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Drone based delivery system: Restrictions and limitations

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Drone based Delivery System: Restrictions and Limitations



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Drone based Delivery System: Restrictions and Limitations

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Purpose: *Considering the idea of drone application in last mile delivery, this paper has examined literature studies about the restrictions and pitfalls which the organizations will face with for using drones in the last mile delivery. Moreover, the recent drone tests for commercial purposes in last mile delivery industry and challenges in these practices are investigated.*

Methodology: *A survey-based approach has been applied to both the potential customers of the drone delivery service and also literature review for discovery of latest practices for drone enabled delivery projects has been targeted to identify the limitations and restrictions.*

Findings: *The study demonstrates the problems that arise when the delivery drone crashes while in the air and the approach of self-exploding drones does not seem to make positive effect on this problem. Also, issues like special area for landing, noise of drone activities, safety and security of citizens in urban area are found to be main concerns.*

Originality: *Very few research studies have been conducted in evaluation of using drones for last mile delivery operations focusing on current limitations and forthrightly downsides of drones of current state of the art. Therefore, this paper has tried to elaborate the limitations and restrictions from two perspectives of potential customers and technology developers.*

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1 Introduction

1.1 Motivation

Increase of digitization technologies and their effects for improvements of interactions among computers and automation, reinforced with autonomous and smart systems have faced industries with the opportunity of process improvements (Keliang , et al., 2016; Delaram & Fatahi Valilai, 2019). This has also enhanced the in-store consumer behavior and the way how end users consume the product. According to Federal Reserve Bank's economic data, the E-commerce retail sales as a percent of total sales has increased from 0.8% in Q1 2000 to enormous 16.1% in Q2 2020 (Federal Reserve Bank of St. Louis, 2021). This means that the customers' preferences are changing towards the online shopping and even when they make in-store purchases about 38.5% of them were digitally influenced (Satish & Sanjeev, 2017). Taking the massive adoption of information and communication technologies as the internet into account, many businesses have reorganized the method of how products will be produced, advertised and purchased (Nestor, et al., 2017). Hence, the eagerness of individuals for online shopping channels has resulted in the introduction of businesses offering e-commerce services compared to the traditional one, especially when global pandemic step on, many businesses survived by going online (Montenegro, 2021).

One of the most successful examples of e-commerce business would be Amazon.com Inc., here forth Amazon, which started as an online book-retailing business with a mission to create real value for customers—by making their shopping easier and convenient (Amazon 2018). The online shopping industry is in process of constant growth and Amazon might be considered as one of the key contributors of this growth, increasing its net sales from \$1.6 billion to \$280.5 billion over the period of two decades between 1999 and 2019 (Amazon, 2020). However, the rapid augmentation in the supply chain of the companies as Amazon, DHL, UPS, etc. and overall consumer consumption rate has come with some challenges in optimization throughout the whole supply chain. For instance, as delivery services become more and more popular, studies showed that the share of last mile service costs accounts for 41% of whole supply chain costs (Capgemini Research Institute, 2018). Additionally, this number is more than two times larger than any other

category of costs incurred in supply chain such as sorting, inventory or other remaining supply chain costs. Moreover, naturally last mile delivery cost is defined as variable cost, and it might get larger in case if overall delivery volume increases. Therefore, coming up with a new approach in last mile delivery to cut losses in cost and time was in interest of above-mentioned companies like the application of drone enabled deliver technologies (Farajzadeh, et al., 2020; Moadab, et al., 2022).

1.2 Research aim

The recent legislation of Drones for commercial purposes by governmental authorities has laid the first stone for the large-scale implementation of UAVs (Unmanned Aerial Vehicle) in last mile delivery of products (Andy & Ferek, 2021; Ahmadi, et al., 2021). During the last decade, a tremendous amount of work has been done on optimization of logistics of drones and their applications in parcel delivery along with advantages the drone-based delivery system has compared to traditional truck-based shipping mode in last mile logistics. However, very little amount of research has been conducted in evaluation of employment UAVs considering the current limitations and forthrightly downsides of drones of current state of the art. Therefore, the framework which will contain all the negative side effects UAV deployment in last mile logistics may bring along through the thorough analysis of previous literature. Additionally, a survey to both the potential customers of the drone delivery service and providers of air delivery will be conducted to identify other limitations and restrictions both parties see. Hence, the results will be added to the framework considering the actual weight of the problem. First, getting acquainted with the previous literature and studies about the Unmanned Autonomous Vehicles and their usage in delivery businesses will be on top priority. The literature and studies being examined will be mainly about the restrictions and pitfalls the organizations forcing the massive avail of drones, for example Amazon, are facing in the last mile delivery. however, the drone examinations for commercial purposes and what challenges the drone delivery is facing with will be deeply considered.

In parallel with the research, a survey will be conducted on studying the vision and preferences of customers regarding the drone delivery system. Subsequently, the data obtained will be thoroughly analyzed through data analysis tools. Then, tendencies and

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trends in customer behavior will be identified and finally the recommendations and advice will be proposed for the future research studies of this topic.

