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Jarosław ZIÓŁKOWSKI[1]*, Šárka HOŠKOVÁ-MAYEROVÁ[2], Volodymyr HUTSAYLYUK[3], Daniel ŁUKASIAK[4]

OPTIMIZATION OF ROAD TRANSPORT WITHIN THE SUPPLY NETWORK – A CASE STUDY FROM POLAND

Summary. Optimization in the area of road transport is the subject of numerous scientific publications. Its analysis uses programming languages (including linear) and tools enabling not only a detailed analysis of the examined process but also including data dynamics (demand variability) and the availability of resources (means of transport) diversified in terms of permissible total mass (GVW). Such tools are useful because they support decision-making processes. This paper uses the example of a military supply network to present a multi-criteria methodology enabling minimization of total transport costs, number and type (due to load capacity) of vehicles used, distance traveled, fuel used, and CO_2 emissions into the atmosphere. Moreover, additional restrictions on existing transport resources were included, considering the number and type of vehicles available at the base. This is of great importance, especially when there is a need to provide emergency deliveries, for example, in the event of a war threat. The proposed method is universal and was developed using an MS Excel spreadsheet with the Solver add-in.

1. INTRODUCTION

The rational organization of transport is a basic problem in planning transport routes. Transport organization is often interpreted as a transport schedule covering the number and type of cruises and the number and the type of means of transport used. Road transport publications include many scientific articles relating to several areas, such as:

1. Minimization of costs [1-3] and fuel consumption [4, 5];
2. Reduction of delivery time [6, 7];
3. Algorithms [8], methods [9, 10] and process optimization [11, 12]
4. Pollutants released into the natural environment [13-16];
5. Determining transport routes [17, 18];
6. Selection of the type of means of transport constituting the fleet [19];
7. Modeling of road transport [20, 21];
8. Method for Calculating the Required Number of Transport Vehicles Supplying Aviation Fuel to Aircraft during Combat Tasks [22];
9. Technical readiness [23] of aviation refueling vehicles [24];
10. Punctuality [25] and reliability regarding the organization of supplies in the enterprise [26], vehicles [27], including military objects [28, 29], spare parts [30], or systems [31-33].

[1] Military University of Technology; gen. S. Kaliskiego st. 2, 00-908 Warsaw, Poland; e-mail: jaroslaw.ziolkowski@wat.edu.pl; orcid.org/0000-0001-8880-5142
[2] University of Defence, Kounicova 156/65,662-10 Brno, Czech Republic; e-mail: sarka.mayerova@unob.cz; orcid.org/0000-0002-3305-529X
[3] Military University of Technology; gen. S. Kaliskiego st. 2, 00-908 Warsaw, Poland; e-mail: volodymyr.hutsaylyuk@wat.edu.pl; orcid.org/0000-0003-4812-5737
[4] Military University of Technology; gen. S. Kaliskiego st. 2, 00-908 Warsaw, Poland; e-mail: daniellukasiak2@gmail.com; orcid.org/0009-0002-1837-8135
* Corresponding author. e-mail: jaroslaw.ziolkowski@wat.edu.pl

Many authors point to the analysis and assessment of cost-effectiveness as the main criterion. Deep reinforcement learning-driven cost minimization for batch order scheduling in robotic mobile fulfillment systems was proposed in [34]. In the paper [35], the authors examined the cost performance of battery electric trucks and autonomous electric trucks (AETs) compared to internal combustion engine trucks (ICETs); they also examined how it varies over different market and technology conditions, charging strategies, and transport applications. In [36], Klepikov et al. presented a method for analyzing the cost relations in the oil supply chain of an energy project in the Eastern Siberia Pacific Ocean (ESPO) Region. The results obtained using the developed method showed that the total cost of transporting one ton of oil for 100 km using ESPO pipelines is six to eight times greater than the cost for similar maritime shipping. In [37], the authors formulated a two-echelon vehicle routing problem with collaboration points (2E-VRP-CP) where the exchange of goods happens between second-echelon vehicles belonging to different logistics service providers. The method uses a mixed-integer linear programming model (MILP) that minimizes the total distribution cost and has been tested on randomly generated instances.

In [12], Liu et al. introduced a heterogeneous fixed fleet vehicle routing problem (HFFVRP) for PC components, where heterogeneous vehicles, allocation of PC components to size-matching vehicles, and hybrid time windows were considered based on three characteristics. In [38], the authors developed an optimization model to analyze the cost-efficient operation of urban air mobility systems. Strategic decisions on vehicle concepts, battery capacity, and charging infrastructure were incorporated and evaluated using a total cost of ownership approach. A measurable feature of the efficiency of vehicle use in transportation companies is the revenue from transport orders, which significantly impacts their profitability. Therefore, it is important to analyze the parameters related to the operation of vehicles and their impact on the bottom line. In [39], Grzelak et al. investigated the economic efficiency of vehicle operation in terms of the financial security of enterprises.

