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Gritsenko S.I. Doctor of Economics, Professor, Professor of Logistics Department of National Aviation University (Ukraine)

ORCID – 0000-0002-3322-3986
Researcher ID –
Scopus author id: –

Dovgan T.I., Students of Logistics Department National Aviation University (Ukraine)

ORCID –
Researcher ID –
Scopus author id: –

Ninich V.Z. Students of Logistics Department National Aviation University (Ukraine)

ORCID –
Researcher ID –
Scopus author id: –

CLUSTER PROSPECTS OF THE USE OF UNMANNED AERIAL SYSTEMS IN SUPPORTING THE LIVING ACTIVITY OF CRITICAL INDUSTRIES

Sergiy Gritsenko, Taisiya Dovgan, Veronika Ninich. «Cluster prospects of the use of unmanned aerial systems in supporting the living activity of critical industries ». *The article considered the prospects for the use of unmanned aerial systems in transport and logistics clusters for the delivery of cargo to critical locations, humanitarian assistance to community members, etc. Identified the main advantages and disadvantages of using unmanned aerial vehicles (UAVs) in peacetime and wartime. The main idea of the article is the use of unmanned aerial systems (UAS) in ensuring the viability of critical industries in cooperation with the Association of Industrial Automation of Ukraine (APPAU), National Aviation University (NAU), joining the Ukrainian Cluster Alliance (UCA) as a regional transport. logistics cluster of unmanned aerial systems and complexes of NAU. Presented the classification of UAS by mass, altitude, flight duration, and range. Determined the composition of units of the unmanned aerial system. Given the characteristics of the designs of air drones (drones) of the manufacturers of world companies and the staff of the National Aviation University. The key priority of formation in the Ukrainian cluster alliance of the regional transport and logistics cluster of unmanned aerial systems and complexes based on the Scientific and Production Center for Unmanned Aviation "Virage ", departments: organization of air transportation, organization of aviation works, and services, logistics National Aviation University and other partner organizations. This will expand its opportunities to enter the European and world aviation markets.*

***Keywords**:* Unmanned aerial vehicle (UAV); drone; transport and logistics cluster; unmanned delivery; areas of critical industries; navigation; quadcopter; aircraft; delivery of the last mile; navigation satellite systems.

Сергій Гриценко, Тетяна Довгань, Вероніка Нініч. «Кластерні перспективи використання безпілотних авіаційних систем в забезпеченні життєдіяльності критичних індустрій». *У статті розглянуто перспективи використання безпілотних повітряних систем у складі транспортно-логістичних кластерів щодо доставки вантажів до критичних локацій, гуманітарної допомоги учасникам спільноти тощо. Визначено основні переваги та недоліки використання безпілотних повітряних суден (БПС) в умовах мирного та воєнного часу. Основною ідеєю статті є використання безпілотних авіаційних систем (БАС) в забезпеченні життєдіяльності критичних індустрій в співпраці з Асоціацією «Підприємств Промислової Автоматизації України» (АППАУ), Національним авіаційним університетом (НАУ), приєднання до Українського кластерного альянсу (УКА) у статусі регіонального транспортно-логістичного кластера безпілотних авіаційних систем та комплексів НАУ. Представлена класифікація БПС за масою, висотою, тривалістю польоту та радіусом дій. Визначено склад підрозділів безпілотної авіаційної системи. Надано характеристики конструкцій повітряних безпілотників (дронів) виробників світових компаній і колективу Національного авіаційного університету. Визначено ключовий пріоритет утворення у складі Українського кластерного альянсу регіонального транспортно-логістичного кластера безпілотних авіаційних систем та комплексів на базі Науково-виробничого центру безпілотної авіації (НВЦБА) «Віраж», кафедр: організації авіаційних перевезень, організації авіаційних робіт та послуг, логістики, зацікавлених підрозділів Національного авіаційного університету та інших партнерських організацій. Це розширить його можливості виходу на європейський та світовий ринки авіаційної техніки.*

Ключові слова: Безпілотне повітряне судно (БПС); дрон; транспортно-логістичний кластер; безпілотна доставка; зони критичних індустрій; навігація; квадрокоптер; літальний апарат; доставка останньої милі; навігаційні супутникові системи.

