Optimization of the Special Cargo Delivery by UAV

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Abstract. During the pandemic, drones helped many FFCs access goods and services to the government and the general population. In response, many regulatory bodies worldwide have shown interest in helping the industry develop. Regulators are now looking for ways to support the development of drone technology by exploring ways to transport heavier goods and people. They are issuing more permits within existing frameworks and adopting more comprehensive frameworks to allow for more drone operations.

Overall, drones are expected to play an essential role in all applications. This makes them an excellent solution for transportation applications.

This study analyzes the role of unmanned aerial vehicles (UAVs) in delivering medical and emergency supplies to remote areas. It outlines potential considerations for operators wishing to use UAVs to provide medical and emergency supplies to remote locations.

The article also discusses some practical considerations regarding the organization wishing to conduct such operations, the operations themselves, and the technology used.

These considerations are primarily driven by the nature of the international regulatory framework for UAV operations and the specifics of using UAVs to deliver medical and emergency supplies.

Keywords: Unmanned Aerial Vehicle (UAV) · Supply chain · Transportation problem · Special cargo · COVID-19

1 Actually of the Subject Matter

As the entire world scrambles to react to the global health crisis caused by the spread of the new coronavirus and the COVID-19 illness, conversations about automation and the role of robotics in society have never been more relevant. In the face of the global COVID-19 pandemic, there have been reported attempts to utilize drone technology in different scenarios.

When organizing the shipment of thermal products, there are a lot of issues related to the delivery of shipments. First of all, it is necessary to choose the methods of organization of transportation and type of UAV.

When rationally selecting the type of UAV, the specialists pay attention to its suitability to the characteristics of the transported cargo. The main criterion is the preservation

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of cargo, the best possible use of space and capacity, lower transportation costs if it is possible. Transportation of thermal luggage by drone is the most expeditious and reliable delivery. The broad geography of the flight, the ability to perform flights over long distances in a short time, and the most remote points of the region, as well as the innocuousness of the medium of transportation, make the use of drones very advantageous and handy, especially under conditions of pandemics [8].

Carriage of this type of cargo by UAV is carried out, in general, by chartered flights on established airlines, to places where regular flights are not carried out. Delivery of thermal cargo is carried out by the shortest route and, as a rule, direct flights.

Transportation of medicines is classified under the category of critical loads. That is why the service is luggage requirements, which relate to the complete preservation of relocation. Transportation and storage must be carried out in compliance with a unique "cold chain" system. The main components of the cold chain are:

– specially trained staff- agents, which ensures the maintenance of refrigeration equipment, proper storage of vaccines, and their delivery to the structural units;
– refrigeration equipment designed for the storage and transportation of vaccines in optimal temperature conditions;
– a control mechanism for compliance with the required temperature regime at all stages of cold storage [2].

The goal is to deliver drugs without losing primary characteristics, preserving their properties. It has controlled not only the state of the vaccines and fluids and the integrity of the packaging, quantity, and quality of products that are delivered to the party. Transportation of medicines is considered successful if the recipient receives the order and does not get a loss.

2 Problem Solution

The limitations must be considered to plan the routes of a group of UAVs connected with selected points. This, together with arranging the shortest path, requires the development of approaches considering this limitation in the calculation.

UAVs can transport special cargo from the point of origin to the point of delivery both at the point of collection, i.e., at the central warehouse of the air terminal and the main warehouse of the delivery point. It is impossible to say a priori which sections of the routes will be assigned to certain types of UAVs and which will be assigned to ground vehicles. The answer can only be obtained by solving an optimization problem. The solution will depend on UAVs' technical and economic parameters (payload weight, range, cruising speed, fares, charges, requirements for takeoff and landing characteristics, etc.), the number of UAVs of each type in the fleet, and the competing modes of transport.

Considering the above efficiency criteria, factors, and general notions of special cargo delivery using air transport, let us define the stages of FFC decision-making to optimize the process.

Methods can be extended to obtain a short path from longer routes to avoid obstacles or synchronize the arrival time of autonomous vehicles. Algorithms for designing the fastest routes are conducted in various fields, such as computational geometry, analysis of operations, and logistics. One of the well-studied problems in computational geometry is that finding the shortest route was known back in 1987. This problem is known in the literature as the "transportation problem" [7].

