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THE USE OF CIVIL DRONES IN FOREST DISTRICT LOGISTICS

Abstract

This article concerns a relatively new technology used in logistics, namely, civilian drones. The experience of various industries shows that drones can be treated as an important element of the organization's logistics support system (LSS).

It is forest districts that were adopted as the research environment. Drones are used in forest areas where research on a wider use of drones in forest management processes is conducted. In the article, a forest district is considered in the categories of a logistics system. The role of drones and their influence on the functioning of a forest district in which activities require to be coordinated and can be treated as logistics processes is also presented.

The main aim of this article is to determine the functionality of drones in terms of acting as one of the essential elements of a forest district system. Processes that can be improved by additional support of drones are identified. Conclusions regarding the integration of drones with the information system of the whole organization are universal and may also apply to other sectors of human activity, including those of a business nature.

Keywords: drones, forest districts, logistics support system, logistics process

Introduction

Unmanned aerial vehicles (UAV), which were originally used exclusively by the military to perform military operations, are becoming more and more available for civilian activities. Despite significant factors that are limiting a widespread use of drones, they have much potential which can be exploited, for example, to collect data on monitored physical flows and to transfer such collected data to the traffic control centre. Including drones in the enterprise's system can be another major milestone in its development, such as wireless telephones or the Internet.

The article consists of a theoretical part which defines a logistics system and the LSS. The next part characterizes a forest district and the processes therein, identifying also the logistics system of a forest district. The drone technology and its types is presented in brief. Finally, the possibilities of supporting forest industry logistics processes by civilian drones are proposed and final conclusions are formulated.

The considered forest districts concern Poland, however, some user experiences from Norway are also included.

1. The logistics system of a forest district

Defining the logistics of a forest district and its basic concepts should begin with understanding the essence of the system itself. A Polish dictionary defines a system (a similar word to the Greek *systema* – a whole made from many pieces which acts as one) as, i.a., a coordinated arrangement of elements, a set that creates the whole, conditioned by a constant and logical ordering of its constituent parts (Polish Language Dictionary, 2004). The notion of a greater whole was already used by ancient philosophers, including the greatest ones, like Aristotle, who in his *philosophia prima* used a metaphor of a set of letters to understand this greater whole and its parts. A thing which is composed of something creates a whole in the sense of unity. In other words, a syllable is not just a set of letters because the word 'cat' is pronounced differently than the single letters of which it is made, namely 'c', 'a' and 't'. Together, they not only create a collection of consonants and vowels, but also a whole syllable, which is a part of a larger set called word. Therefore, as Krąpiec and Żeleźniak state (1966), there is no more expression by splitting the word into components, but syllables only.

According to Gołembska (1994) the logistics system in terms of the subject is a set of elements such as: production, transport, storage, recipient, along with relations between them and between their properties, conditioning the provision of a logistics service.

In terms of the object, the elements of the logistics system are material, financial and information streams in respect of which logistic operations are carried out. These operations combine individual elements together, starting from common goals and the criterion of effectiveness (Chudakov, 2001).

On the basis of the above definitions, it can be attempted to characterize a forest district in terms of logistics and its basic concepts.

A forest district is a basic economic and organizational unit in the structure of the State Forests National Forest Holding. Each of the forest districts is divided into 1-4 forestry sub-divisions, which in turn are divided into several or more forest sub-districts. According to the data of the Geographic Information System (GIS, 2018), there are 430 forest districts in Poland.

The key to a logistics approach to a forest district is to treat it as a warehouse with a production function. A forest district is indeed a warehouse in which animals, plants and various types of raw materials are kept. This peculiar 'natural warehouse' also reveals the characteristics of a manufacturing plant because trees are planted in it so that they can be felled and sold in the form of timber after some time (usually a dozen years or so). After cutting, wooden logs are temporarily stored on a previously separated piece of land, until they are transported to the recipient. Inside a traditional warehouse, objects are displaced in a controlled manner and periodic stocktaking is carried out from time to time. In contrast to goods stored in a traditional warehouse, forest animals (e.g. birds), move spontaneously around the complex, sometimes even beyond its boundaries, which makes it much more difficult to control their quantitative status, compared to a traditional storage facility, where there are physical boundaries, in the form of a fence.