2 Literature review

2.1 Challenges in last mile delivery

Over the last decade, e-commerce business models have shown the increase in the number of on-line orders. Accordingly, vendors have to fulfill the enormous demand from private customers through attaining the lowest delivery time of parcels, mainly low weight and small volume, being shipped while constantly facing the overlap in the time windows of customers (Zeynivand, et al., 2021). Therefore, different players throughout the supply chain are trying to refine their plants by making the production processes available 24 hours a day, reducing the processing time of orders and transportation (Archetti, 2020). Nevertheless, the problems associated with decrease of the costs and resources spent in last mile delivery are still currently challenging (Khaturia, et al., 2022). Examining a closer investigation on the root of the problem, there can be derived that the challenges emerging in the last mile are mostly arose from the fact that shipments are formed from individual customers and from a large scale of diversification of destinations, meaning that each order has to be shipped to different address (Macioszek, 2017).

Additionally, last mile logistics employs the service of freight carriers. Therefore, especially in highly dense areas, freight carrying truck drivers are encountering large deal of problems (Aljohani, 2020). Efficient optimization of urban mobility is a key for the economic success of large metropolitan areas and respectively delivery of parcels on time is also crucial factor for companies to satisfy the customers' need. Recent studies have shown the increasing demand for express and small size parcels in densely populated areas in Europe and there's also a tendency of customers preferring same-day delivery (Mazareanu, 2019; European Commission, 2018). Furthermore, couriers have to travel long distances from distribution centers mainly located in suburban areas to satisfy the wants of end-users vastly located in inner-city areas.

One more factor negatively affecting the logistics in last mile stage is the presence of high skyscrapers, each comprising bunch of various business establishments, retail stores, food shops and public areas in city centers of large urban areas. Despite the fact that those commercial city towers do not span large area compared to other retail stores and businesses located in one single block, they do effectuate complexity as they simply engender vast amount of freight movement. For example, it was estimated that around 4% of all truck movements in all districts of Manhattan was mainly triggered by 56 neighboring business towers (Miguel, et al., 2015). Moreover, enterprises located in skyscraper buildings mainly order parcels through express delivery meaning the shipment in the same day at hand. In general, the city center area suffers from great amount of traditional truck movements. Here are the factors negatively causing the last mile delivery:

1. Restricted and inconvenient infrastructure for parking the freight trucks and loading the shipments.
2. Intense traffic movement caused by pedestrians, cyclists and congested with other private vehicle owners.
3. The local streets in city centers accessible only for pedestrians.
4. Deficit of facilities that would allow truck drivers to load packages beyond the street.

In the e-commerce era, businesses getting more and more digitized, and customers' standards being increased, last mile distribution of shipments to end-users appearing to be an issue entangled more than ever. Additionally, the amount of goods to be delivered door-to-door towards the customer living places is increasing the number of trucks needed to be involved in inner-city traffic and CO₂ emission (Paul & Benjamin , 2018). Accordingly, the emergence of novel last mile delivery concepts was unsurprising and was just a matter of time.

2.2 Advantages of drone-based delivery system

It is undoubtedly that logistics is a dominant factor in businesses as customer's expectations to have their desired products promptly, and hence, logistics companies try to meet customer's ever raising high standards in the most economically viable way. As discussed earlier, traditional truck-based delivery system has a lot of drawbacks and

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most importantly it is economically detrimental. Therefore, there are various transportation modes such as vessels, goods trains, trucks, carts, etc. have been invented. One of the most eminent and notorious concepts being actively developed during recent years is the Unmanned Aerial Vehicles or drones.

A drone, UAV or Remotely Piloted Aircraft is a flying robot which can be controlled remotely or can fly autonomously without the assistance of human pilot (Federal Ministry of Transport and Digital Infrastructure, 2021). As there are many ways the drone can be referred to, in this paper, the terminology 'drone' is selected in further deliberation. Back in 2019, analysts have forecasted that drones and UAVs are highly likely to be prominently employed for commercial purposes as shown in Figure 1. The sales and revenues accounted for 392 thousand and 1.6 billion USD back then and these values were projected to reach 12.6 billion USD by 2025. The demand for drones has exceeded all optimistic forecasts until then, for instance, the sales of UAVs in US alone outreached \$1.25 billion (Insider Intelligence, 2021). Now, Goldman Sachs projecting total market size of drones to hit \$100 billion by 2025. Apart from that, analysts at Insider Intelligence strongly believe that global shipments being operated with the aid of UAV services will reach 2.4 million by 2023 taking the 66.8% of annual compound growth rate (Insider Intelligence, 2021). Also, it is projected that drones will mainly be employed by five main industries: Agriculture, construction and mining, insurance, media and telecommunications, and law enforcement (Insider Intelligence, 2021). Recent years have demonstrated that drones have the potential to be one of the most essential technologies of our time, especially it was vivid in 2020 when contactless services were in high demand because of the pandemic. Nevertheless, drones are already in use in some places and big corporations such as Amazon, Google, UPS and DHL have already tested them in various environments. Furthermore, they are now capable of lifting freight weighing up to 2-3 kg (McKinsey & Company, 2016). The parcelcopter 4.0 of DHL in collaboration with the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH under the German Federal Ministry and German manufacturer Wingcopter have performed 60 km flight in 40 minutes to deliver medicines to remote rural areas during the pilot project in East Africa (DHL, 2020).

