

## Prioritization Methodology for Development of Required Operational Capabilities<sup>1</sup>

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### SUMMARY

*This paper presents the main methodological issues related to the prioritization of Required Operational Capabilities (ROCs) of the Bulgarian Armed Forces (BAF). It is specifically orientated to the achievement of nearly-to-the-real results in the development of military capabilities corresponding to the national and coalition, political and strategic requirements. An approach is proposed in this paper based on experts' opinion and analytical methods for a generic and flexible support of the decision-making that can be used in the effective defense management.*

*This methodology seeks to identify the ROCs that are necessary to be developed in order to address the mission's achievement. These are the ROCs with greatest potential to improve Alliance mission effectiveness and interoperability in the near, mid- and long-term future.*

**Keywords:** *Capability-based Planning, Capability Gap, Multi-Criteria Decision Analysis, Capability Ranking, Effectiveness improvement.*

### INTRODUCTION

The efficiency of any process is assessed in terms of criteria that vary depending on the problem concerned and the particular goals of the interested groups. In general, the prioritization of Required Operational Capabilities (ROCs) complied within the proposed methodology is reduced to solving the multi-criteria analysis task. For that purpose the ROCs valuation criteria are defined and ranged in the first place. Then the weight of each scenario is determined, respectively the capability weight that is function of scenario characteristics.

The next step includes calculation of the relative importance of each ROC as a function of:

- its weight;
- the added utility of the gap between the current and the target state;
- the urgency of the ROC.

A ranked list of ROCs gaps in descending order is elaborated on the basis of the valuation of the ROCs relative importance. In conclusion of this process a final prioritization method is being used including all the factors on which the ROCs are depending on and that have not been taken into consideration before.

The efficiency of a decision taken in such a way will depend on the goals of all interested groups participating in the maintenance process [19]. The applied mathematical model, conducting multi-criteria analysis, allows us to find a way to meet the goals of different processes and to choose an optimal

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# Report Documentation Page

Form Approved  
OMB No. 0704-0188

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1. REPORT DATE <b>APR 2010</b>		2. REPORT TYPE <b>N/A</b>		3. DATES COVERED <b>-</b>	
4. TITLE AND SUBTITLE <b>Prioritization Methodology for Development of Required Operational Capabilities</b>				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) <b>Department of Operational Analysis, Operations Directorate, Ministry of Defense 1606 Sofia, 34 General Totleben Blvd BULGARIA</b>				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT <b>Approved for public release, distribution unlimited</b>					
13. SUPPLEMENTARY NOTES <b>See also ADA564688. Analytical Support to Defence Transformation (Le soutien analytique a la transformation de la Defense). RTO-MP-SAS-081</b>					
14. ABSTRACT <b>This paper presents the main methodological issues related to the prioritization of Required Operational Capabilities (ROCs) of the Bulgarian Armed Forces (BAF). It is specifically orientated to the achievement of nearly-to-the-real results in the development of military capabilities corresponding to the national and coalition, political and strategic requirements. An approach is proposed in this paper based on experts opinion and analytical methods for a generic and flexible support of the decision-making that can be used in the effective defense management. This methodology seeks to identify the ROCs that are necessary to be developed in order to address the missions achievement. These are the ROCs with greatest potential to improve Alliance mission effectiveness and interoperability in the near, mid- and long-term future.</b>					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT <b>unclassified</b>	b. ABSTRACT <b>unclassified</b>	c. THIS PAGE <b>unclassified</b>			

solution. The proposed methodology for development of ROCs is intended to focus and align capability improvement efforts.

## **1. PROBLEM STATEMENT**

The prioritization methodology for development of Required Operational Capabilities of the Bulgarian Armed Forces (BAF) helps us to maximize national security. In order to provide the fulfillment of the new defense tasks and missions [20], it is necessary to analyze the current capabilities and Defense Command and Control Effectiveness. The purpose of the proposed methodology is to be used in the Planning phase of the Planning Process according to the Defense Planning Guidance<sup>2</sup>. The methodology includes procedures and tools for regulating and assuring the ROC Council activity during the prioritization process of capabilities for the whole scenario package. The necessary data for this process are generated in the previous steps of the Planning phase.

The methodology integrates the heuristic experts' approach and analytical methods in a multistage process and aims to derive the relative importance of every capability gap. The different gaps are related to the corresponding capabilities and the envisaged mission [1], [6]. Thus the 'Importance' is a complex indicator of the capability, giving its contribution to the armed forces missions' fulfillment that would take effect in case of overcoming the gap. The outcome of the proposed methodology is a capabilities gap list ordered by their relative importance *I*. It is a starting point for the 'Prioritized List of ROCs Gaps' development.

### **1.1 Starting Conditions**

The starting conditions for the multistage gap prioritization process are:

- Capabilities list corresponding to the ROCs defined in Capability Based Planning (CBP) Process [7]. The definitions and numbering are unified for the whole prioritization process;
- Availability of ROCs for every context scenarios, capability gaps for every frame list capability;
- Set of scenarios, operational planning results and formulations necessary for the prioritization process approved in advance by the ROC Council.

### **1.2 Considerations**

The following considerations are taken into account in this methodology:

- Necessity of balance between comprehensive and precise measurements and prioritization process simplicity and control;
- Optimal tasks distribution between ROC Council and the experts in accordance with their role, responsibility and required expertise.

### **1.3 Assumptions**

We make the following assumptions:

- The operational capability that is planned and provided with resources is assumed to be an available capability;
- It is also assumed that ROCs satisfy the minimal capability requirements;

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<sup>2</sup> Defense Planning Guidance, Ministry of Defense, Bulgaria, (project) 2009.

