

The Efficiency and Effectiveness of Remotely Piloted Aircraft Systems Used in Logistics Problems Solving Due to Territorial Infrastructure

Volodymyr Kharchenko, Marcin Paweska, Dmytro Bugayko, Dmytro Prusov
National Aviation University, Ukraine
The International University of Logistics and Transport in Wroclaw, Poland

The use of Remotely Piloted Aircraft Systems RPAS has been considered for a wide range of tasks performed in global logistics systems and territorial infrastructure. In order to improve the efficiency the advanced methods of using new unmanned vehicles with extensive use of features modular construction and design modifications have been proposed.

Keywords: remotely piloted aircraft systems, unmanned aerial vehicles, logistics, territorial infrastructure, effectiveness, efficiency.

1. INTRODUCTION

The rapid development of global logistics systems and territorial infrastructure requires a search for new methods of monitoring, flow control and navigation. Global satellite navigation systems (GSNS) on-board and land equipment play significant role in solving certain tasks. However, the modern use of these systems is not always sufficiently effective and economically feasible. A new element of this system may be remotely piloted aircraft systems (RPAS) that will achieve the complexity and increase the efficiency of these objectives.

2. DIRECTIONS OF RPAS APPLICATION IN LOGISTICS PROBLEMS SOLVING DUE TO TERRITORIAL INFRASTRUCTURE

RPAS can be used in carrying out these tasks for the global logistics systems and territorial infrastructure:

- logistics systems management;
- geophysical surveying – gathering information about the physical state of the earth's surface and soil;
- mapping – works as defined by the spatial arrangement and combination of elements of

the earth's surface, geometric binding infrastructure to geodesic Earth system;

- territories planning management for the urban development and territorial planning reconstruction of the urban area sections with dense building and difficult engineering-geological conditions;
 - building objects monitoring for the safe and balanced development of built-up territories and more efficient use of housing estates in the present social and economic conditions;
 - results validation of materials processed in survey – it is a collection and processing of the control sample of ground materials and air surveys to confirm the stated accuracy of the measurement of natural objects or process equipment thematic characteristics.
- Contributing factors in creating RPAS for monitoring are as follows:
- high overall level of development of unmanned vehicles in the world;
 - availability of enterprise to professionally develop themes of unmanned aircraft, which allows the use of their experience and production-technical base;
 - significant technological advances in recent years in the field of remote monitoring and data processing, the presence of an extensive network of processing and communications.

The analysis of industry and infrastructure facilities components including requirements for air service allows to formulate a list of tasks that need to be addressed through service aviation maintenance industry by RPAS. The presented list of tasks has imposed specific requirements as to the aircraft as well to the target hardware [1].

In the field of aerial photography RPAS can also bring great benefits and savings. Their opportunities largely depend on the flight altitude. Today the limit is 20 km, and in the long term up to 30 km. At such altitude UAVs can compete with satellites, tracking everything that happens in an area of about one million square kilometers. UAVs can take over the functions of satellite constellation and perform them in real time in the whole region. Unlike satellite, UAV accompanies the point of observation time. After completing the task on the specified height and within the stipulated time, UAV 1 returned to the base, and UAV 2 takes off. This is the main component of the economy, because still from economic point of view UAV is cheaper than satellite. Also UAV can compete with satellites and in the creation of telecommunication networks and navigation systems. The UAV can put continuous time surveillance in a wide range of frequencies. It can make possible to create information field of the country, covering the monitoring and control of movement by air, land and water transport, as UAV is able to take over the functions of land, air and satellite locators (common information from them gives a complete picture of what is happening in the sky, water and earth).

Another priority of logistics tasks that can be solved using RPAS, is monitoring traffic. The remotely piloted aircraft systems used in tasks to identify violators of traffic, a representative of traffic police in cooperation with experts is inside the land control station unmanned aircraft, while several patrol cars equipped with video terminals, patrol the road situation and send video in real time. The aerial patrolling by RPAS will improve traffic and increase safety on the roads.

