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Spatial Premises and Key Conditions for the Use of UAVs for Delivery of Items on the Example of the Polish Courier and Postal Services Market

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Abstract: The use of unmanned aerial vehicles (UAVs) in the delivery of courier and postal items has the potential to provide benefits in breaking down terrain barriers and reducing congestion in urban areas. In addition, the trend to move away from polluting fossil fuels prompts delivery companies to invest in low- and zero-emission means of transport. Electric UAVs reduce environmental contamination in the delivery area and can also be directly powered by renewable energy sources. The aim of this study is to identify the premises and conditions of UAV implementation on the example of companies delivering courier and postal items in Poland. The basic research methods used for the preparation of this study are critical analysis of the literature on the subject, synthesis, and generalisation, which led to the authors' own research conducted through partially categorised oral interviews. The conducted considerations confirm the existence of premises and the ability of UAVs for the effective delivery of items. In Poland, the most important limitation in the implementation and dissemination of this delivery method is the high level of social scepticism, reaching 43%. If actions are not taken to neutralise this attitude of society, this factor may effectively prevent the use of UAVs for delivery services.

Keywords: congestion; UAV; delivery of courier and postal items; social acceptance for UAVs

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1. Introduction

The main centres of economic development of contemporary countries are agglomerations with their surrounding functional areas. Their spatial expansion, intensification of individual transport, and progressive separation of places of residence, work, and services, inevitably cause a decrease in the efficiency of the transport system. The basic manifestation of such inefficiency is transport congestion defined as mutual obstruction of traffic by vehicles due to the existing relationship between the speed of moving vehicles and the volume of flows under the conditions of infrastructure capacity depletion [1]. In scientific terms, this phenomenon has been studied at least since the mid-20th century, with early research on congestion focusing more on technical and organisational problems, based on the technical sciences [2]. Nowadays, there are also economic research projects, which, among other things, seek to determine the economic effects of congestion, including an estimate of losses [3] due to delays, increased operating costs, pollutant emissions, and numerous traffic disruptions. The direct effects of congestion can, therefore, be of two types—operational and economic. The former results from a mismatch between the demand for objects of transport infrastructure objects in the city with its ability to ensure free movement, while the latter arises when it starts to affect transport costs [4]. It should also be pointed out that these effects must be taken into account in the efficient management of urban space.

The losses resulting from the extension of the transport time are borne both by the companies that use cargo transport services and those that provide these services (haulage companies, logistics operators, courier firms, etc.). Congestion delays the delivery of goods, and uncertainty about its timeliness makes it necessary to maintain increased stocks and even to expand warehouse space. The protracted time of transport also results in longer freezing of capital in the cargo, increasing the related costs of transport [5]. Extending the duration of the transport service means that drivers make a smaller number of trips, serve a smaller number of customers, or cover a shorter distance, while remaining longer in the city transport system, thus increasing its load and reducing its passability. For the transport company, this results in the need for more drivers and an expansion of the vehicle fleet, and for the city, an increase in the load on its road network and higher public transport costs. Congestion is, therefore, a major disruption that undermines the efficiency and effectiveness of the supply chain [6].

The time spent in traffic jams is not used productively, so it is a cost of lost profit. According to a report published in 2017 by the European Commission (a study report on urban mobility in terms of urban accessibility), the loss due to this in the European Union was estimated to be more than EUR 155.7 billion per year, equivalent to 1.09% of EU GDP [7]. Calculations in the report 'The Future of the Last-Mile Ecosystem' [8] show that by 2030, in the 100 largest cities in the world, the number of delivery vehicles will increase by 36% and exhaust emissions by 32%. Despite the fundamentally positive trends in the pursuit of reducing greenhouse gas emissions in the EU, it is the transport sector, along with the energy production industry and the combustion of fuels by users, that is the most responsible for the persistence of unacceptably high levels of greenhouse gas emissions, and is the only large emitter of CO_2 that increases these emissions [9].

In this context, it is very important to take measures to stop congestion. Practice shows that attempts to reduce car traffic by favouring public transport and cycling, which involves setting aside dedicated lanes for them, contribute to worsening the traffic situation [10]. Such measures reduce kerbside unloading space and access times, as well as the overall loss of logistics land in city centres. Intensive urban transport infrastructure development is also not a fully effective solution. Cities are increasingly experiencing a deficit of space, especially in city centres, resulting in a high capital intensity of this type of investment. In addition, the allocation of this space for transport purposes eliminates the possibility of using it for other important functions, thus contributing to the deterioration in the quality of life of the inhabitants. Counteracting congestion by creating new transport infrastructure may even strengthen the already existing transport problems. According to the Lewis–Mogridge position, almost every section of a modernised road is automatically filled by drivers, which results in further traffic congestion [11].

One method to reduce congestion may be the use of unmanned aerial vehicles (UAVs) as a transport alternative to wheeled transport. This technology has been intensively tested in recent years, and the experiments so far indicate that its mass implementation requires further in-depth theoretical studies as well as practical experiences. The main subject of the considerations in this study is the analysis of spatial premises and conditions for the mass use of UAVs by courier and postal companies for servicing individual customers.

