METHODS OF STAFF ACTIVITY OPTIMIZATION IN PLANNING MILITARY OPERATIONS

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Abstract: The decision making process has become more and more complex, and requires special skills and expertise in obtaining informational superiority over the adversary, a fact which holds true for all fields of activity and even more so for the military one. Planning command activities has never been easy, staff officers being faced with a very difficult task that they have to accomplish without mistakes, given the serious consequences errors could have upon the course of action of a military operation. As the tactical field changes, the new situations it entails have to be duly and swiftly analyzed, whereas actions have to be reorganized according to the new battlefield characteristics. This can very easily be done with the PERT method, a method applied to plan all activities the completion deadlines of which are not established beforehand but which depend on a series of factors such as: the operator’s skill, ability and training, etc. The manual application of this method can however be very problematic given the large number of activities developed as part of complex military operations. In such cases the use of specialized software that offers quick solutions to the problems staff officers are confronted with becomes imperative. The continuous increase and diversification of the available information, the need to process and transmit it in real time sequences, requires the design and use of an adequate tool that can support the decision making process.

Keywords: mathematical model, PERT method, general staff activities, optimum solution

1. INTRODUCTION

Every day life is marked by decisions irrespective of the activity that we perform and of the role that we play in society or family. But, when we find ourselves in a theatre of operations, and our decision can lead to the loss of subordinates’ lives, then decision-making receives a special meaning. An arbitrary decision, without a proper study of the analyzed situation, can have disastrous consequences. Even more, in the military field, the decision made by leading factors has to depend on a solid scientific base.

The model offered by the PERT (Program Evaluation and Review Technique) method uses random values for specifying the duration of activity completion. Since it is possible for the same activity to be executed in different time intervals by different participants, an average value should be established for the duration of activity completion.

It is an activity which belongs to and is developed exclusively by the Staff officer and military specialists in this type of problems solvable with the help of the PERT method. In order to obtain the data needed for solving a problem with this method, there has to be a close cooperation between chief of staff officers and specialists, the list of activities has to
include all the activities, and the commanders’ needs have to be taken into account.

2. SCENARIO DESCRIPTION
For the execution of a land defence operation, a series of activities to be developed during a specified interval, the time interval dedicated to the elaboration of the BATTLE ORDER, has to be established at the level of a mechanized brigade.

The list of activities includes:

1. Preparing data and proposals
2. Reporting data and proposals
3. Working out the decision
4. Placing the decision on the map
5. Assigning missions to subordinate great units
6. Drawing up the reconnaissance plan
7. Reporting the decision
8. Executing the reconnaissance, mentioning and organizing the cooperation
9. Giving the battle orders and dispositions to the subordinate great units and units
10. Drawing up the combat and operative papers
11. Working out the decision by subordinate great units and units
12. Assembling the operative formation
13. Drawing up the logistic support plan
14. Organizing transportation of equipment
15. Carrying out the transportation of materials
16. Guiding and control activities

17. Battle order, reports.
In this respect, the following operations have to be performed:
- drawing up the Program Evaluation and Review chart (PERT) according to the list of activities
- determining the minimum completion time of activities
- determining the probability of plan completion in due time.

All these researches aim at finding objective methods of analyzing the choices placed in front of the decision-maker and objectively selecting the optimal one.

3. THE MATHEMATICAL MODEL – PERT Method
In the application of the PERT method, the following stages have to be completed:

1. The structure of the set activity (set objective) has to be analysed;
2. The PERT network chart has to be drawn;
3. The PERT network chart parameters have to be computed;
4. The critical path has to be determined;
5. The reserve time and plan completion time have to be computed;
6. The PERT chart and list of activities have to be analysed and possibly reviewed;
7. Activities have to be scheduled (activity development).

The first step is to accurately establish: activity names and the order in which they must be accomplished; the predecessor events, the simultaneous events and the successor events; the duration of activity completion: optimistic time, most likely time, pessimistic time, average time.

In this respect, the list of activities is drawn up as follows:

<table>
<thead>
<tr>
<th>Nr.</th>
<th>Activity name</th>
<th>Symbol</th>
<th>Inter- dependencies</th>
<th>Duration</th>
<th>( t_{ij} )</th>
<th>( \sigma_{ij} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>S</td>
<td>D</td>
<td>a m b</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

where

\( \hat{I} \) = the activity that immediately precedes the scheduled activity;
\( S \) = the activity that is accomplished concurrently with the scheduled activity;
\( D \) = the activity that immediately follows the scheduled activity;
a = optimistic duration - the minimum possible time required to accomplish the activity referred to, assuming all circumstances are favourable;
m = most likely duration - the normal
estimate of the time required to accomplish a task, assuming everything proceeds as normal and taking into account previous experience;

- \( b \) = pessimistic duration - the maximum possible time required to accomplish a task, assuming everything goes wrong.