- Capability gap and ROCs are defined in such a way to avoid overlapping. Every capability is unique but correlation is possible (the realization of one capability may involve the realization of another);
- The defined criteria and the used approaches are applicable to all ROCs and their gaps.

#### **1.4 Limitations**

- The methodology is based on CBP products.
- The methodology is applicable for capability gaps that require ‘material’ decision. The reason for this limitation is the prioritization main point – how the results should be used for Defense Resources Management Process.
- This methodology is best applied to up to 50 capability gaps. If the gaps number is bigger the prioritization process becomes more complicated and requires increased time for analyses due to progressive increment of the underlying procedures.
- The proposed methodology doesn’t take into account the financial resources necessary for overcoming the ROCs gap or the budget limitations for the corresponding period.
- The executions of the external tasks excluded of the possible context scenarios are not considered. For example, such a task is the utilization of useless military ammunitions.

## **2. THEORETICAL BACKGROUND**

Formal multi-criteria analysis (MCA) techniques [3], [6], [8] usually provide an explicit relative weighting system for the different criteria. The main role of the techniques is to deal with difficulties that human decision-makers have been faced by in handling large amounts of complex information in a consistent way. A key feature of MCA is its emphasis on the judgment of the decision-making team in establishing objectives and criteria estimating relative importance weights and in judging the contribution of each option (alternative). The subjectivity of this process can be a matter of concern.

On the other hand, the criteria represent the ‘judging standards’ that should be complete, operational, decomposable, non-redundant and minimal in size [13], [14]. On the basis of this the decision-makers can set about deriving the relative importance of the criteria and then assessing alternatives against each criterion. The analytical hierarchy process (AHP) method [15] is used to face complex decision-making problems. Fundamentally, AHP works by developing priorities for goals in order to value different alternatives. This multi-criteria method has become very popular among operational researchers and decision-making scientists [4], [16], [18]. Saaty [17] has generalized AHP/ANP to capture dynamic judgments both mathematically and by using scenarios to project ahead. AHP helps capture both subjective and objective evaluation measures providing a useful mechanism for checking the consistency of the evaluation measures and alternatives suggested by the team thus reducing bias in decision making.

Multi-criteria methods are suited to the problem of selecting or evaluating a set of well-defined, discrete alternatives, under consideration of a set of attributes, and which resembles the decision problem. The starting point of such methods is a decision matrix, which is composed of alternatives (scenarios/strategies) and decision relevant attributes, against which the alternatives are compared [5], [10].

## **3. METHODOLOGY**

One of the planning tasks for ROCs development is to identify the potential gaps and to overcome them. Due to limited funding the most important task becomes the choice of those capabilities whose gaps are

the most important and need to be filled. The prioritization of ROCs gaps is reduced to solving the multi-criteria analysis task. The efficiency is measured in terms of criteria (depending on the problem concerned and the particular goals). It would be interesting to allow each evaluator to estimate every capability against every criterion as if in a jury. However, this evaluation would need a scientific justification.

The present methodology seeks to identify those ROCs which are necessary to be developed in order to address the mission achievement. These are the ROCs with greatest potential to improve Alliance mission effectiveness and interoperability in the near, mid- and long-term future [1].

### **3.1 The Essence of the Methodology**

The proposed methodology developed especially for the ROCs prioritization purpose of the Bulgarian Armed Forces is aimed to regulate the prioritization process and to bring objective evaluation of available capability gaps in order to satisfy the defined criteria for relative ROCs importance. The highest relative importance  $I$  of the particular ROC gap is the one that indicates the need of overcoming the gap. The main goal of the methodology is to propose an approach based on experts' opinion and analytical methods for a generic and flexible decision support. This prioritization process should be used in the effective management and it focuses on capability improvement efforts.

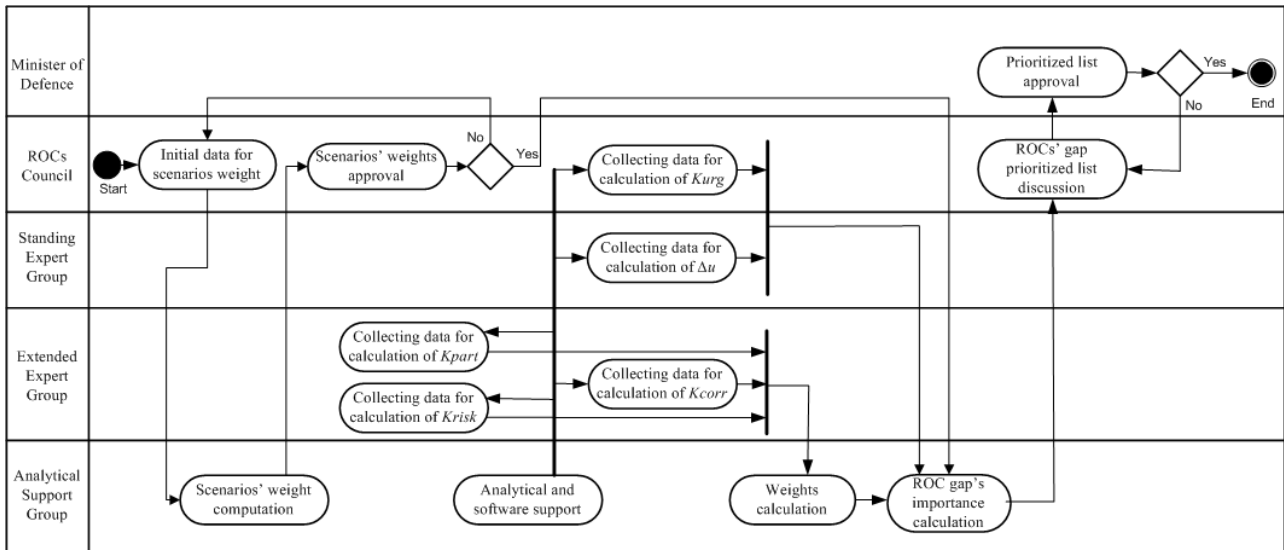
The methodology considers 3 phases of the prioritization process:

- ◆ I – preparation phase;
- ◆ II – analytical phase;
- ◆ III – final prioritization phase.

