DISTRIBUTION OF COMBAT CAPABILITIES ON OBJECTIVES BY USING A TRANSPORT PROBLEM

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Abstract: The transport problem finds its application in situations where the upper echelons must draw up an optimal plan of resources allocation for combat capabilities 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. This paper presents the optimization of military action, showing how to solve a practical problem using the transportation problem.

Keywords: transport, resources, operations

1.   Introduction

Emerged from military needs, the operational research essentially deals with the decision optimization by using mathematical modeling and data provided by an action generically called operation.

The transport problem finds its applicability in situations where the upper echelons have to draw up an optimal plan for the distribution of combat or fire capabilities on the targets. For the results to be as reliable as possible for the real problem, the data required to formulate the mathematical model are gathered from a realistic scenario.

should be divided into sections, each with a

2.   Problem formulation

We need information about the tactical situation information, mission statement, execution, necessary logistic support, and command and communications instructions. From these sets of information, we extract only those necessary to translate the problem into practice into a mathematical model that once solved will provide the optimal solution.

The information about the situation is generally related to the forces of the enemy and our own forces, namely their location and the main courses of action.

So, we suppose to have 3 mechanized infantry battalions found in a defense situation to stop the enemy offensive on their directions of attack. With the support of the upper echelon and effectively using the technical-tactical characteristics of the weapons, exploiting on the natural properties of the battle field and performing numerous offensive retaliation, the subunits managed to stop the enemy offensive.

The execution instructions are divided into three categories: intent, design and coordination instructions. In this case the superior echelon intends to make a series of trips on three main directions of attack. The embarquement will take place on three aerodromes, on the available airplanes. After landing, the permanent passes will be investigated from the immediate vicinity, then the enemy device will be searched, the officers will be captured, the armored vehicles and the communications points destroyed.

Ultimately, the destruction of the enemy command point is attempted. For better efficiency, mixed teams of the three units will be created after landing.

3. Preparing the mathematical model-Solving the problem

In order to prepare the mathematical model, the following notations will be made:

$$a_i \ (i = 1,2,\dots,m), \quad (1)$$

The number of available fighters prepared for boarding in each of the three units A_i;

$$o_j \ (j = 1,2,\dots,n), \quad (2)$$

The number of fighters to be parachuted on each enemy target in the landing districts to cover the entire area of operations;

g_j, The number of troops that can be transported by airplanes from the aerodrome A_i to objective O_j. Into the calculation of this data set were taken into account the standard aircraft loading capacity, the distance from the aerodrome to the target, the flight height, the flight speed and the weight of the battle load, etc;

x_{ij}, The number of troops that can be transported by airplanes from the aerodrome A_i to objective O_j during the whole operation;

y_{ij}, Number of flights / airplane from aerodrome A_i to objective O_j during the whole operation.

In order to make the optimal flight chart, it is therefore necessary to determine the values y_{ij} so that:

- Each aerodrome will send all available personnel (a_i) to maximize the chances of success of the operation;

- To send to each objective the number of fighters (o_j) which was predicted to cover the whole area of operations in an efficient manner;

- The whole operation must be carried out with a limited number of aircraft and with a minimum number of flights.

The mathematical model of a problem of this kind will look like this

A_i/O_j	O_1	O_2	O_3	a_i
A_1	12 x_{11}	10 x_{12}	8 x_{13}	120
A_2	16 x_{21}	15 x_{22}	12 x_{23}	100
A_3	35 x_{31}	40 x_{32}	46 x_{33}	175
o_j	134	156	105	395

Figure1: Problems mathematical model

The numbers above the diagonal are the number of fighters that can be transported by each of the three aircrafts.

Optimized function whose minimum is sought is therefore:

$$F = \sum_{i=1}^{3}\sum_{j=1}^{5} y_{ij} = \sum_{i=1}^{3}\sum_{j=1}^{5} \frac{x_{ij}}{g_{ij}} \quad (3)$$

In order for this minimum to be realized, the x_{ij} values must be determined corresponding to the highest values of g_{ij}. For this purpose, the maximum matrix element method is applied because:

$$min.\sum_{i=1}^{3}\sum_{j=1}^{5} \frac{x_{ij}}{g_{ij}} = max.\sum_{i=1}^{3}\sum_{j=1}^{5} x_{ij} \cdot g_{ij}. \quad (4)$$

The following basic initial solution will be obtained which contains the number of soldiers assigned to each goal:

34	86	0
100	0	0
0	70	105

Figure 2: Initial basis solution

Starting from this solution, the end result is optimized. We check whether the solution is degenerate or not with the formula $m+n-1=$ nr. values $x_{ij}>0$ so: $3+3-1=5$ bigger values than 0 (34,86,100,70, and 105) it results that the solution is non-generated, so the distributive method can be directly applied.