The current state of knowledge on the subject presented in the following parts of the article allows us to state that technological and legal aspects of the UAV market functioning have already been studied to an advanced degree. It results from the fact that UAVs have reached technological maturity and many countries, including EU member states (Poland being one of them), have already adopted regulations allowing commercial use of UAVs by courier and postal companies. It is only a matter of time before the regulations are supplemented by national implementing acts. This statement exempts the authors from discussing this issue in more detail.

A thorough analysis of the functioning of the UAV transport market shows that less importance has been attached so far to the identification of its market, as well as its economic and environmental conditions, and the context of social barriers is almost completely

neglected, both in scientific research and in the practical operation of companies active in this market. The latter phenomenon may soon constitute the most serious limitation in the development of UAVs due to social fears about the revealed inconveniences of their use and the existing possibilities of using them for surveillance conducted by state services or commercial entities.

The above diagnosis was used to construct a research programme containing the use of the results of theoretical and experimental studies carried out worldwide in the field of market research and economic and environmental conditions, while in the case of social conditions, detailed field research proved to be necessary. For this purpose, synergic interdisciplinary research referring to the methodology of economic, sociological, and historical sciences was applied. Their main task was to establish the level of social acceptance for the new service and to diagnose the main fears related to its use. The results made it possible to formulate initial recommendations, both for companies providing the service and public entities perceiving benefits from its dissemination, such as municipal, self-governmental, and state administration.

Geographically, the subject of the authors' considerations is Poland, which is a country with a dynamically developing courier market and rapidly growing transport needs and, at the same time, with a relatively poorly developed infrastructure in this respect. According to the European Commission's 2017 report indicated earlier, congestion costs in Poland reached a total of EUR 7.2 billion (internal costs EUR 6.4 billion + external costs EUR 0.8 billion). In total, these losses accounted for 1.94% of Polish GDP, which is almost twice as high as the average in the European Union. It should be noted that 68.5% of congestion costs in Poland were generated in urban areas [7]. Such a high share of those costs, reflecting high road congestion and limiting transport accessibility, inevitably leads to the deteriorating competitiveness of big cities. As these cities are growth poles for their surrounding areas, this consequently poses a threat to regional development.

An additional factor justifying the choice of Poland as a subject for consideration is the level of environmental pollution in major cities, which is the highest in Europe and still has an upward trend. In a 2020 ranking of the 50 most polluted European cities, 36 of them were in Poland on an updated list published by the WHO (up from 33 on the previous ranking). In Poland, 72% of cities violate the EU's air quality target [12].

It is difficult to expect this situation to change in the near future because Poland belongs to the group of countries with the lowest proportion of electric vehicles among all vehicles (0.1% with the EU average at 1.1%) and, at the same time, has one of the highest ratios of the number of cars per 1000 inhabitants (662 with the EU average at 560) [13].

2. The Basis Idea

The acronym UAV, formed from the words unmanned aerial vehicle, is used in most English-language official and scientific documents. UAVs are also referred to as drones, unmanned aircraft systems (UASs), flying robots, aerial platforms, multirotors, or multicopters. The origin of their use dates back to the 19th century [14], but it was not until after World War II that the use of improved vision, navigation, and electronic systems significantly increased the capabilities of these devices to such an extent that it became reasonable for them to be widely used in practice [15]. In the early days, the main user of UAVs was the military, but since the 21st century, these devices have increasingly begun to find use in civilian services, for research purposes, and in the commercial sector [16–20].

The most common civilian use of UAVs is to collect information through a variety of sensors [21]. Progressive improvements in UAV performance, however, have resulted in increasing efforts to implement them also for civilian transport needs since the beginning of the 21st century [22,23]. Currently, there are four concepts for such UAV use: delivery of goods in rural and hard-to-reach areas, parcel delivery within the first and last mile, catering in urban areas, and automation of intralogistics in factories and warehouses [24]. For courier and postal companies, the attractiveness of the use of UAVs, relative to current delivery methods, is primarily considered due to their ability to efficiently and quickly

overcome physical barriers, including bypassing congested, often poor quality roads. To be sure, a necessary condition for the uptake of this form of delivery is its financial viability [25].

Generally speaking, two basic applications of UAVs by courier and postal companies emerge from past practice. The first use is mainly flights dedicated to the service of items with a specific content (e.g., medical articles, newspapers), often performed over long distances and over terrain troublesome for road vehicles. The second use is the handling of the so-called last mile in terms of delivering the recipient of light loads within a range usually not exceeding several kilometres. Countries in which the first indicated use of UAVs by courier or postal entities has been identified include, among others, China [26], France [27] Indonesia [28], Ireland [29], Canada [30], Kazakhstan [31], Germany [32], Russia [33], Switzerland [34] and the USA [35]. A noteworthy example is Kazakhstan, where, in 2018, the public postal service (Kazpost) delivered more than 11,000 kg of magazines by UAV to 150 towns and cities.

