

USE OF DRONES IN LOGISTICS: OPTIONS IN INVENTORY CONTROL SYSTEMS

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ABSTRACT

New and promising technologies are constantly emerging in the transport and logistic sector. These technologies provide new and effective opportunities in the supply chain. The application of autonomous mobile robots, automatization, artificial intelligence, and unmanned aerial vehicles is not the distant future. We can create more efficient, secure, precious, and rapid solutions with the help of the UAVs' properties like the size, the mobility, the functionality, the capabilities, and the development possibilities. Modern technology and development make them teachable and programmable, furthermore we can develop independent decision-making mechanisms into the solutions. They can have a powerful image and data acquisition, as well as analysis capabilities. There is great potential in this technology. It can reorganize the future supply chains. Businesses can increase their solutions' cost-effectiveness, speed, accuracy, and safety in different areas like billing, inventory, transportation, and workforce productivity. We provide a summary of the UAVs in this article. We demonstrate the spread, the usability, the challenges, and the opportunities of this technology in the transport and logistic sector. Within that, we present more about the usefulness of inventory.

KEY WORDS

unmanned aerial vehicles, legislation, drones in logistics, intralogistics, inventory

CLASSIFICATION

JEL: L86, L93

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PREAMBLE

The Unmanned Aerial Vehicles (UAVs), also known as drones, are no longer the future. The purpose of this article is to demonstrate the multiple usages of drones, with the focus on the logistics sector, more specifically in inventory systems. We provide insight into a wide range of applications, news and trends through the UAVs' history and evolution. This gives us a better picture of challenges and opportunities in the present and future. Nowadays drones are highlighted because of the military utilization. However, in terms of their usage there are non-military UAVs as well. It is important to mention that technical and technological progress of non-military drones comes from the military utilization [1].

Like all emerging technologies, UAVs have many negative prejudices and fears, especially because of military origin and usage. These issues and concerns relate primarily to the capabilities, the limits of the technology, the incomplete regulatory environment and the safe operation. Privacy and security concerns (such as tracking) are common problems as well. But if we take these issues aside, we can admit that the non-military drones can be used in many sectors. Furthermore, cross-sector usage can also work well [2].

In this article we focus on the close and short-range UAVs, but because of their technical abilities and limits we do not investigate the mid-range and endurance ones. Our goal is to have a look at the cutting-edge technologies and automation enhancements in the face of global challenges in the logistic sector. We also investigate the field of logistics utilization. The main focus is the role in supporting intralogistics systems and within that the solutions of the in-stock inventory automation. To the better understanding of the UAVs' inventory and stock management solutions we did an in-depth interview with a startup called Aeriu.

The technology, related developments and regulatory environment is undergoing continuously and changing significantly. It is the reason why this technology, the related products and services can be examined in the short term.

THE SPREAD AND FORECASTS OF THE UAVS

The term "Unmanned Aerial Vehicle" can be used for any aircraft that does not carry a human being. These devices can be controlled independently or they can fly based on a pre-programmed flight plan. With the help of remote access they can achieve more complex tasks and they can be integrated with automation systems. When we talk about drones we need to differentiate the Unmanned Aerial Vehicles (UAV), the Remotely Piloted Aircraft Systems (RPAS) and the Unmanned Aircraft Systems (UAS). In this article, the term 'drone' will be used for all of them.

Their first appearance is due their usage in the military, but at the same time these devices are already widely adapted in the commercial sector. They have a broad spectrum and a wide range of adaptation in civil life. Companies have seen many opportunities to utilize this technology. There are many R&D projects in this topic. UAVs can be adopted in many sectors like agriculture, transportation, construction, logistics, industry, public security, governmental use, etc. [3].

As *Figure 1* shows the growth and economic potential of unmanned aircraft is continuously increasing according to global drone market forecasts. The background of this trend is the multiple usage and adaptability [4].