One of the most important areas of application of unmanned aerial systems in the civil sphere is monitoring areas, waters, roads and borders. There is non on-board UAV crew and life support systems, it is much smaller and less power is required which substantially reduces the cost of flying hours. This will not only reduce the cost of applying RPAS during monitoring, but also increase the intensity of several patrol flights and, consequently, reduce the estimated loss in case of

an emergency. Along with this, the organization process patrols in reality requires more detailed account of heterogeneity serviced routes, route optimization flyby, the location of land infrastructure and the like. The task of monitoring is, from the economic point of view, an important characteristic feature. On the one hand, the more patrols available, the higher the costs of organizing patrols. On the other hand – increasing the intensity of patrols can often update the state of objects, which facilitates rapid elimination of emergency situations, and as a result, reduces the expected losses.

3. THE EFFICIENCY AND EFFECTIVENESS OF THE RPAS DESIGN AND UAV DIFFERENT CATEGORIES TO SOLVE LOGISTICS PROBLEMS OF TERRITORIAL INFRASTRUCTURE

The main directions in the creation of UAV, which provides total solution of tasks can be the following [3]:

- ensuring high performance characteristics of UAVs;
- large areas of the earth's surface can be covered;
- relatively low cost of UAVs;
- multi-functionality and multi-version of UAVs;
- UAV integration into temporary information networks in the areas of application.

Application of aerial reconnaissance and surveillance is a means of improving efficiency, and in conjunction with other technical means and organizational solutions will successfully solve the task. Due to the wide range of tasks listed above, the application of several categories of UAV aircraft has been developed.

However, development and production of modern unmanned aviation is a complex and has extended our traditional technology used in aircraft manufacturing. Below are listed only the basic technologies used in the RPAS production:

- development and production of advanced structural materials, especially composites, using nanocoatings;
- modern computer technology, including multiprocessor systems for collecting, processing and storage;
- theory of automatic control systems, as a branch of Cybernetics, connected with the

- theory of information transmission, encryption, data compression;
- facilities and communication, including space systems;
 - technology of remote sensing (radar, optic system, multispectral sensors);
 - energy technologies, alternative energy sources over- capacity batteries, solar energy, fuel cells;
 - tools and navigation systems, air traffic management through the implementation of automatic dependent surveillance;
 - Geographic Information Systems (GIS);
 - techniques of image processing, pattern recognition;
 - development objectives of human-machine interface;
 - objectives of the artificial intellect development.

The development of UAV types has been carried out in accordance with the principles outlined above. So, given a list of tasks required by the UAV to perform, the UAV should have a fairly high performance characteristics that can make it quite expensive. To reduce the cost requires the use of advanced techniques for developing new techniques with extensive use of modular construction and design modifications at the level of structural design blocks.

Thus, RPAS creation is focused on increasing aircraft utilization while reducing the required series the UAV to one type. The group applications of the same UAV types could provide a multitude problems solving that could require the use of several UAV types. This significantly reduces operating costs associated with the diverse nature of UAV and land facilities, which are part of complexes with UAV.

Application of UAV in solving problems requires not only providing direct control over areas of the earth's surface, but requires the formation of an ad hoc network of information exchange in the areas of activities of tasks. This approach greatly reduces the time spent and allows:

- covering the operational situation in standby time, near to real;
- increasing the selectivity over long distances due to objects accompanied that are being developed;
- increasing the efficient management of material and human resources at carrying out of special measures;

- reducing the volume and duration of inspection procedures at border control.

The National Aviation University conducted a perennial work on the principles of design and creation of experimental remotely piloted aircraft systems [4].

