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Public Acceptance of the Use of Drones in City Logistics: A Citizen-Centric Perspective

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Abstract: The specific use of drones for city logistics has been increasingly studied and analysed by research and industry. An examination of the findings in the literature indicates that drones have proven to be a useful and added-value tool in the most diverse fields. However, the importance of the citizen's perspective has still not been sufficiently incorporated into the deployment of urban air mobility systems. This paper seeks to contribute to a better understanding of the interaction between public knowledge and the awareness of, and engagement with, drones, alongside the concerns and support for their use in city logistics. A survey was carried out in Portugal of the citizens with a view to better understanding their attitude towards such a goal. The survey revealed a positive attitude towards the use of drones in city logistics and that socio-demographic characteristics, namely gender, education level, job occupation, age, and home location are not directly correlated with citizens' attitudes. Moreover, citizens revealed that they favour a potential environmental benefit over a reduction in delivery time, which they would be willing to pay for. The policy implications derived can help develop the knowledge of public perception about drone usage for transport-related tasks.

Keywords: door-to-door transport; urban air mobility (UAM); advanced air mobility (AAM); city logistics; public acceptance

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1. Introduction

Individual online shopping habits have changed, forcing manufacturers and retailers to adapt their services to new demand requirements and leveraging the widespread use of technology and customer data [1]. The growth of e-commerce, aggravated by the lockdown, has transformed the distribution of goods [2] and has led to rapid and on-time delivery by a larger number of vehicles in urban areas [3,4]. E-commerce has proved throughout the pandemic its ability to adapt to customer-centric services and this has led to increased profitability, the expansion of customer bases, and added-value alternatives in ordering goods [5–7]. The increased complexity and variety of demand processes, boosted by e-commerce, have led retailers and logistics operators to offer a wider range of delivery channels and solutions that ensure faster, cheaper, and more flexible services [8]. Added to this challenge, in which the main structure is mostly achieved through digitization [9], operators must keep a competitive edge in the sector through increasing incorporation of emerging vehicle technologies and methods that meet the European Commission's environmental targets.

Due to the growing number of goods vehicle movements in urban areas, intensified by the ever-increasing trade volumes of e-commerce, modern cities are facing congestion, lack of public space, and relevant impacts of air pollution and noise. Moreover, customers have small-package delivery demands and different availability schedules widely distributed spatially, which makes last-mile distribution a complex issue and a bottleneck for traditional freight transport. Under such a scope, conventional vehicles, such as vans and trucks, are

no longer entirely appropriate for delivering packages to individual customers in urban areas. To cope with this situation, technological innovations able to raise vehicle energy efficiency are required along with the implementation of new technologies and engines for clean road transport.

The increasing request for new vehicle technologies and driverless vehicles for last-mile deliveries is contributing to the emergence of uncrewed aerial vehicles (hereinafter referred to as drones), correlated to e-commerce-sourced deliveries [7]. Although the feasibility and legislative approvals of these solutions are still being explored and analyzed [10], cargo drones are already being manufactured and the technology is being upgraded to respond to operational requirements [11,12]. Cargo drones can carry small-sized and lightweight packages in response to the smaller, fragmented, and frequent deliveries generated by e-commerce [7,13]. The lower aggregation of demand results in an increase in the number of vehicles in circulation, the distance traveled, and, consequently, the operational energy requirement and related environmental burdens [4]. In extreme situations, emerging vehicle technologies and the replacement of vans that are poorly consolidated can play an important role in optimizing the system benefits from both an environmental and economic perspective [7].

In addition to the technological and operational challenges, cargo drones must also deal with the crucial factor of social acceptability. Social acceptability relates to the public perception of the positive and negative impacts of the solution in their lives. A range of factors can affect public perception, namely privacy issues, security, safety, public disturbance, cost, environmental pollution, and economical effects [14]. As stated by [15], the form that drones will be adopted in city logistics, as well as respective regulation, is still to be determined and, therefore, there is not enough precision on the volume of traffic likely to be generated, operating parameters, and locations of the respective supporting infrastructures. The lack of a clearly defined supply or delivery system renders it impossible to identify citizens' concerns, as it is not clear what policymakers are asking the public to accept [16]. To fill this gap, it will be necessary to carry out studies and implement initiatives that allow for better knowledge of non-expert attitudes toward the policy under assessment.

This paper attempts to analyze the public perceptions and responsiveness regarding the use of cargo drones for moving toward low-carbon logistics. The work is supported by a survey that explores the perspective of non-experts as to the future integration of drones into transport systems.