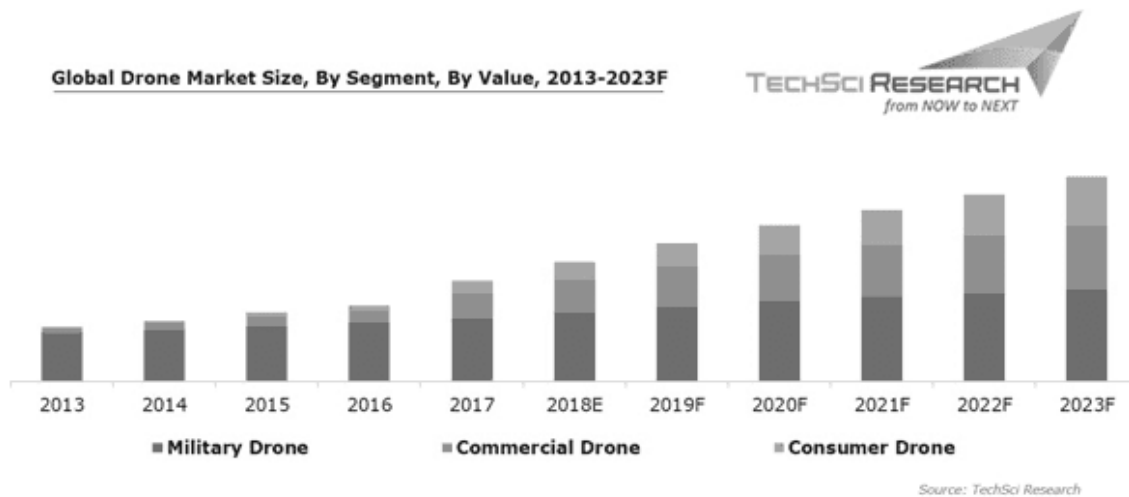


Figure 1. Global Drone Market Size 2013-2023.

The progression of the technology and the new adaptations of the commercial UAVs will increase as the trade of drones. The evolution of regulatory policies and directives has a good effect on the market growth.

REGULATION

The elaboration and the existence of the regulatory environment and the cross-border norms play a key role in the spread and usability of UAVs. Legislation is influenced by several factors and it has some concern as well. There is a wide range of difference among national and intercontinental regulations, meanwhile the harmonization is difficult. This is the main problem both in the European Union and globally. There are some other major regulatory problems like aviation regulation and security issues. General air traffic has become congested and overloaded with the spread of drones and their utilization in many sectors.

The UAVs had controlled and limited access to airspace based on previous aviation regulations. However the airspace became too crowded despite these rules. This particularly affects the big cities. Drones have become disturbing factors for other airspace users like aircrafts. However, uncontrolled drones are and can be a serious security issue. There is a pressing need to modify the airspace usage limitation for these devices. They have to integrate with other users in the airspace. But such modification is not easy. These regulations and integration processes must be enforceable and innovative.

The motion of drones in airspace and their traffic control has another problem: these devices move fast anywhere in multiple directions, unlike other means of transport. In this case there is no limitation as guided land transport has the rails or road traffic has drive-ways. Therefore any malfunction could pose a serious security risk. To make safe operation and usage possible not only airspace regulation is needed, but other factors need close attention as well.

The level of security, malfunction protection and manufacturing technology of the drones must meet serious requirements. These factors can also avoid accidents like crashes of the UAVs. Beyond technical and usage issues we also have to pay attention to data protection problems. The drones are suitable for observation with the connected cameras and sensors. There is an urgent need to regulate this issue. Like all evolving technologies, drones are very risky when it comes to cybersecurity as well. Malicious actors can sabotage and use them to support their own agenda. It can be seen that

drone regulation is a very complex issue. There was and there is a need for a comprehensive package which includes identification, tracing, traffic management and operation as well [5].

The European Union has introduced a number of laws and regulations over the past few years. Such as the Regulation (EU) 2018/1139 of the European Parliament and of the Council (4 July 2018) on common rules in the field of civil aviation and establishing a European Union Aviation Safety Agency, and amending Regulations [6].

On 26 June 2018, the Council also adopted a new proportionate and risk-based rule. This allows the EU aviation industry to grow and become more competitive. Furthermore, the European Commission adopted EU-wide rules (EU) 2019/945) on 12 March 2019, which specifies the technical requirements for drones. The Regulation is in line with the previous European Union Aviation Safety Agency (EASA) Regulation. It sets out important principles regarding security and personal data protection [7].

These new regulations and common rules will also encourage increased investment and innovation in this sector.

DRONE UTILIZATION AREAS

Drones can be used in many areas. These devices have changed a lot since their release. The market offers many variants with many specifications today. Generally the most important election aspects of these vehicles are the price, size, weight, effective ranch, battery time and the service that they provide. Different sectors can have different priorities:

1) Energy and infrastructure

These sectors typically need long distance capability to monitor the infrastructures like roads and wires. UAVs can reduce the cost of the control process. One solution can be the pre-programmed route. In certain cases, experts can take closer measurements to achieve better analysis accuracy.