An integrated approach in the project involves the following objectives:

- determination of construction principles for unmanned aircraft systems on the methodology "The safety management system" according to the international requirements;
- development and production of hybrid composite materials based on the strength criterion;
- nano-technical complex development and manufacturing for the UAS on-board and land equipment;
- development and production of control complex for the board and land RPA systems;
- development of scheme-technical solutions for automation flight trajectory based on new information technologies;
- development and implementation of methods and algorithms for the automation UAV landing on network signals of orbiting satellite systems;
- development of information protected data channel "board-to-land, land-to-board", the flight control system design, and standardization of protocols recommendations;
- UAS standard model design, production, and testing with energy efficient avionics equipment;
- development of training programs for UAV operators and RPAS land personnel;
- development of normative and technical documentation for RPAS certification;
- estimation of efficiency and effectiveness of remotely piloted aircraft systems using.

In the research and production center of unmanned aviation "Virage" of National Aviation University the line of domestic UAVs has been developed: one-engine M-3 "Border", M-6 "Skylark"; two-engine M-7, M-7D, M-7B5 "Sky Patrol" drones (the UAV) and UAV with an electric motor "Eye". Their tactical technical data are as follows [5].

UAV M-7B5 «Sky Patrol»

Purpose: designed for aerial photography, real-time video surveillance, patrolling line objects, and perform other types of aerial work including over populated areas.

**Technical Characteristics:**

Wingspan – 6.0 m;
 Weight of special purpose load – up to 70 kg;
 Launch weight – up to 200 kg;
 Top speed – 250 km/h;
 Engine power – 2 x 17 kW;
 High flight altitude – up to 3000 m;
 Method of launch and landing – as an aircraft;
 Deployment time in the working position – 0.5 h;
 Maximum take-off weight – 200 kg;
 Empty weight – 100 kg;
 Cruising speed – 200 km/h;
 High flight altitude – 3000 m.

Variants according the special purpose load:

Weight of special purpose load – 70 kg / 20 kg;
 Fuel weight – 30 kg / 80 kg;
 Flight time – 5 hours / 14 hours;
 The route distance – 1000 km / 2800 km.

UAV M-7D «Sky Patrol»

Purpose: mapping and aerial photography, real-time video surveillance, patrolling line objects and areas.

**Technical Characteristics:**

Wingspan – 5.1 m;
 Weight of special purpose load – up to 55 kg;
 Launch weight – up to 150 kg;
 Top speed – 190 km/h;
 Engine power – 2 x 12 kW;
 High flight altitude – up to 2500 m;
 Method of launch and landing – as an aircraft;
 Deployment time in the working position – 0.5 h.
 Maximum take-off weight – 150 kg;
 Empty weight – 80 kg;
 Cruising speed – 190 km/h;
 High flight altitude – 2500 m.

Variants according the special purpose load:

Weight of special purpose load – 55 kg / 20 kg;
 Fuel weight – 15 kg / 50 kg;
 Flight time – 3 hours / 10 hours;
 The route distance – 450 km / 1500 km.

UAV M-6 "Skylarc"

Purpose: mapping and aerial photography (M-6K), real-time video surveillance (M-6P), patrolling line objects and areas (M-6CX).



Technical Characteristics:

Wingspan, – 1,6 m;
 Weight of special purpose load – up to 7 kg;
 Launch weight – up to 12 kg;
 Engine power – 1,7 kW;
 Top speed – 150 km/h;
 Max. processing performance – 40 hectare/hour;
 High flight altitude – up to 1000 m;
 Method of launch – catapult;
 Method of landing – aircraft / parachute.

Electric version:

Maximum take-off weight – 7.0 kg;
 Empty weight – 5.2 kg;
 Weight of special purpose load – 1.8 kg;
 Flight time – up to 1 hour;
 The route distance – 80 km;
 Cruising speed – 80 km/h;
 High flight altitude – 300 m;
 Engine take-off power – 2,55 kW.

Petrol version:

Maximum take-off weight – 12.0 kg;
 Empty weight – 5.5 kg;
 Cruising speed – 110 km/h;
 High flight altitude – 300 m;
 Engine take-off power – 2.79 kW;
 Fuel flow rate – 0.51 kg/h.

UAV M-10 "Eye"

Purpose: real-time video surveillance, patrolling the line objects and areas, the small

objects security, the situation in small territories monitoring.