The remainder of the paper is organized as follows. Section 2 provides a review of studies on the application of drones in city logistics, under heterogeneous approaches that include both the technological perspective (including competitiveness and an operational and environmental assessment) and the social acceptability reflecting the perception of citizens towards the emerging solution. In Section 3, a survey on the citizens' perspective on the use of drones for home deliveries is presented, followed by the respective analysis in Section 4. Finally, Section 5 concludes the paper by presenting the policy implications derived based on public perception of drone usage for transport-related tasks.

2. Literature Review

Research and industry have looked at the potential applications of drones in a wide variety of fields and market niches with the aim of meeting civic and industrial challenges. Most of these systems are still in the early stages [15] but the advances and continual development of drones open up considerable potential and opportunities for application in many areas [17]. The diverse drone applications have in common the ambition of developing an autonomous flight system that will reduce the cost, time, labour level, and/or complexity of operations [18]. Applications include, among others, the use of drones for inspection of power facilities and structures [19,20], archaeological prospection [21], agricultural and farming [22], conservation, surveillance and monitoring [23], humanitarian logistics [24,25], emergency care and deliveries [26], security/disaster management [27],

and finally, the focus of this paper, parcel and cargo deliveries [28,29]. The corresponding literature is detailed and documented and presents a wide heterogeneity in terms of optimized objectives, solution methods, applications, and constraints.

The specific application of drones to city logistics has been increasingly studied and analyzed by academic research and industry [30]. From the operational perspective, as drones can maneuver and have autopilot and autonomous capabilities, such technical variations can affect the results of studies, which are dependent on the assumptions on technical capabilities, namely in what refers to the competitiveness with other modes of transport, varying levels of operational feasibility [31]. The authors in [27] state that the potential of drones can be increased when combined with other modes of transport, an argument that is also supported by [32], who present a review on the delivery with drones and state that joint deliveries with trucks and drones yield higher flexibility in terms of delivery systems and decrease delivery times and associated costs. When comparing the costs of trucks and drones, [33] estimate that the cost savings of delivering vaccines by truck exceed the fixed cost required to create a drone infrastructure for that purpose. These outcomes are dependent on technical assumptions, about which there is a considerable lack of practical validation. Despite the considerable level of uncertainty regarding operational feasibility, technical competitiveness with other modes of transport, and market conditions, the industry is testing drones (e.g., Amazon) with a view to increasing customer satisfaction by reducing delivery times and costs [32].

The European Commission's environmental targets have led academic research and industry to pursue the integration of crucial concerns with respect to environmental assessment. Similarly, to what is observed in the technical feasibility studies, the assessment of the impact of drones on the environment can lead to dissimilar results biased by the chosen variables and assumptions from the performed analysis [34]. In [34], the author quantifies the potential effectiveness of drones for reducing CO2e lifecycle emissions in comparison to conventional diesel vans, electric trucks, electric vans, and tricycles (including both the utilization and vehicle production phases). Results indicate that drones are more CO2e efficient for small payloads than conventional diesel vans on a per-distance basis. Considerably different results are obtained when customers are grouped in a delivery route. In such conditions, drones are not more CO2e efficient than tricycle or electric van delivery services. In [35], the author compared the energy consumption of drones with diesel and electric trucks in a unimodal distribution system and through simulation, concluding that, for areas with high customer density, drones have a higher energy consumption than diesel and electric trucks. In the exceptional cases of rural and low-density demand areas, drones proved to have a slightly lower energy consumption. This analysis was based on the drone mission profile and, consequently, the energy assessment refers to the energy used throughout the operation, excluding variables and processes prior to that stage. The authors in [36] also studied greenhouse gas emissions and energy demand for package delivery drones and showed that deployments of drones can reduce greenhouse gas emissions if carefully deployed as an environmentally friendly alternative to traditional distribution and delivery methods. They highlight the importance of and need for more standard and systematic analysis in order to perform a more consolidated analysis on the topic, given that, when including the full drone delivery life cycle in the analysis, the delivery operation leg has the smallest environmental impact whilst most of the emissions result from other stages, such as the production of the drone parts [37].