2) Agriculture / Nature reservation / Environmental protection

Drones can be used to control and monitor the previous category. The more accurate data gathering becomes possible by using these devices. Also the control of the animals and plants can become easier.

3) Construction industry

We can use drones to improve work processes in many different ways in this industry such as territorial analysis of the building areas, aerial photography, data gathering and refinement of design work. UAVs can provide a more cost-effective solution for controlling, monitoring or support of construction work. Furthermore, there may be other usage of construction monitoring and control.

4) Security, critical care, disasters

UAVs with cameras and sensors are excellent for special cases. They can be used to detect disasters and security incidents, as well as to information transfer. It makes the response for incidents and decision-making more effective.

5) Cartography, photography, film industry

We can make significant cost savings in these sectors by using drones. This technology makes possible the usage of better and wider viewing angles, better focusing performance and new viewpoints.

6) Transport, logistics

At the transport and logistics sector there are many possibilities to use UAV technology such as delivery, inspection, inventory. etc. [8]. The following chapter gives a better overview of this specific sector.

DRONES AT LOGISTICS

UAVs can be used in many different ways at the transport and logistics sector because of the integration into and with each other. The devices that can be used here are those that can work with small cargos or without them. They are best to integrate new logistics applications and services into existing and new systems. The load and battery capacity is key when it comes to the consideration of usage of drones in these sectors.

In this article, the utilization area will not be presented fully. Focus will be given to the applicability of the drones in intralogistics. We would like to provide an introduction to each application. Within the areas of use we will discuss and examine their practical application and experience they will give in the inventory system (Figure 2). To carry smaller packages is another important area of usage of drones. We will revisit that topic later in this article.

The reform of delivery methods is expected. This is closely related to the increase in demand. The UAVs can significantly facilitate the access of the crowded beehives at the cities. This solution is expected to play a major role in the future, although transportable cargo and the battery is a problem here as well. The potential of UAVs can be the same as conveyors and wires [9].



Figure 2. Drone supported inventory [10].

In an intralogistic environment, we should focus on areas where drone usage has a significant positive impact on efficiency. Possible areas are cost-effectiveness or replacement of human resources. These can make the process more economical. In our opinion, drones and related smart applications can not replace the human resources today. However, the complex tasks entrusted to them can free up human capacity, even so a complete decision-making process can not be replaced. Human responsibility will remain important in the following recovery areas, although most of the tasks can be done automated with a help of drones:

1. inventory,

Inventory and its control is typically an application area where drones have been proven to be effective. The primary condition of such solutions is the proper position of the cargos, collectors and pallets. Because of the usability of the associated identification marks, tags, barcodes, etc. have to be scannable by the drones. The modification of the storage system and the routes are not

necessary. This kind of preparation does not interfere with material transport. The only criteria is drones have to be customizable and integrable to the given system. They need to have reading, recording and data transmitter capability and applicable cameras. The right controlling algorithms of drones are also important. Such solutions already exist, like Exesee or Aeriu, which we will introduce later in this article.

2. commission,

In case of commission we also need smart devices that can replace human resources. This work can be done faster and more effective with drones instead of human beings. The homogeneous warehouses can be rendered inhomogeneous. In this case drones are also equipped with transportation or grasping add-on besides reading, recording and data transmitter capability. Using multiple devices in the same time is possible similarly as at inventory usage. However, we have to keep in mind that these devices can crash with each other. As we can see, there is a huge potential in this application as well. The challenge here is the stability and strength of the transport mechanism besides the carrying and battery capacity. There are other automated solutions such as portal robots. These can be competitors of drones.

3. delivery,

We already mentioned delivery and shipping out of stock. There is a huge market interest in this area. Depending on the specific need not just indoor devices can be used but the wild range of drones. In this case, it is possible to carry out an autonomous transport task based on GPS coordinates. These drones must be endowed with the appropriate artificial intelligence and they have to have integrated sensors and image recognition solutions as well. The carrying and battery capacity is a serious challenge here. There are other problems that we have to solve here such as unattended control, recognition of the environment, flight control and changing weather conditions. In this case delivery primarily means the delivery within the warehouse and delivery from storage complexes to depots or other landfills. It can also mean getting to the end user. This area of utilization requires even more technological development.

4. working day sampling.

This is a statistical metric of a sift utilization rate. It shows the observation of devices, operators, machines at a factory, a warehouse or other facility from time to time. Using this metric we can optimize our processes because we can easily and more effectively reduce the waiting time for different tasks. To be integrable with the available systems the drones have to be equipped with on-board cameras, reading and transmitting units [9].