The logistics system of the forestry inspectorate is used to rationally and effectively secure the functioning of this unit by:

– supplying people fit to work and materials such as: fertilizers, tree seedlings, plant protection chemicals, machinery and other equipment;
– distribution of plants and animal products;
– sustainable exploitation of fixed assets and responsible management of forest resources;
– protection of the natural environment including soil, water and air, as well as maintaining the natural state of specific ecosystems;
– providing information on quality and usability in terms of the condition of the forest district and its surroundings (e.g. technical, technological, economic).

Figure 1 shows the logistics system of a forest district.

At the input of the working subsystem there are raw materials, manpower, tools, machinery and financial resources. Processes like planting, taking care of plants and cutting down mature trees occur within a working subsystem. Forest animals need extra care only when they get sick or enter a dangerous area during the maturation process. Surplus animals are intended for hunting. Hunting licenses are issued by the forest district as a service. The output of the work subsystem includes end products (wood, hunted animals, plants, forest fruits), services and costs. Depending on its purpose, wood is transported to a sawmill or to the end user as fuel. Other recipients of animal products are: hunters, butchers, butcher shops, end customers.

Decisions are made in the management subsystem, which consists of registration, decision-making, reporting and planning areas. Factors, located in the (distant and near) environment of a forest district, can interfere with the decisions taken. There is an exchange of information between the management, working and security control subsystems. Therefore, it is important to operate logistics support processes dedicated to the entire forestry system, as well as an element that will coordinate and integrate all system activities. This refers to the LSS in all its glory.

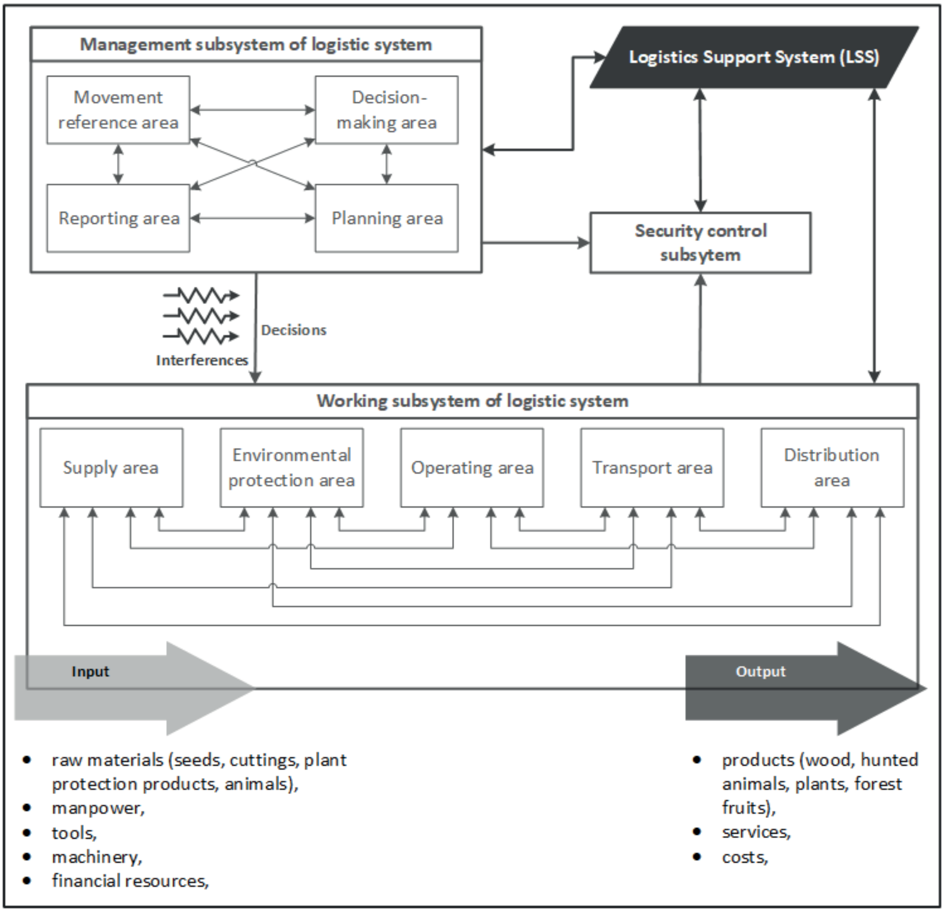

Figure 1. Logistic system of a forest district
Source: (own elaboration)