The scope function is calculated as follows:
$F_{min}=34\div12+86\div10+0\div8+100\div16+0\div15+0\div12+0\div35+70\div40+105\div46=3+9+7++2+3=$ 24 flights. $\qquad$ (5)
The solution obtained is passed to the following table (bold values are the number of fighters to be transported to each goal in order to be optimized):

A_i/O_j	O_1	O_2	O_3	a_i
A_1	12 **34**	10 **86**	8 **0**	~~120~~ 0
A_2	16 **100**	15 **0**	12 **0**	~~100~~ 0
A_3	35 **0**	40 **70**	46 **105**	~~175~~~~70~~ 0 0
o_j	~~134~~~~34~~ 0	~~156~~~~86~~ 0	~~105~~ 0	395

Figure 3: Initial basis solution and intermediate calculations

We check whether the solution obtained is the optimal one by calculating the differences Δ_{ij} so we obtain:
$\Delta_{13}=8-10+40-46=-\mathbf{8}$ (negative difference)
$\Delta_{22}=15-16+12-10=1$
$\Delta_{23}=12-16+12-10=-\mathbf{2}$ (negative difference)

$\Delta_{31}=35-40+10-12=-\mathbf{7}$ (negative difference)
It follows the correction of the negative differences, so the differences Δ_{13}=-8 și Δ_{23} =-23. Because not all the differences Δ_{ij} are positive it means that the initial basis solution is not the optimal one.
The negative difference was given by the corresponding box Δ_{13}=-8, so the cycle will form from the box as follows:

A_i/O_j	O_1	O_2	O_3	a_i
A_1	**34** -19	**86** -86	**0** +105	120
A_2	**100**	**0**	**0**	100
A_3	**0** +19	**70** +86	**105** -105	175
o_j	134	156	105	395

Figure 4: First formed cycle and intermediate calculations

By doing similar to Δ_{23} and Δ_{31} we eliminate the negative differences and come to the solution:

A_i/O_j	O_1		O_2		O_3		a_i
A_1		12		10		8	120
	120		**0**		**0**		
A_2		16		15		12	100
	14		**86**		**0**		
A_3		35		40		46	175
	0		**70**		**105**		
o_j	134		156		105		395

Figure 5: Final solution problem

The new function is:
$$F_{min}\ \sum_{i=1}^{3}\sum_{j=1}^{5}\frac{x_{ij}}{g_{ij}} = \frac{120}{12}+\frac{0}{10}+\frac{0}{8}+\frac{14}{16}+$$
$$\frac{86}{15}+\frac{0}{12}+\frac{0}{35}+\frac{70}{40}+\frac{105}{46}=10+1+62+3=22$$
flights (transport), 22<24 so it's easy to see that the new solution is better than the previous one.

