DE GRUYTER OPEN

DETERMINATION OF AN OPTIMAL PLAN FOR SUPPLYING AN INFANTRY BATTALION IN COMBAT CONDITIONS

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Abstract: The modern battle field is characterized by an increasing number of indispensable information in decision making process, and as a consequence the increasing importance of software components in weapons systems. Under current conditions the commander can not only rely on experience and intuition, so it needs an information-based analytical thinking and reasoning. In this context, the operational research, with its methods and models, represents the scientific basis on which a rational and optimal decision is supported, by involving a minimal risk. This paper presents the optimization of military action, showing how to solve a practical problem using the transportation problem. The paper combines mathematical methods for solving the problem of transport with the requirements imposed by the tactical situations parameters encountered in the course of military operations by exemplifying a complex military operation.

Keywords: optimization, transport, infantry battalion.

1. Introduction

Emerged of military necessity, the operational research, is dealing essentially with the optimization of the decisions by using mathematical modelling and data supplied by a generic action called operation.

The transport problem finds its application in situations where the upper echelons must draw up an optimal plan of resources allocation for means of fighting on objectives. In order to achieve more reliable results for the real problem, the data needed to formulate the mathematical model are extracted from an order of operations.

2. Overall tactical situation. The problem formulation

A motorized infantry battalion of Polish Army equipped with AMV Rosomak is running defensive on national territory. HQ predicts that the action will stretch over a period of 3 days in heavy fighting conditions. The battalion logistics structure must draw up a plan to ensure efficient logistical support to combat. This support is to ensure the 3 fighting companies with ammunition, fuel, water and food. The logistics company's goal is to deliver all of the materials from the supply point at battalion level towards the companies supply points from where the subunits will be later delivered depending on the demand.

In preparing this plan the difficult conditions of combat, the difficulty of accessing the roads necessary for materials transportation, the available technique used for transportation, the climate, and of course the expected loss will be taking into consideration. Of course, the main objective is to achieve minimum costs. A battalion is organized according to Table 1.

Logistics Company include: command crew vehicle, a supply platoon and a maintenance platoon. In this situation, according to Table 1, the supply platoon has at its disposal 21 trucks of 3.5 (t) capacity, 3

water tanks of 3000 (l) and 3 fuel tanks of 4500 (l). The supplies transportation is made on three routes D1, D2 and D3.

3. Centralizing data. Solving the problem

The quantities of supplies needed for each category (ammunition, fuel, food and water) will be calculated.

Calculation of ammunition will be carried out using the data in Table 1 on the battalion organization.

It will therefore deduct the formula: F(kg)·N=UC(kg) where UF- Fire weight of each category of weapons in hand, N- the number of copies from the same category and UC- Fire weight for all the weapons in the same category. By doing so, the results from Table 2 will be obtained.

Table 1: *Organization of a* motorized infantry battalion / AMV - Rosomak

Specifications	Team Recc(UAV)	Staff	Team fighters x 4	Suport comp	Logistic	Med	TOTAL
Personnel	**4**	**66**	**130**	**100**	**78**	**16**	**784**
Weapons							
9 MM gun PW	4	18	20	26	15	8	151
9 MM gun PM		10	39	12	2	8	188
5,56 MM asalt wpn. kbk Beryl	4	52	82	72	76		532
P.S.L7,62 MM kbk AK SWD				12			12
7,62 MM Machinegun PK			3				12
7,62 MM Machinegun PKS		4	6	2			30
RPG- 76		5	12	2			55
Technical and equipment							
Transport Carrier AMV		1	13	3			56
TAB BRDM		3					3
Motorcycle		1					1
Convertible with 4 wheel drive		2					2
Tactical radar		1					1
Launcher PPK SPIKE				6			6
Mortier 98 MM				6			6
Telemeter with laser		1		2			3
Command vehicle	1	2		1	1		5
Radiotelephone UKF	1	3		14	6	4	28
Radiostation UKF kp		10	20	13	2		105
Tractor CKE					1		1
Large transport vehicle		8	2	6	21		43
Small transport vehicle					1		1
Water tank 3000 l					3		3
Fuel tank					3		3
Ambulance			1			3	7
Electricity generator		1			2		3
Total equipments	**2**	**33**	**36**	**51**	**40**	**7**	**211**