Сергей Гриценко, Татьяна Довгань, Вероника Нинич. «Кластерные перспективы использования беспилотных авиационных систем в обеспечении жизнедеятельности критических индустрий». *В статье рассмотрены перспективы использования беспилотных воздушных систем в составе транспортно-логистических кластеров относительно доставки грузов к критическим локациям, гуманитарной помощи участникам сообщества и тому подобное. Определены основные преимущества и недостатки использования беспилотных воздушных судов (БВС) в условиях мирного и военного времени. Основной идеей статьи является использование беспилотных авиационных систем (БАС) в обеспечении жизнедеятельности критических индустрий в сотрудничестве с Ассоциацией «Предприятий Промышленной Автоматизации Украины» (АППАУ), Национальным авиационным университетом (НАУ), присоединение к Украинскому кластерному альянсу (УКА) в статусе регионального транспортно-логистического кластера беспилотных авиационных систем и комплексов НАУ. Представлена классификация БВС по массе, высоте, длительности полета и радиусу действий. Определен состав подразделений беспилотной авиационной системы. Предоставлены характеристики конструкций воздушных беспилотников (дронов) производителей мировых компаний и коллектива Национального авиационного университета. Определен ключевой приоритет образования в составе Украинского кластерного альянса регионального транспортно-логистического кластера беспилотных авиационных систем и комплексов на базе Научно-производственного центра беспилотной авиации (НПЦБА) «Вираж», кафедр: организации авиационных перевозок, организации авиационных работ и услуг, логистики,*

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заинтересованных подразделений Национального авиационного университета и других партнерских организаций. Это расширит его возможности выхода на европейский и мировой рынки авиационной техники.

Ключевые слова: Беспилотное воздушное судно (БВС); дрон; транспортно-логистический кластер; беспилотная доставка; зоны критических индустрий; навигация; квадрокоптер; летательный аппарат; доставка последней мили; навигационные спутниковые системы.

Introduction. More than a month ago, the topic of this article could be any topic related to transport, warehousing or logistics in general, but today Ukraine is faced with a different reality. An open military attack by Russia with the support of Belarus on Ukraine was launched at 5:00 am on February 24, 2022. The invasion is part of the Russian-Ukrainian war waged by Russia in 2014, in which Russia has tried to deny participation. In its resolution of March 2, 2022, the UN General Assembly condemned the Russian invasion of Ukraine and called it the aggression of the Russian Federation against Ukraine.

Today, thousands of homes have been destroyed, and tens of thousands of people killed and injured. Most of the transport connections in Kyiv, Kharkiv, Chernihiv, Sumy, Donetsk, Luhansk, and other regions have been destroyed. Thanks to the staff of the Security Service of Ukraine and units of the SES of Ukraine, the liberated territories are quickly processed (this refers to demining, removal, and dismantling ruins, etc) and try to assist those who need it and not always have access to each of the locations. Effective access to these critical locations is possible using unmanned aerial systems.

The main idea of the article is to use unmanned aerial systems (UAS) in ensuring the viability of critical industries in cooperation with the Association of Industrial Automation of Ukraine (APPAU), National Aviation University (NAU), joining the Ukrainian Cluster Alliance (UCA) as a regional transport- logistics cluster of unmanned aerial systems and complexes of NAU. Determining the main activities of UAS within the UCA are humanitarian aid, delivery of food, emergency care, medical supplies, services for internally displaced persons, support to charitable and volunteer organizations, and delivery of equipment to restore the infrastructure of destroyed cities and regions, and more.

The purpose and objectives of the study. Explore the possibility of delivering essentials and medicines using unmanned aerial vehicles and their main driving force, unmanned aerial vehicles (UAVs), to critical industries, bringing together university, industry, and high-tech communities within regional aviation clusters to win.

The unmanned aerial vehicle system consists of the BPS, ground (air, surface) control point, and communication lines.

Basic material and results. Together with regional clusters and other partners, APPAU [1] launched the Clusters4Ukraine initiative, which aims to establish broad cooperation between the European and other world communities and Ukrainian clusters of industrial and high-tech sectors [2-5] in ensuring the viability of critical industries. These industries include:

1 - industries that provide the population with basic necessities (food, medicine, clothing, etc.);

2 - critical infrastructure facilities.

The initiative aims to clarify the needs of these industries and meet them by:

1. Mobilization and unification of members of cluster communities at the regional and sectoral level, with clarification of their own needs, free resources, and opportunities. Ensuring evacuation - relocation of companies, members of our community, and their families to safe regions.

2. Involvement - assistance to service providers to support the production of critical industries and infrastructure: supply of components, products, individual technologies, and technical assistance.

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3. Establishment of logistics for humanitarian aid.