To eliminate as far as possible human computational errors, we check whether the solution obtained is the optimal one with The Scientist Manager.
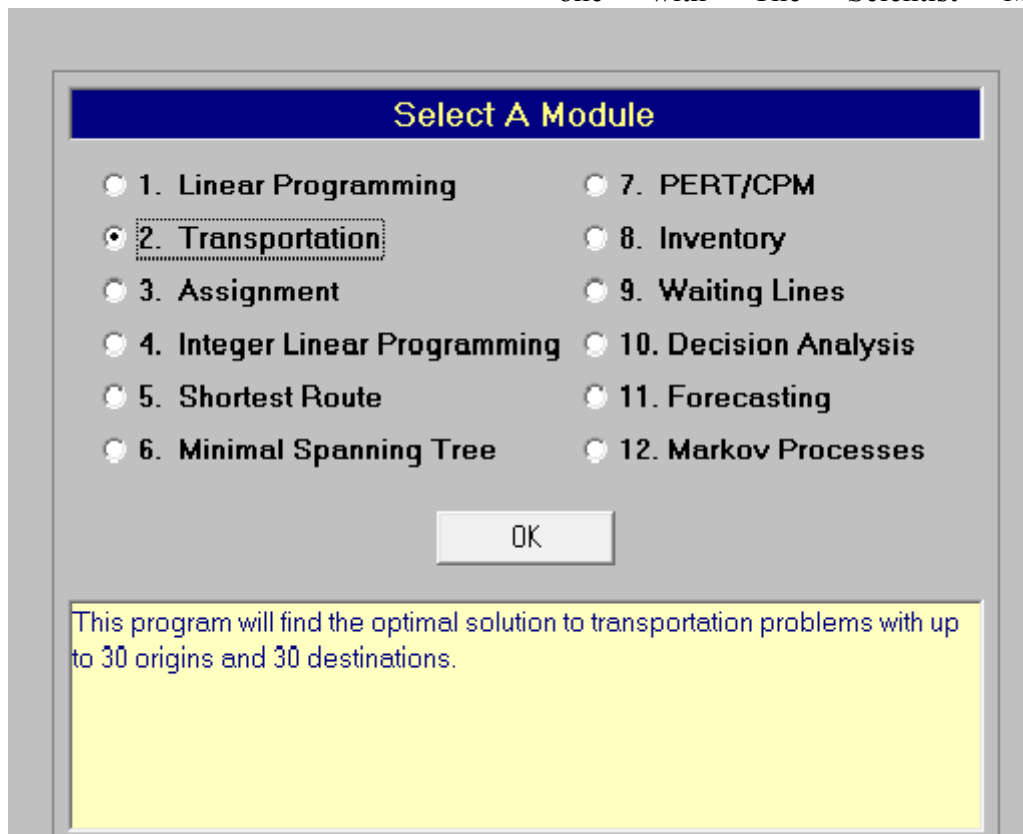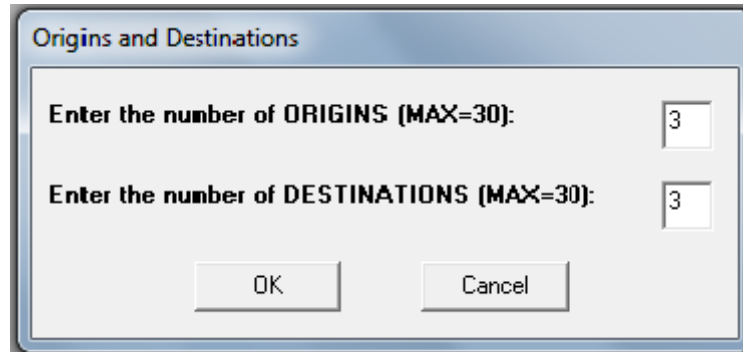

Figure 6: Application interface (main menu)

We enter the necessary data into the application (the number of sources and origins, respectively aerodromes and objectives in this case):

Figure 7: Variable numbers settings

The initial values are added a_i, o_j și g_j as follows :

Figure 8: Initial data insertion

When selecting the type of the objective function, the maximization option is chosen because we set it at first:

$$min. \sum_{i=1}^{3} \sum_{j=1}^{5} \frac{x_{ij}}{g_{ij}} = max. \sum_{i=1}^{3} \sum_{j=1}^{5} x_{ij} \cdot g_{ij}.$$

After running the program we get the following solution which is coincident with the original:

Figure 9: Final result

By making the divisions ($x_{ij} \div g_{ij}$), we will then get the number of flights / airplane from each of the three aerodromes at each of the 3 objectives. The optimal flight schedule is shown in the following table:

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A_i/O_j	O_1		O_2		O_3		a_i
A_1		12		10		8	120
	12		**0**		**0**		
A_2		16		15		12	100
	1		**6**		**0**		
A_3		35		40		46	175
	0		**3**		**3**		
o_j	134		156		105		395

Figure 10: Optimal flights graph

If this plan is respected, the entire number of fighters required for the mission will be carried by air, with the foreseen restrictions on the number of available aircraft at a minimum cost and in the shortest possible time.

Another graph that leads to fewer transports under the given conditions cannot exist..

4. Conclusions

If these methods of operational research are accepted and applied in the decision-making process, they will only develop analytical thinking among the officers, and so they will be able to cope with the demands of the modern battlefield, making more and more rational decisions.

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