With regard to the second use of UAVs by courier and postal companies, i.e., last-mile service, advanced test work in this field is being carried out, among others, in Australia [36], China [37], Cyprus [38], Iran [39], Ireland [40], Qatar [41], Japan [42], Thailand [43], Germany [44], and the USA [45]. Despite the undoubtedly significant development potential of the use of drones in handling last-mile deliveries, it must be noted that their deployment to serve the market is still in its early stages. To a large extent, this is to be explained by the need for the state to ensure both adequate regulation and a system of management and control of the airspace in which numerous delivery UAVs would operate. Indeed, the mass integration of UAVs into the economy requires ensuring their coordination similarly to road traffic [46].

The above-presented examples of the serious interest of courier and postal companies in the use of UAVs for the needs of transport of items require both the identification of key conditions of this implementation and the prioritisation of their significance. It should be pointed out that in its basic, functional dimension, the essence of services offered by courier and postal companies comes down to the transfer of items from a sender to the addressee, whereas quality parameters of these services and technologies used for their provision are subject to differentiation. A characteristic feature of the contemporary market of courier and postal services is the intensive digitalisation of logistic processes and the support of service provision through the use of robotics and automation, especially for simple and repetitive, undemanding logistic activities, which significantly relieves employees and, at the same time, is a solution to the problem of labour shortage.

Providers of courier and postal services, responding to the needs of their customers, often specialise in a specific group of ordering parties: business or individual customers, and in the subject-matter system, first and foremost, in the service of e-commerce, insurance, telecommunication, medical and pharmaceutical, automotive, advanced technologies, publishing, advertising, and financial industries. The medical and pharmaceutical industries are a serious challenge for these companies due to the specificity of transported products requiring special conditions of transport and storage and in terms of ensuring the safety and timeliness of deliveries. Currently, there is a shift in demand from services with the shortest possible delivery time to standard services with a longer but guaranteed delivery time.

Bearing in mind the social and institutional pressure to take measures related to environmental protection, the business strategies of courier and postal companies more and more often take into account economic goals, as well as environmental measures compliant with the concept of sustainable development. The trend to move away from polluting fossil fuels forces courier and postal entities to invest in low- and zero-emission means of transport [47,48].

In Poland, as required by EU law [49], the supply side of courier and postal services consists of universal service operators, i.e., obligatorily offered throughout the country under price conditions regulated by the state, and alternative operators, operating on free market principles. At the end of 2020, 290 entities were registered in the state register of

courier and postal service providers [50]. Table 1 presents the value of revenues, number of services, and their relative shares between 2017 and 2020, by main delivery service type [50,51].

Table 1. Courier and postal services in Poland in 2017–2020 in terms of quantity and value.

Type of Service	2017		2018		2019		2020		Change 2020/2019	Change 2020/2017
Volume in million pieces and relative shares										
Courier items	308	18%	369	21%	441	26%	640	37%	45%	108%
Letter items	1353	80%	1372	78%	1246	73%	1.055	61%	−15%	−22%
Postal parcels	26	2%	23	1%	24	1%	30	2%	19%	15%
Revenues in million EUR and relative shares										
Courier items	912	51%	1065	54%	1187	55%	1575	63%	33%	73%
Letter items	765	43%	826	41%	866	40%	813	33%	−6%	6%
Postal parcels	101	6%	102	5%	108	5%	104	4%	−4%	7%

As can be seen from the data presented in Table 1, the developing segment of the delivery services market in Poland is the segment of courier items, whose dynamic growth is a consequence of the increasing volume of goods delivered purchased in bulk on the e-commerce market. Courier items, despite higher prices than letters or postal parcels, are chosen for delivery of goods in e-commerce because of the more convenient form of sending and delivery, and usually shorter delivery time than in the case of traditional postal services.

According to forecasts, still before the COVID-19 pandemic, the courier services segment in Poland will be one of the three fastest-growing in Europe in the coming years [52]. It was predicted that in 2023, courier operators will serve nearly 850 million parcels, which means a doubling of the volume of parcels in five years and an average annual progression of 11% [53]. In fact, an increase of 34.8% was achieved in 2020, compared with 2019. According to the current forecasts, the volume in this sector will increase by a total of 72% in 2020–2023, an annual average of 19.7% [54].

The subjective division allows distinguishing among the following companies offering courier and postal services in Poland:

- The Polish national postal operator Poczta Polska, legally obliged to provide public services;
- Five companies with global reach: DHL, UPS, FedEx, DPD, and GLS;
- A purely national operator InPost with foreign capital (Advent International);
- Companies with local coverage or specialising in logistics services for a selected group of customers;
- Brokers bringing together offers from at least several courier companies.

The seven companies indicated in the above list by name held a 92.2% share of the courier services market revenue alone in 2020 [50].

Such a strong concentration of market shares in the courier and postal services market by just a few players is due to the fact that the past two decades have seen an intensification of the acquisition of domestic courier companies by globally operating companies. The increasing and individualised expectations of customers and the fact that companies operating in Poland usually use the services of several companies offering courier services stimulates these operators to continuously improve the quality of their services and to search for new, innovative operational and technological solutions in order to maintain their regular business partners and to attract new customers [55]. The strong market position and the resulting capital resources enable these companies to finance research and implementation of such innovations [56]. Regardless of this, the commercial orientation of their business also puts constant pressure on these companies to reduce the costs and time of logistics operations.