Technical Characteristics:

Maximum take-off weight – 3 kg;
 Empty weight – 1.3 kg;
 Cruising speed – 60 km/h;
 High flight altitude – 300 m.
 Variants according the special purpose load:
 Weight of special purpose load – 1.5 kg / 1.3 kg;
 Battery weight – 0.19 kg / 0.38 kg;
 Flight time – 45 min / 1.5 hours;
 The route distance – 45 km / 90 km.

UAV M-22 "Aerotester"

Purpose: practice training for external pilots; "flying laboratory".

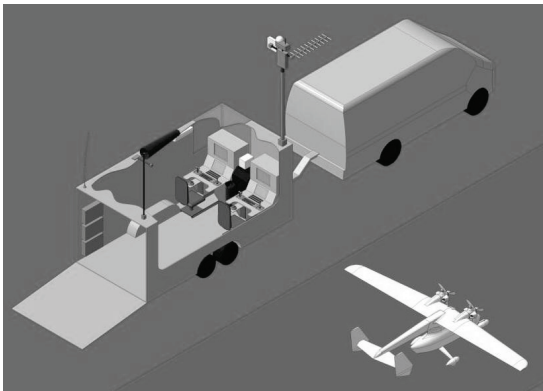


Technical Characteristics:

Wingspan – 2.5 m;
 Weight of special purpose load – up to 8 kg;
 Launch weight – up to 18 kg;
 Top speed – 120 km/h;
 Engine power – 2.7 kW;
 High flight altitude – up to 2000 m;
 Method of launch and landing – as an aircraft;
 Deployment time in the working position – 0.5 h.

Remotely piloted aircraft systems (RPAS) "Ukraine"

Function: mission assurance of the twin-engine aircraft M-7B5 "Sky Patrol" in a dedicated airspace to perform aerial work in the interests of the economy and national defense. Served by ALS "Ukraine" crew of at least four persons. RPAS based on the UAV M-7B5 "Sky Patrol" structurally consists of the one UAV M-7B5 on the trailer-platform in the container; and one land control station (HCK-1-7B5) on the trailer.



Technical Characteristics:

- Complex stationing – in all types of runways;
- Time of autonomous basing – up to 3 days;
- Transportation – 2 trailers are transported by small trucks;
- During start-up trucks available is not necessary;
- UAV flight in the air without refueling – 10–17 hours;
- Range with two-way communication: 100–120 km.
- Routing flight range of UAV – 1000–2800 km.
- High flight altitude of UAV – 3000 m;
- Curb weight – up to 2000 kg.

Together with researchers of the Ukrainian-Polish Research Institute in Wroclaw a comprehensive work on assessing capacity and effectiveness of RPAS to solve logistical problems of territorial infrastructure has been conducted.

4. APPROACHES TO CALCULATING THE ECONOMIC EFFECTIVENESS OF RPAS

At the present stage of the aviation operation and in fragmented market of many independent operating organizations, the aircraft economic efficiency is individual for each potential problem. The economic efficiency criteria and calculation

methods have been evolved in connection with the RPAS economic effectiveness analysis that is based on the appropriate models development, such as volume optimization model patrol flight, which is used to assess the costs of air monitoring at the rate of 1 year, and develop appropriate methods to assess the demand for RPAS and efficiency of their application.

The ideology of the aerial means using for reconnaissance and observation function of unmanned aircraft system determined by the cost of removal of information from one area of the earth's surface is \bar{C}_I an important fact that allows to use the ideology of aerial reconnaissance means and surveillance:

$$\bar{C}_I = \frac{C_{AC} + C_{AED} + C_{FEM}}{n_{AP} \cdot P_{PSP} \cdot F_{\Sigma}^1} \quad (1)$$

where C_{AC} – is a cost of a new aircraft; n_{AP} – is an estimated amount of unmanned aircraft application (multiplicity); C_{AED} – is a cost of additional expendable devices for one flight (the cost of powder accelerators, bolts, etc); C_{FEM} – is a fuel cost and expendable materials (fuel lubricating materials, industrial gases, etc); P_{PSP} – is a probability of simultaneous performance of other tasks; F_{Σ}^1 – is a total area of the earth's surface in one radius [2].