2. Logistics support system of a forest district

The LSS is responsible for integration of resources and coordination of activities supporting the manufacturing process. This system should be understood as an intentionally organized subsystem of any organization which supports its basic process of goods production by integrating all activities related to effective and beneficial flow of necessary resources to produce a basic asset and supporting the production process to provide the necessary equipment for this process, both in terms of its availability and reliability (Chaberek, 2002). Chaberek (2002) also claims that:

– every organization (be it market or non-profit) must have a system supporting its core business, based on the basic process;

– the system supporting the basic activity of the organization is a kind of reflection of the processes in the organization and its structure (elements and relations between them);
– the tasks of the system supporting the basic activity of the organization are focused on the logistics service of the production process of its product.

Figure 2 shows the LSS components.

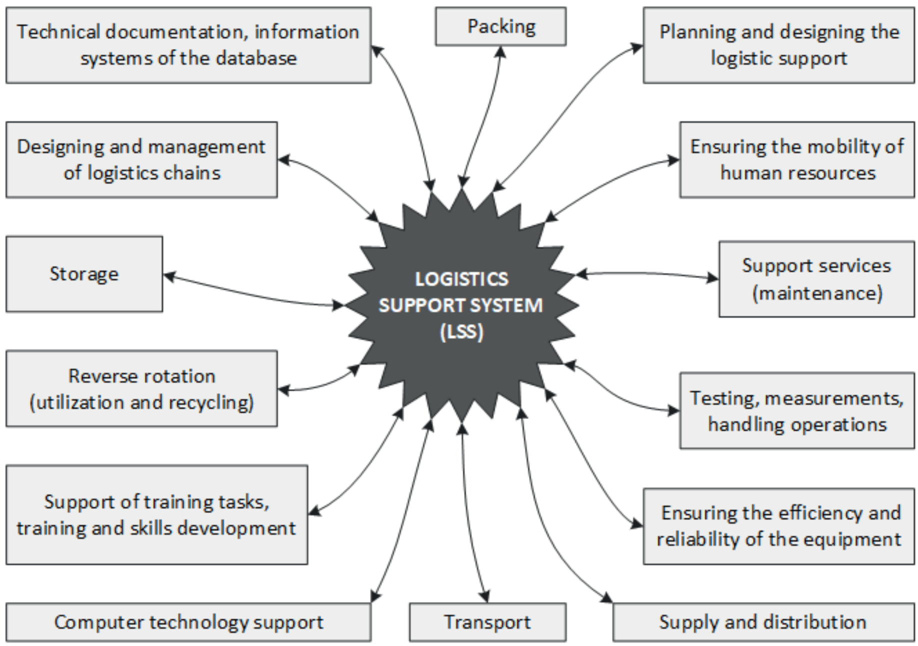

Figure 2. Components of LSS
Source: (own elaboration based on: Chaberek, 2002)

The forest district organization itself, as well as its internal structure (defined inputs and outputs, cause-and-effect relationships between elements) meet the conditions to be considered as flows that are basic for logistics.

The LSS of a forest district should be understood as the sphere of its operation, which supports all its activities (basic and auxiliary), by coordinating and integrating all processes related to an effective and optimal flow of resources which are necessary for the proper functioning of the organization. It also has to guarantee the necessary equipment in terms of availability and reliability. By shortening this definition to a minimum, the LSS of a forest district is responsible for the logistics support for the implementation of the forest district's objectives. The primary objective of every forest district is rational management of the forest space and resources. In addition, the forest district must ensure safety, determined by many negative biotic and abiotic factors such as: hurricanes, floods, droughts, fires and other natural disasters, pests, diseases (e.g. African swine fever virus), as well as destructive human activities. The Forest District also plays the role of a public utility whereby it is necessary to ensure the accessibility of tourist routes.

The essence of the LSS lies in an integrated approach to the overall activities that support a specific process. The key elements are information and its proper management. The technology that supports the operation of the organization's information system including the logistics information system are drones.

