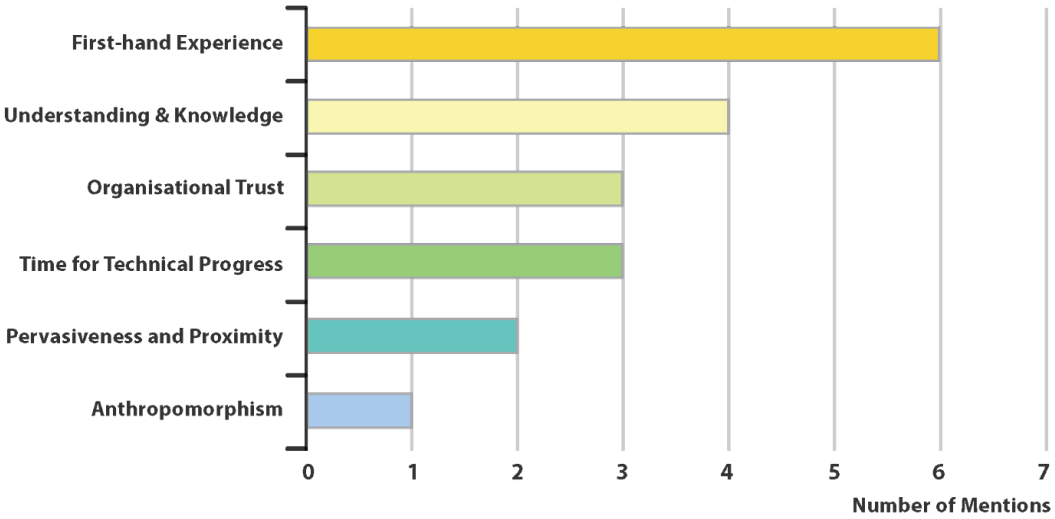

Figure 10 – A graph showing the prevalence of the themes found in the solution interview comments

Figure 11 – Example solution comments, colour coded according to the graph in Figure 9

A large number of comments explicitly or implicitly referred to trust as influential to the perception of the project-at-large. In fact, every topic in Figure 10 was related to trust by some participants. For example, multiple individuals commented that they would not trust devices which they did not understand, and while some participants believed any legal use-case would be trustworthy, others felt that only certain organisations should be trusted to operate drones.

Discussion

Overall, there are greatly conflicting views about the potential consequences of delivery-drones among both expert and non-expert stakeholders. This fact, and the specific results outlined above, raise several action-points with respect to the design of the project-at-large.

- Firstly, it should be developed and analysed with a holistic approach. There is the potential for both positive and negative impacts across a wide range of implicated values. For example, the lifespan of UAVs is likely to be relevant in determining whether it is energy efficient to produce them. Therefore, it is important to balance the impacts within these values, as well as the value-tensions which arise in the system as a whole.

- To enable this, stakeholders should be engaged in the future-development of the project-at-large. The interview results demonstrate that stakeholders are willing to tolerate some negative consequences for the sake of positive ones, but this will require consultation about specific features and use-cases, to satisfactorily solve the value-tensions they give rise to.

In addition, actions should be taken to ensure that the public views future drone-systems positively, to increase trust and calmness.

- The implementation of delivery-drones should be accompanied by public information-programmes. For delivery-drones to be accepted, the public need to understand the benefits, some of which, like sustainability, may be invisible. In addition, education was found to enhance trust which further improves acceptability.

- Finally, gradual implementation may be beneficial. This would enable trust to grow progressively as first-hand experience increases.

Specific desirable design-features for urban delivery-UAVs are also apparent in the results. Many of these were previously known and are expected to be formalised within legal drone requirements, for example the need to avoid collisions, keep noise below a certain threshold, and achieve a certain level of cyber-security. A notable exception identified is the need for transparency in drone operations. To achieve this, drones could transmit public data which allows them to be identified, for example using an app, by bystanders and security-services. This could encourage organisational trust and reduced the feeling of being watched. It could also reduce the privacy and safety risks from malicious-use.

