Utilization of Aerial Drone Technology in Logistics

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Abstract

In order to create a supply chain that is both economically and ecologically sustainable and complies with contemporary standards, the logistics chain must be modernized and should rely on new technology. In this article, the authors will attempt to elaborate the development direction of delivery systems through examples of technology-oriented companies such as Amazon, focusing on the use of unmanned aerial vehicles (drones) for delivering smaller packages within urban and suburban environments. The main goal of using drones in urban logistics is to reduce the burden on city roads and the use of road vehicles that generate the highest gaseous emissions footprint. The use of drones has proven to be extremely flexible and useful in port logistics as well, eliminating the need to send supply vessels into rough seas or putting people in danger during exhaust emission control. However, drones are a relatively new technology, and they have their own limitations, which are still being discovered. The main constraints of the devices themselves are power sources and the power of the aircraft, which currently and likely in the future won't be able to transport heavier commercial loads. Increased use leads to congestion in airspace, posing risks to other modes of transportation such as road or air. Research shows that the current use of drones mainly revolves around test flights or limited applications within a regulated environment.

Key words: *logistics, drones*

1. Introduction

Logistics can be considered a key component of any organizational structure, regardless of the system's size. An efficient logistics operation and the ability to deliver timely products and services are important for involved logistics organizations to gain a competitive advantage [1]. However, the conventional strategies for acquiring an advantage in the marketplace are no longer sufficient. The rapid development and implementation of digital technologies and innovative business models have changed the competitive dynamics of the logistics industry [2]. Technological automation is an essential part of the future progress of the logistics sector, and could improve the efficiency of operations [3], and help reduce costs [4].

An increasing number of researchers recognize the importance of drones in logistics. Drones are also commonly known as unmanned aerial vehicles (UAVs), or pilotless aircraft systems, and can be used in industrial monitoring, delivery operations, military surveillance operations, aid operations, etc. [5]. Drone delivery scenarios are based on the autonomy of drones in flight and removing the human factor from the equation as much as possible.

One of the largest breakthroughs in commercial aerial drone use was made by the US company Zipline, which began delivering medicines and blood plasma via air in Rwanda as early as 2016 [6]. A good example of logistics system modernization is the business strategy of the US company Amazon, which introduced the use of drones for delivering packages to customers through its service Amazon Prime Air on December 22, 2022 [7].

The commercial use of drones is a new principle of utilizing aircrafts in logistics, and new challenges and tasks arise daily that need to be overcome for autonomous unmanned aerial vehicles to function as intended. Amazon, for instance, faced challenges with regulatory issues. The Federal Aviation Administration (FAA), the regulatory body for air traffic, only approved the commercial use of Amazon's drones in 2022, which was far beyond the expectations of Amazon's founder [8].

A more liberal approach to the use of drones in airspace is found in the African country of Rwanda, where Zipline has created a system for delivering medical supplies. The delivery service was established in October 2016 and has developed into the primary means of transporting blood plasma and blood supplies within the country, especially to clinics in rural, poorly connected areas [6]. Zipline's delivery services are carried out by unmanned drones, making this system even more impressive.

The use of drones in the Republic of Croatia is primarily associated with police and military activities, but in January 2020, Croatian Post conducted its first pilot-project drone parcel delivery [9].

In this paper, the authors will outline the concept of operations of aerial drones in logistics, deployment challenges, usage and ongoing development and test piloting the technology in the Republic of Croatia.

2. Concept of operations

Unmanned aerial vehicles can be classified into two types: autonomous drones and remotely controlled drones. Autonomous drones have pre-defined movement algorithms, while remotely controlled drones are controlled by one or more individuals from a control station [10]. Currently, there is a greater use of remotely controlled drones due to their less complex management and programming systems. However, future plans aim to minimize the need for human involvement in the management system.