During the I<sup>st</sup> phase, called '*Experts' valuation*', all necessary data from experts' assessments is collected. It is further needed for the analysis and computation in the next phase.

In the II<sup>nd</sup> phase, called '*Data processing*', are conducted mathematical calculations of the individual experts' valuations. All the parameters and coefficients are derived on the basis of these calculations. In case of available network and appropriate software this phase could be accomplished in parallel with the I<sup>st</sup> phase.

The III<sup>rd</sup> phase includes the final 'ROCs gaps list' development. A final prioritization method is applied where all the factors on which the ROCs are depending and that have not been taken into consideration are included. This is the phase where the objective analytical tools and experts' opinion are combined. The specific character of the applied methods provide for logical and plausible results. They contribute to the improvement of the objectivity and efficiency of decision-making process in the defense planning area. The main steps and prioritization sequences are shown on Fig. 1.



**Figure 1. Activities and main steps of the prioritization process.**

The main activities are those of Defense Minister, ROCs Council, standing Expert Group, extended Expert Group and the Analytical Support Group. During the first phase of the prioritization process the ROCs Council accepts the defined criteria and approves them. After this official acceptance the process continues with calculation of all the parameters that are consequently discussed and approved by the Council. The final decision is made by the Defense Minister and the ROCs prioritization list is issued and legalized.

### 3.2 Computation of the Parameters

The computation of all the necessary parameters for the prioritization process is carried out using well known and soundly defined analytical dependencies from the mathematical theory. In the I<sup>st</sup> phase of the prioritization process all ROCs valuation criteria are defined. Then the weight of each scenario is determined, respectively the capability weight which is function of scenario characteristics.

The Saaty scale is used for the calculation of the ‘scenario weight’ based on the AHP [15] method. Every ROC is characterized by the level of ‘available capability’ and ‘capability gap’. The first one is determined by experts. The *available capability*  $C_{av}$  could be more, equal or less than ROC. The *capability gap* is gathered through comparison between ROC and the  $C_{av}$ . The gap is zero if the ROC is equal to the  $C_{av}$ . If the ROC is greater than  $C_{av}$ , then the difference defines the gap.

The II<sup>nd</sup> phase includes calculation of the relative importance of each ROC as a function of:

- its weight –  $w_j$ ;
- the added utility  $\Delta u$  of the gap between the current and the target state;
- the ROC urgency –  $K_{urg}$ .

A ranked reversal list of ROCs is elaborated on the basis of the valuation of the ROC relative importance.

#### *Calculation of the Weights*

The ROC weight reflects the relative importance of a particular capability in the scope of scenarios set. The higher the weight is, the more important capability gap and ergo the need to overcome this gap in order to fulfill the missions. The parameter  $w_j$  on the other hand depends on the following coefficients:

- Participation coefficient –  $K_{part}$  measures ROC participation in the context scenario. A ROC fraction that participates in the scenario operation is measured and represented with  $K_{part}$ . In case of participating in more scenarios ROC weight will increase, i.e. the “universal” capabilities will be valued higher than the “unique” one.
- Risk coefficient –  $K_{risk}$  measures the potential risk of the operation force goals in case ROC is missing or was not developed. The role and the corresponding risk of not being available are measured for each ROC that is taking part in a scenario. The ROC may play different parts in the different scenarios. The higher the part, the higher the weight.
- Correlation coefficient –  $K_{corr}$  measures the capabilities correlation in the framework of each scenario. While the risk represents the ROC part towards the operation force goals, the correlation reflects the capabilities mutual influence in an operation. The influence rate of one capability complied to the realization of another from the operation package gives the value of the  $K_{corr}$ .

The ‘*scenario weight*’ is used for the ROC weight calculation as well. This weight represents the scenario importance according to the experts. The scheme of the whole process is given on Fig. 3.

### 3.3 Weight Calculation Stages

All the experts’ opinions are collected through questionnaire cards (Fig. 2). The valuation is done in Saaty’s nine degree scale and is given as linguistic terms used for the comparison between alternative/ scenario **A** and alternative/ scenario **B**.

Scenario <b>A</b>	<b>A superiority over B</b>				<b>A and B Equality</b>	<b>B superiority over A</b>				Scenario <b>B</b>
	Abso- lute	Obvi- ous	Major	Minor		Minor	Major	Obvi- ous	Abso- lute	
...										...
...										...

**Figure 2. Questionnaires card for comparison.**

The results from each questionnaires obtained by the experts are summarized in one matrix, where  $A_i$  are the scenarios,  $i \in [1, \dots, n]$  is the scenario number,  $a_{ij}$  – results from the comparison between the scenarios.

$$\begin{matrix}
 & A_1 & A_2 & \dots & A_j & \dots & A_n \\
 A_1 & \left( \begin{matrix} 1 & a_{12} & \dots & a_{1j} & \dots & a_{1n} \\
 A_2 & a_{21} & 1 & \dots & a_{2j} & \dots & a_{2n} \\
 \dots & \dots & \dots & \dots & \dots & \dots & \dots \\
 A_i & a_{i1} & a_{i2} & \dots & a_{ij} & \dots & a_{in} \\
 \dots & \dots & \dots & \dots & \dots & \dots & \dots \\
 A_n & a_{n1} & a_{n2} & \dots & a_{nj} & \dots & 1 \end{matrix} \right)
 \end{matrix}$$