3. Types of civilian drones

The term 'drone', commonly used for civilian purposes, means an unmanned aerial vehicle (UAV) which is remotely operated with no pilot on board (ICAO, 2011). A UAV is a component of an unmanned aerial system (UAS), which includes the UAV with its human operator and the communication system between them. The most important feature of the UAV is the ability to program the aircraft so that it can perform certain operations without the help of its human operator, and flying objects exactly of this particular type are called drones. With each subsequent generation, drones become more and more autonomous, what makes them easier to use and more accessible to people. Civilian drones, unlike military ones, do not serve military but only scientific, entertainment or commercial purposes.

Many various types of drones can be divided into (Custers, 2016):

– fixed-wing drones;
– multi-rotor drones.

Fixed-wing drones have one or more fixed-wings attached and resemble an airplane in appearance.

Figure 3. Fixed-wing drone on the launcher
Source: (UST, 2018)

A fixed-wing drone is driven by a rotor, usually placed at the rear of the vehicle. It has to constantly move forward to glide, and due to this, it is possible to manoeuvre it hovering in the air. A drone is launched into the air from a special launcher, and the landing process follows the same steps as is the case with larger aircraft.

Some models may have one or more pairs of wings. In such case, they are multiplane drones.

Multi-rotor drones are based on the helicopter's scheme, and their type depends on the number of installed rotors. Figure 4 shows the appearance of a multi-rotor drone.

Figure 4. Multi-rotor (quadcopter) drone
Source: (Phantom, 2018)

There are also hybrid drones, which are a combination of fixed-wing and multi-rotor drone features, making it difficult to classify them into one of the previously introduced categories. An example of a hybrid drone is shown in Figure 5.

Figure 5. Hybrid drone
Source: (BirdsEyeView, 2018)

Owing to their design hybrid drones can take off and land vertically. There are also hybrids equipped with wheels that allow them to drive on a surface.

4. Use of civilian drones in logistics

A UAV can be equipped with a range of sensors, cameras and other devices that expand the possibilities of its operation. In particular, global enterprises recognize the benefits of task automation. This was seen, *inter alia*, by the American commercial network Walmart, which replaced some of its employees with drones in distribution centres and warehouses. After attaching a special scanner to the body of the drone, it is able to make inventory up to 30 times faster than a human being. This not only improves the work efficiency, but also effectively reduces the number of errors, which in a broader way translates into better business results of the enterprise (Bołtryk, 2018).

Amazon has a model for delivering small packages up to 5 lbs. According to the assumptions, transport takes place within the city, and delivery time takes up to 30 minutes from the moment of placing an order. However, full implementation of this delivery method depends on appropriate legal regulations which have not been introduced yet. It is assumed that drones can successfully replace traditional couriers (Amazon, 2018). Drones could deliver not only parcels or letters, but also medical samples between research centres and human blood or even organs for transplantation between hospitals (Duszczyk, 2018a).

The tasks of unmanned aircraft in the supply chain may include picking, palletizing, confectioning and packaging of small goods in consumer packaging. This solution was developed and tested by the Dutch company Qimarox, a supplier of warehouse management solutions (Qimarox, 2018).

PKP Cargo used UAVs to monitor trains carrying coal that are stolen (TVN24, 2015). A drone equipped with a camera can notify appropriate services or scare looters. Furthermore, the material recorded on the internal disc of the device can be used as evidence against criminals.

In addition to uniformed and emergency services, civilian drones are also used in construction and agriculture. In the former sector, civilian drones can help, i.a., in verification of land surveying measurements by the so-called land surveying audit and in a periodic inventory of the construction site. Moreover, UAVs can constantly compare the current status of construction with the design and its objectives, thus reducing the risk of having extra adjustments added to the plan and the number of collisions between vehicles on the construction site. Data from the construction site collected by drones, plays a key role in making decisions (SkySnap, 2018).

Conversely in the agriculture, drones are used to take pictures in different bands of light, which are then sent to a program that creates indexes from them. On the basis of measurements of light reflected by plants, it is possible to evaluate the quality of crops and adjust the amount of spraying, which ensures savings for the farmer, who also has constant control over the cultivation (Świat Dronów, 2018).

Drones help to fight against the climate change. They can assess the scale of coral reef erosion and detect freshwater sources. Shortly, UAVs which are able to clean oceans, will enter an initial phase of production (Mazzini, 2018).