The costliest part of the item delivery service process, accounting according to various estimates for up to 28% [57] and even up to 40% [58] of the total cost, is the so-called last mile, requiring significant investment in manpower, the number of vehicles, and time. The basic and indisputable advantage of using UAVs for transport service is higher speed and certainty of delivery than in the case of using wheeled vehicles, limited by road capacity. In the light of research conducted in Poland in 2014 [59], 2018 [60], 2020 [61], the priority criterion for choosing a delivery service was not the price of the transport service but the timeliness of delivery. The indicated advantage of UAVs must, therefore, be treated as an important factor in building a possible market advantage.

The analyses conducted so far do not allow for unambiguous conclusions as to the scale of the possible reduction in last-mile operating costs through the use of UAV delivery services. Its estimates presented in the literature show a wide range, from 9% [62] to 70% [63], and even 80% [64], identifying savings primarily in terms of employee wages and road vehicle maintenance costs.

From the point of view of determining the scale of possible benefits, the most far-reaching seem to be the simulations carried out by Amazon. An experiment carried out by them allowed them to estimate the cost of a single delivery of a 2.5 kg parcel over a distance of up to 20 km by UAV at USD 1 [65]. At the same time, the price of a similar service provided by car by UPS was almost USD 13 and by FEDEX, USD 8 [66]. However, already a change in the parameters of the study produced dramatically different results. In the aforementioned study, one operator could simultaneously monitor between 10 and 12 drones. The subsequent test adopted a 1:1 ratio between UAVs and operators. The effect of this change was to increase the cost of delivering the same item to between USD 10 and USD 17, depending on the detailed parameters of the test [67].

Other publicised estimates for Amazon indicate that the use of delivery UAVs allows for a cost advantage of a third or more per parcel, compared with ground delivery [68]. Amazon's valuation of delivery costs was carried out in the simulated situation of using a multilevel distribution centre, referred to as drone beehives, for which Amazon obtained a patent in the US in 2017 [69]. In 2019, the results of a modelling framework using EU-wide high-resolution population and land-use data were published, confirming the viability of drone beehives in various European urban areas [22].

At this point, it is worth citing the results of yet another attempt to estimate the business case for the deployment of a last-mile UAV, which was performed on the example of a sorting plant in Brussels, distributing 60,000 items per day within the city. The simulations showed that for same-day delivery, the most cost-effective vehicles were e-vans, for which the delivery cost was around EUR 0.14, while for UAVs, this sum was calculated to be EUR 0.59. It is clear from this assessment that the higher payload capacity of a vehicle plays an important role in its efficiency. A car can (and usually does) deliver at least several items in adjacent locations, whereas a UAV has the capacity to deliver only one parcel at a time [70]. Furthermore, a UAV is not able to deliver cargo to all locations due to both the space limitations of the delivery point and the weight and size of the item itself. Nevertheless, in the scenario of express delivery within 30 min of ordering, UAVs become more competitive. In such a scenario, the cost of delivery using a UAV was expected to be EUR 1, while it increased to EUR 4.35 for delivery of an item by e-van [71].

Complementarily, the energy efficiency of using UAVs for the purposes in question should also be noted. The main argument cited in favour of UAVs is that they reach their destination by the evidently shortest route. Less prominent, however, seems to be the obvious argument that the energy expenditure of lifting objects is higher than the effort of overcoming friction and rolling resistance, as in the case of motorised transport. A 2017 Rand report [72] showed that UAVs, on average, used up to 10 times more energy than electric cars when delivering items in densely populated areas. This is because car couriers serving customers on a single street can stop and deliver several parcels on foot. UAVs, on the other hand, as indicated earlier, can only deliver one parcel at a time. This often drastically increases energy requirements. UAVs proved to be more energy efficient only in

sparsely populated rural areas. In the study cited above, a hybrid model, in which electric UAVs deliver the lighter parcels and traditional last-mile trucks handle the remaining deliveries, proved to be the most energy beneficial. The study found that if UAVs took over around 20% of deliveries, this would result in a net fuel saving of around 5.7%. However, transferring some deliveries to UAVs would have little impact on the energy intensity of parcel delivery. This situation is expected to change dynamically in the short term due to the decreasing energy costs of UAV use with technological advances [73].

However, the above considerations ignore another aspect of energy consumption related to the realities of moving in urban traffic. When comparing the energy consumption of UAVs, diesel vans, and electric cars, it turns out that electric cars consume up to 50% less energy than combustion-powered cars due to the fact that vans drive slowly in cities, constantly stopping and starting [74]. These factors are not relevant for UAVs. For them, wind conditions were crucial. If there was a crosswind, for example, the UAV used more energy to stay on course. In contrast, a tail or headwind can often have a positive effect on energy consumption. A UAV needs especially much energy when it has to stay in the air in one place, e.g., waiting for a customer to react.