Overall, the literature shows that many scientific publications have focused on various aspects of improvement in road transport. The above review shows that existing scientific articles did not address issues related to military transport networks, which have specific distribution/supplies and means of transport limited in quantity and quality, representing naturally exhaustible resources. This is especially important during an armed conflict, such as the ongoing aggression of the Russian Federation against Ukraine, in which the losses incurred cannot be compensated by a short-term and effective production process. It is advisable to rationally manage both human resources and the technology used in military transport.

With this in mind, the authors of this paper have presented real problems related to the supply process based on the existing military transport network and indicated possibilities for its improvement in the developed model. The work considers several natural components of the process, such as orders from customers (warehouses) and available transport potential, which is understood as the number and type of vehicles (with different load capacities) equipped at the base. The number and type of necessary means of transport were assessed, as were various costs, including those related to the total distance covered, fuel consumption, and CO_2 emissions generated into the atmosphere. The authors' contribution is the proposed calculation method, and the tool is an MS Excel spreadsheet with the Solver add-in. The method is universal and can be applied to any type of vehicle (i.e., with different unit transport costs and load capacity).

2. DESCRIPTION OF THE PROBLEM AND METHODOLOGY

In peacetime, military supply networks deliver in accordance with the territorial supply system. This means that transportations between network nodes take place from one location (i.e., the logistics base), a kind of distribution center for the network of recipients, which is represented by warehouses located in its area of responsibility. The organization of deliveries is consistent with the assumptions described below:

1) customers report demand for goods that varies over time, measured by the weight of the goods expressed in tons;
2) the distances between the logistics base and the network of recipients (warehouses) are known;

3) the vehicle can deliver goods to each recipient exactly once during one trip;
4) the balance of demand and supply in the network is balanced;
5) to carry out deliveries, the base uses a rolling stock of different numbers and transport capabilities, which is represented by three types of road transport means with different load capacities.

A graphical interpretation of the above-described problem is shown in Fig. 1.

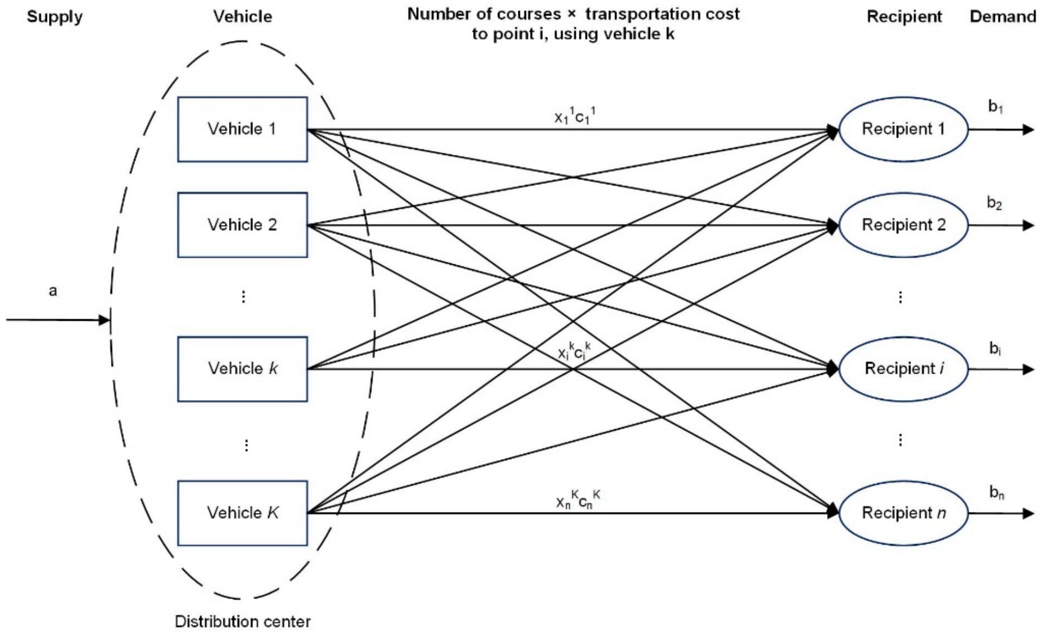

Fig. 1. Graphical illustration of the decision-making problem

Within the military network, supply is carried out from one central point to eleven locations, and customers $r_i; i \in \{1, \ldots, 11\}$ report specific amounts of demand $b_i[t]$ to the military base S during the research period of one calendar year. These values are expressed in tons of cargo for which means of transport with a total tonnage greater than or equal to that expressed as the permissible total weight (GVW) of the vehicle must be secured. In the next step, the total demand should be converted into the number of cruises carried out by a given means of transport with a specific capacity. Three types of vehicles with different GVMs are used to conduct transport within the military supply network. They represent three groups, namely delivery vehicles (up to 3.5 tons), low-tonnage vehicles (up to 7.5 tons), and high-tonnage vehicles (over 12 tons).