The variability of the results described in the scientific references reflects the lack of consolidated arguments with respect to the competitiveness of drones vis-à-vis other modes of transport, operational feasibility, or environmental benefits. However, these are not the only fundamental factors that must be considered prior to the deployment of drones for cargo logistics purposes. The authors in [38] identified, categorized, and prioritized barriers to implementing drones within city logistics. These authors were able to identify regulations, privacy and security threats, public perception, environmental issues, technical aspects, and economic aspects as the main barriers to the implementation

of drones for cargo logistics. Policy regulation was the most critical obstacle, with the economic aspect revealed to be a less critical factor. Regulations restrict the parameters for drone operations, limiting them to certain airspace zones, and also set limits in terms of proximity to infrastructures and citizens while ensuring safe compatibility with air traffic, which can reduce the convenience of their usage. Regulations are also the most effective tool for guaranteeing that public perception is considered in the operation of drones [33]. In [28], while also looking at potential barriers and problems, respective solutions, and the expected benefits of drones for parcel and passenger transportation, the authors concluded that social benefits and public involvement should be the basis for the deployment of drone systems. Recent studies have explored public involvement in both a range of drone applications and specific use cases and indicate concerns that focus on privacy and safety, and differences have been observed in levels of acceptance by different demographic and stakeholder groups [15]. The authors in [39] present a survey on the public acceptance of drones in Germany, reaching the conclusion that citizens were not in favor of utilizing drones for public leisure, package delivery, or advertising but they approved using drones for research, rescue missions, and civil protection. The research in [40] had similar results when the authors carried out a survey in Singapore. They concluded that applications such as search and rescue, wildlife reserve management, disaster management, and monitoring atmospheric conditions have a higher acceptance rate, while there was a lower support rate for moving people, videography, and issuing speed and car park tickets.

Moreover, examination of the findings in the literature would indicate that, although numerous papers have recently been published in which drones have proven to be a useful and added-value tool in different fields of application, the importance of the citizen's (and non-expert's) perspective is still not sufficiently incorporated into the deployment of urban air mobility systems [41]. The literature review presents outcomes regarding competitiveness with other modes of transport, operational feasibility analyses, and environmental assessment practices, although most of those results refer to technological issues. The deployment of drones for cargo logistics is not a merely technological challenge analyzed by technical experts; citizens (non-experts) must reflect their attitude and acceptance towards such a solution in order to provide guidance for authorities to translate those concerns into regulation. This paper seeks to contribute to a better understanding of the interaction between public knowledge, awareness, and engagement with drones, and the concerns and support for their use in city logistics. The policy implications derived can help develop the knowledge of public perception about drone usage for transport-related tasks.

3. Citizens' Perspectives on the Use of Drones

Research on public acceptance tends to take place in the post-commercialization phase of new technology when public concerns begin to emerge. Therefore, it is needed to encourage the proactive effort to identify public perceptions and values prior to commercialization when strategic decisions have not been made and the public can participate in the research and development process. Public acceptance should be ruled by three typical principles: (a) public knowledge, (b) awareness, and (c) engagement. Public knowledge entails that information about drones should be communicated in a correct, user-friendly, and timely manner, and include, in a transparent manner, the key concerns and perceived risks surrounding the usage of drones and how legislative levels will include their concerns. The better people are informed about the possible risks, the more they accept the use of drones if the benefits outweigh the risks. Awareness means that there is a need for targeted outreach and public awareness efforts regarding the extended functionalities of drones and their capacities. Engagement means that the affected individuals are part of the policymaking discussion and can influence the decision-development process. All in all, attitudes of the public about drones, in general, are not stable and can easily be altered by how and when the subject is introduced. Asking people about their views on the acceptability of new technology such as drones is not only about obtaining their favorite technical features or perceived risks but recognizing that there are normative and political priorities as well.

3.1. Methodology

In this paper, the authors tried to explore the perception of citizens (non-experts) on the use of drones for city logistics through the implementation of an online survey. To the best of our knowledge, it was the first Portuguese survey on the topic.

The survey constituted 30 questions and was disseminated through online channels between 23 March and 9 May 2022. Questions were binary, not including the options of different levels of acceptance or agreement.

The questions of the survey were designed with the goal of shedding light, among others, on whether characteristics such as gender, education level, occupation, age, home location, and online shopping habits contribute to the attitudes of public perception on drones for city logistics purposes and if the perspectives of non-expert and expert individuals differ (in what refers to competitiveness, operational, and environmental aspects). The survey also tries to clarify what are the benefits and risks that citizens identify in such technology, whether they support public investment in operational infrastructure, and their acceptance of drones flying over their residential homes.

3.2. Participation and Survey Results

The sample was conducted online and, therefore, using random location sampling. The authors sent the survey to mailing lists and other online channels, reaching 2000 individuals. The response rate was 15%, with 300 respondents completing the survey. Results had a confidence level of 95% with a margin of error of 5.22%. In all, 80% of the sample was from the four most populated districts (Lisbon, Porto, Coimbra, and Aveiro). The widespread location of the respondents and the size of the sample do not allow us to unequivocally state that the respondents represent a specific residential district.