As highlighted earlier, the delivery UAV is limited to visiting one customer during each flight and, upon returning to the warehouse, can only make another delivery after the battery has been replaced or recharged. The low efficiency of such a solution has led to the development of the last-mile delivery concept, which involves the synchronisation of the UAV and the delivery vehicle [75]. The base station of the UAV is then the roof of the delivery vehicle, and the driver of the vehicle loads the parcel into the UAV and directs it to the delivery point. While the UAV is operating, the courier can make other deliveries [76]. In 2016, the postal operator UPS successfully tested such coordinated UAV and truck distribution [77]. Empirical research has shown that, with today's technological advancements, making a coordinated delivery by a delivery truck and UAV is always more efficient than other solutions in terms of delivery time [78]. Simulations using continuous approximation modelling techniques further suggest that hybrid truck-drone delivery can be particularly economically advantageous with several drones working together with a delivery vehicle. However, these benefits are highly dependent on relative operating costs and marginal standstill costs [73].

It should be stressed that the estimates cited above require in-depth verification by business practice due to the primarily test dimension of UAV exploitation in courier and postal companies already indicated above. The above considerations indicate that wide use of UAVs as alternatives to traditional forms of item delivery in Poland may be treated as market justified and, in certain conditions, economically profitable.

The aforementioned conditions, related to the need for energy in transport operations, are directly connected with the high level of pollutant emissions that are its consequence. Overall, 15% of global CO_2 emissions are attributed to the transport sector, with the majority of these emissions caused by road transport [79,80]. Urban transport accounts for a large share. In the EU, it is estimated to be responsible for 23% of greenhouse gas emissions [81].

Demands to change this situation and improve air quality are particularly important in Poland, given the level of air pollution. It should also be pointed out that Poland is specific in that it has the second-highest number of cars per 1000 inhabitants in Europe (after Luxembourg). In addition, the share of cars over 10 years old exceeds 73% [82]. Measurements of pollution carried out in 2011 in Warsaw, the capital city of Poland, indicated that 63% of this pollution originates from transport, with 20% of this pollution caused by vehicle powertrains, and the remainder from the so-called secondary release (dusting), i.e., raising pollutants deposited on the roadway by passing cars in the air [83]. The pollutants that make up secondary release are mainly caused by the abrasion of tyres, brakes, and the road surface [84].

As UAVs are overwhelmingly electric vehicles, they are widely considered among environmentally friendly modes of transport. However, it has been shown in previous discussions that delivery via UAVs is generally more energy intensive than delivery by

wheeled transport. In this case, however, higher energy consumption does not necessarily mean that UAVs are less environmentally friendly. Even if, with today's level of technology and delivery organisation, they require more energy, especially in cities, they can be alternatives to wheeled vehicles. The advantage of implementing electric UAVs for transport purposes is a reduction in environmental contamination in the delivery area resulting from the reduction in reasons for its degradation other than energy consumption, as well as contributing to the reduction in diesel fuel consumption by trucks. In addition, the increased energy demand of UAVs, compared to cars, need not be a burden on the environment when using environmentally friendly alternative energy sources [85].

In the above context, it should be emphasised that electromobility, i.e., replacing combustion-powered cars with electric wheeled vehicles, seems to be a relatively much less effective method of reducing transport pollution than implementing UAVs that eliminate delivery vehicles from the roads. From a practical point of view, the beneficial changes in road traffic would of course only be significantly felt with the massive use of delivery UAVs.

A study published in 2021 on the impact of battery electric vehicles (BEVs) on greenhouse gas emissions in 29 European Union countries indicates that the reduction in energy consumption caused by these vehicles is not sufficient to mitigate greenhouse gas emissions in the European region due to the low share of BEVs in the fleet [9].

The number of cars of companies delivering courier and postal items in Poland in 2020 was approximately 30 thousand (authors' own estimate based on data published on company websites), which corresponded to 0.65% of all delivery vehicles driving on national roads. At the end of 2021, nearly a thousand cars of courier and postal companies were electric vehicles. The progressive replacement of delivery vehicles with low- or zero-emission vehicles in these companies seems to result from both legal and image-related reasons. In the first case, the EU-wide CO_2 emission standards for heavy goods vehicles, adopted in 2019, set stringent targets for reducing the average emissions of new cars for 2025 and 2030 [86]. On the other hand, companies are fully aware that consumers are increasingly often and more sensitive to their pro-ecological commitment manifested by care for the natural environment and work [87]. The reputation based on pro-ecological activities is a tool with which they are able to compete more effectively on the market for the favour of customers. To be sure, the effectiveness of these activities largely depends on the so-called ecological sensitivity of society, which is derived from its ecological awareness and maturity.

As indicated in the earlier consideration, although UAVs show great potential for parcel delivery, they are not yet widespread in commercial use; however, many companies have conducted pilot tests and are likely to make efforts to generalise their use in the future. Whatever companies decide, acceptance by potential customers appears to be essential to the success of such a venture [88]. Research attempting to identify customer attitudes towards this form of delivery is sporadically presented in the literature; moreover, only some of it can be considered representative, according to statistical rules, for the entire population from which the research sample was selected. In addition, this research was profiled for different specific purposes, which makes it difficult to collate its results.

Restricting ourselves to publications from the last decade, the first to point to is a 2014 US study using three different online survey platforms, which revealed that parcel delivery was the least supported use of UAVs across all areas of potential UAV use [89]. In a nationally representative online survey of 1465 people in the US in 2016, 44% of respondents accepted the idea of delivery by UAVs, 34% opposed it, and the remaining 22% were undecided [90]. In yet another online survey from the same year, 51% of US customers accepted parcel delivery by UAVs [91].