Let's assume each center stores drugs in a warehouse; these district centers can serve each other on-demand. Considering the transport problem for the region on the profitability of the request. The main criterion is cost. The estimated cost per ton-km (USD) for the large fixed-wing roughly equals 6 USD/ton-km. The weight of one full container of Pfizer Softbox, where the vaccines and medicaments can be transported, is 36 kg. The *Pfizer Softbox thermal container can temporarily store the vaccine for up to 30 days from delivery (the container should be refilled every five days if the container is opened up to 2 times a day for less than 3 min at a time) [3].

DHL and other logistics companies were already transporting pharmaceutical products at minus 70 °C in boxes packed with dry ice before the coronavirus pandemic. They also use passive cooling systems for freezer and refrigerator temperatures for other products. The challenge for coronavirus vaccine logistics concerning these cooling systems is to adapt the known technology as quickly as possible to specific requirements such as package size as well as storage and transport times [1].

The commercial load of a UAV is 150 kg, so the maximum that 1 UAV Agroaircraft can carry is four containers (see Table 1). According to the distance between cities, we can calculate the delivery cost. As of May 25, 2022, 37% of Ukraine's population is fully vaccinated. According to this data and the number of people in the administrative center, we can roughly determine the needs for the 26th of May to meet demand and consumption.

Table 1. Agroaircraft flight characteristics.

Maximum takeoff weight, kg	300
Wing span, m	5.8
Empty weight, kg	150
Length, m	2.4
Height on ground, m	1.7
Capacity of caisson tanks, l	90
Flighing time, hours	6–12
Hourly fuel consumption, l/h	14–15
Commercial load, kg	150 (in containers)
Cruising speed, km/h	280 -300
Cost of production UAV, USAD	50–60 thousand
Gasoline engine, low-horsepower, hp	64 (Rotax-582)
Autopilot	1 ('Pixhawk')

Let's say there are supplies, six suppliers, and seven consumers. Certain medicines can be shipped both ways from where it is more expedient to send (see Table 2).

Table 2. The cost of shipping a container between cities in the Kyiv region.

Departures	Destinations							Supply (a_{ij})
	Obukhiv(B_1)	Vyshhorog(B_2)	Vasylkiv(B_3)	Skvyra(B_4)	Tarascha(B_5)	Slavutich(B_6)	Boguslav(B_7)	
Kyiv(A_1)	20	8	17	51	50	60	52	8
Bila Tserkva(A_2)	26	45	22	17	20	98	31	7
Boryspil(A_3)	18	21	25	58	47	66	58	6
Brovary(A_4)	23	14	25	59	54	56	54	5
Bucha(A_5)	29	10	21	50	31	57	61	4
Fastiv(A_6)	27	34	16	21	36	86	46	4
Demand(b_{ij})	3	4	2	3	1	2	1	

Table 3. Model of the transportation problem.

	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8	Supply
A_1	20	8	17	51	50	60	52	0	8
A_2	26	45	22	17	20	98	31	0	7
A_3	18	21	25	58	47	66	58	0	6
A_4	23	14	25	59	54	56	54	0	5
A_5	29	10	21	50	31	57	61	0	4
A_6	27	34	16	21	36	86	46	0	4
Demand	3	4	2	3	1	2	1	18	34

The number of departure points m = 6, and the number of destination points n = 7. Therefore, the reference plan of the problem is determined by the numbers in m + n–1 = 6 + 7–1 = 12 filled cells of the table. The matrix gives the tariffs for transporting a cargo unit from each point of departure to all destination points.

Cargo availability at suppliers is equal:

$$\sum A_i = 8 + 7 + 6 + 5 + 4 + 4 = 34.$$

The total demand for cargo at the destinations is equal:

$$\sum B_i = 3 + 4 + 2 + 3 + 1 + 2 + 1 = 16.$$

Since $\sum A_i \geq \sum B_i$, the model of the transportation problem is open. To obtain a closed model, we enter an additional destination point B8 with requirements 34–16 = 18. We assume that transportation tariffs from the points of departure to B8 equal zero. As a result, we obtain a closed model of the transportation problem:

Table 4. Solved reference plan of the transportation problem.

	B_1	B_2	B_3	B_4 **1**	B_5	B_6	B_7	B_8	Supply
A_1	20	8 **4**	17	51	50	60	52	0 **4**	0 [8].
A_2	26	45	22	17 **3**	20 **1**	98	31 **1**	0 **2**	0 [7].
A_3	18 **3**	21	25	58	47	66	58	0 **3**	0 [6].
A_4	23	14	25	59	54	56 **2**	54	0 **3**	0 [5].
A_5	29	10	21	50	31	57	61	0 **4**	0 [4].
A_6	27	34	16 **2**	21	36	86	46	0 **2**	0 [4].
Demand	0 [3].	0 [4].	0 [2].	0 [3].	0 [1].	0 [2].	0 [1].	0 [18].	34
	$B_1=18$	$B_2=8$	$B_3=16$	$B_4=17$	$B_5=20$	$B_6=18$	$B_7=31$	$B_8=0$	

△11=18-20-0=-2

△13=16-17-0=-1

△14=17-51-0=-34

△15=20-50-0=-30

△16=56-60-0=-4

△17=31-52-0=-21

△21=18-26-0=-8

△22=8-45-0=-37

△23=16-22-0=-6

△26=56-98-0=-42

△32=8-21-0=-13

△33=16-25-0=-9

△34=17-58-0=-41

△35=20-47-0=-27

△36=56-66-0=-10

△37=31-58-0=-27

△41=18-23-0=-5

△42=8-14-0=-6

△43=16-25-0=-9

△44=17-59-0=-42

△45=20-54-0=-34

△47=31-54-0=-23

△51=18-29-0=-11

△52=8-10-0=-2

△53=16-21-0=-5

△54=17-50-0=-33

△55=20-31-0=-11

△56=56-57-0=-1

△57=31-61-0=-30

△61=18-27-0=-9

△62=8-34-0=-26

△64=17-21-0=-4

△65=20-36-0=-16

△66=56-86-0=-30

△67=31-46-0=-1

Stage I. Finding the first reference plane. In this step, we find the reference plan of the problem by the minimum element method.

There are no positives among the α_{ij}. Consequently, this reference plan is optimal. Solution. In this plan, the cost of transportation is calculated as follows:

S = 8–4 + 17–3 + 20–1 + 31–1 + 18–3 + 56–2 + 16–2 = 332 USD.

Resource allocation:

– From warehouse Kyiv (A1), send container (4) to Vyshhorog (B2).
– From store Bila Tserkva (A2) ship container (3) to Skvyra (B4).
– From warehouse Bila Tserkva (A2) ship container (1) to Tarascha (B5).
– From warehouse Bila Tserkva (A2) ship container (1) to Boguslav (B7).
– From warehouse Boryspil (A3) ship container (3) to Obukhiv (B1).
– From warehouse Brovary (A4) ship container (2) to Slavutich (B6).
– From warehouse Fastiv (A6), send container (2) to Vasylkiv (B3).

3 Conclusions

In the global cold chain context, UAVs could change how medicines are delivered for undemanding care in remote areas.

It was suggested to transport medications using a UAV. From the regional center to the district – UAV "Agroaircraft"; from district centers to villages -VTOL. The minimum cost, the distance between cities of the region, the weight of the contains, the maximum payload of the drone, and the number of necessary resources depending on the population number were taken into account,

The introduction of this technology could be a significant step toward providing blood products or vaccines to a person infected with the disease, the time it saves in delivering could prove crucial to the end of their life. UAVs can change the way of delivering medicines to provide non-demanding assistance in remote areas. The time that this technology saves on delivering blood products or vaccines to a person who has been infected with the disease could be crucial for the end of his life.

As part of the design section, the functional structure of the system for organizing thermal cargo delivery using unmanned aerial vehicles is considered, and the mathematical structure of the formation of UAV routes is described in detail. Algorithms for the organization of the delivery of thermal cargoes using unmanned aerial vehicles with the justification of choice are given.

Principles, methods, and mathematical models are an integral part of the methodology of special cargo delivery cost-effectiveness management and provide flexibility in making FFC decisions on determining the optimal variant of special cargo delivery in case of changes in the competitive situation in the special cargo transportation markets. Using the developed model will increase the work of managers for the transportation of thermal luggage, thus reducing the amount of time spent on the route to calculate the cost of special cargo and improving the quality of managers in the enterprise.

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