Although the number of participants was increased from 15 to 23 since the original study-plan, the scale of this study is insufficient to come to comprehensive conclusions about a project which would impact millions of people. In addition, since almost half the participants were previously known to the researcher, the results are unlikely to be representative of the views across society. The variations in results between the age and gender groups in the quantitative analysis highlight the importance of engaging a wide range of demographic groups in future-studies.

Despite this, the opinions and consequences identified, and the actions suggested in response, are expected to have a positive impact on the continuation of the project-at-large. They provide guidance which will encourage the ethical and socially-acceptable development of the initial system-design.

References

Brewster M (2022) Annual Retail Trade Survey Shows Impact of Online Shopping on Retail Sales During COVID-19 Pandemic. US Census Bureau. Available at: https://www.census.gov/library/stories/2022/04/ecommerce-sales-surged-during-pandemic.html [Accessed: 10/12/2022]

Briest P, Dragendorf J, Ecker T, Mohr D, Neuhaus F (2019) The end game for postal networks: How to win in the age of e-commerce. McKinsey Reports. Available at: https://www.mckinsey.com/industries/travel-logistics-and-infrastructure/our-insights/the-endgame-for-postal-networks-how-to-win-in-the-age-of-e-commerce [Accessed: 10/12/2022]

Brown S (2019) Consequence Scanning Manual. Version 1. London: Doteveryone
DFT (2016) Public dialogue on drone use in the UK, Moving Britain Ahead. Drones dialogue Report. Available at: https://sciencewise.org.uk/projects/drone-usage/ [Accessed: 15/11/2022]

Duffy R (2018) Understanding the public perception of drones. Nesta Futurescoping. Available at: https://www.nesta.org.uk/blog/public-perception-of-drones/ [Accessed: 14/11/2022]

EASA (2021) Study on the societal acceptance of Urban Air Mobility in Europe. EASA Reports. Cologne. Available at: https://www.easa.europa.eu/en/newsroom-and-events/press-releases/easa-publishes-results-first-eu-study-citizens-acceptance-urban#group-easa-extra [Accessed: 16/11/2022]

European Commission (2022) A Drone Strategy 2.0 for a Smart and Sustainable Unmanned Aircraft Eco-System in Europe. EC Mobility and transport Strategies. Available at: https://transport.ec.europa.eu/news/drone-strategy-creating-large-scale-european-drone-market-2022-11-29_en [Accessed: 01/12/2022]

Mascarenhas L, van Egmond P (2022) Public and stakeholder acceptance – Interim report. AiRMOUR Project. Available at: https://drive.google.com/file/d/1ZxPc1WV0TBN6kgfE_j73pjLtU1OcTmkV/view [Accessed: 16/11/2022]

Richards D (2022) Flying high: a human perspective of unmanned aerial systems in future cities, Theoretical Issues in Ergonomics Science, 23:3, 290-305

Szazs L (2022) The impact of COVID-19 on the evolution of online retail: The pandemic as a window of opportunity. Journal of Retailing and Consumer Services. 69: 103089.

Upadrasta V, Hamdan J, Leitner R, Kolrep H (2022) Who Are the Stakeholders of Drone Use? Roles, Benefits, Risk Perceptions, and Solutions Human Interaction, Emerging Technologies and Future Systems V. IHIET 2021. Lecture Notes in Networks and Systems, vol 319. Springer, Cham.

Appendix A – Participant Details and Stakeholder Categories

Stakeholder Categories:

Reg = Regulation
Dev = Development and Production
Op = Operations
Ut = Utilisation
By = Community/ Bystanders

All stakeholders can be considered members of the bystander group, as city inhabitants or workers, and as members of the utilisation group, as current receivers of delivered packages. Therefore, Table A1 only assigns the By/Ut label if the person has no other association to the system. The By and Ut labels are used individually if the person is a member of these categories in other ways (for example the pilot, W5, is a bystander as an urban airspace user).