4. Integration - liaison with local administrations and other field coordinators.

In addition, the continuation of projects with the EU also requires the cooperation and support of our startups, SMEs, and universities, as the EU is ready to continue many projects, but we need consolidated efforts and some guarantees from us on the ability to implement them in wartime. It is necessary to determine the strategies of international economic activity of clusters in the global and regional markets [2, p. 6] using unmanned aerial vehicles (UAVs).

Analysis of the development of the world's unmanned aerial vehicles (UAVs) as components of UAS over the past 20 years shows a steady trend to increase their size and weight, as well as range, altitude, and duration of the flight (Table 1).

Table 1 – Classification of UAV by mass, height, flight duration and range [6, p.15]

Code	Name	Mass, kg	Action radius, km	Flight height, m	flight duration, h
TACTICAL					
micro	Micro	≤ 5	≤ 10	250	1
mini	Mini	≤ 20/25/30/150	≤ 10	150/250/300	≤ 2
CR	Very short range	25-150	10-30	3000	2-4
SR	Short-range	50-250	30-70	3000	3-6
MR	Medium range	150-500	70-200	5000	6-10
MRE	Medium range and long duration	500-150	≥ 500	8000	10-18
LADP	Low altitude	250-2500	≥ 250	50-9000	0,5-1
LALE	Low altitude with a long flight duration	15-25	≥ 500	3000	≥ 24
MALE	Medium altitude with a short flight duration	1000-1500	≥ 500	5000-8000	24-28
STRATEGICAL					
HALE	High-altitude with a long flight duration	2500-5000	≥ 2000	20000	24-48
Strato	Stratospheric	≥ 2500	≥ 2000	≥ 20000	≥ 48
EXO	Outside the stratosphere	-	-	≥ 30500	-
SPECIAL					
UKAV	Combat UAV	≥ 1000	+/- 1500	12000	2
LET	Disposable UAV	-	300	4000	3-4
DEC	UAV-targets	150-500	0-500	50-5000	≤ 4

In order for the UAV to be able to fly, an unmanned aerial vehicle (UAS) is required, which consists of the following elements: the UAV itself; UAV control (management) stations; software and systems for monitoring the condition of the UAV; means of communication (ground/air and air/ground) for air traffic control and payload of UAV; data processing terminals; landing system; launch systems and in-flight recovery systems; equipment for maintenance and upkeep of the UAV and its systems; UAS storage and transportation systems. At the same time, UAS should be serviced by qualified ground personnel [6, p. 16].

Delivery by so-called «smart drones» to hard-to-reach points is a method of delivering cargo by unmanned aerial vehicles (UAVs), which are used to transport packages, medicines, food, or other goods.

«The Economist» recently named the civilian drone industry one of the most

promising industries for business. Let's find out in what areas drones are currently used and what is the secret of the popularity of flying robots. Last summer, scientists launched a trial version of the giant Aquila drone, a drone that is powered by solar panels and can therefore fly for three months without interruption.

Drones have also begun to be used as a delivery service tool. The Wing project, developed by Google Alfabet, will work with two Australian companies - medical and restaurant. The Guzman y Gomez network of Mexican establishments and the Chemist Warehouse pharmacy company use Alfabet drones to deliver food and medicine to rural customers. Typically, such customers have to drive 40 minutes by car to get an order, since the nearest grocery store, restaurant, or pharmacy is far from their home.

The project is experimental; meaning those who will use its services will participate in the study of the efficiency of drone delivery. This method is not yet ideal, because, despite a system that can pre-configure routes, drones rely on onboard sensors to avoid interference. However, the more routes traveled, the more information drones will be able to gather, and the better the sensors will work on the ground which will be able to protect drones from collisions. This method is also convenient for businesses - restaurant owners say that such delivery will help them fine-tune the logistics of sending products to customers while they are still hot. It will also help them understand how much time it takes to prepare, pack and load food as quickly as possible. At the same time, unmanned delivery of over-the-counter medications and vitamins will help pharmaceutical companies find the best way to package different drugs and optimize the number of items that can be delivered in one flight [7].

Commenting on the possibilities of drone deliveries, it can be noted that this project is promising and interesting, however, despite the publicity and the illusion of mass use of technology, it is not perfect and is still under development. Practical examples of regular cargo delivery routes in the world are scarce. Such projects exist in artificially created conditions, within a clearly defined space, and they cannot be transferred to other territories.

The problems with delivery now are not in the technological sphere, because it is possible to send a loaded drone from point A to point B without obstacles, but in the legal one. Currently, the use of drones is allowed only in the line of sight, meaning when the pilot of the drone sees the device throughout the flight. EU countries are developing regulations that will allow drones to be used out of sight. Such introductions will affect the drone delivery industry. There is also the problem that the drone, using automatic navigation, must follow specific rules and altitudes to avoid collisions with other flying objects [8]. However, such laws have not yet been defined.