The formal, legal, and economic basis for calculating the costs of transporting a specific type of means of transport is *Order No. 89 of the Head of the Inspectorate of Armed Forces Support of March 31, 2022 on updating unit operating cost indicators of selected equipment of the tank and car service* [16]. It is used to value services provided using equipment from the tank-car service. It contains a list of unit operating cost indicators for selected groups of military equipment (ME). For each unit of equipment distinguished in the order mentioned above, unit cost indicators are calculated, such as depreciation, maintenance, petrol, oil and lubricants (POL), and a collective indicator calculated as a unit indicator of the operating costs of a given means of transport. In addition, an efficiency index is calculated for each type of hardware unit, which is defined as the load capacity quotient [t] and the unit operating cost index $[\frac{PLN}{km}]$. Table 1 lists the basic data regarding the indicators of the means of transport available at the military base.

Table 2 lists the actual transport distances $d_i[km]$ between the nodes of the network under consideration and the demand volume $b_i[t]$ reported by individual warehouses.

A matrix containing the amounts of transport costs c_i^k to each warehouse using three types of vehicles available in the military base was determined based on unit cost indicators (Table 1) and the distances between the distribution center and individual warehouses (Table 2). These values were obtained as the product of a single indicator and twice the distance, considering the return to the base. They were used to create a matrix determining the unit cost of transport to the *i*-th depot with the *k*-means of transport (Table 3).

Table 1

Unit cost indicators for base military vehicles

Vehicle type K_k	1	2	3
Vehicle name	Iveco Stralis AT260 S35YP	Star 266 M2	Volkwagen Crafter 2.0 TDi
Number of vehicles available [pcs.]	15	65	50
Vehicle load capacity q^k [kg]	18,800	5000	1300
Unit indicator POL costs c^k_{POL} $[\frac{PLN}{km}]$	8.25	2.37	1.03
Unit indicator operating costs $c^k_{ekspl}[\frac{PLN}{km}]$	18.81	8.61	3.91
Efficiency index $[\frac{t \cdot km}{PLN}]$	1.00	0.58	0.33

Table 2

List of actual distances d_i[km] between supply network nodes and the volume of demand b_i[t] from individual warehouses in a calendar year

Warehouse no. *i*	The distance between the distribution center and the warehouse d_i[km]	Demand reported from individual warehouses b_i[t]
1	92	12
2	53	47
3	155	6
4	77	45
5	206	115
6	188	63
7	192	59
8	291	64
9	222	50
10	251	130
11	32	3
Total demand		594

In the next stage, the above-defined dataset is used to start writing a mathematical model with the following objective function (*OF*) and constraints:

$$OF = f\left(x_1^1, \dots x_i^k, \dots x_{11}^3\right) = \sum_{i,k} x_i^k c_i^k \rightarrow min, \tag{1}$$

where: $k \epsilon \{1, \dots, 3\} \wedge i \epsilon \{1, \dots, 11\}$

$$OF = \sum_{i=0}^{11} \sum_{k=1}^{3} x_i^k c_i^k \rightarrow min \tag{2}$$

$$\sum_{k=1}^{3} x_i^k q^k \geq b_i \quad i \epsilon \{1, \dots, 11\} \tag{3}$$

$$\sum_{i=1}^{11} x_i^k \leq K_k \quad k \epsilon \{1, \dots, 3\} \tag{4}$$

$$x_i^k \geq 0 \tag{5}$$

$$x_i^k \in C \tag{6}$$

where:

x_i^k – a decision variable denoting the number of deliveries to the *i*-th warehouse, carried out using the *k*-th means of transport;

c_i^k – unit cost of transport to the i-th warehouse, carried out using the k-th means of transport [PLN];
q^k – load capacity of the k-th means of transport [t];
b_i – demand reported by the i-th warehouse [t];
K_k – available number of k-type vehicles, whereby: $k \in \{1, \dots, 3\}$;
i – number of warehouses, whereby: $i \in \{1, \dots, 11\}$.