DRONES IN INVENTORY - THE HUNGARIAN STARTUP, AERIU

The control of inventory is one application of drones. It can make the process easier and faster. We can find workable and proven solutions at many international companies from Africa, Singapore, US, France and Hungary. It means practical experience and measurable results are available from the field of utilizing drones in logistics. Proven results in measuring its effectiveness are accessible. We conducted a personal interview with Gergely Ellenrieder, the CEO of Aeriu. Aeriu is an international startup from Hungary. They are active in this sector. Gergely answered our questions and shared his experiences with us.

Auriu is a software development company with a revolutionary product. They operate with man-driven drone(s) in a warehouse environment. It is able to scan and read the ID on pallets and products while flying in “S” shape. The software can be controlled via an iOS-based Iphone [11].

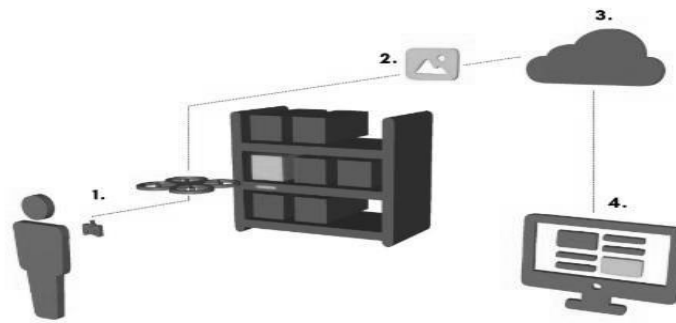


Figure 3. Principle of operation [12].

As can be seen in Figure 3, the data captured by the drone is transmitted to a synchronized cloud. It makes the information available to the application's users. Aeriu mostly focuses on software development. That is why they do not need to develop their own drone. Their solution is able to work with any commercially available device. The customer doesn't need to buy new hardware, because Aeriu can operate with drones purchased for other purposes earlier. The solution of Aeriu is easy-to-implement, and it can be used and maintained simply. This is Aeriu's unique value proposition comparing to their competitors. They provide full service to their customers. They also give advice and technical expertise besides the software itself. After assessing the customer's unique storage environments and endowment they optimize the software, the devices and other necessary resources [11].

The company was established by five young IT professionals in 2017. After the idea and initial thoughts, they thoroughly investigated the warehousing and logistics environment. They realized there are many problems with traditional manual inventory. Inventory with forklifts is a very slow process when accident prevention rules are followed. Furthermore, a manpower-controlled forklift was slow and the operator had to overcome serious maneuvering obstacles. The number of people working as a forklift operator has decreased, but their inventory job had to be done. Using modern solutions seemed like a sustainable approach that can provide a faster, more efficient, and more secure inventory. The founders firstly collected a wide range of information about the challenges and needs of the corporates - and they figured out what the real problem was [11].

The main issues with forklift-used inventory were the shortage of manpower, problems of the monotonous work, slowness, inaccuracy and hazardous working environment. Furthermore, the chance of making mistakes was also very high, not to mention the fact: inventory of forklifts requires at least two people. E-commerce and the change of the market environment are putting an increasing amount of pressure on storage systems. Speed and cost-effectiveness are increasingly important. Aeriu started to test their new solution at Waberer's, Nestle and Hell.

According to Aeriu, using drones makes the time spent on inventory become 50 % faster. Drones can scan a pallet of barcodes in about 8 to 10 seconds. This means if we use 2 drones and they do the inventory work for at least 6 hours, approximately 3 000 pallets can be accurately captured without an error. Initially, it was difficult to convince companies that inventory with drones can be a safe and fast solution in tight indoor warehouses. However, after tests and comparative analysis, it became clear that the security risk is much lower. Moreover, the videos captured by drone cameras capture additional relevant information as well, which can be analyzed. Such as permissive waste can be monitored or quality defects in products and storage systems can also be detected. A machine learning algorithm can prevent potential threats, too [11].

The company promises their solution makes inventory 50 % faster, 99-100 % greener and safer, and about 20 % cheaper. For the time being, the drones must be controlled by humans. In order to handle the Aeriu software correctly, employees need to participate in a 16 hours long training. Their services are available in several packages as of now (Figure 4).