Table 2: Calculation of ammo rations and quantity

Weapons category	Battalion AMV Rosomak		
	Quantity	Mass UC /kg	Transport coefficient
9 MM gun PW	**173**	8,30	0,02
9 MM gun PM	**188**	67,68	0,14
5,56 MM asalt wpn. kbk Beryl	**554**	531,84	1,06
P.S.L7,62 MM kbk AK SWD	**12**	7,20	0,01
7,62 MM Machinegun PK	**12**	65,52	0,13
7,62 MM Machinegun PKS	**30**	326,70	0,65
RPG- 76	**80**	80,00	0,08
Total ammo/weapons		**1018,76**	**2,04**
TAB BRDM	**3**	108,00	0,11
	3	36,00	0,04
AMV Rosomak carrier	**56**	896,00	0,90
Total ammo for carriers		**1040,00**	**1,04**

Table 3: The fuel daily ration for each category of military equipment

Vehicle type/Equip.	Measure RZ	RZ		Capacity		No. of RZ
		/dm³/	/kg/	/dm³/	/kg/	
Wheeled Vehicles						
TAB BRDM	[dm³/100km]	39,0	29,3	290,0	217,5	**7,4**
Convertible vehicle Honda	[dm³/100km]	10,0	7,5	17,0	12,8	**1,7**
Motorcycle ETZ	[dm³/100km]	3,0	2,3	12,5	9,4	**4,2**
Large transport vehicle Star-660	[dm³/100km]	40,0	30,0	300,0	225,0	**7,5**
AMV Rosomak carrier	[dm³/100km]	87,0	74,0	304,0	258,4	**3,5**
Tractor	[dm³/12mtg]	9,5	8,1	50,0	42,5	**5,3**
Medium vehicle Kraz	[dm³/100km]	55,0	46,8	330,0	280,5	**6,0**
Small vehicle Landrover	[dm³/100km]	13,0	11,1	170,0	144,5	**13,1**
Command vehicle Mercedes B-1300	[dm³/100km]	25,0	21,3	160,0	136,0	**6,4**
Ambulance AMV Rosomak	[dm³/100km]	87,0	74,0	304,0	258,4	**3,5**
Water tank Sam. Star-200	[dm³/100km]	21,0	17,9	150,0	127,5	**7,1**
Fuel tank Sam. Star-266 CT	[dm³/100km]	31,0	26,4	300,0	255,0	**9,7**

Table 4: Table with the known average for the coefficients

Coefficient category	Coefficient value
Military operations type /$C_{op.}$	
Offense	**2,5**
Defence	**2,0**
Movement	**1,5**
Action to slow the enemy	**1,0**
Land type /$C_{t/}$	
Plain	**1,0**
Hill	**1,2**
Mountain	**1,5**
Climate type /$C_{c/}$	
Tropical	**0,9**
Temperate	**1,0**
Winter	**1,3**

If we add the total UC all that we have achieved is 1018.76 (kg) ammunition for individual weapons and 1040 (kg) ammunition for fighting machines and conveyors, so a total of 2058.76 (kg). On the last column in Table 2 are the transport coefficients expressing the volumetric characteristics of ammunition crates to be loaded on trucks. By collecting all coefficients we reach a unique coefficient for ammunition, in this case 3.08. This factor is multiplied by the total quantity of ammunition and results in a final weight of 6350 (kg) for a day of battle. Multiplying by 3 we reach a weight of 19050 (kg) ammunition to be transported.

Calculation of the quantity fuel is performed using the information in Table 3 which contains the daily rations for each type of used technique. The RZ formula will be used, RZ (kg)·N=RZC , where RZ-weight of the daily fuel ration for each technical element, N-number of items in the same category RZC the total amount of - allocated items in a category. For the four fighter companies we have 13 4 = 52 AMV Rosomak, 2 4 = 8 trucks and 4 ambulances. So we calculate for each category: 74(kg)·52=3848(kg),46,8(kg)·8=374,4 (kg) and 74(kg)·8=592 (kg). By summing these

values we obtain a weight of 4814 kg. In the forecasting process regarding the fuel consumption we will take into account the following external factors:

- The coefficient for the type of military operation;
- The coefficient for the type of land;
- Climate coefficient.