Table 3

Matrix of unit transport costs in the base-warehouse relationship

Unit transportation cost c_i^k [PLN]			
Warehouse no. i	Vehicle no. k		
	1	2	3
1	3461	1584	719
2	1994	913	414
3	5831	2669	1212
4	2897	1326	602
5	7750	3547	1611
6	7073	3237	1470
7	7223	3306	1501
8	10,947	5011	2276
9	8352	3823	1736
10	9443	4322	1963
11	1204	551	250

In the model formulated above, the number of decision variables is equal to the product $(i \cdot K_k) = 11 \cdot 3 = 33$, and the objective function expressed in Equation (1) constitutes the total cost of executing the transport task. This function is minimized, allowing for the identification of the optimal solution. It is expressed as the sum of the products of the number of trips and unit costs for the i-th warehouse carried out using the k-th means of transport. Inequalities (3) and (4) reflect limiting conditions. Condition (3) ensures that transport with a total capacity that is not less than the requested demand will be sent to each warehouse, and the number of recorded conditions will be equal to the number of warehouses (i). In turn, Inequality (3) indicates that the total number of k-type vehicles will not exceed the number of objects available in the database (resource limitation). The number of saved conditions (3) corresponds to the number of vehicle types (K_k) available in the military base. From a mathematical point of view, Inequality (3) is the lower limit, while Inequality (4) is the upper limit in the set of possible solutions. Dependencies (5) and (6), in turn, reflect non-negativity and an integer number of decision variables. A graphical interpretation of the optimization problem described above is shown in Fig. 2.

According to Fig. 2, the set of empirical data consists of the number of warehouses $i \in \{1, \dots, 11\}$; the demand values $b_i[t]$ of each warehouse; vehicle load capacity $q^k[t]$; and the unit transportation costs c_i^k to the i-th warehouse, calculated for the k-th means of transport and the number of transport means of a given type K_k: $k \in \{1, \dots, 3\}$ (i.e., with different GVW) included in the base.

3. A CASE STUDY FROM POLAND – RESULTS

The mathematical model written above and the data listed in Tables 1–3 were used to develop an appropriate tool containing computational algorithms for the analyzed decision-making problem in an MS Excel spreadsheet. From the task conditions, it is known that the total load capacity of vehicles sent to a given depot must be greater than or equal to the total demand reported by a given depot. Additionally, the number of vehicles of a given type used for transport cannot be greater than the number of means of transport available at the base (Table 1). The components of unit transport costs listed in Table 3 were the basis for calculating the total transport costs. The objective function was defined as the sum of the products of the number of cruises and the unit costs of transport by means of transport with a specific capacity in a given route. The next step was to define the key components of the optimization process in *Solver*. According to these definitions, an objective function aimed at minimization was set. Then, cells representing decision variables were marked, and limiting conditions were introduced. With lower restriction accuracy, the program selected variables that did not meet the integer condition or did not meet the limiting conditions at all. In the example discussed, the time needed to find the optimal solution ranged from several dozen minutes to several hours. The calculations yielded the transport schedule (Table 4, Variant 1) and showed that the minimum value of the objective function was 314387.7 [PLN]. This value was interpreted as the minimum total cost of transport performed in a given network.