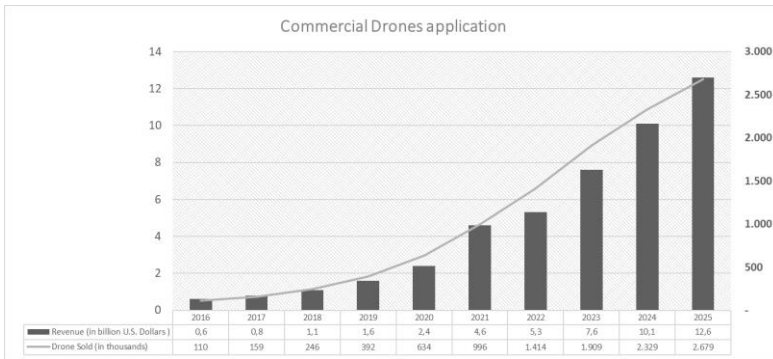


Figure 1: Projected worldwide market growth for commercial drones
(Buchholz, 2019)

The fourth generation of parcelcopter is able to speed up to 130 km/h, fly 65 km distance with full battery level and carry up to 4 kg cargo and also have shown that drones can operate in spite of 'natural barriers' and can be a complete game-changer in the areas where the road system is not available (DHL, 2020). Furthermore, partnering with EHang DHL have launched first completely UAV based delivery mode in urban area of China in 2019 (Hartmann, 2019). They highlight the fact that they could reduce cost per delivery by 80%, shorten the 40 minutes lead time to 8 minutes and with significantly less energy consumption and CO₂ emission (Hartmann, 2019). As an entirely autonomous solution, drones, can lift packages up to 5 kg per flight and operate being atop of special intelligent cabinets where sender can simply load/unload the shipment (Hartmann, 2019).

Whereas DHL's rival companies as Amazon, UPS, FedEx and Google's sister company Alphabet's Wing are also in process of making drone delivery reality. Amazon's Prime Air service already offers its customers living in 15 miles within the selected areas to get delivered their items weighing less than 5 pounds (2.3 kg) in less than 30 minutes (Wilke, 2019). The drone is equipped with AI system which will help to recognize obstacles, animals, people, etc. and will need a small area around the delivery location to unload the parcel (Wilke, 2019). Plus, Amazon claims the weight limit of 5 pounds covers around 75-90% of purchased items in the platform (Wilke, 2019). While Wing drone has

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completed hundreds of deliveries to real customers in Australia since 2014 starting from first-aid-kit, candy bars, water to farmers and hot food.

2.3 Challenges and constraints

Generally, drones are naturally very vulnerable to any weather events and wild animal or bird attacks. High speed wind, turbulence, freeze, precipitation, fog and cloud, for instance, might drastically affect travel distance and control system of drone because of their design, dependency on battery level and light weight (Karpowicz, 2018). Any micro-climate contrast, temperature change, or overcoming the physical obstacle as hills will consume the battery; a burst of wind, heavy rain, icing, etc. will not only consume more battery, but will also force the unmanned autonomous aircraft to fall. The safety is the fundamental disturbance for both consumers and regulators and weather are the first danger for drone's safe operation. Furthermore, drones are also prone to be attacked by wild birds. There have been number of incidents detected when birds of prey attack UAVs worldwide, including Australia, Africa, some US states, some areas in Europe and South America (Wade, 2017). One of the drone users in Australia affirms almost 40% of the time he has to perform at least one attacking bird avoidance (Wade, 2017). It might cause serious damage for both the UAVs and birds living around, hence, the surrounding environment and has to be addressed by drone manufacturers, logistics service providers and authorities.

Jeff Wilke, former CEO of Amazon Worldwide Consumer, said to qualify for Amazon Prime Air 30-minute drone delivery, the order has to be less than 5 pounds (2.26 kg) and small enough to fit into the cargo box that the drone will carry (Wilke, 2019). Plus, the recipient must also be located within a 10-mile radius from Amazon's corresponding distributing center, Additionally, in UK, for example, drones are only permitted to fly under 400 feet altitude, during the daytime when there's low wind speed and well visibility (Wilke, 2019). This, undoubtedly, adds up the lifting power issues of drone delivery system which often cuts heavier product categories and adds up to challenges in battery and design.

Moreover, drones are designed to be significantly big, particularly the types that are developed to fly long-distances at lowest cost, and therefore, it may require at least $2 m^2$ special area from the recipient to perform landing maneuvers (Yoo, et al., 2018).

Certainly, so-called technology will evolve by time, however, in reality it will be really difficult to provide even smaller drones with proper landing area in densely urban areas. This constraint technically could be surpassed with assigning the smaller and low weight packages that have to be delivered to rural areas, where it might be uncomplicated to find landing space. Nevertheless, if the shipments are also bounded by limited number of time-windows and has to be transported on the same-day, it may take approximately 250,000 pieces of drones in 2025 in US alone to satisfy the demand (McKinsey & Company, 2016). Additionally, one more compelling point is that none of the earlier mentioned enterprises, such as Amazon, does not address the obscurity of the procedures and protocols in reverse logistics, when the customer will need to send the item back. The cost of returning movement of goods away from their actual final destination is estimated to be \$642 billion worldwide for Amazon per year (Mazareanu, 2020), for example. Hence, this could be a major pitfall to deploy drone services at full extent for online retailers and logistics companies, also it's preventing entire last mile logistical operations from becoming fully environmentally sustainable.