These factors have known standard values; thereby we choose from the table (Table 4) those values for the type of military operation undertaken, the type of terrain and specific climatic factor. Thus follows: 4814,4 (kg)·2·1,5·1= 14443,2 (kg) for a day of fighting that total 43 330 (kg) for 3 days.

For the calculation of the amount of food: a military consumes 3 meals daily (3x0,33 Kg) which weigh about one kilogram. In this situation the chosen solution is the use of food packages prepared in advance which will be transported and distributed. The result is obtained simply by multiplying the number of troops from a company with number of companies and the weight of the 3 daily meals: 130·4·1 (kg) =520 (kg) for 1 day respectively 1 560 (kg) for 3 days.

The minimum amount of water required is 3l,so he calculation of the amount of water required is130·4·3 (kg)=1560 (kg) for 1 day, respectively 4680 (kg) for 3 days.

Given the quantities of supplies we can calculate the total weight to be transported towards the 3 supply points: 19050(kg) ammo+43330 (kg) fuel+1560 (kg) food+4680 (kg) water =68620 (kg) supplies.

The designated routes for transport are the following:: D1-road in mountainous terrain, inaccessible, distance 20 (km); D2-road in mountainous terrain of medium difficulty, distance 17 (km); D3-accessible road in hilly area , distance 21 (km). We have the 4 sources (M-ammunition, fuel-C, H-A-food and water) wherefrom shipments to the 3 recipients will be made (KPZ-points for supply for companies).

Knowing all that data: UC-unit consumption expressed in l needed to lead one element of military equipment on a distance of 100 km (is specific to each category of vehicle); Cop - The coefficient for the type of military operation; Ct - The coefficient for the type of land; CC-coefficient climate; CCC - Fuel consumed, the calculation of fuel / 100 km for each category of military equipment will be done using the following formula:

$$UC (l) \times C_{op} \times C_t \times C_c = CCC (l) \quad (1)$$

Knowing that the unit price of diesel is 5 zloty / liter and ammunition is transported by truck route D1, the transportation costs are calculated as follows:

CCC(l)·(2D1/100(km))·5(zl)=55·2·1 ,5·1·(2·20/100)·5=165·0,4·5=330 (zl). For the D2 route we have CCC(l)·(2D2/100) (km))·5(zl)=55·2·1,5·1·(2·17/100)·5=165·0,34·5= 280 (zl). We proceed the same for D3, by mentioning that the coefficient for the road conditions change: CCC(l)·(2D3/100) (km))·5(zl)=55·2·1,2·1·(2·21/100)·5=132·0,42·5=277 (zl).

By using the same method for sources C,H and A , we obtain the following costs, ordered in Table 5.

Table 5: Table with the known average for the coefficients

SOURCES/DEST.	KPZ31	KPZ32	KPZ33	STOCK (T)
M	330	280	277	**19**
C	186	158	156	**43**
H	330	280	277	**2**
A	126	107	106	**5**
NEEDED (T)	**23**	**23**	**23**	**69 (T)**

To the same table we added a column that contains quantities of supplies in each source. The objective being to distribute the entire amount of supplies to recipients equally, the last line was completed with the incumbent amount for each recipient in part as follows: 68620 (kg)/3=≈69 (t)/3=23 (t). By having this data we can consider this case to be transposed from the practical case offered by the battalion ordinary logistic process.