A nationally representative online survey of 2043 UK adults found that only 32% of its participants favoured the use of drones for deliveries, and at the same time, this was the second least preferred use of drones after passenger transport [92]. A 2018 telephone survey with 832 respondents from Germany examined, among other things, the level

of acceptance for 10 forms of civilian UAV use (catastrophe response, rescue operations, research purposes, monitoring of infrastructure, medical transport, agriculture, video news, leisure time activities, parcel delivery, video advertising). Acceptance was highest for catastrophe response and rescue operations, while it was lowest for parcel delivery and advertising activities. In terms of individual willingness to use UAVs, of the five purposes identified to respondents (first aid services, leisure time, parcel delivery, police and fire service, air taxi), it was lowest for parcel delivery and air taxi [93].

Among the identified research whose results have been published is also an online survey conducted in Poland in 2021 with 219 participants. Among other things, the survey asked about the respondents' inclination to choose the option of parcel delivery by UAV. 47% approved, 20% were reluctant, and 33% could not give an answer.

The presented results lead to the conclusion that courier and postal companies intending to carry out deliveries of items using UAVs face the phenomenon of low social acceptance for such activity. However, the problem is not merely a potential fear of unsatisfactory sales of UAV delivery services. This is because the flights made by UAVs cause both the customers served by UAVs as well as bystanders to experience the effects of the presence of this technology. Flying UAVs will disturb the silence and privacy of all people living in the served area.

3. Field Research

3.1. Methods

Referring to the results of the research presented in the literature, several aspects should be pointed out that diminish its usefulness for the analysis that is the subject of this study. Firstly, only a part of the research samples have the value of representativeness, and only these are generally suitable for making generalisations. Secondly, the passage of time is likely to have affected the perception of delivery UAV technology among the surveyed populations, so the results, especially of the most recent research, may differ from the current distribution of the characteristics surveyed in those populations. Thirdly, only the last survey presented was conducted in the territory of Poland, so only this survey considers the possible specificity of the population to which the UAV delivery under this analysis would be provided. Fourthly, all the indicated surveys were conducted online, with the exception of the German survey, which was conducted by telephone. People who actively use the internet have distinctive characteristics that include, among other things, more formal education and greater knowledge of technological innovations, as well as a greater willingness to use them than is the case for the general population [94]. It is safe to assume that this factor influences the results of the research.

The indicated premises strengthened the authors' conviction that it is necessary to carry out their own research with regard to the level of Poles' acceptance of delivery of items using UAVs. The research method used to collect the information in question from respondents was face-to-face interviews in a partially categorised form, which means that the researcher used a previously prepared set of questions with the possibility of changing the order of asking them and supplementing them with additional questions. The interviews were conducted openly, i.e., the interviewees were informed about the purpose of the interview and were aware of their participation in the research. The research was conducted with only one interviewee at a time, who was guaranteed anonymity. For the random selection of the research sample, an online statistical calculator and the randomisation function of the Excel spreadsheet were used. The following initial assumptions were made: 95% confidence level with 6% maximum error. This allowed the size of the intended group for the research to be set at 267 units. According to the authors, such a maximum error level ensures the possibility of obtaining quite a good orientation in the distribution of the examined trait while significantly limiting the sample size. This limitation was advisable due to the objective difficulty of conducting face-to-face surveys under conditions of the COVID-19 pandemic.

Geographically, the research covered the part of Dobra municipality directly adjacent to the Szczecin agglomeration (400,000 inhabitants). For the purposes of the research, a list of residential properties of this municipality was prepared on the basis of the spatial information system data made public by the municipality. The group of respondents consisted of adult residents of the properties selected for the survey. It was not possible to interview the residents of 78 of the properties drawn, with 53 cases due to refusal to participate. The items missing to fulfil the quantitative assumptions of the research were selected in supplementary draws.

The choice of Dobra municipality resulted from its features corresponding to the requirements of the planned research. The premises which guided this selection were as follows:

- The municipality is, in its essence, a suburban district of Szczecin, inhabited almost entirely by people professionally connected with Szczecin, as a result of which they experience permanent and intensive traffic jams;
- The vast majority of the municipality's buildings are single-family houses, on whose properties it is possible to set aside places for parcel deliveries using UAVs. The assumption was that only respondents who could consider the use of a delivery UAV as realistic would be invited to participate in the survey. Eurostat data shows that 56% of Poles live in single-family houses, and the trend is upward [95]. Residents of tenement houses, as they do not have backyard land or even a veranda, are, in Polish reality, a priori eliminated from the possibility of receiving direct deliveries by UAV to their home address. For UAV delivery, it is also impossible to use the roofs of tenement houses, to which, for architectural and safety reasons, access is very difficult in Poland for ordinary citizens;
- The municipality of Dobra does not have specific features that could be considered unique in Poland.

