Shipment delivery challenges using unmanned aerial vehicles

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Abstract

A UAV (Unmanned Aerial Vehicle) is an unmanned aerial vehicle or aircraft that can be monitored remotely or flown independently using a pre-programmed flight plan. Simply, a drone is a self-propelled vehicle heavier than air. From their beginnings and first forms to modern drones as we know them today, people have discovered many areas for their application. As the power and carrying capacity of drones has grown, so does the possibility of using them for different purposes such as logistics and postal services. The main advantage of drones in urban areas is the independence from road infrastructure and fast delivery, but several challenges need to be addressed for this type of delivery to be competitive with other modes. Many projects have dealt with this topic, but none of them has widespread use to this day. In this paper, we will present the basic challenges that arise in the use of drones for shipment delivery. The paper will present activities that should be prioritized to make a competitive type of service. The paper will present also the advantages over other types of shipment delivery and the current limitation with a future possible research area.

Keywords: Unmanned Aerial Vehicle, logistic, shipping, challenges

1 Introduction

The emergence of modern technologies has conditioned the development of new, modern concepts around the world. These concepts are the answers to today's growing challenges, such as reducing environmental pollution and traffic congestion, increasing accuracy and reliability in the delivery of products/services, and automating all aspects of everyday life, all to facilitate and improve quality of life.

Logistics, as one of the special areas of business that contributes to positive economic results, has long been the subject of research and analysis of opportunities for improvement and modernization. Development of new techniques and technologies has contributed to the emergence of smart tools for overcoming numerous challenges in the supply chain.

Increasing demands for logistics services are also contributing to increased environmental pollution. Precisely for these reasons, in the realization of such growing demands, special attention should be paid to finding solutions for the provision of logistics services under more favorable conditions for the environment, as well as human health and life.

The daily increase in demand for e-commerce requires efficient and effective logistical support. In order to respond to the growing demands of the market, it is necessary to modify existing logistics methods and introduce new, more modern, efficient and effective working principles on which logistics processes will be based.

In everyday speech, the term "drone" is mostly used for drones, although there are essentially some differences between the two. In this paper, the focus will be on drones that are autonomous, because only an autonomous system in terms of costs is an advantage over other types of logistic delivery.

Only in very special situations, drones will be able to replace traditional urban delivery methods, but they emerge also as an option to complement existing delivery networks [1]. Within the e-commerce business, delivery time is paramount when choosing a carrier. Drones would enable a fast delivery to a predetermined point, without much human activity and other resources required for transport [2]. In particular, Amazon claims that in the case of e-commerce, 86% of the packages weighed less than 5 pounds
In terms of distance, Walmart claims that 70% of the customers were located within 5 miles of a center [1]. The transformation of the logistics sector that has taken place in the past decade has been significantly marked by the introduction of drones into the logistics system, more precisely: the involvement of drones in logistics processes has become a noticeable and significant element of these processes.

2 Research review

Article [1] states that drones will be used for special situations, especially for inaccessible areas, but they will also be used as an additional activity to classic types of delivery. It is also stated that their advantage is in urban areas and that they can be used in combination with other vehicles. Also, a large percentage of respondents are not familiar with these technologies according to paper [4]. This paper critically examines the research on public acceptance of drones finding the conflation of a diverse range of drone applications has led to ambiguity in the prevailing concerns and that the absence of clear parameters for drone use in local transport environments limits scope to develop informed opinion [5]. The goal of this paper is to analyze four city logistics concepts that differ in consolidation type, transformation degree of flow of goods (direct and indirect, multi-echelon flows), and the role of drones [6].

Authors in paper [7] state that automation enables further growth of postal traffic and also the development of innovative technologies that reduce the cost of shipment delivery, which allows postal operators to create new and better services that ultimately lead to more satisfied users.

Article [2] analyzed the cost-effectiveness replacing motorized delivery with a drone - a case study showing the benefits and cost-effectiveness analysis of the use of drones making the comparison of delivery costs with a light delivery vehicle and a drone.

To compare these costs with the costs of a drone, it was necessary to show the cost of delivery of a light delivery vehicle over a length of 16 kilometers (given that the radius of the drone from the base station is 16 kilometers).

The obtained price per kilometer is divided by an average of 40 packages in the vehicle, which represents the final cost of delivery of one package within a radius of 16 kilometers, which is 4.8 HRK. For a drone, the cost per package is 8.11 HRK. The amount was obtained by putting it in a relationship; the price of the drone and its software increased by the number of required drones divided by the average number of packages shipped to city of Zadar.

Paper [8] presented a multimodal mode of transport where unmanned road robots are used in combination with unmanned aerial vehicles. This has been particularly significant in pandemic conditions where physical contact with humans has been reduced to a minimum.