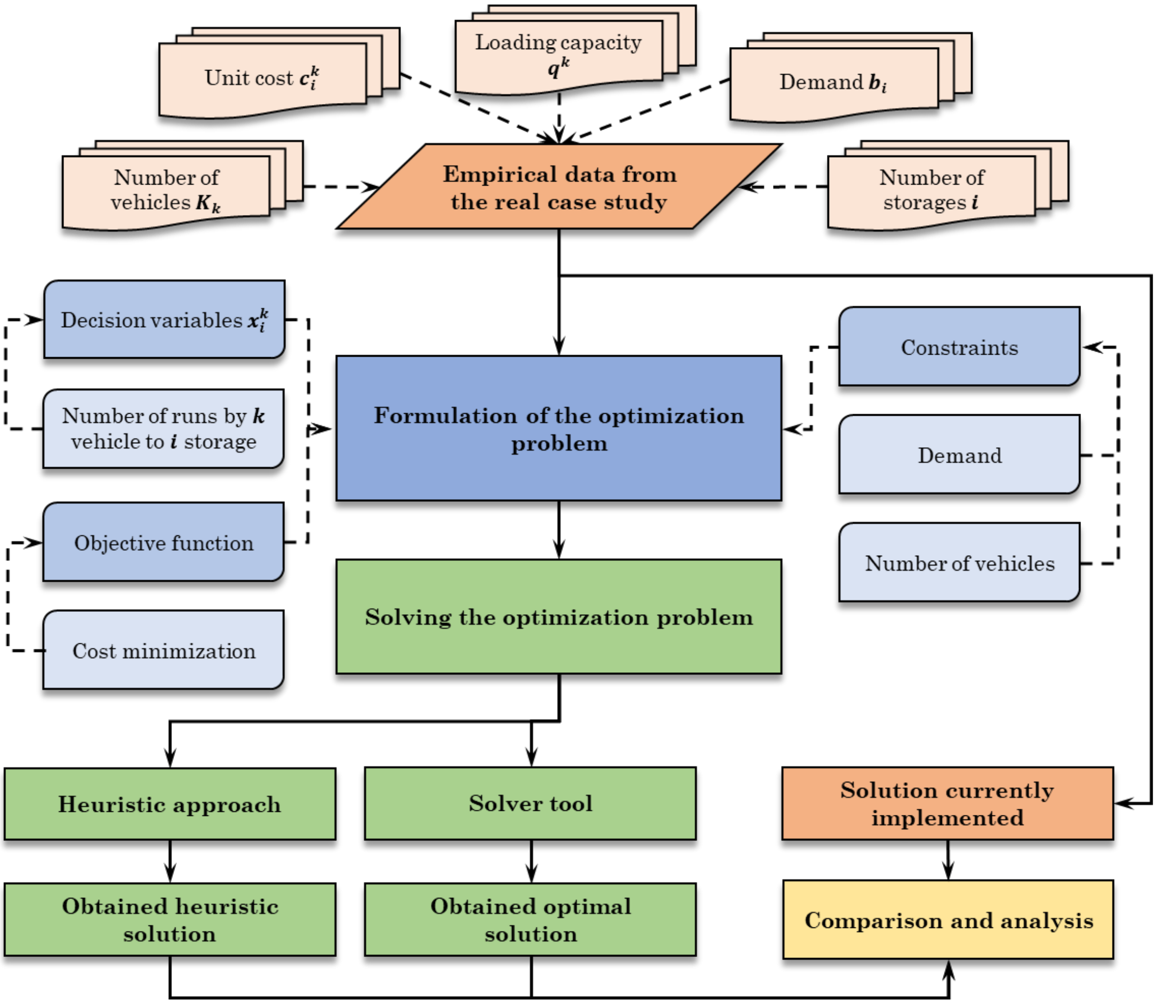

Fig. 2. Algorithm for the optimization problem in the supply network

An additional attempt was made to arbitrarily "manually" solve the task. According to this method, vehicles with the highest efficiency index were assigned to depots more distant from the base, and means of transport with lower efficiency values were assigned to those closer to the base. An additional criterion was the use of as much cargo space as possible in a given vehicle. After conducting the analysis, we obtained an acceptable solution (Table 5, Variant 2) with an objective function of PLN 317,215.

Calculations aimed at maximizing the objective function were carried out to conduct a comparative analysis to examine the cost range of the analyzed decision-making problem. We obtained the most expensive possible variant, for which the total transport cost amounted to PLN 454,667 and required the involvement of a total of 130 vehicles. Based on the documentation, including the list of transports actually carried out in the analyzed supply network (empirical data based on the database documentation, Variant 4), the total (actual) transport cost was calculated, which was PLN 411,763. A comparative analysis of the four transport variants described above has been graphically presented in Fig. 3.

Concerning the results presented in Fig. 3 above, it should be stated that there is a significant difference (PLN 137,269) between the worst and the best solutions. The actual transport plan carried out within the military supply network was an expensive solution, as it was as much as 31% more expensive than the optimal one and only 9% cheaper than the financially worst variant. Moreover, we compare the solutions obtained with the time and amount of work needed to achieve them (Fig. 4).

Calculations carried out using software, lasting up to about 8 hr[5], allowing for significant improvement in the organization of transport and leading to the minimization of total costs in the area of transport. An additional aspect of this work is the burden on the natural environment. With sustainable development (transport) in mind, it is important to compare the total distance, fuel consumption, and CO_2 emissions into the atmosphere for each solution (Fig. 5).

Table 4

Optimal solution obtained using the *Solver* add-in (objective function minimization), Variant 1