Due to the fact that the minimum cost for transport is desired and the minimal operative time used we appeal to the minimum line method in order to find the initial basis solution:

Table 6: Table with initial solution and intermediate computations

SOURCES/DEST.	KPZ31	KPZ32	KPZ33	STOCK (T)
M	330	280	<u>277</u>/**19**	~~19~~ 0
C	<u>186</u>/**16**	<u>158</u>/**23**	<u>156</u>/**4**	~~43~~ ~~39~~ ~~16~~ 0
H	<u>330</u>/**2**	280	277	~~2~~ 0
A	<u>126</u>/**5**	107	106	~~5~~ 0
NEEDED(T)	~~23~~ ~~7~~ ~~5~~ 0	~~23~~ 0	~~23~~ ~~4~~ ~~2~~ 0	69 (T)

630=13

By applying the minimum line method we reached the following initial basis solution:

		9
6	3	

Starting from this solution, the next step will be the optimization of the final result. We check if the solution is degenerated or not with the formula $m+n-1=$ number of values, $x_{ij}>0$ so: 4+3-1=6 bigger values then 0 (19,16,23,4,2 and 5) so it results in a non-degenerated solution. Next, we directly apply the distributive method. The aim function is calculated as follows:

F_{min}=0·330+0·280+19·277+16·186+23·158+4·156+2·330+0·280+0·277+5·126+0·107+0·106=5263+2976+3634+624+660+

787.The regular solution is to be found in Table 7, so it can be optimized

By calculating the following differences, we check if the solution is optimal Δ_{ij} :

Δ_{11}=330-277+156-186=23

Δ_{12}=280-277+156-158=1

Δ_{32}=280-330+186-158=**-22**(negative difference)

Δ_{33}=277-330+186-156=**-23**(negative difference)

Δ_{42}=107-126+186-158=9

Δ_{43}=106-126+186-156=50

Next, we adjust the negative differences, Δ_{32}=-22 and Δ_{33} =-23. Given the fact that not all Δ_{ij} are positive, it means that the initial basis solution is not optimal.

Table 7: Table used for optimizing the initial solution

SOURCES/DEST.	KPZ31	KPZ32	KPZ33	STOCK (T)
M	330	280	277/**19**	19
C	186/**16**	158/**23**	156/**4**	43
H	330/**2**	280	277	2
A	126/**5**	107	106	5
NEEDED (T)	23	23	23	69 (T)

The negative difference was given by the $\Delta_{32}=-22$ box, so the cycle will be formed starting from this box, as:

	kpz31	kpz32	kpz33	STOCK (t)
M			19	19
C	16 +2	23 -2	4	43
H	2 -2	+2		2
A	5			5
NEEDED (t)	23	23	23	69 (t)

We act the same for the $\Delta_{33}=-23$ box and we obtain the new solution:

Table 8: Table with the new intermediate solution

SOURCES/DEST.	KPZ31	KPZ32	KPZ33	STOCK (T)
M	330	280	277/**19**	19
C	186/**18**	158/*23*	156/**2**	43
H	330	280	277/**2**	2
A	126/**5**	107	106	5
NEEDED (T)	23	23	23	69 (T)

The new aim function is:

F_{min}=0·330+0·280+19·277+18·186+23·158+2·156+0·330+0·280+2·277+5·126+0·107+0·106=5263+3348+3634+312+554+630=13741, 13741<13787 so we can observe that the new solution is better than the previous one.

For the empty boxes, we check if the solution is already optimal by forming the Δ_{ij} differences:

Δ_{11}=330-277+156-186=23

Δ_{12}=280-277+156-158=1

Δ_{31}=330-186+156-277=23

Δ_{32}=280-158+156-277=1

Δ_{42}=107-126+186-158=9

Δ_{43}=106-126+186-156=10

Given the fact that all the obtained differences are positive the solution is final and optimal.

4. Results interpretation

The interpretation of the results for the actual plan is as it follows:

-the supply point kpz33 will receive 19 tons of ammo from source M M;

-all the supply points (kpz31, kpz32, kpz33) will receive fuel from source C in the next order: 18, 23 respectively 2 tons;

-the whole food quantity will be transported from the source H to the supply point kpz33;

-the whole quantity of water will be transported from source A to the supply point kpz31.

6. Conclusions

If these operational research methods are accepted and applied within the decisional making process, it will facilitate the development of the analytical thinking among the officers, so they will be more and more adapted to the modern warfare and more rational in making decisions.

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