A review of the literature revealed that there are many more review papers than case studies and classical research papers, which represents a great potential for future research. Paper [9] explores central issues to be addressed and briefly discusses and outlines a number of interesting new research pathways relevant to drone-based package delivery systems.

This study [10] reveals that regulations (R) and threats to privacy and security (Th) are the most critical barriers to drone implementation in the logistics sector. Other important obstacles are public perception (P), environmental issues (En), technical aspects (Te) and economic aspects (Ec), in descending order of their criticality. When we compare UAVs with road transport and if the road route has direct costs, such as tolls, and parking fees, then delivery by drone is better in terms of costs [2].

Paper [11] emphasizes insufficient research where the actual parameters of the drone are examined (battery, endurance, payload, and where the drone would operate in complex
trajectory conditions (congestion, meteorological situation, changing obstacles). There is also a lack of research where drone-based logistics models would be examined and to find under which circumstances they would really be more competitive than conventional types of shipment delivery. Most of the work examining drone performance took into account one drone or one pair of drone-vehicle. It is necessary to investigate the performance indicators of the system and how it will behave in relation to other types of delivery.

In addition to the academic community, a large number of shipping companies have launched their research programs and pilot programs where they have used different delivery methods as well as different types of drones as we can see in figure 2 and 3.

Fig. 2. Delivery time in logistics (minutes) [11]

We can see the drones already used to deliver shipments by different companies. Most of the drones are VTOL aircraft and have a relatively low speed. Fixed-wing aircraft have higher speeds but are not suitable in urban areas where high maneuverability is required. The following graph shows the range of individual aircraft.

Fig. 3. Drone range for logistics purposes (miles) [11]

3 Type of drones used in logistics

The largest number of drones used in shipment delivery are fixed-wing drones. Fixed-wing and rotorcraft UAVs, classified based on the way lift is generated. Fixed-wing UAVs are similar to passenger carrier aircraft in which the wings are used to provide lift while a jet engine provides the forward thrust for take-off.

A drone system includes the airframe and propulsion system and a typical airframe includes a fuselage and a landing gear (Figure 4). The fuselage acts as the platform to carry all the equipment of a drone. For a well-designed drone, all factors including the scale, shape, material, strength, and weight should be carefully taken into consideration. The weight of the fuselage is mainly determined by its size and material. Propulsion system includes a propeller, motor, battery, and Electronic Speed Controller (ESC).

A propeller is a component that provide the thrust force and torque to control a drone. The propeller model is described by a four-digit number, such as a 1045 (or 10 x 45) propeller, among which the first two represents the diameter of the propeller, and the latter two represent the propeller pitch. [12].

Depending on the mission requirements, a rotorcraft aerial robot can have two, three, four, six, or more rotors (Figure 5), most commonly driven by electrical motors supplied by power from the electrical battery (somewhat less common, but still available, are fuel cells). For heavier payloads, 2-stroke small-scale internal combustion engines are used to drive rotors.

Fig. 4. Drone components

Choosing appropriate propellers is a direct way to improve the performance and efficiency of a drone (thrust vectoring).
Drone motors are mainly brushless DC motors (Figure 7) for the various advantages such as high efficiency, potential to downsize, and low manufacturing costs. Brushless DC motors are used to convert electrical energy (stored in battery) into mechanical energy for propeller.

The overall performance of the propulsion system depends largely on a well-matched combination of motor (nominal voltage 10-24 V).

The drone would be able to be powered only with internal power in the form of batteries which limits the power received and the time in which it is able to fly, while at the same time being able to perform VTOL. There are many types of batteries, where the Lithium Polymer (LiPo) battery and Nickel Metal Hydride (NiMH) battery are the most commonly used ones because of superior performance. The basic parameters of the battery include voltage, discharge capacity, internal resistance, and discharge rate. The nominal voltage of a single cell of LiPo battery is 3.7 V

The basic function of Electronic Speed Controller (ESCs) is to control the speed of motors based on the signal that autopilots send, which is too weak to drive brushless DC motors directly.

The milliAmpere-hour (mAh) or is a technical index that how much electrical charge a particular battery has. The capacity of 5000 mAh for a LiPo battery means that the discharge of the battery will last for an hour with the current of 5000 mA when the voltage of a single cell is decreased from 4.2 to 3.0 V [12]. Energy density is the amount of energy stored in a given system or region of space per unit volume or mass named specific energy are (Watt × hour)/kg.

An RC transmitter is used to transmit commands from remote pilots to the corresponding receiver. Receiver, passes the commands to the autopilot after decoding them and multicopter flies according to the commands.

A drone autopilot is a flight control system used to control the attitude, position, and trajectory of a drone. It can be semi-automatically (needs commands from remote pilot) or fully automatically. Autopilots have a control framework which is often based on Proportional-Integral-Derivative (PID) controllers, leaving parameters to be tuned for different drones. GNSS receiver is used to obtain the location information of drone [12].