Unfortunately, even the most sophisticated Unmanned Aircraft Systems are not completely protected from external events such as weather and wild birds. In 8th of July 2020, there has been a drone incident: a UAV was being operated over the large building in a built-up space for commercial purposes, following the pre-programmed prepared flight path (UK Government, 2020). The chosen drone has passed all the norms and checks before the beginning of the flight, including the assessment of possible wild animal (bird) intervention. However, when the drone entered the autonomous flight mode it was attacked by a gull, which damaged the drone's front propeller, hence, even the pilot was not able to control it manually. As a result, a drone weighing 6.14 kg fell onto the rooftop (UK Government, 2020). Albeit, even if the drone manufacturers will prepare the Unmanned Aircraft Vehicle to every possible way of danger, there might still be some unseen scenario which could lead to catastrophic outcome (Popper, 2014). Therefore, Amazon have patented a self-destructing drone technology that falls apart in an emergency situation, intending to cause less harm if the crash is inevitable (Vincent, 2017). However, even with the idea of self-exploding drones, the citizens living around are not fully protected from the danger above. In such cases, people might get injured,

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and properties could be damaged and there emerges the question of who should take the responsibility for the failure and the damage to surrounding people? What will happen to the ordered item? May be there is the intervention of 3rd party insurance company is needed. These questions, of course, remain open to discussion.

3 Methodology and Data Collection

3.1 Survey design

The relationship between the providers of drone delivery and the potential customers of that service will be analyzed in this paper. This section of the paper will explain how this relationship will be tested. As stated in the previous sections of paper, utilization of Unmanned aircrafts has its limitations and restrictions. It is expected that the rapid deployment of so-called technology in last mile logistics is threatened by those negative factors, plus the cultural recognition might take some time so customers would get used to the contact with novel technology. Furthermore, customers will also demand the response from the manufacturers of drones and providers of the service. Therefore, it made a sense to conduct a survey questionnaire among both the potential customers to identify their view on the possible inconveniences the drone technology may bring together and the providers of air delivery service with the reason to determine their vision on the problems and what approaches they are planning to employ to minimize the impact of those negative effects.

First group of respondents will be identified as future clients of UAV shipment option consisting of the residents of different countries, cultures, age groups, genders, etc. and making regular online purchases. Overall, 252 respondents participated in this research survey, and it took place online via Google forms platform. The questionnaire had 13 general questions and was designed to capture the customers' judgement and severity of the limitations from the perspective of customers' experience. The combination of both multiple-choice questions with predefined answer lists and open-ended questions is found to be present in the survey. Moreover, respondents were able to choose and rank among number of variants or to grade on a scale from 1 to 5, where 1 is very bad/strongly

disagree/very difficult and 5 is very good/strongly agree. For such questions additional space line was provided to explain and elaborate on the answer. This kind of open-ended questions play a role of great importance in the survey as it helps to properly interpret the obtained data and might shed a light into new unseen valuable material. The multiple choice and ranking questions, in its turn, allows to gather and analyze great amount of data and identify the trends and tendencies in the data.

On the other hand, the second group of respondents are found to be the specialists professionally operating closely to the development of air delivery services. Their visions on the identified issues were recorded online through Google forms platform. In general, experts who are working in the sustainability, mobility & transportation, and supply chain management departments and drone projects of the companies in German and international market participated in the survey. The questions were mix of short & long text answers to pre-described issues and multiple/ranking questions afterwards to rank the severity of each problem.

3.2 Potential customers

From 245 of all respondents, 97.2 %, who participated in the survey were in 18-29 age group and 7 were found to be older than 29. Thus, all the respondents can be stated as the target audience of the providers of drone delivery system with more focus on young generation which are more eager to know more about such technologies and also are more demanding to benefit from shorter lead times of delivery. Also, the first group of respondents were supposed to specify whether they live in Urban area or suburban area. 55.6% of people who participated in the survey as the potential customer are living in urban area or city center were the issues as congestion, GHG emission, and noise pollution are mostly critical. Moreover, 231 out of 252 respondents have confirmed that they have purchased goods on-line within the last 12 months. Furthermore, the ones who have indicated that they shopped online throughout the last year were also asked to describe how often they are likely to place the order and more than third of them order products online once a month on average, 77.8%.

The responders also had an opportunity to pick one or more weight categories out of the given variants to which they feel their average package's weight belongs. The vast

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portion of the packages ordered are found to be under 2.25 kg (5 pounds) and none of the orders exceeded 5 kg mark. The questionnaire has revealed that 38.9% of all respondents, that is 98 people, lack special place of at least 2 m² in open space of their living place for the drones to perform unloading process of packages. Plus, 69.4% of answerers state that they can wait from 2 days to weeks to get their mail delivered, which minimizes the need for quick drone delivery option.