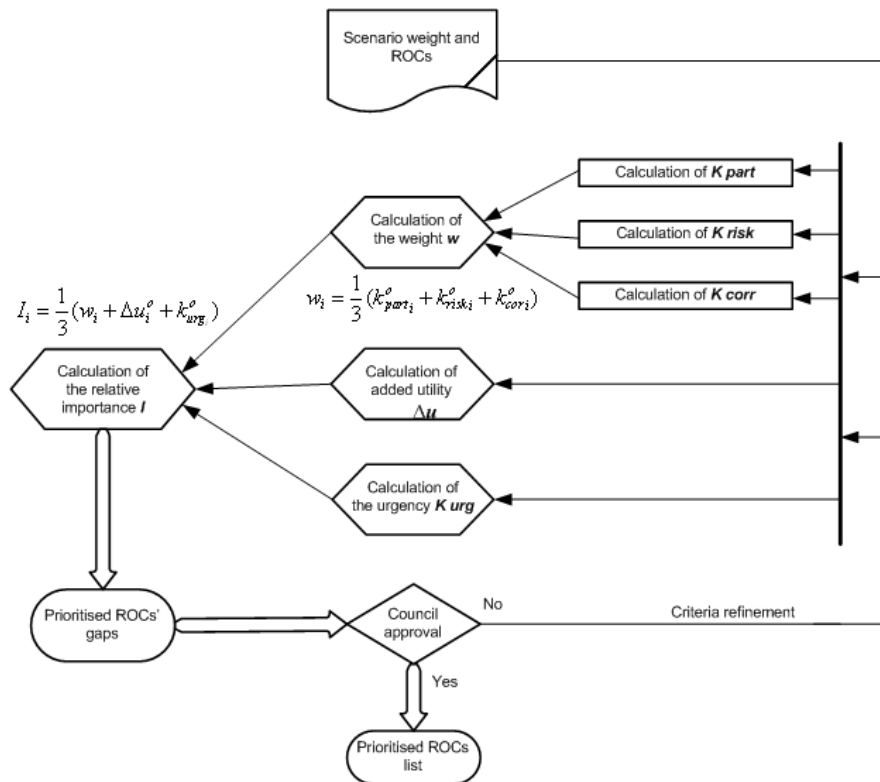
For every element  $a_{ij}$  it holds:

$$1/ a_{ij} = 1 \text{ for } i=j, \tag{1}$$

$$2/ a_{ij} = \frac{1}{a_{ji}} \text{ for } i \neq j. \tag{2}$$

The value for the element  $a_{ij}$  is obtained as follows:

- $a_{ij} = 1$ , if  $A_i$  and  $A_j$  are of an equal importance;
- $a_{ij} = 3$ , if  $A_i$  is more important in minor rate than  $A_j$ ;
- $a_{ij} = 5$ , if  $A_i$  is more important in major rate than  $A_j$ ;
- $a_{ij} = 7$ , if  $A_i$  is obviously more important than  $A_j$ ;
- $a_{ij} = 9$ , if  $A_i$  is absolutely superior to  $A_j$ .
- $a_{ji} = 3$ , if  $A_j$  is more important in minor rate than  $A_i$ ;
- $a_{ji} = 5$ , if  $A_j$  is more important in major rate than  $A_i$ ;
- $a_{ji} = 7$ , if  $A_j$  is obviously more important than  $A_i$ ;
- $a_{ji} = 9$ , if  $A_j$  is absolutely superior to  $A_i$ .



**Figure 3. The scheme of the calculation steps of the ROCs prioritization process.**

In the next step are calculated the „rank vector”  $\bar{P}$  for the given matrix  $A$ . The mean geometric values for each scenario are computed and normalized (formula 3).

$$P = \begin{pmatrix} p_1 = \sqrt[n]{\prod_{j=1}^n a_{1j}} \\ p_2 = \sqrt[n]{\prod_{j=1}^n a_{2j}} \\ \dots \\ p_n = \sqrt[n]{\prod_{j=1}^n a_{nj}} \end{pmatrix} \quad \bar{P} = \begin{pmatrix} \bar{p}_1 = p_1 / \sum_{i=1}^n p_i \\ \bar{p}_2 = p_2 / \sum_{i=1}^n p_i \\ \dots \\ \bar{p}_n = p_n / \sum_{i=1}^n p_i \end{pmatrix} \quad (3)$$

The vector elements give the weight coefficients for every rank. So, the element  $\bar{p}_1$  is the weight coefficient of the scenario ranked at the 1<sup>st</sup> place; the element  $\bar{p}_2$  - the weight coefficient of the scenario ranked at the 2<sup>nd</sup> place; etc. Each expert calculated the rank vector  $\bar{P}$ . It contributes to the computation of the common rank vector  $\bar{P}^o$  (formula 8).

**Step 1:**

In the first step of the analytical phase the consistency ratio coefficient  $K_{CR}$  is calculated. The consistency ratio ( $CR$ ) tests the consistency of every decision matrix  $A$ . A totally consistent matrix  $A$  has a  $CR$  equal to 0. Notwithstanding, a  $CR$  less than 0,1 is acceptable [2]. In the case of group decision-making, the most extended tool for aggregating the experts' judgments is the geometric mean over numeric entries of the paired comparisons  $a_{ij}$  [16]. The maximal **eigen** value  $\lambda_{\max}$  of rank vector  $\bar{P}$  is calculated according to formula (5). The  $K$  is obtained like this:

$$K = \begin{pmatrix} k_1 \\ k_2 \\ \dots \\ k_n \end{pmatrix} = \begin{pmatrix} 1 & a_{12} & \dots & a_{1n} \\ a_{21} & 1 & \dots & a_{2n} \\ \dots & \dots & \dots & \dots \\ a_{n1} & a_{n2} & \dots & 1 \end{pmatrix} \times \begin{pmatrix} \bar{p}_1 \\ \bar{p}_2 \\ \dots \\ \bar{p}_n \end{pmatrix} \quad K^* = \begin{pmatrix} k_1^* = k_1 / \bar{p}_1 \\ k_2^* = k_2 / \bar{p}_2 \\ \dots \\ k_n^* = k_n / \bar{p}_n \end{pmatrix} \quad (4)$$

$$\text{and } \lambda_{\max} = \frac{1}{n} \sum_{i=1}^n k_i^* \quad (5)$$

The  $\lambda_{\max}$  is used as an assessment of the concordance and it reflects the preference proportion. As  $\lambda_{\max}$  is getting near to  $n$  (number of elements), the more consistent is the result. The deviation from this consistency is  $K_{CR}$  and is given as:

$$K_{CR} = \frac{\lambda_{\max} - n}{n - 1} \quad (6)$$

Then the  $CR$  is calculated as the ratio between  $K_{CR}$  and the randomness index ( $RI$ ). This index is given by the random generated matrix  $A$  with elements 1÷ 9 and their reciprocals. The values of  $RI$  are given in the table below. The value of  $CR$  is showing how much  $K_{CR}$  distinguishes from the maximum possible value of the random matrix.

**Table 1.**

Matrix order	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
<i>RI</i>	0	0	0.49	0.81	1.01	1.14	1.23	1.30	1.35	1.39	1.41	1.44	1.46	1.48	1.49

$$CR = \frac{K_{CR}}{RI} \quad (7)$$

If  $CR \geq 0.1$  the expert needs to analyze again the details and to conduct a new scenario comparison.

If  $CR \leq 0.1$  the results from the comparison are acceptable.

After the validation of the CR by each expert (according to the requirements), the common rank vector  $\bar{P}^o$  is calculated in the final step of the process:

$$\bar{P}^o = \begin{pmatrix} p_i^o = \frac{1}{m} \sum_{j=1}^m \bar{p}_{1j} \\ \dots \\ p_i^o = \frac{1}{m} \sum_{j=1}^m \bar{p}_{ij} \\ \dots \\ p_n^o = \frac{1}{m} \sum_{j=1}^m \bar{p}_{nj} \end{pmatrix} \quad (8)$$

where:  $\bar{p}_i^o$  – the common rank of  $i$  scenario;  $\bar{p}_{ij}$  – the rank for the scenario  $i$  according to expert  $j$ ;  $n$  – the number of scenarios;  $m$  – the number of experts.

**Step 2:**

At that step  $K_{part}$  is calculated. The matrix  $A$  looks like this:

$$A = \begin{pmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \dots & \dots & \dots & \dots \\ a_{p1} & a_{p2} & \dots & a_{pn} \end{pmatrix} \quad (9)$$

where  $a_{ij}$  – is a number  $\in [0, 1]$  that gives the degree of participation of the  $i$ -th capability in the  $j$ -th scenario and  $1 \leq i \leq p, 1 \leq j \leq n$ , where  $p$  is the number of capabilities and  $n$  is the number of scenarios.

Different scenarios have different weights as calculated in formula (12). The participation coefficients  $K_{part}$  are obtained by the multiplication of two vectors  $A$  and  $\bar{P}$ . The vector  $K_{part}$  is:

$$K_{part} = A \times \bar{P} = \begin{pmatrix} k_{part_1} \\ k_{part_2} \\ \dots \\ k_{part_p} \end{pmatrix} \quad (10)$$

where  $k_{part_1}$  – is the participation coefficient of the 1<sup>st</sup> ROC;  $k_{part_2}$  – is the participation coefficient of the 2<sup>nd</sup> ROC; etc. Each expert calculated vector  $K_{part}$ , that contributes to the computation of the common rank vector  $k_{part}^o$  by analogy to formula (8).

**Step 3:**

The risk coefficient  $K_{risk}$  is calculated identically to  $K_{part}$ . The difference consists in the possible values that are fixed and are coded as follows:

- „small” – ‘0.33’.
- „middle” – ‘0.66’.
- „big” – ‘1’.

**Step 4:**

The necessary data for the correlation coefficient calculation  $K_{corr}$  are collected from inquires of the type shown on Fig. 4. The correlation matrix is then constructed by replacing the linguistic assessments with the corresponding codes:

- „doesn’t depend” – value ‘0’;
- „minor dependence” – value ‘2’;
- „major dependence” – value ‘4’;
- „highly depends” – value ‘6’;
- „absolutely depends” – value ‘8’.

Does capability ..... depend from					
capability:	Doesn’t	Minor	Major	Highly	Absolutely
...					
...					
...					

**Figure 4. Inquires for capabilities correlations.**

The data from the questionnaires are summarized in a matrix B which looks like matrix A (9).

The column values are added and the vector **B** is obtained. The sum of the vector elements is then computed and normalized (**B\***). The new vector  $K_{corr}$ , which elements are the capabilities correlation coefficients, is in the form:

$$K_{corr} = (k_{corr1} = \frac{b_1}{B^*}; k_{corr2} = \frac{b_2}{B^*}; \dots; k_{corr_n} = \frac{b_n}{B^*}) \quad (11)$$

where  $k_{corr1}$  is the correlation coefficient of the first capability;  $k_{corr2}$  – the correlation coefficient of the second capability, etc.

The common correlation coefficient for each capability is computed by analogy to formula (8).

**Step 5:**

Finally, the ROC *weight* is calculated as the mean of the three parameters given in formula (12):

$$w_i = \frac{1}{3}(k_{part_i}^o + k_{risk_i}^o + k_{cor_i}^o) \quad (12)$$

**3.4 Calculation of the Added Utility**

For the calculation of the Added Utility  $\Delta u$  are used inquires with assessment scale shown on Fig. 5:



**Figure 5. Assessment scale for capability development level.**

The MIN value on the first left position of the scale denotes the starting point of a capability, when a decision has been taken to develop it. The parameter MIN, scored ‘0’, is the value for the minimum capability at the beginning.