Radio telemetry refers to using Digital Signal Processing (DSP) technology, digital modulation and demodulation, radio technology to transmit data with high accuracy, and it is equipped with functions of forward error correction and balanced soft decision.

### 4 Results and discussion

Several problems still need to be addressed for this mode of transport to be competitive. In addition to the design and capabilities of the aircraft, it is necessary to develop additional infrastructure in cities that would be favorable for drone operations. The introduction of drones into the existing distribution system requires major changes and adaptations. Some of these changes include the construction of take-off and landing facilities, battery charging sites, the assignment of drone truck adaptations, changes in surveillance systems and regulation of drone navigation capabilities. There are also currently very active services and expansion of e-commerce and some of the innovative solutions of city logistics are PUDO (Pick up and drop off), delivery technology in the last mile and is based on delivery using parcel machines. Systems that rely on small autonomous delivery robots are also in use. Delivery robots represent a new opportunity to improve last mile delivery concept in urban areas. Based on previous research, an overview of the advantages and disadvantages of using drones in logistics is given in the next table.
The development of technology and autonomous systems has enabled postal and logistics operators to reorganize and optimize their operations. In its history, drones have been mostly used for military purposes, but with the development of e-trading, it is increasingly used for civilian and logistics purposes.

Drones can provide a lot of advantages over traditional means of transport and ground based delivery. The most crucial factor is the reduced cost of operation and easy management. Delivery services and courier companies can take help of drones to resolve the pain points for last-mile delivery. Drones are set to become the future of logistics with their reduced cost, higher convenience and delivery times of less than 30 minutes. Last-mile delivery of goods is often carried out by vans, most of which have internal combustion engines. Drones may represent a helpful and innovative transport system to decrease environmental and noise pollution and congestion.

With the development of technology and intensive urbanization, the need for logistics services is becoming increasingly important. Drone shipment delivery is one of the innovative methods that has its advantages over classic types of shipments.

The traditional delivery system when it comes to variable and fixed costs is not more expensive than the modern way of delivery by drone. The introduction of this delivery method in Bosnia and Herzegovina would be of great importance, especially since most of the territory of BiH consists of very mountainous terrain as well as large urbanization. This urban first and last-mile use case is probably the most tangible and spectacular in the logistics industry.

### Table 1. Drone advantages and deficiencies

<table>
<thead>
<tr>
<th>ADVANTAGES</th>
<th>DEFICIENCIES</th>
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<tr>
<td>Inaccessible and remote sites operation</td>
<td>Limited capacity, range, duration and weight of batteries</td>
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<tr>
<td>Autonomous unmanned systems</td>
<td>Limited operations in adverse weather conditions</td>
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<td>Vertical takeoff and landing</td>
<td>Signal strength, loss of signals</td>
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<td>Lower maintenance costs compared to conventional aircraft</td>
<td>Danger of injury or damage to property from drone falls, especially in urban areas</td>
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<tr>
<td>Adequate for last-mile delivery, especially in urban areas</td>
<td>Noise pollution</td>
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<td>Low environmental impact</td>
<td>Privacy and security and distrust of people</td>
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<td>High-speed delivery</td>
<td>Air traffic regulations/use of airspace</td>
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<td>Advantages of multimodal delivery - the possibility of combining with other modes of transport</td>
<td>Limited infrastructure on the ground for safe and secure delivery of the shipment to the user</td>
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<td>Suitable for cities where there is large urbanization on uneven terrain (easier access by drone from vehicles)</td>
<td>Obstacles in urban areas (power lines, trees, buildings)</td>
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<td>Great development potential, especially in the field of artificial intelligence that will relieve the human need to manage this type of shipment.</td>
<td>Cyber security and package damage</td>
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<td>Aircraft with vertical and horizontal flight capabilities (higher speed)</td>
<td>Drones need to be autonomous to be competitive with other types of transport, hence AI, but AI has not yet progressed to that level (drone does not differentiate between person and dog or terrain and pool)</td>
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<td>Greater safety and relief of roads</td>
<td>Significant pilot training or development of autonomous systems is required</td>
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<td>Substitutes vans and relieves traffic congestion</td>
<td>The cost of transporting drones per unit weight is much higher than many other solutions due to energy-intensive requirements.</td>
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<td>Great competition from traditional methods of shipment delivery</td>
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5 Conclusion

This paper analyzes the challenges facing this system and provides insight into future needs and research and how to make this method of delivery competitive. The advantages and disadvantages of such type of shipping are given. We conclude that this type of transport still has many obstacles that need to be addressed in the future. Infrastructure and places where drones will move and operate need to be adapted and developed in parallel with drone technology.

Based on this paper, we conclude that drone technology will slowly replace and the human factor in certain jobs and activities in which until then only man was responsible. The use of drones will greatly improve living conditions, but also change the world we know.

References