Some 45% of the sample are female and participants' age spanned from 16 to 62 years. Plus, 23% are aged between 16 and 21 years old (Generation Z), 58% are aged between 22 and 41 years old (Generation Y), 18% are between 42 and 61 years old (Generation X), and 2% are over the age of 62. In addition, 65% have a university education. A total of 42% are students and 43% work full-time with a contract.

In their responses, 42% of respondents prefer to go to a store to buy their products, while 24% prefer to do so online, and the remainder does not have a preference. There is no correlation between the preference in terms of online shopping versus physical purchasing and the respective education level of the buyer or their job/occupation. Respondents who do not buy online mostly choose that option due to a preference to visit the physical store (37%) and security concerns (18%). Respondents that buy online mostly do so for reasons of convenience (65%) and product diversity (43%).

A total of 90% of respondents stated that they bought products online in the last year and 45% of those were female. Some 92% of online buyers stated that they were satisfied or very satisfied with their online shopping experience. There is no gender correlation regarding the satisfaction level with online shopping.

A total of 84% of respondents who bought products online stated that they did so sporadically up to four times per year (40%) or irregularly up to once per month (44%). Some 12.5% buy online products at a frequency of once per week and 2.5% do so two or more times per week. A total of 67% of online buyers have a university degree but there is no direct correlation between the frequency of online shopping and the education level. Online buyers are mostly students (43%) and people working with full-time contracts (42%). Some 92% of students stated they buy sporadically or irregularly, whilst 81% of workers with a full-time contract have a similar frequency pattern. Some 85% of online shoppers purchase products through the brand websites, 51% stated that they use platforms such as Amazon and eBay to meet their demands, and 42% order on-time groceries and takeaways online. The share of online buyers that use hypermarket websites or apps is 21%, while 19% stated that they use C2C platforms, and 12% use marketplaces on social networks. Some 74% of online shoppers state that they used platforms to purchase clothes, shoes, and accessories, while 50% have bought technology and software. Books and music players

were acquired online by 42% of the respondents, cosmetics by 32%, sports by 29%, home furniture and decoration by 17%, and pharmaceutical products by 12%. Online shoppers indicated that home deliveries are mostly carried out by vans (68%), motorbikes (26%), and trucks (19%). The significant share of motorbikes has to do with the increasing market for food delivery on demand.

As far as the use of drones to deliver cargo ordered online is concerned, 21% of female respondents were aware of this, while for men a more substantial share (50%) was registered. While 33% of respondents are aware of the use of drones in city logistics, no direct correlation was established between this knowledge and the respective education level. Students and workers on a full-time contract are those with greater familiarity with drones, although there is no direct relationship. Some 71% of respondents say that they would use drones for home delivery if that option existed at the same fee as the business-as-usual logistics fee. This share would significantly decrease to 45% if the service would be faster than other modes of transport but that implied an additional fee. Results revealed to be statistically highly significant, as $p < 0.001$, and are similar to the ones referred by [15], include a share of 64% of respondents supporting the use of drone deliveries. A higher percentage of respondents (69%) would accept paying an additional cost if the service were more environmentally friendly than other modes of transport and 66% would accept it in exchange for greater flexibility in choosing the delivery location and schedule. There is no direct correlation between this potential acceptance and the educational level or occupation. When trying to understand what the monetary fee for such a service should be, 24% stated they would pay up to EUR 0.99, 35% between EUR 0.99 and 1.99, 18% up to EUR 2.99, and 3% consider it would be worth more than EUR 3.00 per delivery. There is no direct correlation between this potential acceptance and the educational level or occupation.

Concerning the potential for public acceptance in cities, the survey asked if respondents considered that there were benefits of using cargo drones for cities and citizens. Respondents were also asked if they would accept drones flying over their houses with the purpose of delivering goods. Some 76% are of the opinion that drones for city logistics purposes can have positive impacts on cities and citizens, and 62% would accept drones flying over their homes in their area of residence. In addition, 70% of respondents say that traffic reduction is one of the main benefits of the use of drones in cities. A reduction in pollution is highlighted by 65%, followed by a reduction in delivery time, highlighted by 47%, and both noise and accessibility, highlighted by 29% for each. Despite recognizing the value for cities, only 52% believe that the infrastructure for drones should be built with public investment. There is no direct correlation between this potential acceptance and the educational level or occupation.