Warehouse no. i	Demand values b_i [t]	Number of vehicles k	Vehicle type			Totally
			1	2	3	
		Name of vehicle	Iveco Stralis AT260 S35YP	Star 266 M2	Crafter 2.0 TDi	
		Vehicle load capacity q^k [t]	18.80	5.00	1.30	
		Number of vehicles available K_k [pcs]	15	65	50	
1	12	Number of deliveries	0	2	2	4
		Total load capacity [t]	0	10	2.6	12.6
		Cost [PLN]	0.0	3168.5	1438.9	4607.4
2	47	Number of deliveries	0	9	2	11
		Total load capacity [t]	0	45	2.6	47.6
		Cost [PLN]	0.0	8213.9	828.9	9042.9
3	6	Number of deliveries	0	1	1	2
		Total load capacity [t]	0	5	1.3	6.3
		Cost [PLN]	0.0	2669.1	1212.1	3881.2
4	45	Number of deliveries	0	9	0	9
		Total load capacity [t]	0	45	0	45
		Cost [PLN]	0.0	11,933.5	0.0	11,933.5
5	115	Number of deliveries	1	19	1	21
		Total load capacity [t]	18.8	95	1.3	115.1
		Cost [PLN]	7749.7	67,399.1	1610.9	76,759.7
6	63	Number of deliveries	1	9	0	10
		Total load capacity [t]	18.8	45	0	63.8
		Cost [PLN]	7072.6	29,136.2	0,0	36,208.8
7	59	Number of deliveries	3	0	2	5
		Total load capacity [t]	56.4	0	2,6	59
		Cost [PLN]	21,669.1	0.0	3002.9	24,672.0
8	64	Number of deliveries	3	1	2	6

[5] Calculations were made with medium-class computer: Intel(R) Core(TM) i7-8750H CPU @ 2.20GHz, 16 GB RAM, Windows 10

		Total load capacity [t]	56.4	5	2,6	64
		Cost [PLN]	32,842.3	5011.0	4551.2	42,404.5
9	50	Number of deliveries	0	10	0	10
		Total load capacity [t]	0	50	0	50
		Cost [PLN]	0.0	38,228.4	0,0	38,228.4
10	130	Number of deliveries	7	0	0	7
		Total load capacity [t]	131.6	0	0	131,6
		Cost [PLN]	66,098.3	0.0	0,0	66,098.3
11	3	Number of deliveries	0	1	0	1
		Total load capacity [t]	0	5	0	5
		Cost [PLN]	0.0	551.0	0,0	551,0
Required number of vehicles of a given type			15	61	10	86
Total Costs [PLN]						314387.7

Table 5

Minimum solution obtained arbitrarily ("manually") oriented towards minimizing the objective function, Variant 2

Warehouse no. i	Demand values b_i [t]	Number of vehicles k	Vehicle type			Totally
			1	2	3	
		Name of vehicle	Iveco Stralis AT260 S35YP	Star 266 M2	Crafter 2.0 TDi	
		Vehicle load capacity q^k [t]	18.80	5,00	1,30	
		Number of vehicles available K_k [pcs]	15	65	50	
1	12	Number of deliveries	0	2	2	4
		Total load capacity [t]	0	10	2.6	12.6
		Cost [PLN]	0.0	3168.5	1438.9	4607.4
2	47	Number of deliveries	0	9	2	11
		Total load capacity [t]	0	45	2.6	47.6
		Cost [PLN]	0.0	8213.9	828.9	9042.9
3	6	Number of deliveries	0	1	1	2
		Total load capacity [t]	0	5	1.3	6.3
		Cost [PLN]	0.0	2669.1	1212.1	3881.2
4	45	Number of deliveries	0	9	0	9
		Total load capacity [t]	0	45	0	45
		Cost [PLN]	0.0	11,933.5	0.0	11,933.5
5	115	Number of deliveries	2	15	2	19
		Total load capacity [t]	37.6	75	2.6	115.2
		Cost [PLN]	15,499.4	53,209.8	3221.8	71,931.1
6	63	Number of deliveries	0	13	0	13
		Total load capacity [t]	0	65	0	65
		Cost [PLN]	0.0	42,085.7	0.0	42,085.7
7	59	Number of deliveries	0	12	0	12
		Total load capacity [t]	0	60	0	60
		Cost [PLN]	0.0	39,674.9	0.0	39,674.9
8	64	Number of deliveries	3	1	2	6
		Total load capacity [t]	56.4	5	2.6	64

		Cost [PLN]	32,842.3	5011.0	4551.2	42,404.5
9	50	Number of deliveries	3	0	0	3
		Total load capacity [t]	56.4	0	0	56.4
		Cost [PLN]	25,054.9	0.0	0.0	25054.9
10	130	Number of deliveries	7	0	0	7
		Total load capacity [t]	131.6	0	0	131.6
		Cost [PLN]	66,098.3	0.0	0.0	66,098.3
11	3	Number of deliveries	0	0	2	2
		Total load capacity [t]	0	0	2.6	2.6
		Cost [PLN]	0.0	0.0	500.5	500.5
Required number of vehicles of a given type			15	62	11	88
Total Costs [PLN]						317,215

Fig. 5 shows that finding the optimal solution is vital from the point of view of environmental protection. The optimal variant determined using the Solver module compared to the actual plan reduces CO_2 emissions by as much as 32%. This is a significant difference, which is why the presented methodology can contribute to the effective implementation of sustainable development policy, which has recently become an important direction of economic development.