5. Use of drones by forest districts

Every operation performed by a UAV must be based on the current map of the area where the task is to be performed. The Forest Numerical Map (FNM) indicates the boundaries of specified areas for which many statistics can be read, such as the dominant tree species in a given area along with its harvesting age. In addition, the FNM takes into account linear infrastructure elements such as paths, roads, tracks, tourist and water trails, and point infrastructure elements (e.g. hunting facilities). The surroundings of forest districts and tree stands are constantly changing, therefore, the FNM should be constantly updated. For this purpose, forest districts need to create orthophoto maps using drones and update the FMN on such basis. They can do it themselves or outsource this task to specialized entities.

A drone equipped with a narrowband camera or a remote sensing device is able to collect data for an IT system that will count trees on its basis. As each object reflects electromagnetic radiation in a characteristic way, the system is able to determine the tree species and whether the tree is alive or dead.

Animals are counted following similar principles to the inventory of tree stands, with the difference that the drone is equipped with a thermal sensor. The UAV scours the area by taking thousands of photos in natural colours (RGB) and in infrared.

In the years 2013–2015, research under the name *The use of remote sensing to determine population of large game in selected forest complexes* was carried out. There were five research areas: *Puszcza Niepołomicka*, *Puszcza Białowieska*, *Lasy Janowskie*, *Beskid Niski* and *Pogórze Przemyskie*. The registered area was over 6.000 km2, the drone flight lanes were 2850 km in length, during which over 29.000 RGB images and 75.000 thermal images, were taken. The study made it possible to conclude that this method allowed a reliable and effective estimation of the population size of large animals. This animal group is the most important for forest management. A huge advantage of using drones for this task is the ability to cover a large area within 1 day, which would require a team of 100 people working continuously for 10 days in the traditional conditions. Moreover, this method is non-invasive and allows animals to be observed in their natural environment in a way that does not affect their behaviour (Okarma, 2015). Figure 6 shows the selected map of the drone flight route.

There are crimes committed in forests including illegal hunting, or leaving municipal waste. The drone acts as a trail camera which is able to monitor forest areas. In summer, when the likelihood of a fire is high, drones equipped with a heat sensor can detect fire early and alert the competent services. UAVs also carry out inspections of hard-to-reach areas and areas with an increased risk level, such as, for example, swamps.

Drones also help to estimate losses after cataclysms, such as storms. The Opoczno Forest District took advantage of this possibility after the storms in 2016. The safety of employees was greater because they did not have to overcome fallen trees or be careful to avoid falling branches. The results obtained during drone flights were compared to those obtained by employees to make sure that they were meaningful. Both results were similar and differed only as far as the time of their acquisition was concerned because the drone did it much faster than human workers.

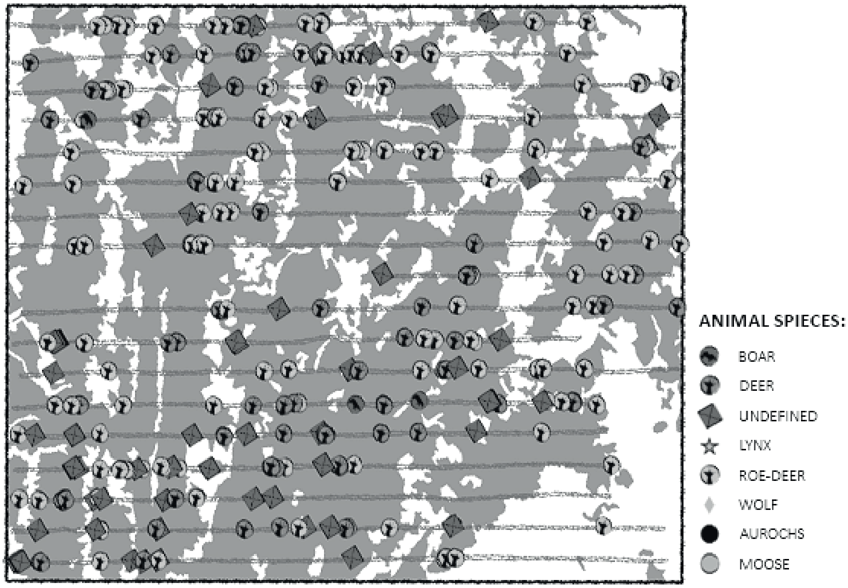

Figure 6. Results of drone flight over the Pogórze Przemyskie area
Source: (Okarma, 2015)