4. Analysis of Results

The survey characterized the respondents based on gender, education level, occupation, age, and home location. These characteristics were not identified as being representative in justifying the attitudes in terms of public perception of drones for city logistics purposes. Most of the respondents have a university degree, which can be explained to some extent by the fact that the topic of the use of drones for city logistics is still not a familiar one for a significant number of the survey recipients. The survey was disseminated online, which contributed to students and workers with a full-time contract, aged between 16 and 61 years old, making up the highest share of respondents.

More respondents prefer to buy their products at the store over online shopping, but one-third of respondents do not have a preference. Respondents who purchase products online are satisfied or very satisfied with online shopping but most are not frequent shoppers. Most online shoppers have a university degree and occupations that imply a more probable and frequent usage of smartphones and computers. The channels used for online shopping and reasons for online shopping are diverse but there is a preference for certain products, namely from the fashion and technology sectors. Moving such products using drones will depend on the intrinsic characteristics of the parcel to be delivered.

However, the significant share of current deliveries made by motorbikes, associated with small-weight parcels, can be an interesting niche for drone usage. Most respondents state that they would use drones for home delivery if that option exists without any additional cost when compared to the business-as-usual logistics fee. If the service were to be paid for, then respondents clearly value the environmentally friendly side of using drones more, as well as the flexibility of delivery that it can assure rather than the speed of the transport. This factor should be highlighted, as it differs from the perspective of experts, who value travel time as the basis for the competitiveness between modes of transport. The fact that respondents would accept paying for deliveries if this meant an environmental benefit, with many of them even opting for higher payments, would seem to reveal that if drones can demonstrate that they are less harmful to nature, their public acceptance could be higher.

In terms of the potential for public acceptance in cities, most respondents consider that drones for city logistics purposes can have positive impacts on cities and would accept the area of residence to have drones flying over their homes. The high acceptance revealed by respondents is higher than expected and seems not to value the visual intrusion and noise that have been identified as crucial points of discussion in similar studies. Despite recognizing the value for cities, respondents do not fully support public investment in building the required infrastructure for drones. Considering citizens recognize the benefits of drones for cities, such a position might reflect priorities in the perception of non-experts regarding public investment areas. However, as the survey did not specify the type of infrastructure needed to support the use of drones for city logistics, this can have an influence on respondents' perceptions about its magnitude and needed investment.

Overall, the survey results on citizens' views towards the use of drones for city logistics revealed a positive attitude towards this goal and revealed that the selected socio-demographic characteristics, namely gender, education level, job occupation, age, and home location are not directly correlated with citizens' attitudes.

5. Conclusions

The paper endeavors to provide a perspective from citizens, who are also non-experts, on the use of drones for city logistics. The survey revealed that citizens consider that drones for city logistics purposes can have positive impacts on cities and that they would accept drones flying over their homes in their area of residence. These results can form the basis for further actions from cities towards the integration of urban air mobility infrastructures in transportation networks, in line with the current environmental goals set by the European Union. The fact that urban space is limited on the ground and in the air makes it difficult to meet the needs of all stakeholders. The deployment of urban air mobility solutions must be user-centric, which in the case of cargo deliveries by drone, means having considerable knowledge of citizens' perspectives. The fact that while citizens recognize the benefits of drones for cities, they do not fully support public investment for building the required infrastructure, indicates that such activities are still not considered a priority or that the precepted magnitude of the investment is higher than the one that citizens are willing to accept.

Citizens perceive a potential environmental benefit that they are willing to pay for. Their focus is not on the delivery time but on the environmental harm or lack thereof. Added to the significant number of low-weight parcels delivered by motorbikes, this fact can represent a potential niche market for cargo drones.

Nevertheless, despite the originality of the results of the survey, namely with regard to the primary focus on the environmental benefit and the lack of a representative influence of the selected socio-demographic factors on the attitudes of citizens towards cargo drones, this study does contain a few limitations: Firstly, the empirical evidence is based on one region and results, and policy recommendations, could be different in other countries. Secondly, the survey dealt with the potential of drones for city logistics purposes only and did not correlate public acceptance with other delivery methods, accordingly, the results are only valid for this application. Thirdly, the survey quantifies the monetary

effort that citizens are willing to make so that the service is environmentally friendly but did not establish how that result could be reflected in the drone design and technology development. Future research could aim at extending this present study with regard to the aforementioned limitations. Additionally, we propose the conduction of comparable studies in different locations and circumstances. From a methodological point of view, it would be interesting to take a more holistic approach and try to define how these results can be incorporated both into drone design and in terms of urban policies. Drones must be designed so that they are acceptable to the citizens, not the other way around.

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