The survey was conducted in May/June 2021. Due to the need to maintain social distance, the survey was conducted with a resident of the property without entering the property. This situation imposed a requirement to absorb the respondent's attention as briefly as possible. During the survey, respondents were asked four basic questions, previously developed with the focus group:

(1) Does the respondent understand the idea of item delivery by UAV?
(2) What is the respondent's attitude to the delivery of items using UAV by courier and postal companies? The choice of answers included general acceptance, no acceptance, and no opinion.
(3) What arguments could the respondent use to justify their position expressed in response to question 2?
(4) If courier and postal companies started using UAVs to deliver items, would the respondent use such a service? The choice of answers was yes, no, and do not know.

3.2. Results of Field Research

To the first question, which was of a closed nature, 12% of respondents answered negatively, and in no case was this associated with a lack of a general idea of what UAV is. Moving on to the next question required the interviewer to give a synthetic explanation to respondents willing to continue participating in the study (seven people dropped out at this stage). To the second question, also of a closed nature, the distribution of answers was as follows: 38% indicated general acceptance of delivery of items using UAVs, and 43% showed no acceptance, while 19% expressed no opinion. The discussion of the third question, of an open nature, requires a wider reference. Grouping the most frequently given answers to the third question, it can be concluded that among the arguments raised by respondents accepting delivery by UAV, 83% of them considered it generally as an attractive innovation that they are willing to test. In fact, 27% of this group even showed enthusiasm by seeking to obtain information from the researcher when they would be able to use this service. Slightly more than half (54%) stressed the expected greater speed and

even the desired express dimension of such delivery. Almost one in four respondents (23%) regarded delivery by UAV as a positive manifestation of civilisational progress.

Respondents who negated the sense of using delivery UAVs in the first place indicated the lack of need for such a service. Such an argumentation was presented by 92% of the opponents of the use of this technology. Almost as many, 80%, pointed to the broadly understood potential disruption to peace, including interference with privacy, that flying UAVs introduce. For 17% of respondents, concerns were expressed about whether the UAV would crash or collide with another object, which could be a threat to life, health, and property. Four respondents signalled negative experiences with recreational UAVs.

Respondents who answered the second question that they had no opinion were informed that the third question did not concern them, although they could respond to it if they wanted to. Overall, 32% of the respondents in this group indicated that they did not have sufficient knowledge to take a position on this matter.

The answer to the fourth question was in principle fully predictable in terms of those expressing acceptance and not expressing acceptance for UAV deliveries. However, an interesting shift occurred in the group of respondents with no opinion. Indeed, the distribution of answers to this question was as follows: 41% would use the service in question, and 54% would refuse, while only 5% were undecided.

From the point of view of the level of acceptance/scepticism towards the delivery of items by UAV, the results of the conducted survey are in general similar to the results of previously presented, publicised findings. With the exception of the 2016 American findings, none of the analysed populations showed a majority share of accepting attitudes towards this form of delivery. Particularly worth highlighting in both Polish surveys is the difference—of up to 9%—in acceptance levels for delivery UAVs. This difference may confirm the distorting influence that limiting the selection of respondents to the population of internet users may have on the results of the survey. In conclusion, according to the authors, social conditions are the most serious and critical obstacle for the commercial use of UAVs by courier and postal companies.

4. Discussion

In Poland, a clear concentration of economic potential and population occurs in the most economically strong metropolitan areas, which determine the pace of socioeconomic development at the regional and national levels. Currently, significant disproportions can be observed between the transport needs and the possibilities of their implementation at the desired quality level. The condition of Polish roads and their capacity is a significant impediment for courier and postal companies, both in terms of ensuring the timeliness of deliveries and creating a logistic network.

As it has already been shown, the use of delivery UAVs has an unquestionable value from the point of view of urban spatial management. Their use can positively influence the reduction in vehicular traffic, especially in areas characterised by a large deficit of space, and also contribute to the reduction in environmental pollution. The use of UAVs in the service of transport is undoubtedly an innovative technology. At the current stage of development, this technology has reached implementation maturity, both from the point of view of design solutions [96,97], as well as the ability for autonomous, collision-free flight [64,98,99] and navigation precision [71]. Surely, it still needs further improvement, as indicated, among other things, by incidental accidents involving delivery UAVs [32,100].

As indicated earlier, the massive integration of UAVs into the economy requires ensuring the coordination of their use in air traffic. In Poland, as in the whole of the European Union, all aspects of airspace management and control in the field related to the operation of UAVs are referred to by the commonly accepted term U-space [101]. One of the most advanced systems in Europe called PansaUTM is responsible for the implementation of the U-space concept in Poland. This system provides electronic coordination of UAV flights and the creation of missions performed beyond visual line of sight (BVLOS). It is also flexible enough to evolve with future U-space legislation.

It should be added that from the beginning of 2021, common regulatory provisions for UAVs have been in force in the European Union countries, basing their operation on a risk assessment [102]. These provisions stipulate that, from the point of view of conducting commercial activities, the use of UAVs will, in most cases, be open to the public. The solution adopted allows individual states a great deal of flexibility in defining zones within their territory where UAV operation will be prohibited or restricted.