The MAX value on the last position of the scale denotes the capability level for which a maximum utility will be obtained. The aimed Required Operational Capability is scored ‘10’ and is the maximum capability value.

The input score of the current level of capability is marked ‘NOW’ and is the real assessment value of the ROC. The NOW position of the scale denotes the current level of the ROC development (when the assessment is conducted). If the parameter NOW is scored ‘7’, the expert believes that another three points of improvement are possible.

The parameter AIM is the desired capability level. It is positioned below the MAX value and denotes the ROC development that should be reached. The ideal variant is when AIM equals MAX, but this couldn’t be attained at the moment.

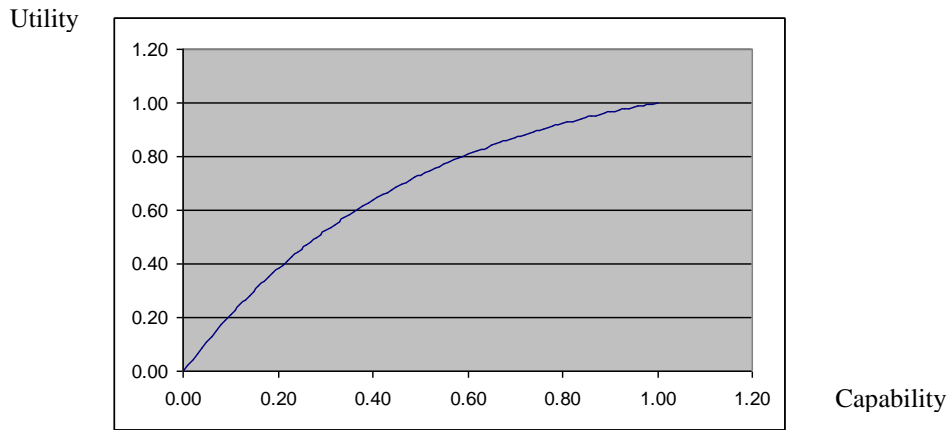
The experts have to indicate the NOW and AIM values from the scale for each capability. Then these scores are scaled as:

$$C_{NOW} = \frac{NOW - MIN}{MAX - MIN} = \frac{NOW}{10} \quad (13)$$

with the assumption that  $MIN=0$  and  $MAX=10$ .

$$C_{AIM} = \frac{AIM - MIN}{MAX - MIN} = \frac{AIM}{10} \quad (14)$$

According to the economics law for general utility increment [11], the utility raises but with decreasing rates, so that saturation is reached (Fig. 6).



**Figure 6. Capability versus Utility dependencies.**

The analytical function of the general utility is of an exponential type:

$$Y = 1 - e^{-ax} \tag{15}$$

where  $a$  is the coefficient of which the projection of the function depends. When  $a < 1$  the graph will approach the linear function graph, and at  $a = 0.1$  it will coincide with it. When  $a > 4$  the graph is projecting strongly and becomes useless to practice. For the needs of the present methodology we use the equation  $a=2$ .

The function's variable  $x$  is examined in the range of 0 to 1. The values calculated for the function  $Y$  by formula (15) should be standardized. The maximum value of the function belongs to  $x=1$  and is  $y=0.86$ .

The standardized function  $\bar{y}$  looks like this:

$$\bar{y} = (1 - e^{-2x})/0.86$$

The added utility of capability  $i$  with value  $B_{NOW}$  is:

$$u_{iNOW} = \bar{y}(x_i = B_{NOW})$$

The added utility of capability  $i$  with value  $B_{AIM}$  is:

$$u_{iAIM} = y(x_i = B_{AIM})$$

The added utility value that has to be found for the  $i$ -th ROC gap  $\Delta u_i$  is:

$$\Delta u_i = u_{iAIM} - u_{iNOW} \tag{16}$$

The total added utility of the  $i$ -th ROC gap  $\Delta u_i^o$  is calculated as an average arithmetical value of the estimated gap added utility values derived from each expert's questionnaire. When the experts' number is  $k$ , we obtain the following equation:

$$\Delta u_i^o = \frac{1}{k} \sum_{j=1}^k \Delta u_j \quad (17)$$

### 3.5 Calculation of the Urgency

The urgency of a capability may be computed in two ways depending of the necessary a priori information availability. The following information is needed for the calculation:

$T_i$  – the number of years (counted from the current moment) after which the capability gap have to be filled;

$\Delta T_i$  – the time needed to be filled the gap  $G_{Ci}$  of the  $i$  capability.

In the first possibility, if  $T_i$  and  $\Delta T_i$  are available, the generalized gap urgency  $K_{urg}^o$  is:

$$k_{urg_i}^o = \frac{1}{T_i - \Delta T_i + 1} \quad (18)$$

The second possible way happens when there are no  $T_i$  and  $\Delta T_i$  data. Then the experts' judgment is used (from inquires). For the assessment of the parameter  $K_{urg}$  is coded as follows:

“non urgent” -  $K_{urg} = 0.33$   
 “mean urgent” -  $K_{urg} = 0.66$   
 “very urgent” -  $K_{urg} = 1$ .

The generalized urgency  $k_{urg_i}^o$  is the mean value from the experts' judgments (by analogy to formula 17).