Mass drone deliveries are the creation of a large regional aviation infrastructure above ground level, rather than one-day delivery by one drone in one hand. Therefore, it is necessary to create many legislative initiatives, and change many documents, not only in Ukraine but all over the world. In Ukraine, everything is complicated because the legal framework doesn't define drones as an independent transport unit [9].

Advantages and disadvantages of using UAV for cargo delivery

Delivery of cargo by quadcopters and other such aircraft has many advantages. However, there are several shortcomings, without which such a solution is unlikely to become widespread. Let's take a closer look at the main pros and cons [10].

The main advantages of this method of cargo delivery include:

- complex terrain (mountains, jungles, etc.) is not a problem. Drones overcome it relatively easily, which in many cases significantly reduces the route, speeding up delivery time;

- independence from transport infrastructure restrictions. For example, old railways or a broken road that negatively

affect the movement of conventional land transport;

- high speed of delivery is provided since drones aren't affected by situations on the road (traffic jams, accidents, and other possible problems);

- Quadcopters have such an interesting feature as the possibility of vertical landing, which allows to ensure very high delivery accuracy thanks to the GPS sensor;

- Compact drone, powered by an electric battery, has a much smaller negative impact on the environment than a truck or car;

- in the long run, the commercial use of drones, due to their high energy efficiency and the ability to work in hard-to-reach places, can have a positive impact on many sectors of the economy.

Some disadvantages prevent us from using drone delivery everywhere:

- small carrying capacity (up to 3-4 kg) does not allow the use of quadcopters for transporting large loads. Delivery of large household appliances or furniture in this way will not work;

- restrictions on battery life (up to 30 minutes) significantly limit the radius of possible delivery, and for the commercial use of technology you need to create an entire infrastructure from scratch;

- The issue of privacy remains relevant - the drone uses GPS to move to the exact destination, as well as a built-in camera that avoids interference during the flight and land safely;

- legal issues - in some countries the use of drones is not regulated, but in the United States and other Western countries, regulators are already actively working in this direction;

- Physical security is another potentially problematic issue, as it is unlikely that many city dwellers will be thrilled if hundreds of drones flying overhead, one of which could fail and hit one of the pedestrians.

They can also pose a potential hazard when used near airports due to the risk of collisions with aircraft [11].

Drones help with last-mile delivery because they can transport drugs and vaccines, as well as deliver medical specimens to and from remote or inaccessible areas.

So far, the delivery of goods by quadcopter is, rather, a test. Copters are readily used in advertising, for show delivery of goods during promotions, and to achieve a wow effect: passers-by are happy to record and photograph drones, distributing videos and photos on social networks. But logistics experts are confident that drone delivery will become commonplace in the future.

The main task is to quickly restore safe logistics chains in the liberated territories and to establish the supply of humanitarian aid to the affected cities of the region [12].

To accomplish this task, local authorities may involve medical response drones and search-and-rescue drones manufactured in North America. An innovative temperature-controlled medical cargo box will be included in medical drones. A payload box can hold up to 35 pounds of medical supplies, including blood, pharmaceuticals, insulin/medicine, vaccines, water, and wound care kits. It is also mounted on top for safer and more convenient delivery.

The army of air drones of some world manufacturers can deliver cargoes from 20 kg to 500 kg of critical cargoes across all of Ukraine. With a huge range of fixed-wing aircraft, helicopters, gyro-helicopters, and hybrid aircraft operating in a coordinated network of short and long-distance supply lines, we could provide an almost inexhaustible supply of everything that is needed by frontline troops or civilians, without risking any human life.

Night flights, close to the ground, and the use of specialized technologies that allow flights in areas where Global Navigation Satellite Systems (GNSS) are jammed and the coverage is designed to significantly reduce the radar cross-section, could significantly improve supply lines to the front line, and locations and territories dominated by Russians. Of course, there would be losses, but

the replenishment of these unmanned vehicles would be quick and cost-effective.

Drones can be used in many ways: fast, quiet airborne drones can be used in electronic warfare to disrupt Russian communications on the ground or confuse Russian planes; small systems can be used to deliver passive beacons to detect targets that increase the effectiveness of strikes against the enemy [13].