The analyses conducted for the purposes of this study confirm the existence of premises and the ability of UAVs for the effective delivery of items. In Polish conditions, however, the most important limitation in the implementation and popularisation of this delivery method is the high level of social scepticism, reaching 43%. Courier and postal companies which want to popularise delivery of items with UAV in Poland in the near future should, first of all, take actions to neutralise the aversion to this technology. The survey shows that the greatest concerns of Poles are related to the fears of privacy violation by UAVs. Unmanned aerial vehicles unquestionably pose a real threat in this respect. Poles' anxiety may be partly rooted in the fact that local laws do not regulate the strong protection of citizens against such use of UAVs. The freedom of recording images in public space, which is binding in Poland, creates a threat against unauthorised use of flying objects by their operators and violation of citizens' right to privacy. Each time such actions are revealed, they evoke a vivid response and social objections. In some countries, the authorities, aware of these threats, have decided to introduce significant restrictions. The most restrictive regulations in Europe were introduced in Sweden in 2016–2017, where every UAV with a camera was qualified as a surveillance tool, and its use required a difficult-to-obtain license [103].

Even the possible introduction of similar legislation in Poland does not guarantee a significant increase in acceptance for the presence of drones in public space. The low level of public confidence in the effectiveness of law enforcement by the authorities may cause citizens to resort to unlawful methods to prevent UAV activity that they do not accept.

According to the authors, an additional factor intensifying the aversion to privacy violations is the particular sensitivity of Poles to respect for relatively recently acquired freedoms and rights. The sources of this trait go deep into the historical experience of Poles. Over the past 250 years, Poland has enjoyed full sovereignty only between 1918 and 1939 and between 1989 and 2022. During the other periods, its territory was under the rule of neighbouring states. In the period following the establishment of modern states and nations (1772–1918), these were Austria, Russia, and Prussia, during World War II it was Hitler's Germany and Stalin's Soviet Union, and from 1944/5 to 1989, political supremacy was imposed on Poland by the USSR. Several generations of Poles were brought up in the ethos of opposition to foreign, oppressive political regimes, which, even today, translates into a strong distrust towards the intentions of those in power and even active resistance to their actions assessed as threatening privacy and inviolability of the home. Additionally, it is the use of UAVs, with their ability to provide comprehensive imaging, that is perceived as a tool for possible surveillance of citizens. This factor—as indicated above—should be considered as one of the main barriers to the commercial use of UAVs, despite its benefits for urban planning and the reduction in environmental pollution.

5. Conclusions and Policy Implications

As a result of the conducted considerations, the key, critical, according to the authors, condition for the implementation of UAVs delivering parcels in Polish cities was identified, i.e., the low level of social acceptance for such a potential service. In order to neutralise this reluctance, we recommend that courier and postal companies interested in implementing this service take the following actions:

- To initiate and coordinate a public discourse in which the potential benefits and challenges of UAV are presented in an unbiased and transparent manner;
- To make the public as familiar as possible with the physical aspects of delivery UAVs, including in particular the manner (altitude, speed) and precision of flight,

the noise emitted, technical reliability, and collision avoidance capability. For this purpose, it makes sense to use both purely demonstrative solutions and the provision of pilotage services.

Given the potential characteristics of delivery UAVs, such as their ability to play important roles in urban transport by effectively supplementing, or even replacing, other modes of transport, reducing traffic congestion, and their potential to function as sustainable means of transport that reduce atmospheric pollution, their dissemination should also be of interest to municipal and local administrations.

These institutions should also consider the risks connected with the use of UAVs, such as possible collisions, the probability of which increases with the increasing number of UAVs in the airspace, as well as the loss of jobs for some drivers of wheeled delivery vehicles. An important question facing city authorities will concern the role that UAVs can be assigned to in the urban transport system. UAVs can become both one of the elements in the planning and development of urban infrastructure and mobility and an important pillar in the creation of urban innovation strategies. The operation of UAVs from common urban hubs should be considered in urban planning.

The considerations carried out also allow conclusions and recommendations to be drawn in terms of economic and energy policy. In this context, government policy should encourage the development of electric UAV services and the necessary infrastructure for them, in order to support the practice of green economic growth. Individual states and the entire EU should develop a regulatory framework for an efficient and safe U-space environment.

6. Limitations of the Study

The course, organisation, and partly probably also the results of this research were significantly influenced by the fact that the research was conducted in the midst of the COVID-19 pandemic. On the one hand, it significantly stimulated the e-commerce market, and consequently increased the volume of items. Thus, the interest in the forms of their delivery increased. At the same time, however, it triggered a tendency to behave limiting direct interpersonal contacts. Taking these factors into account irresistibly leads to the conclusion that respondents in such conditions may have shown a more favourable attitude towards modern technological solutions, including the potential use of item delivery using UAVs. Assuming that the COVID-19 pandemic will end in the not-too-distant future, the authors consider it reasonable to conduct research verifying public attitudes towards the service under analysis. The second generation of research will also be accompanied by an increase in its precision, which was limited for pandemic reasons, in order to reduce the size of the research sample.

Further research aimed at extending the spectrum of the analysis to include other market sectors also seems justified. The research of social attitudes based on the opinions of individual customers, i.e., in the business-to-consumer (B2C) relationship, seems to have a basic dimension; however, it should be considered that, in Poland, regarding the volume of items delivered by courier and postal companies, the share of the B2B segment is almost 35% [51]. Therefore, the next direction of research seems to be the identification of interest and attitude towards the UAV delivery service on the part of institutional entities.

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