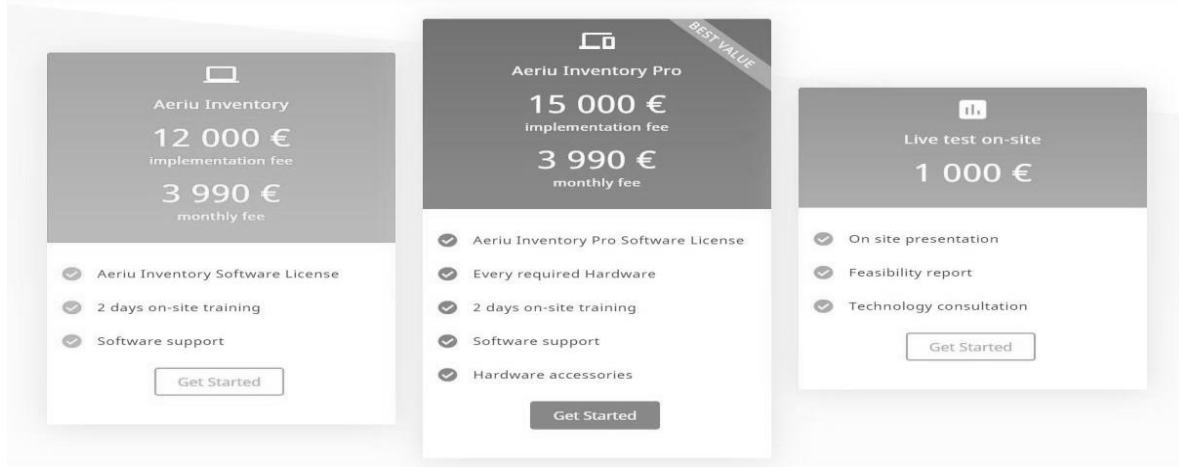


Figure 4. Aeriu packages and pricing [12].

The Aeriu system can be fully customized and integrated to the customer's existing systems. In addition, custom upgrades and devices are also available. They use implementation and monthly fees. As drones are not developed by Aeriu they cooperate with Duplitech Ltd. They are DJI's official partner in Hungary. That is why they can be replaced immediately if the customer's drones fail. The first customer of Aeriu was IKEA in Hungary. Here they use the company's products to carry out the inventory work [11].

At the end of 2019, Aeriu was invited to Milan (Italy) by a multinational company, RGIS. They deal with inventory as their main activity around the world. RGIS has ordered the full service package. Such inquiries and concluded contracts show that there is a need of Aeriu's services [11].

Aeriu plans to conclude additional domestic and international contracts. They want to expand into the region and Europe and also hit international markets such as the US and Canada. Product development will not stop, and they are working on team and services extension. Achieving autonomous flight is also a development plan. For the time being, they are still thinking about indoor usage [11].

SUMMARY

Unmanned aerial vehicles and drones are expanding into new areas and new market segments. As a matter of fact, the increasing proliferation of assets has changed the market itself. There are new technologies, developments, new services and applications for such devices. Current forecasts suggest that drone recovery will cut a larger slice of the global market. The utilization areas are numerous. Drones can be applied in several sectors both indoors and outdoors. The transport and logistics sector is also taking advantage of the opportunities that are offered by unmanned aerial vehicles.

This technology is going through an immense amount of improvements, however, it faces lots of challenges as well. The creation of a safe and identifiable usage of the drones in the airspace is also a major regulatory challenge. Legislators have made progress in many areas to create a better regulatory environment, but there are still regional and global issues which need to be resolved. The main problems are the safe technical and physical parameters, the identifiability, the security of the extracted data and airspace control. There are issues with the battery capacity that cause a short range of the UAVs. In addition to these basic challenges, the design of vehicles suitable for transport is also a challenge. Furthermore, we have to find a way how we can use drones in the

security and control sector. Using them in different integrated systems can be a dual perspective. While it can cause the elimination of jobs, on the other hand, it can solve a shortage of labor.

Drones have been investigated primarily for use in the transportation and logistics sector in this article. The usage of these devices was examined at intralogistics, because measurement results are already available mainly in indoor use and the regulatory environment is also better. We have introduced effective, fast, accurate, and secure applications for inventory and its control system. We have also examined their opportunities and major applications. We conducted a personal interview with the Hungarian startup, Aeriu to gain better understanding about the practicalities of using UAVs. They have provided inventory solutions with drones. The received information has confirmed what we had known so far. The use of drones in logistics gives measurably more effective results.

The used technologies and the direction of developments offers many opportunities not only for the transport and logistics sector but also for many other sectors. The transportable drones will bring improvements and new applications with the help of integration. The usage of machine learning and artificial intelligence can also lead the developers into new dimensions. Better regulation environment and the improvement of technical parameters and capabilities may cause a reform of the use of drones in the market.

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