The average duration of activity completion is roughly approximated to be as follows:

\[ t_{ij} = \frac{(a + 4m + b)}{6}, \]

whereas the variance (mean square deviation), i.e. the distribution of points along the curve is as follows:

\[ \sigma^2 = \left(\frac{(b-a)}{6}\right)^2. \]

The higher the variance i.e. the wider apart points “a” and “b” are, the higher the uncertainty i.e. the least precise the three time approximations have been (a, m, b).

The activity list should also include the dependencies influencing the completion of activities. These dependencies can result either from the need to have a close logical link between activities, from normative acts, or from the fact that all activities are performed with the same forces or resources – relative dependencies.

The minimum duration is denoted by \( t^0_{ij} \); task duration is computed by starting from the initial node for each activity, with the relation:

\[ t^0_{ij} = \max \{ t^0_i + t_{ij} \} \]  (1)

and by considering all the arcs of the \( X_j \).

The maximum duration – denoted by \( t^1_i \) – is computed by starting from the final node and moving towards the initial node, with the relation:

\[ t^1_i = \min \{ t^1_j - t_{ij} \} \]  (2)

and by considering all the arcs of the \( X_i \).

In the military environment, determining the critical path holds special importance for both the preparation and the development of combat actions. By using the PERT method for each activity, we figure out the necessary time and establish a well determined duration. When computing the value of the critical time (\( T_n \)) we consider the longest path. This path that helps us to complete the project is called critical path. Determining the critical path is an important part of the command process, allowing the commander to make all the important decisions and guide the entire process according to critical operations. It also draws the attention of the commander to the operations that have to strictly follow the schedule, according to the plan, as well as to those operations all efforts and support actions should be channelled on.

Another advantage of determining the critical path is that it warns the commander as to the difficulties he might encounter during the development of the process, helping him at the same time to take the necessary measures in order to eliminate such difficulties.

A correct determination of the critical path will help the command structures to establish not only the right amount of forces and resources adequate to each operation but also the right time when such forces and resources are to be used.

For a \( P_j \) to belong to the critical path of the network, the following relation has to be fulfilled:

\[ T_i = T_j, \]  (3)

where \( T_j \) is the maximum admissible time limit and \( T_i \) is the minimum time that each activity will take to completion.

A \((P_n, P_j)\) operation can be included in any critical path of a network, when its total time reserve \( RT \) meets the relation:

\[ RT = 0. \]  (4)

The PERT method is indicated especially when norms are not available, the duration of an operation having a stochastic character. In such situations, it is very useful to determine the probability of project completion in due time. Knowing the values of the plane time (\( T_{pl} \)) (the time established by the beneficiary for project completion), the minimum time the project will take to completion (the value of the critical path) \( T_n \) and the variance summed up for all activities, we can compute a reduced \( Z \) standard deviation with the relation:

\[ Z = \frac{(T_{pl} - T_n)}{\sigma T_n}, \]  (5)

\[ t_{ij} = \frac{(a + 4m + b)}{6}, \]

whereas the variance (mean square deviation), i.e. the distribution of points along the curve is as follows:

\[ \sigma^2 = \left(\frac{(b-a)}{6}\right)^2. \]
Upon filling in the activity list, we can determine the minimum time necessary for activity completion, and attach the following graph to the activity list presented in figure 1.

This graph allows us both to better observe the order of activities and to identify those developed concurrently.

In order to determine the minimum time it takes for scheduled activities to be completed as well as the probabilities of accomplishing the plan, we will use the STORM program.

We will first choose the Project Management option from the program Menu, then start a new application by selecting the Create a new data set option from the menu and we will have to type the following data:

- Program name;
- Number of activities in our graph;
where \( \sigma_{Tn} = \sum_{i, j \in Dc} \sigma_{ij}^2 \), iar \( \sigma_{ij}^2 = \frac{[(b-a)/6]^2}{} \).

Having established the reduced Z standard deviation we will look it up in the Laplace normal law function table (the table presenting the values of N(0,1) normal law’s distribution function), and thus establish the probabilities of plan completion.

Depending on the value of plan completion probability we shall have:
1. \( p < 0.4 \) - total uncertainty as to plan completion;
2. \( 0.5 \leq p \leq 0.7 \) - mere certainty as to plan completion, but with certain conditionings;
3. \( p > 0.7 \) - the plan will definitely be completed.

If the conclusion resulting from our analysis is that the execution process has to be improved, the network has to be reviewed and adjusted accordingly. When adjusting networks one should not overlook the following:

a) the \( t_{ij} \) or \( a, m, b \) events may not be adjusted based on the mere allocation of other values or evaluations. This is only allowed if during the execution of an activity, there are new elements (resources) which fundamentally reduce the duration;
b) it is possible to replace simpler activities by introducing a supplementary event and dividing it into two activities.