The use of drones for logistics purposes is primarily intended for the delivery of smaller and medium-sized packages within a local area, specifically focusing on the development of urban logistics. Although not limited to this condition, large companies like Uber are developing drones for transporting people. The main goal of using drones is to reduce the need for delivery drivers using road vehicles, thereby alleviating the traffic pressure in already congested urban centers [11]. The working principle involves programming drones to autonomously deliver packages to specific addresses based on GPS coordinates. Drones determine their current location and the delivery destination using GPS systems [12]. The sender's task is to enter the correct delivery address, usually through an application, and then the drone calculates the most optimal delivery route and begins the delivery process. The computer inside the drone, with the help of the Electronic Speed Controller (ESC) component, collects data from each sensor and regulates the power flow within each rotor, determining the speed of rotation for each rotor and controlling the drone's movements. Equipped with built-in cameras, drones use visual recognition of the environment to create a 3D map of reality, allowing them to adjust their route in case of encountering obstacles [13]. The Figures 1. and 2. below illustrate the positioning system using GPS and the visualization of the surroundings.

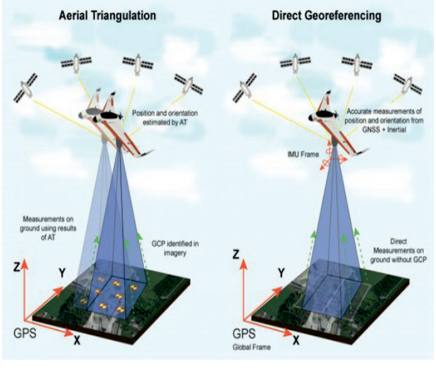

Figure 1.: Surface positioning of a drone during flight (conceptual overview) [14]

Figure 2: Visal mapping of the drone surroundings [15]

After arriving at the desired location, the drone performs the delivery of a specially designed package using one of three methods. The first method of delivery is landing the drone on a predetermined surface, where the customer must retrieve the package either manually or through mechanical release. The second method involves the drone lowering the package to the ground using a cable from a safe height upon reaching the designated location.

The third method involves using a parachute for package delivery. After the package is delivered, the drone returns to the initial location, and continues the delivery cycle.

Figure 3.: Drone delivery using parachute [16]

Figure 4.: Drone delivery using cable [17]

An example of drone usage in l

The usage of drones in logistics can also be demonstrated using the example of the maritime industry. The use of drones is suitable for various purposes in port centers, such as delivering packages to ships, conducting visual inspections of vessels, checking exhaust gas emissions, and similar tasks. On May 20, 2020 the first drone delivery to a ship took place at the Port of Rotterdam. The collaboration between Delta Drone, Allseas, and the Port of Rotterdam facilitated the supply of the Pioneering Spirit, the largest vessel in the world in terms of gross tonnage [14]. Although this was a test flight, it provides a clear vision of the future use of unmanned aerial vehicles and the development plans associated with port logistics.

3. Challenges of drone use in logistics

With the increasing use of drones, their limitations and problems associated with their use are being tackled. It is important to highlight some of the significant issues related to drone usage in everyday logistics.

According to Sah, B. et al. [15], the regulations, and threat to privacy and security, public perception, environmental issues, technical aspects, and economic aspects are one of the main challenges for the implementation of drones in logistics sector. Çıkmak et al. [16] have also concluded that the largest challenges are the regulatory issues, followed by security and safety.

Regarding the security, delivery drones are vulnerable to privacy violations due to their possession of consumer information and built-in cameras. There is a risk of drones being compromised by hackers who can exploit them to unlawfully obtain personal data and deceive individuals [17].

Drones pose a danger to pedestrians and drivers due to potential falls from high altitudes and blade injuries. Flight paths must be coordinated accordingly. Most recreational drones fall into the micro drone category, while drones used in urban logistics fall into the lightweight category, typically weighing between 5 to 50 kg and flying at heights of 30 to 50 meters. [18], [19].

The method of package delivery that drones use is also quite problematic. Currently, as stated above, the delivery methods include dropping the package from a height using a delivery cable, dropping the package from a height with free fall or a parachute, and landing the drone on the ground and releasing the package. Each of these methods carries its own set of risks, such as the possibility of the drone getting stuck or stolen when landing, the risk of package damage during free fall or parachute delivery, and the potential for entanglement and drone damage when using a delivery cable. The use of drones for package delivery is still not economically viable compared to traditional delivery vehicles, as drones are mostly limited to one package per unit. They cannot compete with conventional delivery vehicles in terms of efficiency, especially when cargo volume is taken into consideration. [20]