The productivity calculation of aerial survey works performance on linear objects is carried out in accordance to the treated area in one shot. When flying UAV aerial photographs size calculated according to the following formulas [7,8]:

$$\frac{1}{2}L = H \times \operatorname{tg} \frac{1}{2} \lambda (\beta); \quad (2)$$

$$S_{3H} = L_x \times L_y;$$

where H – is high, m; λ, β – are viewing angles without approximation respectively horizontal and vertical, deg; S_{3H} – is size of aerial photographs, m^2 ; L – is side of aerial photographs:

$$\frac{1}{2}L_{x1} = H \times \operatorname{tg} \frac{1}{2} \lambda; \quad (3)$$

$$\frac{1}{2}L_{y1} = H \times \operatorname{tg} \frac{1}{2} \beta .$$

Treated area per hour:

$$S_{\text{hour}} = (S_{\text{ph.}} - p) \times N_{\text{ph.}}; \quad (4)$$

where p is longitudinal overlapping of aerial photographs, %; N_{ph} is frames per hour; $N_{\text{ph}}=3600/t$;

Calculation of hourly productivity UAV in processing linear objects is performed at a linear photographing areas. The time between each frame is calculated by the formula:

$$t = \frac{L_y - p}{V}; \quad (5)$$

where V – is the speed, m/s; p – is longitudinal overlapping of aerial photographs, %.

Markets patrol operations and UAV are relatively new and rapidly developing in recent years [9]. On the one hand, it gives rise to new methodological problems in the area of marketing. On the other hand –solving these problems may be relevant for the traditional market segments of aviation, which is entering a period of profound structural change. With increasing demand for new types of aircraft, new monitoring tools, information and control systems, organizations interested in applying RPAS, increase economic efficiency and safety of their operations, and contribute, in turn, to a certain extent the development of science intensive industries and diversify Ukrainian economy.

Thus, the demand for UAV used for patrol work is determined by economic efficiency patrols. Application of Policy Patrol can bring substantial savings not only through the reduction of patrol flights, but by reducing the expected loss due to early detection of abnormal and emergency situations, which is achieved by increasing the intensity of patrols.

Considerable uncertainty output, depending on the specific areas and tasks of RPAS, requires parametric calculations in a wide range of model parameters [6]. The appropriate economic and mathematical models development can be an effective marketing tool that allows developers and potential customers of RPAS to predict the

effectiveness of their use in the civilian sector, evaluate and coordinate the approximate volume of their output, specifications and prices.

5. CONCLUSIONS

The use of RPAS for a wide range tasks performed in global logistics system and territorial infrastructure is promising as it enables complete list of services that are being provided by Global Navigation Satellite System (GNSS), on-board and land equipment and thus significantly reduce the cost of their complex. In order to improve the efficiency advanced methods used for new unmanned vehicles development with extensive use of features modular construction and design modifications at the level of structural design blocks have been proposed. It should be noted the substantial experience of the National Aviation University in defining the principles of design and creation of effective remotely piloted aircraft systems. Recent years have seen further implementation of joint research with scientists of the Ukrainian-Polish Research Institute in Wroclaw for development opportunities and increase in the effectiveness of RPAS to solve logistics problems of territorial infrastructure in Ukraine and Poland.

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Volodymyr Kharchenko
National Aviation University, Ukraine
kharch@nau.edu.ua

Marcin Paweska
The International University of Logistics and
Transport in Wroclaw, Poland
mpaweska@cl-consulting.com.pl

Dmytro Bugayko
National Aviation University, Ukraine
bugaiko@nau.edu.ua

Dmytro Prusov
National Aviation University, Ukraine
prusov@nau.edu.ua