4. THE OPTIMAL SOLUTION
The maximum time interval for activities to be completed is 2640 minutes. In order to determine the minimum completion time, we first have to draw up a chart timetable scheduling activities and mentioning the time it takes for each activity to be achieved, from at least three perspectives: optimistic, most likely and pessimistic, which are presented in table 1:

- the optimistic duration – represents the minimum possible time required to accomplish the activity referred to, assuming all circumstances are favorable;
- the most likely duration - the normal estimate of the time required to accomplish a task, assuming everything proceeds as normal and taking into account previous experience;
- the pessimistic duration - the maximum possible time required to accomplish a task, assuming everything goes wrong.

### Table 1 Data on activities’ development

<table>
<thead>
<tr>
<th>Nr. Crt.</th>
<th>Activity name</th>
<th>Symbol</th>
<th>Predecessor</th>
<th>Duration (in minutes)</th>
<th>TN</th>
<th>( \sigma^2 n )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Preparing data and proposals</td>
<td>01</td>
<td>-</td>
<td>120 150 180 150 100</td>
<td>150</td>
<td>100</td>
</tr>
<tr>
<td>2.</td>
<td>Reporting data and proposals</td>
<td>02</td>
<td>01</td>
<td>180 200 220 200 44.4</td>
<td>200</td>
<td>44.4</td>
</tr>
<tr>
<td>3.</td>
<td>Working out the decision</td>
<td>03</td>
<td>01</td>
<td>210 240 270 240 100</td>
<td>240</td>
<td>100</td>
</tr>
<tr>
<td>4.</td>
<td>Placing the decision on the map</td>
<td>04</td>
<td>03</td>
<td>50 60 70 60 11.11</td>
<td>60</td>
<td>100</td>
</tr>
<tr>
<td>5.</td>
<td>Assigning missions to subordinate GU's</td>
<td>05</td>
<td>03</td>
<td>100 120 140 120 11.11</td>
<td>120</td>
<td>11.11</td>
</tr>
<tr>
<td>6.</td>
<td>Drawing up the reconnaissance plan</td>
<td>06</td>
<td>02,05</td>
<td>50 60 70 60 11.11</td>
<td>60</td>
<td>11.11</td>
</tr>
<tr>
<td>7.</td>
<td>Reporting the decision</td>
<td>07</td>
<td>04,06</td>
<td>80 90 100 90 177.77</td>
<td>90</td>
<td>177.77</td>
</tr>
<tr>
<td>8.</td>
<td>Executing the reconnaissance, mentioning and organizing the cooperation</td>
<td>08</td>
<td>07</td>
<td>200 240 280 240 100</td>
<td>240</td>
<td>100</td>
</tr>
<tr>
<td>9.</td>
<td>Giving the battle orders and dispositions to the subordinate GU's and Us</td>
<td>09</td>
<td>07</td>
<td>150 180 210 180 44.44</td>
<td>180</td>
<td>44.44</td>
</tr>
</tbody>
</table>
• Activity time option (DETERMINISTIC, PROBABILISTIC);
• Activity representation option (ARCS/NODES);
• Maximum number of predecessor activities.

We will then introduce the application data, i.e. the time it takes for each activity to be completed: optimistic time, likely time and pessimistic time and specify the predecessor activities. When introducing these data we will type the number of minutes between nodes and the number of the activity immediately preceding the one referred to, as illustrated in the figure 2.

Once these operations performed, we will run the application by pressing the F7 key and thus find the optimal solution. The program will display the minimum project completion time, in our case 2550 minutes and the standard deviation (Z=3.2) which we will later on use in order to compute the project completion probability as in figure 3.

The program will then display a chart according to which all activities have to be scheduled and performed so that they shall not exceed the minimum completion time presented in figure 4.
The program will then make it possible for us to work out the probability of activity completion depending on different time intervals. To that end, all we need to do is to fill in the empty field (“Enter target for project completion”) by introducing the value we would like to compute the completion probability for. Thus, if we introduce the minimum value previously computed we will get an activity completion probability of 50% as in figure 5.

We can also compute the activity completion probability for a time interval of 2,640 minutes (the maximum completion time) presented in figure 6. For the maximum time for project completion of 2,640 minutes we will get a probability of 99.91%.
CONCLUSIONS

This method will allow us to rationalize command activities; establish a logical sequencing of activities; establish the maximum duration for the completion of each scheduled activity; permanently and systematically monitor all the activities and especially the critical ones; correct possible planning mistakes; perform the activities at higher standards.

The military activities the PERT method is most suited for are organizing and planning specialized and tactical training meetings as well as planning staff activities such as: planning combat duration; planning combat training in units and great units; planning the activity of different departments within units and great units.

The PERT method is a tool, commanders and department heads may find useful for rationalizing the command, execution and control workload.

Bibliography


Reinhard Diestel, Graph Theory (3rd edition), Berlin, New York: Springer-Verlag, 2005.