3.2.1 Results and analysis

After the first round of questions clarifying the preferences and details of the responders entitled to be as potential drone delivery service clients, they were given pre-described possible scenarios in the next round. The first case contained the scenario in which drone crashes because of unconditional weather events (e.g. high speed wind, rain, icing, etc.) or wild bird attacks or unseen technical issues onto an innocent resident or their property (e.g. house, car, belongings, etc.). Participants of the survey were given options and space line to describe who they think have to pay the compensation for the injured person and damaged property. As shown in Figure 2, 44.4% of participants reckon that in case of drone crash drone delivery providers such as Amazon, Google, UPS, DHL, and so on has to pay the compensation to injured person and their property. Whereas other half of the respondents deem there should be an insurance company employed for every delivery and they should compensate the damage. In this scenario, the ordered item being delivered by UAV is also likely to be damaged and 44.4% of answerers think the hired insurance company should also cover the cost of the item being delivered. While the same quantity of people feels the carrier has to take the responsibility to cover the cost of spoiled item being shipped and deliver the new item sent to the customer free of cost. Surprisingly, 28 people, that is 11.1% deem that the seller or store has to send a new item or fully refund to the customer.

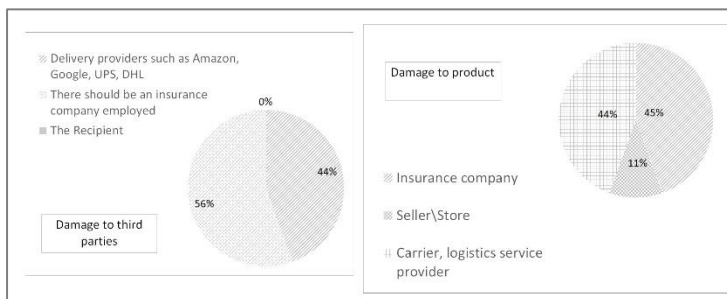


Figure 2: Breakdown of the damage of drone crash (Left)

After the first scenario, the examinees were supposed to rate on a 1-5 scale to which extent they agree/disagree with the drones flying nearby their living places. The vast majority looks neutral to the operation of UAVs nearby residential areas, however the 13.9% of respondents equally agree and disagree with the drones flying around their living place. The next question demonstrated the Amazon inspired city which fully operated with the service of Amazon Air Prime as a visualization of future cities. Afterwards, it was followed up with the question to rate to which extent they are sensitive to noise. More than half of the respondents indicated they are either sensitive or very sensitive to noise which obviously contradicts with the noise level generated by various types of drones.

In the final part of the survey, participants were asked to announce whether they are willing to use drone delivery option as a customer considering all the restrictions and limitations described before. Where 1 is very likely to use, 3 is neutral and 5 is less likely to use. Nevertheless, as illustrated in Figure 3, 47.2% of all respondents were found to be prone to be the customer of drone inspired delivery system, while only 27.7% were skeptical to employ drone service. In the end, first group of respondents were given a space line to explain why they support or not UAV based shipment of goods.

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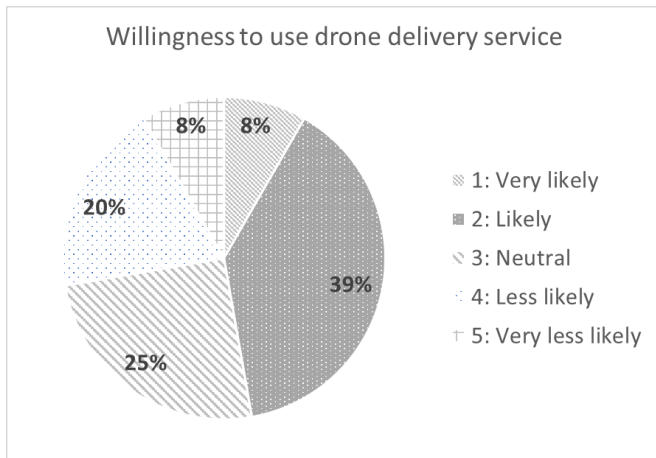


Figure 3: Willingness to use drone delivery service

3.3 Experts

The experts whom were contacted in this survey were working in Sustainability, Mobility, Logistics, and drone projects of various enterprises for more than four years. The questionnaire itself consisted of two parts. The purpose of first part was to obtain the points of view of those specialists on various pre-described restrictions of drone technology. While the second part was generated in order to allow the responders to rank the severity of issue on 1-5 scale, where 5 is very complex, 4 is slightly complex, 3 is neutral, 2 is slightly negligible, 1 is negligible. The first question explained the problem of battery and charging of drones. To address this issue, some adjustments in city infrastructure as charging stations or beehive buildings where drones could be able to stay and charge their batteries is needed. This leads to other problems as city authorities, residents and cultural acceptance. Additionally, flying maneuvers at low battery levels can be catastrophic compared to when traditional truck runs out of fuel. The responders deem that the installment of charging stations where they will not disturb urban traffic at all would minimize the effect of this issue.