The legal regulations regarding drone usage in urban areas are not up to date, which limits their use. Another challenge is related to drone battery autonomy, which determines the distance and payload it can carry [17]. The weight of the drone is a crucial factor that determines its aerial capacity in terms of possible flight distance and potential payload. The ratio of weight to payload is essential in determining the overall utility of the drone. Larger drones consume more energy, and they are generally more expensive to manufacture. Most drones are capable of carrying only one package, so careful planning is required to ensure economic viability. [21]

Programming drones to select the most optimal routes to reach customers within urban centers can also represent a challenge. Urban centers are complex systems with numerous variables that need to be considered and pre-programmed for drones. The use of machine learning technology is an integral part of drone programming, which is highly sophisticated and costly. [22]

Furthermore, increased drone usage in urban logistics leads to airspace congestion, which can potentially result in air accidents. The need arises for defining designated air routes for safe drone flights. Restricted airspace areas such as airports or military bases further limit the available space for drone deliveries. [23].

Establishing the necessary infrastructure requires significant capital investments. Drone storage must be in controlled conditions due to the sensitive electronics within the device, and the creation of dedicated take-off and landing strips is necessary. [24]

Although today's drones are robust and resistant to natural elements, like all aircrafts, they are still limited by weather conditions. This limitation reduces their utilization and, consequently, their level of efficiency. [25]

Drones have limitations in terms of delivery capabilities. To successfully complete a delivery, they require a designated platform at the recipient's location, often with a QR code to confirm the order and validate the correct delivery location as a security measure. As a result, they cannot deliver to residential buildings and are restricted to houses with sufficiently large yards for landing the aircraft. [26]

4. Usage and ongoing development of drone logistics technology

The increasing use of door-to-door services and the rapid growth of online commerce have created significant pressure on logistics operators, forcing them to modernize their delivery methods. In line with growing constraints and the demand for environmentally friendly alternatives, most renowned global logistics operators have turned to implementing drones in their delivery systems. Companies such as DHL, UPS, and FedEx are working on their versions of drone delivery systems [27]. While mainstream drone delivery was envisioned by tech giants like Amazon in the early 2010s, is not yet widespread, there are commercial drone deliveries primarily associated with specialized packages, often with short shelf lives or B2B product shipments. UPS has already implemented a system for delivering medical supplies in collaboration with WakeMed, a private clinic in Philadelphia, using a fleet of M2 drones manufactured by Matternet with a maximum payload capacity of 2 kg [28]. The courier service FedEx, through its subsidiary Wing, offers premium delivery services for its packages. Manna is the first licensed drone delivery company in Europe and currently operates in the Republic of Ireland, delivering food and beverages. The Figures 5. and 6. below depict the aforementioned drones from FedEx and Wing in flight.

Figure 5.: UPS delivery drone deployment methodology [34]

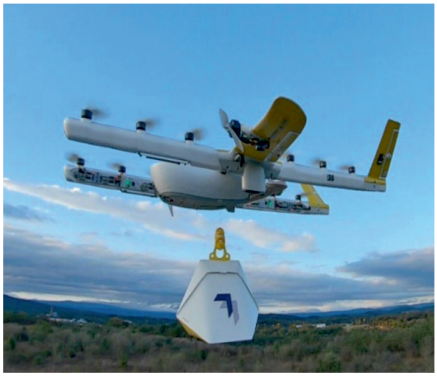

Figure 6.: Wing drone deployment technology [35]

The most advanced use-case of drone usage in logistics is that of Amazon. In a television interview in December 2013, Amazon founder Jeff Bezos made a grand announcement about the development and implementation of drones in everyday delivery, specifically addressing the "last mile delivery" cost [29]. The service, known as Amazon Prime Air, was envisioned as a package delivery system for items weighing up to 5 pounds (2.3 kilograms) within a 10-mile (16-kilometre) radius of a distribution centre, to be completed within 30 minutes of placing an order [29]. Bezos believed this ambitious plan could be achieved within 5 years. However, the first commercial flight of Amazon Prime Air took place at the end of 2022, well beyond the initially projected timeline. It is clear that Bezos miscalculated when considering the costs of drone delivery. According to estimates from the American investment bank Wells Fargo, the cost of package delivery using Amazon's fleet of delivery vehicles is $3.47 per package. When relying on external logistics distributors, the cost ranges from $4.5 to $5.5 per package. Currently, the cost of drone delivery per package is estimated at $484, with the goal of reducing it to $65 by 2025 [30]. It is also important to note that the price of a single delivery drone is $146,000, which is twice as expensive as a delivery van. For example, the price of a 2023 Mercedes-Benz Sprinter, which is part of Amazon's delivery vehicle fleet, was used for comparison [31]. Simply from a mathematical standpoint, the use of drones is not cost-effective for everyday use, especially for low-value packages where the low price cannot compensate for the high delivery costs. Drone delivery can be compared to air transport, as both provide fast delivery of "smaller" shipments with high delivery costs and should be utilized accordingly, for delivering expensive packages with limited shelf life.