Relatively recently, the concept of «flying platform» was developed, according to which they began to build UAVs, connecting the payload with onboard systems, such as multi-purpose UAV «Proteus» (USA), which can compete with satellites [6, p. 30]. Unlike the satellite, the UAV monitors the observation point constantly. After completing the task at an altitude of 20 km for 24 hours, he returns to base, and he is replaced by another in the sky. Another UAV is in reserve. This is the main component of savings, as UAV is an order of magnitude cheaper than satellites.

In the world market, aviation equipment is gradually gaining its right to life qualitatively different from traditional aircraft without a pilot on board. Given the reasons stated above and awareness of its leading role in the development of aviation technology, the staff of the National Aviation University (NAU) over the past decade has made a worthy contribution to the development of unmanned aerial vehicles. More than 40 different designs of unmanned aerial vehicles (UAVs) were developed and implemented [6, p. 240-247].

Unmanned aerial vehicles and their complexes made by NAU have a wide range of applications: for cargo transportation - it is an unmanned four-engine helicopter PKM-14 «Saturnia» for the transportation of small cargo at a distance of 3 km in automatic mode; for reconnaissance, monitoring, and other purposes - this is the unmanned aerial vehicle complex (UAVC) «Ovod» M106 designed to perform reconnaissance from the air day and night with the transmission and recording of video or infrared images in the «online» mode; unmanned aerial vehicle M-6 «Zhayvir» for technologies of biological protection of crops; unmanned aerial vehicle system M-56 «Module» in law enforcement agencies can be used as a carrier of high-precision weapons; planning self-propelled mini-ammunition PMB-03, which is dropped from the aircraft carrier, achieving the goal in the planning mode on the battlefield, and during special operations [6, p. 114-181].

It is known that the modern market of «clean» UAVs is volatile and is activated mainly in the event of hostilities. It takes a long time (about 4-6 years) to bring a clean UAV project to sales, because of significant expense and struggle with the corporations of the leading countries, which have been long known in the «clean» UAV market and hold most of it.

Our key priority in this initial organizational period of the UAV market is to pool and mobilize resources within aviation clusters in global and regional markets. Thus, on March 24, 2022, 16 clusters and cluster organizations of Ukraine merged into the Ukrainian Cluster Alliance (UCA) and this growth continues. This is the first association of clusters in Ukraine, which undertakes the mission of developing the entire cluster movement [14]. The Ukrainian Cluster Alliance (UCA) has started a series of meetings with European clusters. Traditionally, this format of communication is called C2C (clusters2clusters) and it is more effective because it offers a direct dialogue between the parties. A special marketplace of assistance to Ukrainian clusters and SMEs has been launched on the European Cluster Cooperation Platform (ECCP). This is an initiative of the European Cluster Alliance (ECA) for humanitarian aid to Ukrainian clusters, launched in late February 2022 in conjunction with the cluster committee Industry4Ukraine, the predecessor of UCA. Europeans offer mostly humanitarian and other assistance to refugees, while our clusters need help to restore supply chains and added value.

The mission of the association is to accelerate the clustering of economic sectors

of Ukraine by consolidating and growing members of the cluster movement, and their development following European best practices and standards. During the war, UCA's priority was to support clusters of critical industries responsible for food security, drug production, clothing, health care, and critical infrastructure.

Transport and logistics clusters with their active component of unmanned aerial systems, which will help to restore the chains of unmanned aerial vehicles, should become a connecting link in the Ukrainian cluster alliance.

Conclusions. The formation of a regional transport and logistics cluster of unmanned aerial systems and NAU complexes will help integrate unmanned aerial vehicles to solve many scientific and applied problems related to geology, ecology, meteorology, zoology, agriculture, climate research, mining, etc. Unmanned aerial vehicles can optimize the tracking of migration of birds, mammals, and fish, changes in meteorological conditions and ice conditions on rivers, the movement of ships, the movement of vehicles and people, radar reconnaissance, aerial, photographic and cinematographic, multispectral up to 100 meters, etc. [6, p. 31].

The Regional Transport and Logistics Cluster of Unmanned Aerial Systems and Complexes of NAU within the Ukrainian Cluster Alliance (UCA) will provide conditions at the stage of formation of transitional aviation to initiate competitive flagship projects of unmanned aerial vehicles aimed at helping critical industries. European clusters are expected to help with supply, new projects and orders, and integration into innovative projects. To intensify its activities, the Regional Transport and Logistics Cluster of Unmanned Aerial Systems and NAU Complexes needs to agree on its positions, priorities, action program, and key messages and submit them to the UCA Coordination Center to prepare for C2C meetings with a group of stakeholders. Commission on the European Cluster Cooperation Platform (ECCP).

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