The next question raised the issues of unwanted noise amount generated as a result of drone operations. Indeed, this issue can get even more severe when entire cities will employ thousands of drones in last mile logistics. One of the responders mentioned that drones don't cause much noise than cars, trucks, and other urban traffic does, and residents will get used to it by the time passes. While another specialist noted that drone delivery mode should be allowed only for essential deliveries and in restricted amount. As discussed earlier the variability of packages which needs to be delivered by drone is restricted by their weight limit. Amazon air prime, for instance, can ship products below 5 pounds or 2.25 kg at once. One of the specialists said: "Once the drones will be successfully used in everyday delivery services for packages up to 5 kg, and if the clients will be satisfied and demand will be high, then the ways of upgrading the drones could be considered". In case demand is high, there should be enough funding and resources for the upgrade. However, half of the responders consider this issue as slightly complex, one as very complex, and one looks at this neutrally.

Apart from that, in case of emergency, some drones will activate self-explosion mode so smaller pieces will fall down, and less damage will be caused (Vincent, 2017). Responders pointed out that this technology is very dangerous and another approach as the implementation of built-in parachute which will be activated in case of falling should be studied. 75% of specialists considered the problem as either as slightly severe or very difficult. In case of drone accidents, there might be several parties being deteriorated: the shipper who sent the item and lost it; the owner of the property (e.g. house, car, etc.) the drone pieces fell onto; a customer who won't be able to get his item on time. The specialists think the involvement of insurance company in this process would help to distribute the responsibility fairly, saying that if the carrier will have to cover the whole expenses associated with the damage caused due to drone crash the replacement of traditional delivery with drone services won't be possible in near future. Hence, all of the respondents rated this issue as either slightly severe or very complicated.

Some citizens living in residential area where drones were being tested are concerned about their privacy and safety, especially the camera recordings of drones (Cherney, 2018). To mitigate this problem, the organization of educational events raising public awareness would make sense. The answerers reckon the detailed information about

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navigational purposes should be made public and they all rated this issue as slightly difficult.

3.4 Discussions

The results show that though the 47.2% of respondents are planning to use drone delivery mode regularly, there are number of challenges which needs to be overcome. For example, 38.9% of responders don't have the ability to offer a special area for landing maneuvers of drones. For this issue, respondents in the second group of survey suggested the DHL's approach which involves the installment of intelligent cabinets that were specifically developed for the completely autonomous loading and unloading of the shipments. Another problem is associated with safety and security of the well-being of citizens living around as 19.5%, almost 1 out of 5 people, do not feel safe and protected if drones were flying around. This phenomenon might provoke other issues connected with the mental health of residents. The studies demonstrate that there's a raising tendency that city dwellers are moving to suburbs in search of better quality of life.

Moreover, drone propellers generate great amount of noise which eventually adds up to this problem. Consequently, the challenge gets especially crucial with the 52.8% of respondents identifying themselves as either slightly or very sensitive to noise. Additionally, 69.4% are willing to wait their packages from 2 days to 1 weeks which eliminates the need for instant drone delivery. Furthermore, respondents have noted that they don't feel comfortable living around drone activity areas backing it up with the little development in computer vision and navigation algorithms. It can be concluded that there is a direct relationship between how people feel around drone operating area and their willingness to use the service. On the other hand, some believe that infrastructure and regulations must catch up to drones before wide-scale adoption to prevent violations in privacy and airspace. Plus, the environmentally sustainability of drones also positively influenced the respondents' vision on whether they support the drone delivery adoption or not.

When it comes to the responses of specialists, the most crucial problem was found to be the question of who should take the responsibility if delivery drone crashes in the air. They have mentioned that the involvement of 3rd party insurance company would make

the situation easier. However, there emerges another question of who should cover the cost of that insurance company's service? The carrier? The sender, online shop, retailer? Or the recipient? The data protection and privacy of people was happened to be the second most important restriction in deployment of drone technology in last mile logistics. Drones possess a great deal of cameras, LIDAR (Light Detection and Ranging), sensors, and actuators that monitor the real-time surrounding environment and that is essential in drone operation. The selected responders indicated that the detailed information about navigational purposes should be made public and the camera recordings should have an expiration date, meaning the camera footages will be deleted after set time. This period should be discussed with representatives who live in testing area and consent form should be signed. Surprisingly, the solution with self-exploding drones and drone crash while in the air were also occurred to be one of the most severe issues the carriers have to address to execute the massive employment of UAVs in delivery industry. Even though there were number of difficult challenges discussed, responders seem to be optimistic about drone future and think we will see the replacement of traditional truck-based delivery system with UAVs in 2-5 years.

In the very beginning of the paper the majority of challenges that exist in the development of UAV based air delivery were identified. At first, they were discussed with potential customers of the novel technology and the most essential problems were sorted out. In parallel, those issues were also disputed with the specialists professionally working close to this industry. As a result, the possible solutions that might help to mitigate some of those issues were proposed and the most important, hard-to-crack problems were distinguished. Both two survey results illustrate that the availability of special area in the living place of the receiver, limitation in the weight of package the drone is able to deliver, lifting power of drones and installment of charging stations are the challenges that make little sense.