5. Utilization of drones in logistics in the Republic of Croatia

The regulation of drones in Croatia is carried out by the Croatian Civil Aviation Agency, but as a member of the European Union, general regulations are established based on the European Union Aviation Safety Agency (EASA). This regulatory agency is responsible for air traffic safety in the EU airspace and establishes all regulations and standards that are then implemented by individual member states. It also deals with all issues related to drone classification and regulation. According to EASA, drones are categorized into 7 categories from C0 to C6, ranging from smaller to larger drones [32]. The parameters for categorization include the aircraft's mass, speed, power, and energy consumption. General flight rules for drones in Croatia are prescribed by the Regulation on Unmanned Aircraft Systems [19]. To obtain a drone pilot license, it is necessary to pass an exam at the Croatian Civil Aviation Agency. For non-recreational flights, approval from the Croatian Air Traffic Control and possession of an insurance policy and identification mark for the aircraft are required for each planned flight. For recreational flights, insurance is not required if the drone's mass does not exceed 20 kg. The maximum flight altitude is 120 m, and flight operations are prohibited within a 3 km radius of airports [33]. The use of drones is experiencing significant growth in the agriculture and forestry sectors. Drones are primarily used for field and forest monitoring, including crop control, pest protection, and field assessment.

The majority of drone use in Croatia, for non-commercial purposes, is still related to military and police operations for border control and search and rescue missions, often in coordination with the Mountain Rescue Service (GSS). Regarding delivery operations, unmanned aerial vehicles are still in the testing phase, both globally and in Croatia, with a few exceptions. It is worth mentioning that the Croatian Post successfully conducted the first drone delivery as part of a pilot project with the Croatian company AIR-RMLD [9]. The drone with the package flew on a pre-defined route from the port of Gaženica in Zadar to the island of Ugljan, specifically to the town of Preko. The drone autonomously flew for about 12 minutes, reaching a speed of 35 km/h. Many postal operators began testing drone delivery several years ago and identified certain shortcomings. A similar trial flight was carried out in the Kranjska Gora area in Slovenia.

6. Conclusion

The constant need to reduce delivery costs leads to non-traditional solutions for executing delivery services, such as using drones for last-mile package delivery. The implementation of these devices is the focus of numerous research efforts by logistics giants like Amazon, FedEx, UPS, and others. Pilot projects and smaller-scale commercial uses that show significant results are currently present worldwide. Through the example of Amazon, we have recognized the challenges that come with

introducing this technology into the delivery process. Perfecting the delivery method and overcoming regulatory hurdles are the main tasks that need to be overcome to fully utilize the potential of drones in the future. Today's use of drones in logistics is just an indicator and a first step toward realizing future plans and methods of using these systems in delivery, which are likely to focus on delivering higher-value packages with shorter time frames in non-urban environments. While recreational drone use is popular, drones are increasingly being utilized in agriculture, forestry, military, and police operations.

This paper also provides an insight into the current use of drones in Croatia. Delivery operations using drones are still in the testing phase globally, including in Croatia, with a few exceptions. Notably, the Croatian Post successfully conducted a pilot project for drone delivery. Despite ongoing testing and identified shortcomings, the use of drones for delivery purposes shows potential for further development. Due to the pronounced lack of scientific contribution on this topic, especially in the logistics, this paper represents the first step for a deeper analysis of its use in Croatia. As future directions of research, it is necessary to identify success factors and barriers that affect the implementation of drones in logistics in Croatia. Drone delivery presents itself as a promising delivery method, offering numerous solutions and benefits, and plays a promising role as a complement to traditional delivery rather than a replacement. However, it is still in the early stages of development and requires significant research efforts to realize its full potential.

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