ON CERTAIN METHODOLOGIES OF TECHNOLOGY ASSESSMENT FOR NATIONAL SECURITY

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Abstract. The main topic of the article, as presented in a title, deals with current possible methodologies of technological assessment for national security. It analyses different criteria and options for military equipment and armament selections that are optimizing specific military capability. As it is stressed, the proper methodology is necessary for fulfillment of those many needs and requirements, such as tactical, technical, and others, in contemporary forces specific environments of action. In reality, it is a basic tool for decision-making process in military systems acquisition fulfilling the world standards. Since it is difficult to find a comprehensive literature referring to those issues, considerations presented in the article can be a basis for further discussions on a subject.

1. Introduction

Traditional cost-benefit analyses have been frequently criticized among others because of the difficulties in measuring and determining benefits from application of given technology in national security system.

The asymmetry between relatively simple costs' and complicated benefits' evaluation together with the risk connected with implementing – e.g. expensive technologically advanced system which could never be used – seem to be the main obstacles in justifying expenses on technological support of national security. Different methodologies have been developed with the purpose of supporting decision-makers in comparing and evaluation of particular variants of technological systems. The existing acquisition procedures of armament and military equipment are good examples of constant quest for satisfying solutions.

Selecting armament and military equipment the decision-maker should take into account among others [2]:

- functions it has to carry out;
- structures in which it has to operate;
- features (parameters) it has to have;
- necessary quantities of particular types of armament and military equipment.

Complex acquisition process of armament and military equipment requires analytical tools supporting decision making on particular stages. The acquisition process consists of many activities the purpose of which is making the best possible decision in determined conditions. Choice or designing the appropriate method of acquisition requires reviewing and verifying the existing accessible methods and then adapting them according to the specificity of evaluated weapons system and to the stage of acquisition process in which the decision is being made.

2. Acquisition stages of armament and military equipment

The acquisition process could be divided into four basic stages:

- analyzing and defining threats,
- analyzing and defining capabilities armed forces have to achieve,
- specifying the ways of achieving the defined capabilities,
- selection of armament and military equipment (if the ways of achievement the capabilities are: procurement, research and development or modernization).

The first stage (fig. 1) starts from analysis of the environmental conditions which would affect the national defense system and armed forces. Following conditions should be subjected to the analysis:

- resulting from military alliances,
- political,
- technological,
- economic,
- financial,
- social,
- cultural, etc.

As a result of the carried out analysis the set of threats or scenarios of possible operations in the assumed time horizon should be determined. Selection of the threat (scenario) of high probability (the most real one) could be facilitated through application of one or several of the following methods:

- the method of experts,
- the Delphi method,
- the method of cruciform influences,
- the method of scenarios.

The use of two methods – for instance the method of cruciform influences and the method of scenarios – seems to be most reasonable. The method of cruciform influences in conjunction with the Delphi method is labour-consuming, but can give as a result certain ordered sequence of threats (scenarios) [1]. Final result of this stage is then the ordered set of threats (scenarios) according to the criterion of the highest probability of appearance. It seems important to stress that the problem arises of rejection or not the unreal threats. As the history of last years has proved

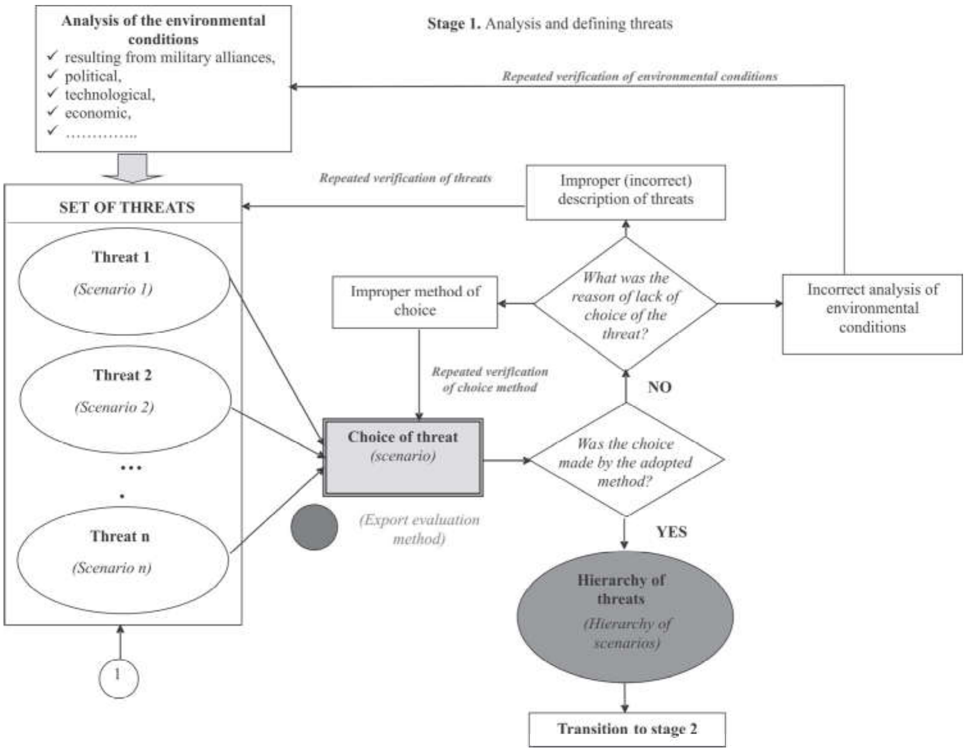

Fig. 1. The stage of analyzing and defining threats (scenarios)

many threats appeared considered before less probable or even unreal and not taken into account in countermeasures planning.