Some forest districts in Norway use drones as an element of monitoring and early warning. The drone is connected to the power line with a cable of such length that it allows it to move freely within a dozen or so meters. This maximizes the run-time of the drone. In Norway drones are included also in one of the forestry subprocesses in mountain areas. Originally, felled logs were transported, from the cut-off point (A) to temporary storage (B), where they were assessed and valued by employees. Then, the logs were loaded onto a truck and sent to the destination point. This process started to be supported by a drone, which was scanning the log with various sensors, during its transportation from point A to B. The collected data was sent to the system on an ongoing basis, which calculated the mass and price of the log, according to data received. As a result, employees receiving the log at point B could immediately load it onto the truck. In this way, the whole process (Figure 6) becomes faster and more efficient.

In Poland, all of the above-mentioned applications of drones are only tested in forest district conditions. Therefore, the use of drones on a large scale in Polish forest districts is out of question, at least for now. An exception are flights associated with creating orthophoto maps, as they are made in all districts, even several times a year. An orthophoto map can be used by the forest district to plan new transport routes and to facilitate fieldwork monitoring. The image from the drone camera enables a different perspective on activities such as soil preparation, planting, cleaning, logging and much more. This leads to better coordination of operations of individual cells and provides up-to-date information on the quality and progress of the work carried out, so hat it is possible to respond accordingly.

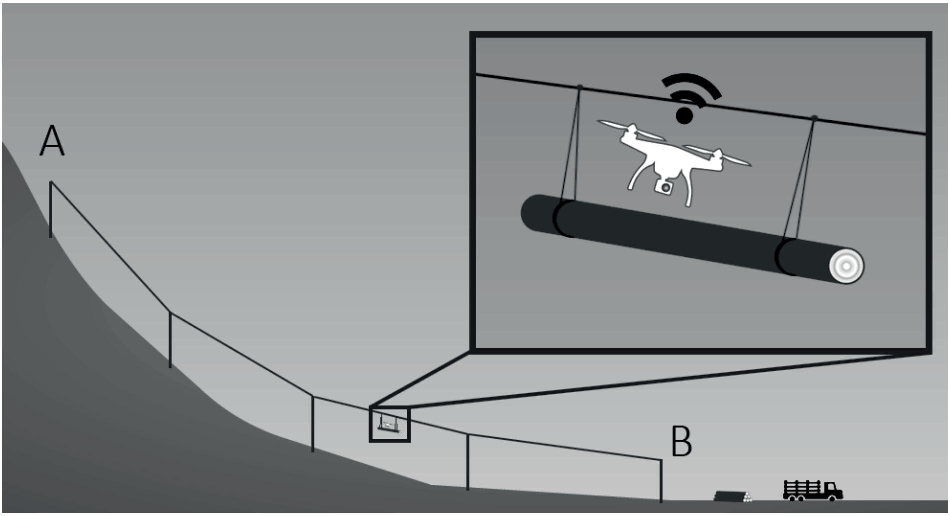

Figure 7. The process of felling a tree in a mountain area in Norway, supported by a drone
Source: (own elaboration based on: an interview with J. Duszkiewicz who has contacts in Norway forest districts, 2018)

6. Possibilities of supporting forestry logistics processes by civilian drones

It is worth considering to use one of the types of passive transponders (biochip) to mark (tag) animals encountered by the drone during the flight. The drone equipped with a scanner could count animals at a distance, just like goods in a warehouse, by sending a biochip stimulating a beam that would activate the chip and force it to send back information about the nearby presence of an animal. Such a solution would be possible, but difficult to implement, because animals walk their own paths, but similarly to fast-moving consumer goods in a warehouse, they are replaced by new younger specimens. Therefore, it should be treated more as an alternative to counting animals by remote sensing.

A drone can be used in log or timber transport. The situation in Figure 8 shows a vehicle carrying wooden logs that is heading towards a fork on the road.

Both roads lead to the same destination, but only one of them is passable. The second road is blocked by animals lying on it and a fallen tree a bit further up. Continuing driving on the route marked in white, would require the driver to turn back and it could cause a delay. The drone sent earlier for reconnaissance could warn the driver and plan an alternative route, so that the transport would reach the destination point on time. As the truck driver must focus on the road, an additional person would have to be the pilot who would take control over the drone and pass the information to the driver. However, once fully autonomous flights of drones (without any human intervention) are legalized in Europe, the drone itself could fly out several hundred meters ahead of the vehicle and display an image of the current condition of the road on the screen of a tablet or GPS navigation installed in the vehicle. Furthermore, it should be borne in mind that timber transport is one of the most costly and complicated operations in the wood raw material production cycle (Greulich, 2003).