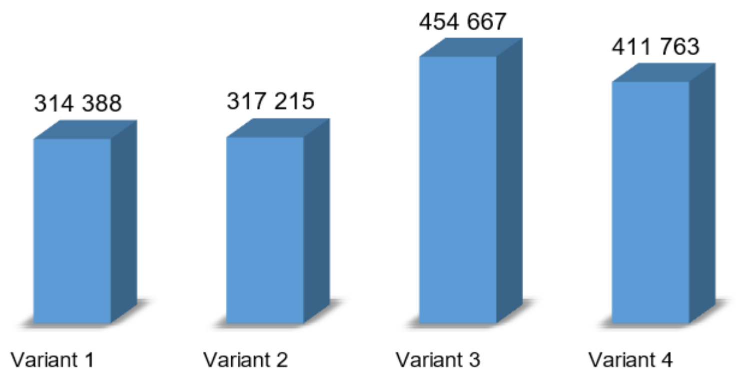

Fig. 3. Comparison of total costs for the analyzed transport variants [PLN]

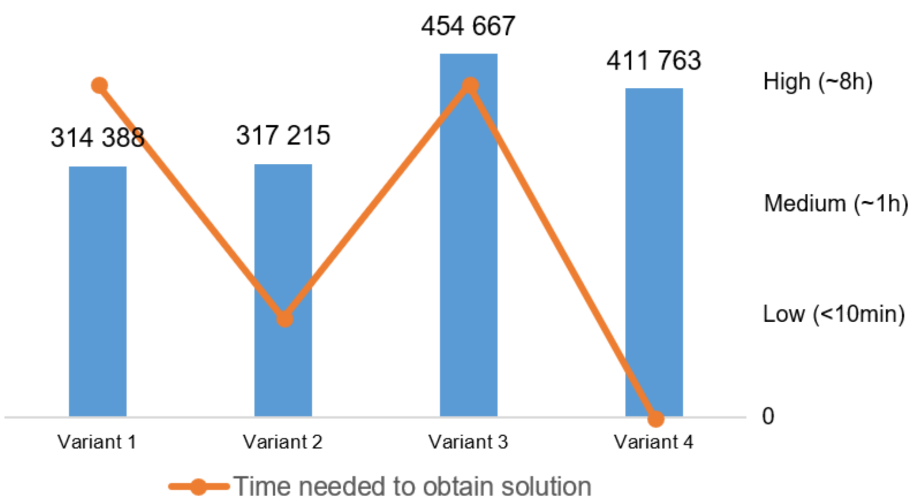

Fig. 4. Comparison of the analyzed transport variants [PLN] along with the time necessary to obtain a solution

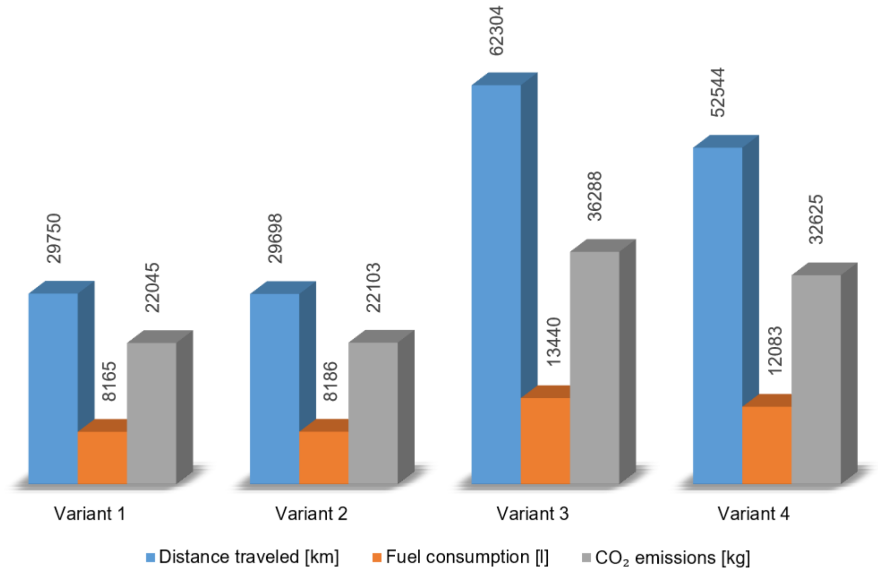

Fig. 5. Comparison of the obtained solutions in terms of total distance, fuel consumption, and CO_2 emissions into the atmosphere

4. CONCLUSIONS

The present work presented four different variants of transport carried out within a real military supply network. The basic parameters used for their assessment were total transport costs, the number of means of transport of each type necessary to make deliveries, the total distance traveled, fuel consumption, and CO_2 emissions into the atmosphere. Table 6 summarizes the results obtained for these five criteria for each variant.