### 3.6 Relative Importance Calculation

In the end, the calculation of the ROC relative gap importance  $I$  is accomplished like this:

$$I_i = \frac{1}{3} (w_i + \Delta u_i^o + k_{urg_i}^o) \quad (19)$$

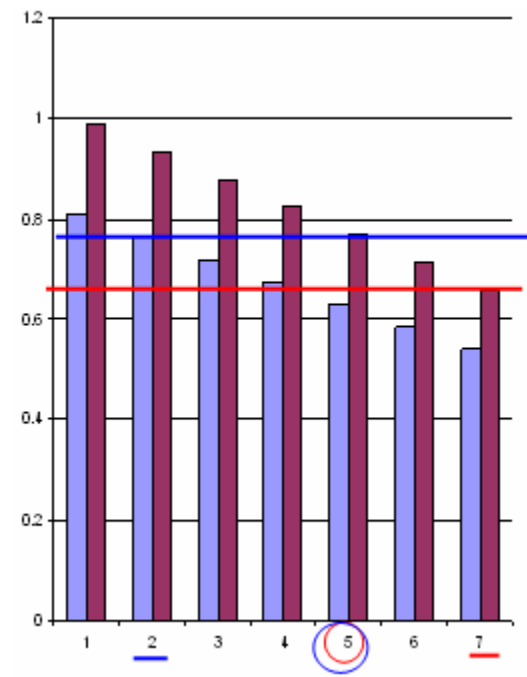
where  $i$  is the capability number. If there is a set of possible scenarios, the ROCs considered importance is produced separately for each scenario and there will be as much prioritization lists as the number of scenarios. The result from the prioritization process is a final ROCs gaps prioritization list, prepared in descending order according to their importance  $I$ .

### 3.7 Final Phase with Illustrative Example

The final phase “Prioritization” begins with defining a percentage  $a\%$  that gives the tolerance from the computed ROC relative gap importance  $I$ . Basically the percentage is taken to be 10%. This tolerance gives the upper and lower bound of the gap importance. For every position in the prioritized list (prepared in the preceding phase) there will exist a ROC group which has overlapping importance from the interval  $[I - a\%; I + a\%]$ . In the final phase one ROC solely must be preferred from the group of possible candidates to take a particular position.

First of all, for each ROC gap importance is calculated the tolerance interval  $[I - 10\%; I + 10\%]$ . Then the lowest possible position of the ROC is obtained after a comparison between its lower and the upper bounds of the next candidate from the list. An **illustrative example** is shown on Fig. 7.

For the samples from Table 2 the possible candidate's positions are given in the last column. Every ROC could be shifted in the frame of the tolerance interval after experts' consensus. For example, the ROC<sub>2</sub> lower bound is 0.765 and is visualized on Figure 7 with blue line. The lowest possible position of ROC<sub>2</sub> could be the 5<sup>th</sup> position (marked as a blue circle on Fig. 7) because there are 5 candidates with upper bounds in the interval  $[0.990 \div 0.765]$ . Graphically it can be obtained, if we look from position 2 (marked with blue dash) to the right until the last possible upper bound in the range over the blue line. The last candidate is ROC<sub>5</sub> with position 5. Thus this is the lowest possible position for ROC<sub>2</sub> in case other ROCs are preferred to it.



**Figure 7. Prioritization list and possible tolerances.**

Analogously, the ROC<sub>7</sub> upper bound is 0.660 and is visualized on Figure 7 with red line. The highest possible position of ROC<sub>7</sub> could be the 5<sup>th</sup> position (marked as a red circle on Fig. 7) since there are 3 candidates with overlapping lower bounds in the interval  $[0.540 \div 0.660]$ . Graphically it can be obtained, if we look from position 5 (marked with red dash) to the left until the last possible lower bound in the range under the red line. This is the ROC<sub>5</sub> lower bound = 0.630. Thus we identify the highest possible position of ROC<sub>7</sub> in case other ROCs are not preferred to it.

**Table 2.**

ROC		ROC importance $I_i$			Possible positions
№	Name	Computed value	Lower bound	Upper bound	
1	ROC <sub>1</sub>	0.90	0.810	0.990	1,2,3,4
2	ROC <sub>2</sub>	0.85	0.765	0.935	1,2,3,4,5
3	ROC <sub>3</sub>	0.80	0.720	0.880	1,2,3,4,5
4	ROC <sub>4</sub>	0.75	0.675	0.825	1,2,3,4,5,6
5	ROC <sub>5</sub>	0.70	0.630	0.770	2,3,4,5,6,7
6	ROC <sub>6</sub>	0.65	0.585	0.715	4,5,6,7
7	ROC <sub>7</sub>	0.60	0.540	0.660	5,6,7

### 3.8 Prioritization Results

The necessary condition for integrating the prioritization process in the framework of the CBP is the prior ROCs list availability. This ROCs list serves as a basis for objective and consistent assessment of the national and international engagements.

The final result of the prioritization process is the “Prioritized List of Required Operational Capabilities Gaps” made by the ROCs Council. The gaps are listed in a descending order according to their relative

value of importance. The list is offered to the Defense Minister for approval and serves as a basis for decision-making on the final ROCs Gaps Prioritization List.

Since the criteria serve as performance measures for the MCA, they need to be operational. A measurement or a judgment needs to specify how well each option meets the objectives expressed by the criteria. The number of criteria should be kept as low as is consistent with making a well-founded decision. In our case the criteria are 3: *capability weight*, *added utility* and *urgency*. For the first criterion a more detailed specification is made. It depends from participation –  $K_{part}$ , risk –  $K_{risk}$ , and correlation –  $K_{corr}$ . Indirectly the scenarios weight also influences the relative value of importance.

In the last phase of the methodology the individual assessments are shared and the opportunity to review and adjust the values is offered to the participants. Essential positive characteristics of the methodology are that it allows checking of the consistency is an essential part of proper scoring and encourages realism and consistency. Our methodology supports the tasks taking place at the decision analysis phase or at the operation and maintenance phase in order to have an explainable, transparent and high-quality prioritization process. That is the reason for capturing the military judgment and improving the BAF by making it more capable and interoperable.