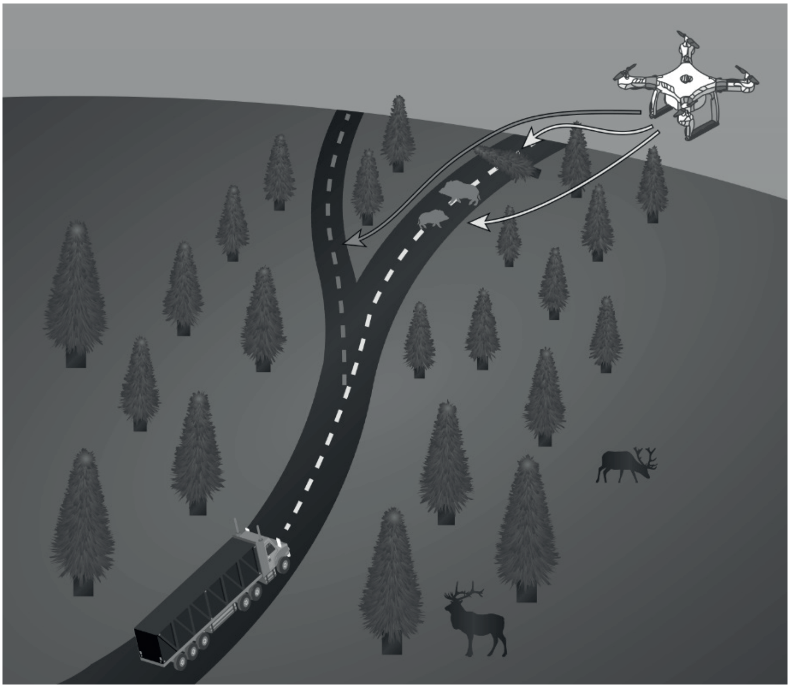

Figure 8. Early warning and alternative route planning system
Source: (own elaboration based on: Greulich, 2003)

Conclusions

Rzepin is one of the forest districts that have noticed the potential of drones and decided to establish the Central Training Centre for Drone Operators for Forestry Needs (Polish shortcut: COSODPL), which is the first centre of its kind in Poland. The employees of the Rzepin Forest District and the COSODPL instructors already now have considerable experience in the current possibilities of using drones, as well as new options for their wider application in forest area logistics. Drones are used also by other forest districts, including Szczecinek, Jabłonna and Bytnica. However, the current use of drones in Polish forest districts is mainly limited to the creation of orthophoto maps. Perhaps after the introduction of appropriate legal regulations, which are a key determinant for the use of drones in Poland, local forest inspectorates will use their drone potential on a wider scale, such as in Norway.

The examples cited in the article show that civilian drones are able to improve the functioning of a forestry district, primarily by collecting data needed to ensure the continuity and fluidity of resource flows, those consumed (like information), and produced (like wood). Nonetheless, the condition for maximizing the benefits of using UAVs in forest districts is, skilful implementation of drones in the LSS, e.g. as data communication between different users. Drones could contribute to the improvement of processes, not only in individual forest districts, but also in the entire National Forests, by integrating the data transfer into a common server. The role and place of drones in the LSS of a given organization, such as the forest district, is an interesting direction for further research.

However, not every forest district needs support from drones. Some smaller units may not feel much of a difference because the equipment that they currently have is fully sufficient to perform the tasks on a smaller scale. Investing in the drone technology would be like moving around the city centre in a sports car which can reach a speed of over 180 mph, while the road signs and congestion limit the maximum speed of driving down to 30 mph. For such forest districts, it is recommended to outsource such tasks to a company that provides various services with UAVs. The value of the Polish drone market was over PLN 251 million in 2017 and two years earlier it was worth PLN 164 million. It is forecasted that this value in 2018 will amount to nearly PLN 320 million (Duszczyk, 2018b). Nevertheless, it is not the numbers that are most important here, but the increase in the value of the drone market in Poland, as well as the various possibilities of using UAVs, as shown in the article.

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