In the second stage (fig. 2) basing on the set of threats or scenarios the set of tasks for national defense system and armed forces is defined.

The list of tasks is then compared with present potential of armed forces and with limitations which could influence building the potential. The result of the comparison is the list of capabilities with full description of every of them. Final result of this stage is definition of the capabilities which are not possible to achieve in the assumed time horizon.

The third stage consists in specifying the ways of achieving defined capabilities (fig. 3). For example the defined capability could be crossing the water obstacles by mechanized units (the basic information on e.g. widths of the obstacles, the speed of water, etc. should be included in the precise description of the capability). The question appears: *how could this capability be achieved?*

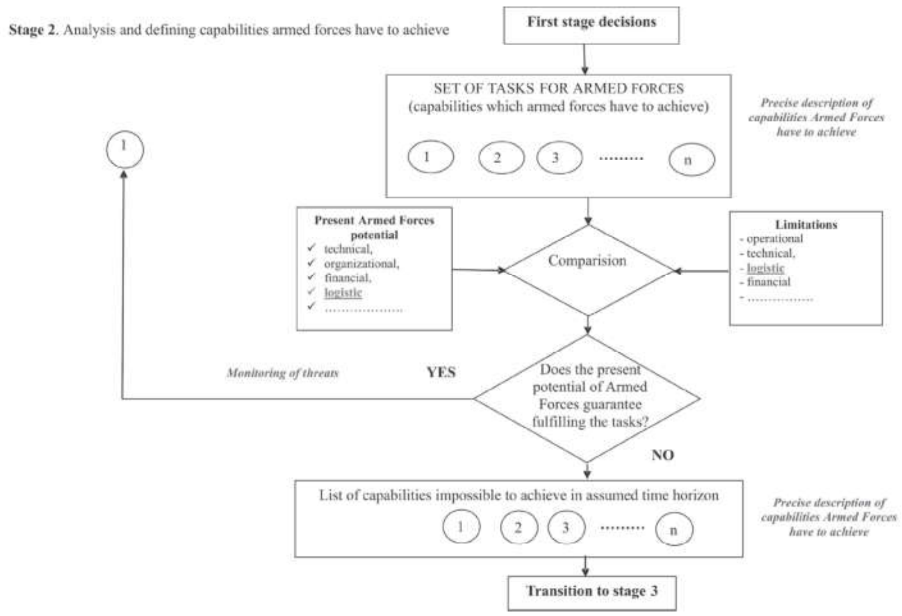

Fig. 2. Stage of analysis and defining the capability requirements

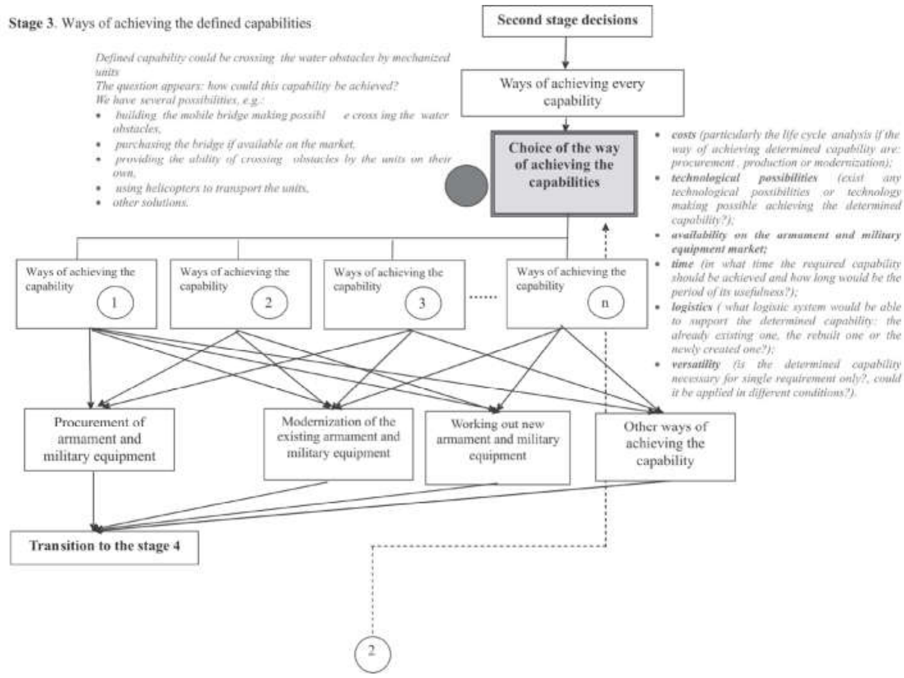

Fig. 3. Ways of achieving the defined capabilities

We have several possibilities, e.g.:
- building the mobile bridge making possible crossing the water obstacles,
- procurement the bridge if available on the market,
- providing the ability of crossing obstacles by the units on their own,
- using helicopters to transport the units,
- other solutions.

The decision-making problem consists in questions: *which variant is the best?*, *which criteria will decide about this and what limitations determine the set of admissible solutions?* To solve the problem the AHP (*Analytic Hierarchical Process*) method could be used as one of the tools of optimization.

The AHP is a multicriteria method supporting the choice of optimum decision. The problem analysis in AHP method consists in three steps:
1. Constructing of the hierarchical model.
2. