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LOGISTICS METHODS FOR MANAGING THE TRANSPORTATION OF HUMANITARIAN CARGO NEAR THE WAR ZONE

This article analyzes existing logistics systems, identifies problematic aspects of their functioning, and develops practical recommendations for optimizing the transportation of humanitarian cargo. The logistical delivery of humanitarian cargo faces many challenges near the war zone. The authors research the impact of various factors, including security risks for carriers, limited access to transport and infrastructure, adverse weather conditions, and insufficient coordination between different humanitarian organizations and local authorities. The characteristics of cargoes provided to citizens as humanitarian aid are considered, and a means of transport for transporting goods from large warehouses to intermediate storage facilities is selected, and transport routes are developed, taking into account the uncertainty of route selection due to shelling. Simulating the routes for delivering humanitarian aid to frontline settlements has been carried out. The research emphasizes that efficient transportation of humanitarian cargo from central warehouses to frontline areas is a complex but solvable challenge. Transporting cargoes from central warehouses to intermediate ones, developing routes for further transportation to humanitarian aid distribution points, and optimising the transport fleet are the main stages in developing an effective transport and logistics system. Specialised algorithms of linear programming tasks were used to allocate vehicles and minimise costs. In the event of a danger associated with hostilities, the availability of developed alternative routes ensures continuity of supply. Risk probability analysis makes it possible to choose the safest routes.

Key words: *humanitarian logistics, frontline areas, alternative logistics routes, humanitarian cargo.*

Музикін М. І., Нестеренко Г. І., Бібік С. І., Чубенко О. І. Логістичні методи управління перевезеннями гуманітарних вантажів поблизу зони бойових дій

Статтю присвячено аналізу існуючих логістичних систем, виявленню проблемних аспектів їх функціонування, а також розробці практичних рекомендацій для оптимізації процесів транспортування гуманітарних вантажів. Поблизу зони бойових дій логістична доставка гуманітарних вантажів стикається з багатьма труднощами. Досліджується вплив різних факторів, зокрема безпекові ризики для перевізників, обмежений доступ до транспорту та інфраструктури, складні погодні умови, а також недостатня координація між різними гуманітарними організаціями та місцевими органами влади. Розглянуто характеристику вантажів, які надаються громадянам у якості гуманітарної допомоги, обрано транспортний засіб для перевезення вантажів з великих складів до проміжних складів та розроблено маршрути перевезення, враховуючи невизначеність вибору маршруту через обстріли. Виконано моделювання маршрутів розвезення гуманітарної допомоги в прифронтові населені пункти. В дослідженні підкреслюється, що ефективне перевезення

гуманітарних вантажів від центральних складів до прифронтових районів є складною, але вирішуваною задачею. Перевезення вантажів від центральних складів до проміжних, розробка маршрутів для подальшого транспортування до місць видачі гуманітарної допомоги та оптимізація транспортного парку є основними етапами розробки ефективної транспортно-логістичної системи. Під час виконання розподілу транспортних засобів та мінімізації витрат використано спеціалізовані алгоритми задач лінійного програмування. У разі наявності небезпеки пов'язаної з бойовими діями, наявність розроблених альтернативних маршрутів забезпечує безперервність постачання. Аналіз ймовірності ризиків надає можливість обрати найбезпечніші маршрути.

Ключові слова: *гуманітарна логістика, прифронтові райони, альтернативні логістичні маршрути, гуманітарні вантажі.*

Problem statement. The modern world faces numerous challenges, one of which is conflicts and armed confrontations, which create a need for humanitarian assistance. In situations where the lives and well-being of millions of people are at risk, it is especially crucial to ensure the efficient transport of humanitarian cargoes. The timely delivery of such cargoes can be vital for saving human lives, supporting the survival of affected communities, and providing basic needs [1].

Logistics strategies for handling the transportation of humanitarian cargoes near war zones are critically important in today's world, where armed conflicts leave millions without livelihoods and essential protections. That is why this article is relevant.

Analysis of recent research and publications. Humanitarian cargo includes a wide range of vital resources, such as medicines, food, clean drinking water, clothing, and other essential items [3]. However, the logistics of these cargoes near the combat zone are often accompanied by numerous difficulties and challenges [12]. Among them, it is worth highlighting security risks for carriers, limited access to transport and infrastructure, difficult weather conditions, as well as insufficient coordination between various humanitarian organizations and local authorities [8].

We have witnessed and participated in another wave of unprecedented mobilization not only of the Ukrainian people, but also of people around the world, to assist both the Armed Forces of Ukraine and the Territorial Defense Forces, as well as to provide humanitarian assistance to those affected by russian military aggression. At the same time, we are forced to admit that the network potential of Ukrainians for cooperation, which ensured the supply chains of necessary assistance, although it played a critically important role, remained untapped due to the lack of effective coordination mechanisms. Logistics specialists in the global humanitarian community are making increasing efforts to formulate principles, protocols, and a structure for effective interaction in the field of humanitarian aid delivery. [9]

The team of authors in the work [11] proposes to use the method of hierarchy analysis to determine the criteria for optimization and selection of the optimal transportation route in conditions of military conflict.

The article states [10] that volunteer organizations play a crucial role in meeting the humanitarian needs of the population in Ukraine. The research analyzes in detail the volumes and types of assistance provided by various organizations, and also emphasizes the importance of coordinated logistical processes and effective organization. Much attention is paid to humanitarian logistics, which needs further development.

The purpose of the article is to comprehensively study methods and strategies that can increase the efficiency of humanitarian cargo transportation near the combat zone. The research aims to conduct an in-depth analysis of existing logistics systems, identify problematic aspects of their functioning, and develop practical recommendations for optimizing transportation processes. The main focus is on studying the best international practices, implementing innovative approaches, and utilizing modern technologies to enhance transportation efficiency.

Presentation of the main material. More than three years have passed since the full-scale invasion of Ukraine began, and the humanitarian needs of the affected population remain high. An estimated 14,6 million people are in urgent need of humanitarian assistance and social and legal protection services in 2024. Since the start of the year, people across Ukraine have been suffering from widespread rocket attacks, which have killed and injured civilians and damaged homes and critical infrastructure. The ongoing fighting in frontline and border communities in the north, south, and east of the country is negatively impacting the population and forcing people to evacuate. From January to March 2024, a total of 9,700 attacks were recorded across Ukraine. [1]

As of the end of December 2023, almost 907,000 people in Ukraine had received assistance to get through the autumn-winter period from the United Nations High Commissioner for Refugees (UNHCR) and partners. It provides cash assistance of UAH 6,660 per person. This aid is planned to reach over 617,900 people with special vulnerability criteria to help them cover increased expenses during the winter months. [1]

Almost 249,000 people received essential items to get through the winter period (namely thermal blankets and regular blankets), of which 77,000 people received winter clothing.

Over 11,800 people received housing assistance during the autumn-winter season. This includes nearly 8,500 individuals who received seasonal home insulation kits to keep their homes warm, such as materials traditionally used in Ukraine to improve thermal insulation: heat-reflecting screens, transparent polyethylene film for windows, foam sealants, and construction tape.

At the same time, in close coordination with the authorities, the distribution of generators to communities continues. As of today, more than 80 of the 147 planned generators have already been provided to communities. This support will help people and communities be prepared for power outages and keep their homes warm.

To support internally displaced persons in temporary housing nationwide, UNHCR also helped repair and insulate premises, as well as maintain heating and electricity systems. This support improved the living conditions of nearly 28,200 IDPs in temporary accommodations.

In 2023, UNHCR provided multi-purpose cash assistance to 899,039 internally displaced families, returnees, and individuals with special vulnerabilities to help cover basic needs such as food, medicine, clothing, shelter, utilities, and energy costs during the autumn-winter season. This included 565,236 people who received three months of multi-purpose cash assistance and 617,926 individuals who received cash support to help offset additional costs related to the autumn-winter period. Many families with special vulnerability criteria received payments from both programs. Over $223.6 million was allocated in 2023 to assist internally displaced and other war-affected populations through multi-purpose cash assistance and energy cost support during the colder months.

UNHCR signed a Memorandum of Understanding with the Ministry of Social Policy of Ukraine and the Pension Fund of Ukraine to provide additional support to the Ukrainian population during the winter period of 2023-2024. According to the Memorandum, UNHCR will provide cash assistance for the purchase of solid fuel for more than 85,000 families with special vulnerabilities, including households of older people and families with people with disabilities.

In December, UNHCR also provided cash assistance to 120 refugee families remaining in Ukraine to cover their basic needs and rent.

UNHCR supplies standard essential items, such as blankets, kitchen sets, and solar lamps. Non-standard items, like feminine hygiene products, mattresses, and clothing, are also being provided (Fig. 1). All this support is distributed to those in need, mainly in frontline areas and among newly displaced people, as well as in areas where access has recently been restored and which have been affected by shelling for months. The distribution of non-food items is carried out with the help of implementing partners and local authorities. Assistance is delivered directly to those in need or through participation in inter-agency responses.

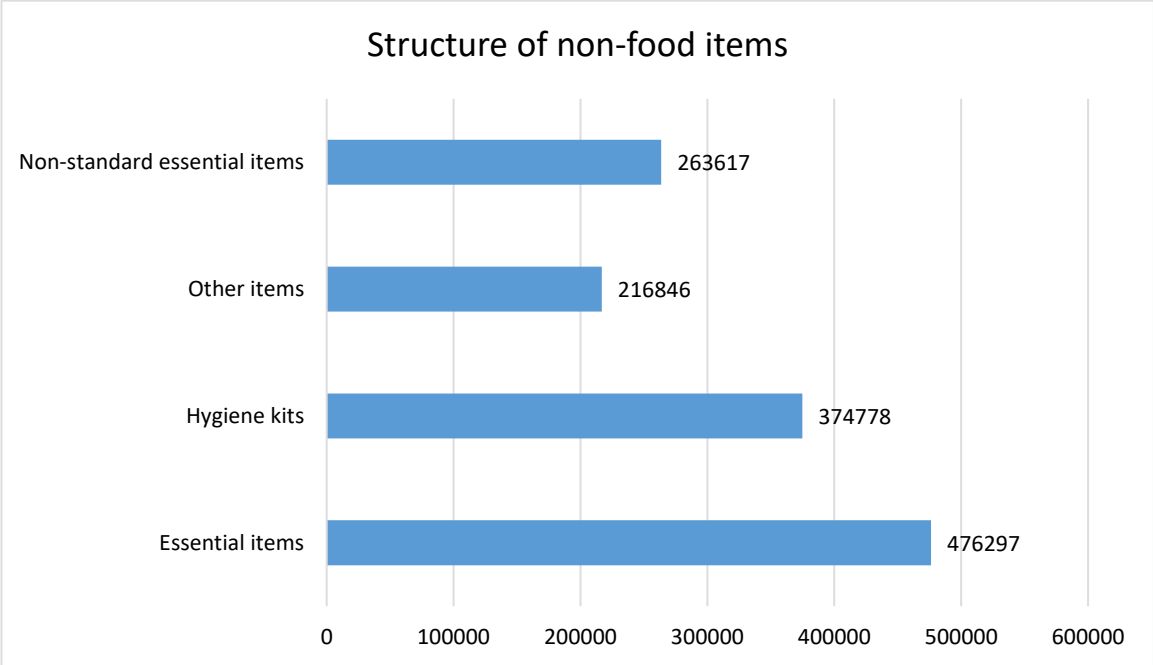

Fig. 1. Structure of non-food items

Helping war-affected families living in frontline communities meet their basic needs remains a priority. UNHCR joined and provided essential items, including tarpaulins, plastic sheeting, blankets, solar lamps, and bedding sets, for six inter-agency convoys in December, including three to Donetsk, two to Kherson, and one to Kharkiv regions.

In total, UNHCR provided 3,120 tarpaulin sheets, 1,374 solar lamps, 30 rolls of plastic sheeting, 300 blankets, 300 bedding sets, 1,500 sleeping bags, and clothing for the six convoys. These items will help families in frontline communities, including vulnerable people and people with disabilities, stay warm this winter.

Overall, more than 575,270 internally displaced and war victims have received essential items this year, including people affected by renewed shelling across the country and people living in hard-to-reach frontline areas.

A summary of the assistance received by item is shown in (Fig. 2).

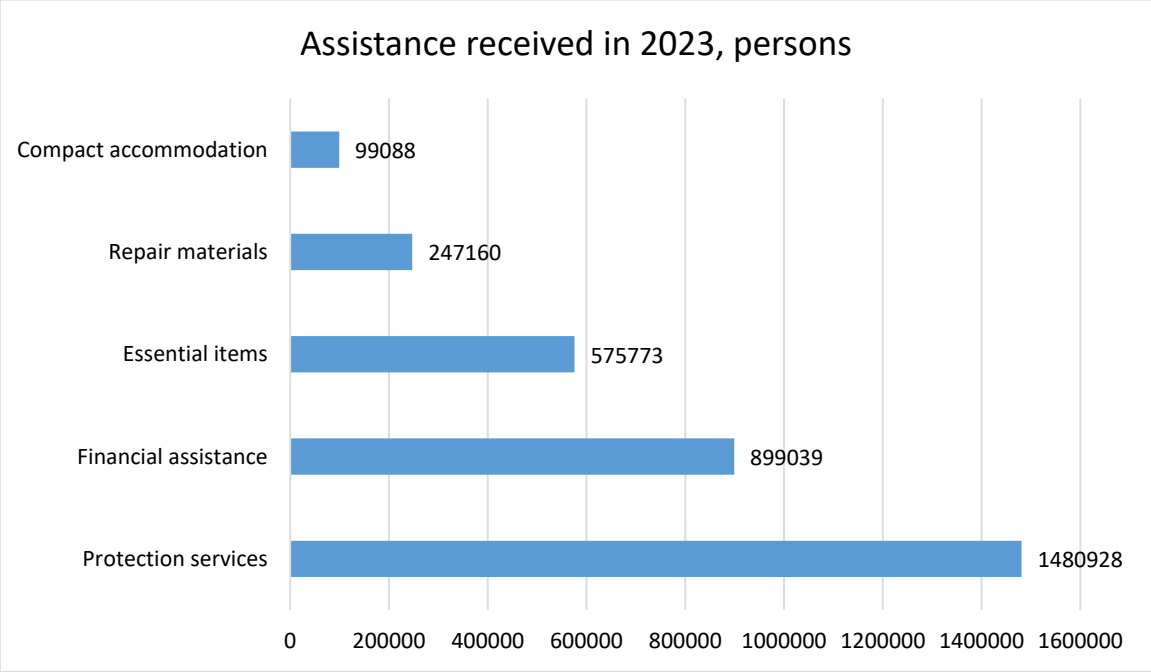

Fig. 2. Aid received in 2023, persons

UNHCR's shelter programme supports people affected by the war in three ways:
– providing emergency shelter to those in urgent need in areas directly affected by shelling;
– repairs and housing solutions to help people return to their homes, where possible;
– improving conditions or creating new places in collective accommodation for IDPs who cannot return home.
The number of people who received assistance in 2024 by month is shown in (Fig. 3).

Almost 2.9 million people were provided with food and agricultural supplies, mostly in frontline communities. Almost 1.7 million people received health assistance.

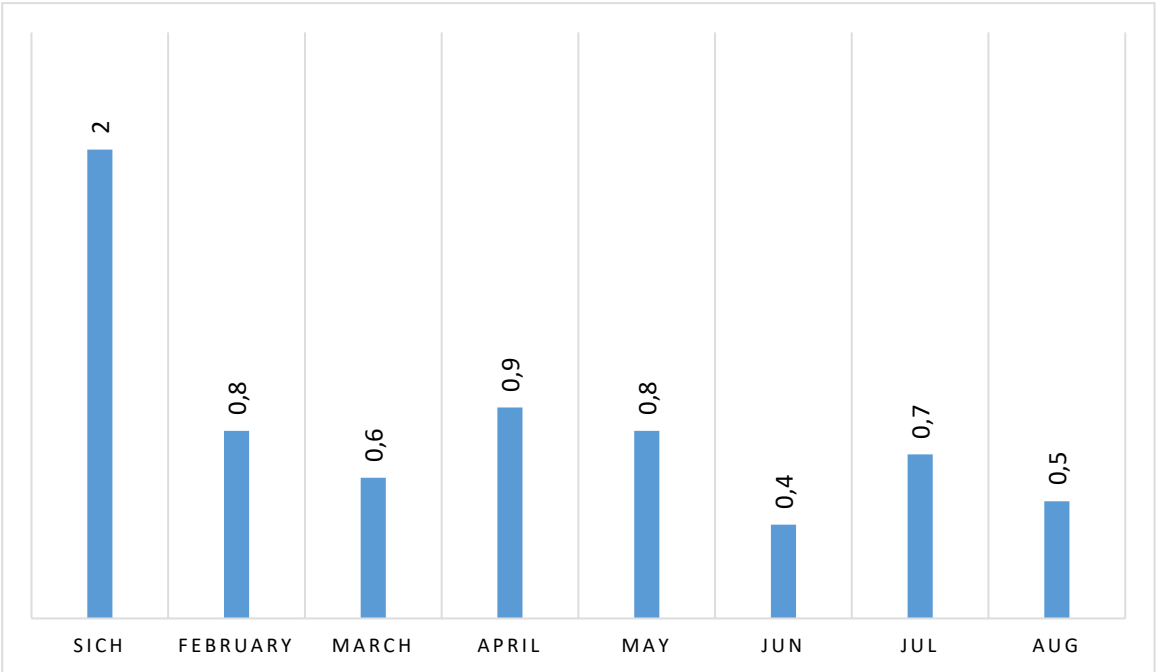

Fig. 3. Number of people who receive assistance in 2024 by months, in millions of people

To prepare for the autumn-winter season, over 1.2 million people received fuel and supplies to repair damaged homes, along with other non-food items. Humanitarian workers also offered protection services, including social and legal support, child protection, gender-based violence prevention and survivor assistance, and mine action, such as explosive ordnance risk education.

To reach frontline areas where access is difficult due to the security situation, humanitarian partners delivered 28 inter-agency convoys with assistance for almost 45,000 people in Donetsk, Zaporizhia, Kharkiv, and Kherson regions, in addition to regular humanitarian assistance activities. The distribution of people assisted by region is shown in (Fig. 4).

Fig. 4. Distribution of people by region [5]

Among the statuses of citizens, assistance is provided to citizens of the following statuses: internally displaced persons (IDPs), people who have returned to their places of residence, and non-displaced (Fig. 5) [5].

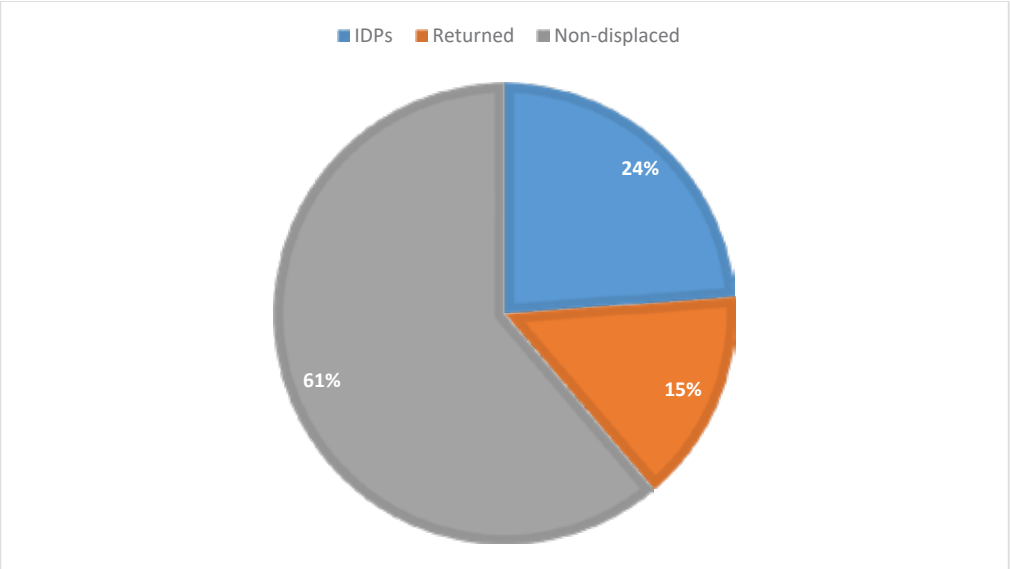

Fig. 5. Population groups provided with assistance for January-September 2024

Humanitarian aid is provided by many Ukrainian manufacturers, which is delivered to central warehouses in the cities of Dnipro, Poltava, Kropyvnytskyi. Then, after the formation of sets, the goods are transported to an intermediate warehouse in the cities of Kramatorsk, Chuhuiv, Izium, Zaporizhzhia, after which, for safety reasons, they are reloaded onto smaller cars (pick-ups) and delivered to settlements in the frontline area.

It is essential to consider the characteristics of goods provided to citizens as humanitarian aid, select a vehicle for transporting goods from large warehouses to intermediate warehouses, develop transportation routes from large to intermediate warehouses, and simulate these routes for delivering humanitarian aid to frontline settlements from Kramatorsk. In the initial phase of transportation, cargo should be moved from central warehouses with humanitarian aid in cities such as Dnipro, Poltava, and Kropyvnytskyi to intermediate warehouses in Kramatorsk, Chuhuiv, Izium, and Zaporizhzhia. In the second phase, delivery routes should be planned from Kramatorsk to frontline cities (Kostiantynivskyi district).

The mathematical model of the transport process of transporting humanitarian cargoes looks like this. If x_{ij} is the volume of humanitarian cargo transported from warehouse *i* to intermediate warehouse *j*, then the transport work for such transportation is equal to $c_{ij}x_{ij}$. The total transport work for the transportation of all cargo will be $\sum_{i=1}^{m}\sum_{j=1}^{n}c_{ij}x_{ij}$. Transport work must be minimised, so the target function of the transport task will be as follows [4]:

$$Z(X)=\sum_{i=1}^{m}\sum_{j=1}^{n}c_{ij}x_{ij}\to Min. \tag{1}$$

The system of constraints contains two groups of equations. The first group of *m* equations indicates that the stocks of all *m* warehouses are transported in full, i.e.

$$\sum_{j=1}^{n}x_{ij}=a_i,\ i=1,2,...m. \tag{2}$$

The second group of constraints from *n* equations indicates that the needs of all consumers are fully satisfied, i.e. $\sum_{i=1}^{m}x_{ij}=b_j,\ j=1,2,...n$. Considering that $x_{ij}\geq 0$:

$$\sum_{i=1}^{m}x_{ij}=b_j,\ j=1,2,...n \tag{3}$$

$$x_{ij}\geq 0,\ i=1,2,...m,\ j=1,2,...n. \tag{4}$$

In the transport problem model under consideration, it is assumed that the total warehouse stocks equal the total requirements of intermediate warehouses, i.e., the condition is met

$$\sum_{i=1}^{m}a_i=\sum_{j=1}^{n}b_j \tag{5}$$

Such a problem is called a problem with a correct balance, and its model is called closed. If equality (5) is not satisfied, then the problem is called a problem with an incorrect balance, and its model is open.

When solving a transport problem, it is necessary to find a transportation plan, a matrix

$$X=\begin{pmatrix} x_{11} & x_{12} & ... & x_{1n} \\ x_{21} & x_{22} & ... & x_{2n} \\ . & . & ... & . \\ x_{m1} & x_{m2} & ... & x_{mn} \end{pmatrix}=\left\{x_{ij}\right\}_{i=1;j=1}^{m\quad n}, \tag{6}$$

that satisfies the system of constraints (2), (3), (4) and minimises the objective function (1).

A transportation plan that satisfies the system of constraints (2), (3), (4) is called admissible.

A transportation plan in which the objective function is minimal is called optimal.

The transportation problem is a linear programming problem and can be solved by the simplex method algorithm. Since this problem has several features, namely:

1) constraints are given in the form of equations;
2) each unknown appears in only two equations;
3) the coefficients for unknowns are units.

Special algorithms have been created for its solution [5].

There are 3 types of vehicles and 9 settlements where humanitarian aid needs to be delivered. The requirements for the number of food packages and their weight are given in (Tab. 1).

Table 1

Requirements for food packages by settlements

No.	Settlement	Number of food parcels, pcs	Total weight, kg
1.	Oleksiievo-Druzhkivka	7000	35000
2.	Stepanivka	400	2000
3.	Predtechyne	300	1500
4.	Ivanopillia	700	3500
5.	Illinivka	1000	5000
6.	Kostiantynivnka 1	1100	5500
7.	Kostiantynivnka 2	1150	5750
8.	Kostiantynivnka 3	1300	6500
9.	Kostiantynivnka 4	800	4000

Considering the capacity of vehicles in terms of load capacity, the cost of transportation to the *i*-th settlement relative to the *j*-th type of vehicles, the cost of renting each type of vehicle, and the distribution of vehicles between intermediate warehouses, we obtain the optimal transportation route based on linear programming tasks [2]. Thus, the objective function for the first stage of transportation will be as follows:

$$F(x) = 349.28x_{11} + 376.56x_{12} + 390.51x_{13} + 220.06x_{14} + 161.25x_{21} + 215.87x_{22} + \\ +250.80x_{23} + 205.00x_{24} + 189.01x_{31} + 183.37x_{32} + 187.42x_{33} + 70.00x_{34} \rightarrow min \quad (7)$$

With the following constraints:

By stocks:

$$x_{11} + x_{12} + x_{13} + x_{14} \leq 500$$
$$x_{21} + x_{22} + x_{23} + x_{24} \leq 450$$
$$x_{31} + x_{32} + x_{33} + x_{34} \leq 500$$

By needs:

$$x_{11} + x_{21} + x_{31} = 300$$
$$x_{12} + x_{22} + x_{32} = 250$$
$$x_{13} + x_{23} + x_{33} = 450$$
$$x_{14} + x_{24} + x_{34} = 450$$

Food packages provided as humanitarian aid to war-affected people include canned goods, cereals, pasta, flour, yeast, oil, salt, sugar, tea, bottled drinking water, and beverages. These goods do not have special storage temperature requirements, but some of them require storage and transportation in dry places.

Choosing the right vehicle for transporting goods is of great importance for the success and efficiency of any logistics process. The right solution in this area can reduce costs, improve transportation safety, and ensure the timely delivery of goods.

Key factors to consider when choosing a vehicle:

Type of cargo: The characteristics of the cargo, such as its size, weight, and sensitivity to transport conditions, influence the choice of transport vehicle. Considering the transportation of goods that only need to be protected from moisture, special vehicles (SV) are not required for transportation.

Choosing the right vehicle can significantly reduce transportation costs. Optimizing fuel, maintenance, and other operating costs helps to increase the profitability of logistics operations.

Choosing a vehicle that meets the needs of fast and reliable delivery guarantees the timely arrival of the cargo at its destination. This is especially important for companies working with urgent orders or perishable goods. Given that the delivery takes place in an area close to the front line, speed is also of great importance.

Vehicles that meet modern environmental standards help reduce environmental impact. Choosing a vehicle with low CO_2 emissions supports corporate responsibility and contributes to a positive company image.

Reliable vehicles with special safety systems ensure the safety of cargo during transportation. This reduces the risk of damage to goods and losses associated with accidents or other incidents on the road.

The correct choice of a motor vehicle allows you to optimize transportation processes, reduce costs, and increase the overall efficiency of logistics. This is a strategic decision that requires careful analysis and consideration of all aspects of transportation.

The selection of the optimal vehicle model from three competitive ones is based on a comparison of the results of technical and operational calculations, as well as technical and economic calculations. Three types of rolling stock were selected for comparison: DAF FX105, Mercedes-Benz Actros, and Renault Magnum [6]. A comparison

of vehicles is given in Table 2. In the future, the selected model will be used for cargo transportation along the Dnipro-Kramatorsk route.

Table 2

Comparative table of rolling stock of vehicles

No.	Indicator	Option 1	Option 2	Option 3
1.	Car brend	DAF FX 105	Renault Magnum	Mercedes-Benz Actros
2.	Euro compliance	Euro 5	Euro 5	Euro 6
3.	Transmission	Manual	Manual	Automatic
4.	Power (horsepower)	410	480	448
5.	Fuel type	diesel	diesel	diesel
6.	Fuel consumption (litres per 100 km)	30	33	28
7.	Load capacity (kg)	45000	45 000	45000
8.	Year of manufacture	2017	2017	2018
9.	Car price	24000 dollars	23000 euros	36000 euros
10.	Car tyre cost	10500 UAH	10500 UAH	10500 UAH
11.	Technical speed (km/h)	85	75	80
12.	Productivity (t)	1.55	1.38	1.45
13.	Productivity (t/km)	1074.18	957.29	1050.76

According to the calculations, the first option (DAF FX 105) showed higher hourly productivity, so we chose it for transportation.

Considering the amount of cargo for different settlements that transport aid directly to the front line, we suggest choosing vehicles of different load capacities.

The vehicle with a load capacity of up to 1.5 tons.

We will prepare the initial data in Excel and provide information on distances, stocks, and requirements (Tab. 3).

Table 3

Initial data for calculating the transport task

	Chuhuiv	Izium	Kramatorsk	Zaporizhzhia	Stocks
Kropyvnytskyi	349.28	376.56	390.51	220.06	500
Poltava	161.25	215.87	250.80	205.00	450
Dnipro	189.01	183.37	187.42	70.00	500
Needs	300	250	450	450	

The obtained results are shown in (Fig. 6).

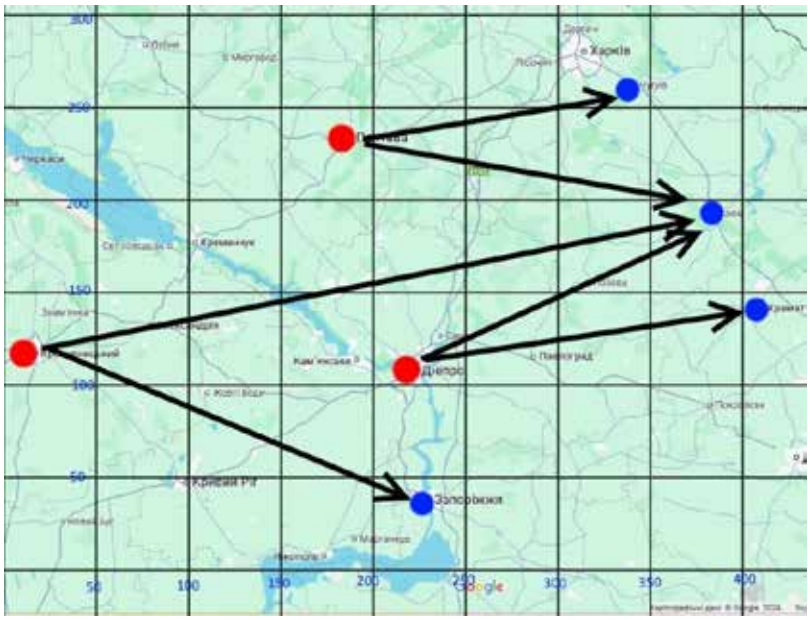

Fig. 6. Transportation scheme based on the solution of the transportation task

Thus, the minimum transport work will be 292114 t-km. From Kropyvnytskyi to Izium, 50 tonnes of cargo are delivered, and to Zaporizhzhia, 450 tonnes. From Poltava, 300 tonnes to Chuhuiv and 150 tonnes to Izium. From Dnipro 50 tonnes to Izium and 450 tonnes to Kramatorsk.

To solve the transport task, distances were calculated using the criterion of minimum distance; however, due to the proximity of the front, it is necessary to have alternative routes in case of shelling.

In case of shelling of this territory, alternative routes can be used, one through Synelnykovo and Vasylkivka, and the second through Pokrovsk.

Since it is essential to deliver food and hygiene products to people in settlements as quickly as possible, we choose the route that is both the shortest and fastest in terms of delivery time. We also have two alternative routes passing through the cities of Pokrovsk and Vasylkivka. Let us analyze the probabilities associated with these alternative routes. Along a similar route, 60% of vehicles carrying humanitarian cargo pass through Pokrovsk, while 40% go through Vasylkivka. Additionally, 5% of vehicles near Pokrovsk come under fire, compared to only 2% near Vasylkivka. We need to calculate these probability indicators.

Let us formulate two hypotheses: H_1 – the vehicle passed through Pokrovsk, H_2 – the vehicle passed through Vasylkivka. Let event A – the vehicle was waiting for the end of the shelling.

To determine the probability that a random vehicle with humanitarian cargo was waiting for the end of the shelling near the city of Pokrovsk, we need to use the Bayes formula, according to which [8]:

$$P(H_1 / A) = \frac{P(H_1) \cdot P(A / H_1)}{P(H_1) \cdot P(A / H_1) + P(H_2) \cdot P(A / H_2)} = \frac{0,6 \cdot 0,05}{0,6 \cdot 0,05 + 0,4 \cdot 0,02} = \frac{0,03}{0,038} = 0,79 = 79\%$$

Then, by the property of probabilities that their sum is equal to 1, we have that the probability of downtime in Vasylkivka will be as follows:

$$P(H_2) = 1 - 0.79 = 0.21$$

Thus, for the alternative transportation route, we choose route No. 2, via Vasylkivka, because this route has a lower probability of coming under fire.

There are 3 types of vehicles and 9 settlements where humanitarian aid needs to be delivered. The requirements for the quantities of food packages and their weights are given in (Tab. 4).

Table 4

Requirements for food packages by settlements

No.	Settlement	Number of food parcels, pcs	Total weight, kg
1.	Oleksiievo-Druzhkivka	7000	35000
2.	Stepanivka	400	2000
3.	Predtechyne	300	1500
4.	Ivanopillia	700	3500
5.	Illinivka	1000	5000
6.	Kostiantynivnka 1	1100	5500
7.	Kostiantynivnka 2	1150	5750
8.	Kostiantynivnka 3	1300	6500
9.	Kostiantynivnka 4	800	4000

So, according to the terms of the task, the optimal transportation option should be as follows: four vehicles with a load capacity of 8 tonnes (the third type) and one vehicle with a load capacity of 3 tonnes (the second type) go to the urban village of Oleksiievo-Druzhkivka; two vehicles with a load capacity of up to 1.5 tonnes (the first type) go to the village of Stepanivka; one vehicle of the first type goes to the village of Predtechyne; one vehicle of the first type and one of the second type go to the village of Ivanopillia; one vehicle of the third type goes to the village of Illinivka; one vehicle of the third type goes to the city of Kostiantynivka (the first district); another of the third type to Kostiantynivka (the second district); one vehicle of the third type to Kostiantynivka (the third district); and one vehicle of the first type and one of the second type go to Kostiantynivka(the fourth district). This allocation and distribution of the vehicle fleet ensures minimal costs for transporting humanitarian cargo.

After three years of a full-scale invasion of Ukraine, the humanitarian crisis has not eased; rather, the needs of the affected population remain high. Massive rocket attacks and ongoing hostilities have caused significant civilian casualties and destroyed infrastructure, forcing thousands of people to leave their homes. Organizations such as UNHCR are working to provide a variety of assistance – from monetary to material support – meeting the basic needs of those affected and helping them survive the autumn and winter months.

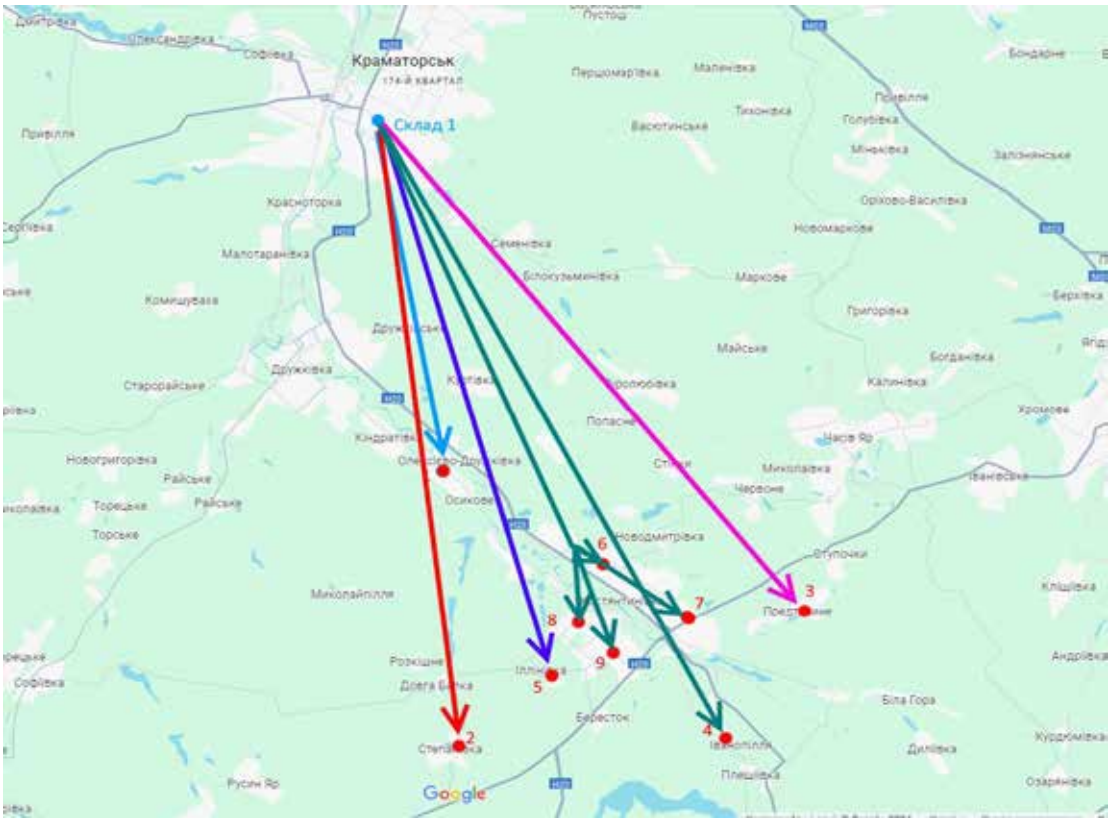

Fig. 7. Transportation scheme from the warehouse to issuing points

Overall, humanitarian assistance in Ukraine as of the end of August 2024 has achieved significant results thanks to the efforts of more than 580 organizations. It was able to support 6.7 million people by providing water supply, food, healthcare, and non-food items. Successful preparations for the autumn-winter season enabled support for over 1.2 million people with fuel and materials for house repairs.

It is worth noting the important role of multi-purpose cash assistance, which helped more than 600,000 people meet their basic needs. Also, providing education to almost 530,000 people is a significant achievement.

Thanks to inter-agency convoys, it was possible to reach hard-to-reach frontline areas and provide assistance to nearly 45,000 people, which is an important step in overcoming the consequences of the conflict.

Humanitarian partners continue to work to improve the living conditions of internally displaced persons and provide necessary support to citizens of various statuses, which is crucial to a further successful response to humanitarian challenges in Ukraine.

Conclusions. Despite numerous challenges, both international and local efforts focus on supporting the most vulnerable groups, improving living conditions for internally displaced persons, and providing them with housing. The success of these initiatives is vital for ensuring the survival and dignity of those facing hardship due to the war. The daily work of coordinating humanitarian aid and responding to emergencies continues to be crucial in overcoming the war's impacts and maintaining stability in the country.

The effective transportation of humanitarian cargo from central warehouses to front-line areas is a challenging but solvable task. Developing an efficient delivery system based on logistics management methods involves several key stages: moving cargo from central warehouses to intermediate depots, creating routes for further transportation to distribution points, and optimizing the transport fleet. Using specialized algorithms for linear programming tasks helps find the best solutions for vehicle allocation and cost reduction.

Choosing the right vehicle for cargo transport is crucial for the success of logistics operations. The proper choice can significantly cut costs, enhance safety, and ensure on-time delivery. Optimizing delivery routes and selecting rolling stock with different capacities helps reduce transportation expenses and improve transport efficiency. The minimum transport work for the first stage will be 292,114 t-km, with 50 t delivered from Kropyvnytskyi to Izium, 450 t to Zaporizhzhia, 300 t from Poltava to Chuhuiev, and 150 t to Izium. Additionally, 50 t move from Dnipro to Izium, and 450 t to Kramatorsk. In the second stage, selecting and distributing the vehicle fleet minimizes transportation costs for humanitarian cargo.

During threats like shelling, having alternative routes ensures supply continuity. Risk analysis helps identify the safest routes. Overall, careful planning, modern vehicles, and route optimization are key to successfully delivering humanitarian aid, especially during military operations.

Bibliography:

1. Публікації – UNHCR Україна. UNHCR Україна. URL: https://www.unhcr.org/ua/publications (дата звернення: 01.10.2024).
2. Самойленко М., Кобець А. Інформаційні технології в розв'язанні транспортних задач : монографія. Харків : ХНАМГ, 2011. 256 с.
3. Тюріна Н. М. Логістика: навч. посіб. Київ : «Центр навчальної літератури», 2015. 392 с.
4. Транспортна задача. навч. посіб. для студ. спеціальності 121 «Інженерія програмного забезпечення», спеціалізації «Програмне забезпечення розподілених систем», «Програмне забезпечення Web-технологій та мобільних пристроїв». КПІ ім. Ігоря Сікорського ; уклад.: О. К. Молодід. Київ : КПІ ім. Ігоря Сікорського, 2018. 37 с.
5. Україна: гуманітарне реагування у 2024 році. Situation Reports. URL: https://reports.unocha.org/uk/country/ukraine (дата звернення: 30.10.2024).
6. Renault Magnum 460.44T : фото, технічні характеристики Автомобілі. ONLINE.UA. URL: https://auto.online.ua/ukr/catalog/artics/renault/magnum/magnum/58732/ (дата звернення: 30.11.2024).
7. Музикін М. І., Попов Г. В., Біляченко М. В. Дослідження аварій з транспортними одиницями з використанням ризико-орієнтованого підходу. *Інформаційно-керуючі системи на залізничному транспорті* : тези стендових доповідей та виступів учасників 34-ї Міжнародної науково-практичної конференції. Харків : УкрДУЗТ, 2021. С. 45–46
8. Бех П. В., Нестеренко Г. І., Стрелко О. Г., Музикін М. І. Управління вантажними перевезеннями в умовах ризиків конкурентного середовища. *Системи та технології*. 2021. № 1 (61). С. 85–97.
9. Музикін М. І., Буряк А. С. Шляхи підвищення ефективності перевезень гуманітарних вантажів автомобільним транспортом. *Економіко-правові та управлінсько-технологічні виміри сьогодення: молодіжний погляд : матеріали Міжнародної науково-практичної конференції* : у 2 т. Т. 2. Дніпро : УМСФ, 2024. С. 440–442.
10. Nesterenko H. I., Muzykin M. I., Bibik S. I., Strelko O.H., Aleksieieva A. O. Analysis of organizing the delivery of humanitarian aid in crisis situations. *Системи та технології*. № 2 (68). 2024. С. 130–139.
11. Помазков М. В. Моделювання інтелектуальних маршрутів перевезення гуманітарних вантажів в умовах воєнного часу. *Подільський вісник: сільське господарство, техніка, економіка*. 2023. № 41 С. 46–53.
12. Гринів Н. Гуманітарна логістика як інструмент трансформації логістичних потоків в умовах воєнного часу. *Економіка та суспільство*. 2023. № 56. URL: https://doi.org/10.32782/2524-0072/2023-56-4 (дата звернення: 01.10.2024).

References:

1. Publications – UNHCR Ukraine. UNHCR Ukraine. (2024). Retrieved from: https://www.unhcr.org/ua/publications (Accessed on 01.10.2024).
2. Samoilenko, M., & Kobets, A. (2011). Information technologies in solving transport problems: monograph. Kharkiv: KhNAUE. 256 p.
3. Tyurina, N. M. (2015). Logistics: teaching guide. Kyiv: Center for Educational Literature. 392 p.
4. Molodid O. K. (2018). Transport task: teaching guide for students of specialty 121 "Software Engineering", specializations "Software of distributed systems", "Software of Web technologies and mobile devices". Kyiv: Igor Sikorsky Kyiv Polytechnic Institute. 37 p.
5. Ukraine: humanitarian response in 2024. Situation Reports. (2024). Retrieved from: https://reports.unocha.org/uk/country/ukraine (Accessed on: 30.10.2024).
6. Renault Magnum 460.44T : photos, technical specifications of Cars. ONLINE.UA. Retrieved from: https://auto.online.ua/ukr/catalog/artics/renault/magnum/magnum/58732/ (Accessed on: 30.11.2024).
7. Muzykin, M. I., Popov, G. V., & Bilyachenko, M. V. (2021). Research of accidents with transport units using a risk-oriented approach. *Information and control systems in railway transport*: *abstracts of poster presentations and speeches of participants of the 34th International Scientific-Practical Conference*. Kharkiv: UkrSURT, pp. 45–46.
8. Bekh, P. V., Nesterenko, H. I., Strelko, O. H., & Muzykin, M. I. (2021). Freight transportation management in conditions of competitive environment risks. *Systems and Technologies*, 1 (61), 85–97.
9. Muzykin, M. I., & Buryak, A. S. (2024). Ways to improve the efficiency of transportation of humanitarian cargo by road. *Economic, legal and managerial and technological dimensions of the present: a youth perspective:* Proceedings of the *International Scientific-Practical Conference*: in 2 volumes. Vol. 2. Dnipro: UMSF, pp. 440–442.
10. Nesterenko, H. I., Muzykin, M. I., Bibik, S. I., Strelko O.H., & Aleksieieva A. O. (2024). Analysis of organizing the delivery of humanitarian aid in crisis situations. *Systems and Technologies*, 2 (68), 130–139.
11. Pomazkov, M. V. (2023). Modeling of intellectual routes for transporting humanitarian cargo in wartime. *Podolskyi visnyk: agriculture, technology, economics*. (41), 46–53.
12. Hryniv, N. (2023). Humanitarian logistics as a tool for transforming logistics flows in wartime conditions. *Economy and Society*, (56). Retrieved from: https://doi.org/10.32782/2524-0072/2023-56-4 (Accessed on: 01.10.2024).

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