Table 6

Summary of the results

	Variant 1	Variant 2	Variant 3	Variant 4
Total costs [PLN]	314,387.7	317,215	454,667	411,763
Number of transport means *k* 1/2/3/totally	15/61/10/86	15/62/11/88	15/65/50/130	15/64/49/128
Distance traveled [km]	29,750	29,698	62,304	52,544
Fuel consumption [l]	8165	8186	13,440	12,083
CO_2 emissions [kg]	22,045	22,103	36,288	32,625

The results in Table 6 should be considered in many aspects, namely:

a) economic terms, including the total distance, fuel consumption, and total (total) transportation costs,
b) the organizational and technical area (both in peacetime and during armed conflict), interpreted as the number and type of means of transport engaged in transport;
c) environmental aspects consistent with the 2030 Sustainable Development Strategy [40], including CO_2 emissions into the atmosphere.

In the military transport network analyzed in this work, the optimal solution focused on minimizing the number of means of transport, fuel consumption, and the total transport cost. The best solution in almost all the above-mentioned aspects is Variant 1, for which the lowest total transport cost of PLN 314,387.7 was obtained. An additional advantage of the above-mentioned solution is that it involves the fewest means of transportation, with 86 (Table 6). The minimal number of means of transport involved in transport compared to other variants is of particular importance both in peacetime and during war. In peacetime, it increases the security of supplies due to the greater surplus of equipment available. Meanwhile, in crises or wartime situations, it creates additional potential to increase transport capacity. The percentage of the fleet involved in transportation tasks for the particular solutions is slightly different for Variants 1 and 2 and somewhat different when compared to Variants 3 and 4. In the optimal result (Variant 1), it was 66%. For Variant 2, it was slightly more (68.5% of the means of transport involved). For Variants 3 and 4, the percentage shares of the fleet involved were 100% and 98.5%, respectively.

In the case of transport performed by a vehicle of the same type, the distance covered, fuel consumption, and CO_2 emissions into the atmosphere are positively correlated. This means that increasing the distance traveled also increases fuel consumption and CO_2 emissions into the atmosphere. Fuel consumption and CO_2 emissions into the atmosphere for Variant 1 were also the lowest. Only the total distance traveled was not minimal, as it amounted to 29,750 [km], which was 52 km more than Variant 2, calculated “manually” and using common sense. The reason for the higher total fuel consumption and CO_2 emissions for Variant 2 (in relation to Variant 1) was the use of two additional means of transport (one type 2 vehicle and one type 3 vehicle; Table 6).

Variant 4, based on documentation, had the second worst results compared to the optimal solution. It required the use of 128 vehicles, which created an unnecessary loss from using as many as 42 additional means of transport (i.e., 49% more). This is particularly important from economic, organizational, and technical points of view. Additionally, during a crisis or war, one must consider additional (often accidental) demand for which there may simply be insufficient funds (vehicles). The total distance traveled was also unfavorable, amounting to as much as 52,544 [km], which was almost 77% more than Variant 1. Moreover, in terms of fuel consumption and CO_2 emissions into the atmosphere, Variant 4 caused mismanagement and environmental damage of almost 50% (an increase of almost 48% in both cases). Considering the least effective scenario (Variant 3) and comparing it to the optimal solution (Variant 1) in economic terms reveals that the total transport costs were almost 31% higher and required the use of an additional 44 means of transport (i.e., 34% more). Moreover, the total distance covered was as much as 32,554 km longer (i.e., more than twice as long as Variant 1). Interestingly, the total distance traveled was not positively correlated with fuel consumption and CO_2 emissions into the atmosphere, which for Variant 3 was 164% in both cases. This is due to the total number of means of transport involved (86 vehicles for Variant 1 and as many as 130 vehicles for Variant 3) and, primarily, the type of vehicles used for transport within the network. The data presented in Table 6 show that the largest difference occurred for vehicle no. 3, which required the involvement of only 10 Crafter 2.0 TDi vehicles (Table 4) for Variant 1 and as many as all 50 Crafter 2.0 TDi vehicles (Table 6) for Variant 3. The disproportion of as many as 40 Crafter 2.0 TDi vehicles was crucial in the analyzed case and affected both fuel consumption and CO_2 emissions into the atmosphere.

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