4 Conclusion

This paper has elaborated the limitations and restrictions of drone-based delivery system. This research has discussed the most prominent challenges in the development of UAV based shipment mode have been identified through the study of various scientists' research study, case studies and customers' feedback. The paper has conducted surveys for the representatives of both parties, the specialists, and customers in order to identify the most significant challenges and to disregard the ones that are less important, or the possible solution is available. The paper has examined the respondents' view on the limitations and restrictions in the cultivation of drone delivery method based on the current solutions of Amazon's Prime Air, DHL and EHang's drone delivery service, and Google's sister company Alphabet's Wing. The studies demonstrate the problems that arise when the delivery drone crashes while in the air and the approach of self-exploding drones has not been found to make positive effect on this problem. The interesting area for future studies could be conducting research on introducing another solution for drone crashes while operating in the air.

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References

- Ahmadi, E., Wicaksono, H. & Fatahi Valilai, O., 2021. *Extending the Last Mile Delivery Routing Problem for Enhancing Sustainability by Drones Using a Sentiment Analysis Approach*. 13-16 Dec. 2021, Maria Bay Sands, Singapore, IEEE, pp. 207-212.
- Aljohani, K., 2020. *An Examination of Last Mile Delivery Practices of Freight Carriers Servicing Business Receivers in Inner-City Areas*. [Online] Available at: <https://www.mdpi.com/2071-1050/12/7/2837>
- Amazon, 2020. *Annual reports, proxies and shareholder letters 2020*. [Online] Available at: <https://ir.aboutamazon.com/annual-reports-proxies-and-shareholder-letters/default.aspx> [Accessed 18 Mar 2021].
- Amazon, 2018. *What is Amazon*. [Online] Available at: <https://www.aboutamazon.de/%C3%BCber-amazon/Was-ist-Amazon> [Accessed 4 Feb 2021].
- Andy, P. & Ferek, K. S., 2021. *The Wall Street Journal*. [Online] Available at: <https://www.wsj.com/articles/faa-approves-first-fully-automated-commercial-drone-flights-11610749377>
- Archetti, C., 2020. *Recent challenges in Routing and Inventory Routing: E-commerce and last-mile delivery*. [Online] Available at: https://onlinelibrary.wiley.com/doi/full/10.1002/net.21995?casa_token=W2l1LLUObSIAAAAA%3Ak1XzgXZDyeyJoCicbcA9l-S_7tFUWGU8T9tdk_8Ht5mhJvnUEz1jr6SmQSShRnN7cW6OYjmzeKrz132p
- Buchholz, K., 2019. *Commercial Drones are Taking Off*. [Online] Available at: <https://www.statista.com/chart/17201/commercial-drones-projected-growth/>
- Capgemini Research Institute, 2018. *The Last-Mile Delivery Challenge*. [Online] Available at: <https://www.capgemini.com/wp-content/uploads/2019/01/Report-Digital-%E2%80%93-Last-Mile-Delivery-Challenge1.pdf> [Accessed 2 Mar 2021].

Drone based Delivery System: Restrictions and Limitations

- Cherney, M., 2018. *Delivery Drones Cheer Shoppers, Annoy Neighbors, Scare Dogs*. [Online] Available at: <https://www.wsj.com/articles/delivery-drones-cheer-shoppers-annoy-neighbors-scare-dogs-11545843552>
- Delaram, J. & Fatahi Valilai, O., 2019. An Architectural Solution for Virtual Computer Integrated Manufacturing Systems using ISO Standards. *Scientia Iranica*, 26(6), pp. 3712-3727.
- DHL, 2020. *Video-Deliver Future: Parcelcopter 4.0 | Delivering vital medicines by drone*. [Online] Available at: <https://www.dhlexpress.be/en/shipping-and-receiving/dhl-parcelcopter/> [Accessed 20 Feb 2021].
- European Commission, 2018. *Postal services*. [Online] Available at: https://ec.europa.eu/internal_market/scoreboard/performance_per_policy_area/postal_services/index_en.htm [Accessed 17 Mar 2021].
- Farajzadeh, F., Moadab, A. & Fatahi Valilai, O., 2020. A Novel Mathematical Model for a Cloud-Based Drone Enabled Vehicle Routing Problem considering Multi-Echelon Supply Chain. *IFAC-PapersOnLine*, 53(2), pp. 15035-15040.
- Federal Ministry of Transport and Digital Infrastructure, 2021. *Clear rules for the operation of drones*. [Online] Available at: <https://www.bmvi.de/SharedDocs/EN/Articles/LF/clear-rules-for-the-operation-of-drones.html> [Accessed 14 Feb 2021].
- Federal Reserve Bank of St. Louis, 2021. *Retail Trade*. [Online] Available at: <https://fred.stlouisfed.org/series/ECOMPCTSA> [Accessed 10 Feb 2021].
- Hartmann, S., 2019. *DHL launches its first regular fully-automated and intelligent urban drone delivery service*. [Online] Available at: <https://www.dpdhl.com/en/media-relations/press-releases/2019/dhl-launches-its-first-regular-fully-automated-and-intelligent-urban-drone-delivery-service.html> [Accessed 14 Mar 2019].
- Insider Intelligence, 2021. *Drone market outlook in 2021: industry growth trends, market stats and forecast*. [Online] Available at: <https://www.businessinsider.com/drone-industry-analysis-market-trends-growth-forecasts?r=DE&IR=T> [Accessed 12 Mar 2021].