#### 4. RELATED WORK

Classical methods of multi-criteria optimization and determination of priority and utility function were first applied by V. Pareto<sup>3</sup> in 1896. These methods were strongly related to economical theory concerning the averages of thousands of decisions<sup>4</sup>. Methods of MCA were developed in the 1960's to meet the increasing requirements of human society and the environment. In 1980 F. Seo [18] suggested a MCDM method that was concerned with balancing some conflicting objectives in a hierarchical structure. R. L. Keeney and H. Raiffa [10], [12] offered the representation theorems for determining multi-criteria utility functions under preferential and utility independence assumptions. R. L. Keeney [9] outlined the essential features and concepts of decision analysis, formulated axioms and major stages. T. L. Saati [16] showed the global importance of solving problems with conflicting goals by using multi-criteria models and presented decision-making models with incomplete information for solving political and economical problems. In his latest works [17] Saaty analyzed measuring problems in assignments associated with uncertainty conditions and applied the AHP method to solve resource allocation problems. He also analyzed the peculiarities of decision-making based on the AHP method and the necessity to use the eigenvector<sup>5</sup> for priority determination.

Basically, AHP fits our purposes better because it has methodological tools for structuring the decision problem, weighting criteria/goals and alternatives and analyzing judgment consistency. As negative points, it requires a larger number of inputs than other discrete multi-criteria methods. Nevertheless, these inputs can be reduced by optimizing the hierarchy.

In the case of group decision-making, the most extended tool for aggregating the expert judgments is the geometric mean over numeric entries of the paired comparisons  $a_{ij}$  [16]. Sometimes there are a large number of alternatives that need to be assessed. In these cases, the absolute measurement can be applied to rank the alternatives. Here, we apply the AHP method, being considered as one of the main techniques for multi-attributes decision-making problems. It can be used to evaluate an alternative from the set of alternatives characterized in terms of their attributes. It is based on a simple intuitive concept, but it enables a systematic and consistent aggregation of attributes.

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<sup>3</sup> Pareto, V., (1896) Cours d'économie politique professé à l'université de Lausanne, 3 vol., 1896-7.

<sup>4</sup> Pareto, V., (1935), The Mind and Society [Trattato Di Sociologia Generale], Harcourt, Brace.

<sup>5</sup> Saaty T.L., (2003) Decision-making with AHP: why is the principal eigenvector necessary, European Journal of Operational Research, 145, 85-91, 2003.

Resting on fundamental micro-economic and accounting principles, SUCCESS [8] integrates three widely used business management frameworks that underpin many commercial Enterprise Resource Planning 3 applications, together with the PPBS: (1)• Activity-Based Costing, (2)• The Balanced Scorecard, (3)• Total Quality Management. This programming tool considers that all evaluations of criteria are treated as purely quantitative, where ORESTE [8] only allows rankings (qualitative criteria). TOPSIS (Technique for Order Preference by Similarity to an Ideal Solution), known as a classical multi criteria decision method, has been developed by Hwang and Yoon<sup>6</sup>. The basic principle of the TOPSIS is that the chosen alternative should have the "shortest distance" from the positive ideal solution and the "farthest distance" from the negative ideal solution. The TOPSIS introduces two "reference" points, but it does not consider the relative importance of the distances from these points.

## 5. CONCLUSION

The results obtained in solving the prioritization problem reveal that evaluating criteria weights an objective relative importance for each ROC gap is elaborated. Based on it the final prioritization list is produced in descending order. Multi-criteria analysis of capabilities gaps allows for complex evaluation of the criteria from the perspective of their agreement with the needs and technical and financial possibilities. The needs are described in terms of a set of criteria and values, with the importance of the criteria expressed in terms of their significances. ROCs criteria are chosen taking into account the interests and objectives of BAF as the other factors affecting the efficiency of defense tasks accomplishment.

The contribution of the developed methodology is value-added by closing the gap between how the BAF is currently delivering a capability and the extent of this capability required to reach the Level of Ambition from both a quantity and quality perspective. The prioritisation process described in this paper differs from the ACT methodology [1] in supplementary added criteria and the refined functional dependencies that are not limited to the linear mode. For this *gap analysis* the usual MCA step sequence has been tailored to our specific needs. A gap analysis consists of two stages: first, scoring where we are now and where we aim to be, and second, determining how much we care about the gap between our aim and where we are now for each of the ROC gaps.

Our methodology provides much needed content and clarity to a commander's strategic vision. It enhances the quality of information available to decision makers by adding structure to the commander's vision and subsequently decomposing the vision into actionable capabilities. These generated capabilities define the future effects needed for agencies to meet their mission and transform into a more agile and adaptable force.

The prioritization process allows participants to try different judgments without commitment, to see the results, and then to change their views as appropriate. MCA works best and can release the creative potential of participants if the style of decision making allows for consultation and deliberation and the participants are open to change.

Open questions for solving are:

1. When gathering data on each criterion the final result is obtained on the basis of average value from each subject matter expert individual value, or one common value proposed by all subject matter experts on the basis of consensus.
2. What should be the limit of subjectivity used during the final stage of the methodology so that it's influence to be such as not to distort the objective results obtained during the first two stages?

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<sup>6</sup> Hwang, C.L., K. Yoon, (1981) Multiple Attribute Decision Making - Methods and Applications: A State-of-the-Art Survey, Springer-Verlag, New York.

The paper reflects the outcome of the Operational Analysis Department work at the Operations Directorate, Ministry of Defense, which is responsible with the analytical support of the decision-making process by the ROCs Counsel under the Bulgarian Defense Minister.

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