Table A1 – Details on the participants

ID	Stakeholder Categories	Occupation	Age	Gender
W1	Op, Ut	Deliveroo Cyclist	18-24	M
W2	Ut/By	Gym Coach/Receptionist	25-29	F
W3	Dev	UAV Electrical Engineer	30-34	M
W4	Reg, Op	Police Officer & Drone Hobbyist	40-44	M
W5	Dev, By	UAV Software Engineer & Plane Pilot	25-29	M
W6	Ut/By	Climbing Route Setter	25-29	F
I1	Dev	UAV Designer	18-24	F
I2	Dev	Design Engineering Student	18-24	M
I3	Ut	Nurse	25-29	F
I4	Dev	Geology Student	18-24	F
I5	Reg, Dev	Computer Science Researcher	18-24	F
I6	Reg, Dev	Geology Researcher	25-29	M
I7	Dev	Architect	25-29	M
I8	Ut/By	Chemistry Researcher	18-24	M
I9	Reg	Lawyer	30-34	F
I10	Ut/By	Archaeology Researcher	55-59	F
I11	Ut/By	Anthropology Lecturer	50-54	M
I12	Op	Warehouse Worker	30-34	M
I13	Ut/By	Investment Banker	55-59	M
I14	Ut	Hospitality Manager	35-39	M
I15	Reg	Retired City Planner	65-69	M
C1	Op, Ut	Shop Worker using Delivery Robots	35-39	F
C2	By	Paragliding Instructor	50-54	M

Appendix B – Semi-Structured Interview Questions

For the quantitative questions, participants were additionally shown the scales in Figure 8 to ensure the questions were properly understood. For the qualitative questions (preceded with ~) the exact wording, especially the text in italics, was varied based on the interviewee's previous responses. Further questions were asked to gain further insights into their comments, where necessary.

1) Can you rank the following in order of importance for you? (1st to 3rd)

- How calm/relaxed I feel in my London
- How safe I feel in my London
- How environmentally sustainable London is

2.1) On a scale of 1 to 5 how supportive are you of the idea of delivery drones in London?

2.2) ~ I ask you to think of 2 positives and 2 negatives what comes to mind?

3.1) On a scale of 1 to 5, how do you feel delivery drones could change how calm you feel in London, if they replaced current delivery solutions?

3.2) ~ What emotions do you imagine would be raised if you saw a delivery drone flying above you?

3.3) ~ What do you think you would find the most *agitating/annoying/stressful/calming/relaxing*?

4.1) On a scale of 1 to 5, how do you feel delivery drones would influence your safety in London if they replaced current delivery solutions?

4.2) ~ What dangerous events do you foresee *increasing/emerging/reducing* with delivery drone

4.3) ~ What could change your mind? Would this be easy?

5.1) Do you think urban delivery drones would improve environmental sustainability compared to current solutions, based on your current knowledge of them? (Yes, no, or no change/ don't know)

5.2) If you were told delivery drones were the most sustainable delivery option, on a scale of 1-5, how much would this influence your acceptance of them ?

5.3) ~ What aspects do you think make them *more/less* sustainable?

5.4) Would you be willing to compromise on the previous topics for the sake of environmental benefits? (Yes, no, or maybe)

Appendix C – Quantitative Interview Results by Age and Gender

Table C1 – The quantitative interview question results

Question		Overall	< 30 yrs	30-49 yrs	> 50 yrs	Female	Male
1 - Ranking	**Calmness**	2.60	2.75	2.67	2.25	2.67	2.56
	Safety	1.27	1.13	1.00	1.75	1.17	1.33
	Sustainability	2.13	2.13	2.33	2.0	2.17	2.11
2.1 – Initial Support of Concept		3.27	3.25	3.00	3.40	2.50	3.78
3.1 – Impact on Calmness		2.27	1.75	2.33	3.25	1.83	2.56
4.1 – Impact on Safety		3.13	3.13	2.67	3.50	3.17	3.11
5.1 – Opinion of Sustainability		0.53	0.38	1.00	0.50	0.50	0.56
5.2 – Influence of Sustainability		4.27	4.25	4.00	4.50	4.17	4.33
5.4 – Willingness to Compromise		0.27	-0.13	0.67	0.75	0.00	0.44

Note: The values for the 30-49 years old category are included in this table for completeness, but they were not used as part of the results analysis, because of the small sample size of 3 in this bracket.