- Karpowicz, J., 2018. *TruWeather Proves Why the Drone Industry Need Better Weather Data*. [Online] Available at: <https://www.commercialuavnews.com/infrastructure/truweather-drone-industry-better-weather-data>
- Keliang , Z., Taigang , L. & Lifeng , Z., 2016. *Industry 4.0: Towards future industrial opportunities and challenges*. [Online] Available at: <https://ieeexplore.ieee.org/abstract/document/7382284/authors#authors>
- Khaturia, R., Wicaksono, H. & Fatahi Valilai, O., 2022. *SRP: A Sustainable Dynamic Ridesharing Platform Utilizing Blockchain Technology*. Bremen LDIC (2022), Springer International Publishing.
- Macioszek, E., 2017. *First and Last Mile Delivery – Problems and Issues*. [Online] Available at: https://link.springer.com/chapter/10.1007/978-3-319-62316-0_12
- Mazareanu, E., 2019. *Forecast of the express and small parcels market size in Europe from 2012 to 2020*. [Online] Available at: <https://www.statista.com/statistics/1015113/express-small-parcels-market-size-europe/>
- Mazareanu, E., 2020. *Reverse logistics - statistics & facts*. [Online] Available at: <https://www.statista.com/topics/4323/reverse-logistics/#dossierSummary>
- McKinsey & Company, 2016. *Parcel delivery: The Future Of Last Mile*. [Online] Available at: https://www.mckinsey.com/~media/mckinsey/industries/travel%20transport%20and%20logistics/our%20insights/how%20customer%20demands%20are%20reshaping%20last%20mile%20delivery/parcel_delivery_the_future_of_last_mile.ashx [Accessed 20 Feb 2021].
- Miguel, J., Xiaokun (Cara) , W. & Jose , H., 2015. Large urban freight traffic generators: Opportunities for city logistics initiatives. *Journal of Transport and Land Use*, pp. 51-67.
- Moadab, A., Farajzadeh, F. & Fatahi Valilai, O., 2022. Drone routing problem model for last-mile delivery using the public transportation capacity as moving charging stations. *Scientific Reports*, 12(1), pp. 2045-2322.
- Montenegro, L., 2021. *How Small Businesses Can Survive In An Online, E-Commerce World*. [Online] Available at: <https://www.forbes.com/sites/forbesagencycouncil/>

Drone based Delivery System: Restrictions and Limitations

[2021/01/29/how-small-businesses-can-survive-in-an-online-e-commerce-world/?sh=4f81e2d44e19](https://www.entrepreneur.com/article/345678)

- Nestor, D.-B., Lukasz, G., Andre, R. & Frank, V., 2017. The impact of online sales on consumers and firms.. *International Journal of Industrial Organization*, p. 31.
- Paul, H. & Benjamin , W., 2018. *Road freight emissions in Germany*. [Online] Available at: <https://www.cleanenergywire.org/factsheets/road-freight-emissions-germany>
- Popper, B., 2014. *I almost killed someone with a drone*. [Online] Available at: <https://www.theverge.com/2014/11/13/7205741/i-almost-killed-someone-with-a-drone>
- Satish, M. & Sanjeev, K., 2017. *Forrester Data: Digital-Influenced Retail Sales Forecast, 2017 To 2022 (US)*. [Online] Available at: <https://www.forrester.com/report/Forrester+Data+DigitalInfluenced+Retail+Sales+Forecast+2017+To+2022+US/-/E-RES140811#>
- UK Government, 2020. *Loss of control following bird attack*. [Online] Available at: <https://www.gov.uk/aaib-reports/aaib-investigation-to-dji-matrice-m200-uas-registration-n-a-080720?utm>
[Accessed 16 Feb 2021].
- Vincent, J., 2017. *Amazon patents self-destructing drone that falls apart in an emergency*. [Online] Available at: <https://www.theverge.com/2017/12/1/16723190/amazon-self-destructing-drone-falls-apart-midair-patent>
- Wade, M., 2017. *When Birds Attack! — Experienced Drone Operators Discuss This (Surprisingly Common) Mission Threat*. [Online] Available at: <https://www.sensefly.com/blog/bird-drone-attacks-avoid-threat/>
- Wilke, J., 2019. *A drone program taking flight*. [Online] Available at: <https://www.aboutamazon.com/news/transportation/a-drone-program-taking-flight>
- Yoo, W., Yu, E. & Jung, J., 2018. *Drone delivery: Factors affecting the public's attitude and intention to adopt*. [Online] Available at: <https://www.sciencedirect.com/science/article/pii/S0736585318300388>

Zeynivand, M., Ranjbar, H., Radmanesh, S.-A. & Fatahi Valilai, O., 2021. Alternative process routing and consolidated production-distribution planning with a destination oriented strategy in cloud manufacturing. *International Journal of Computer Integrated Manufacturing*, 34(11), pp. 1162-1176.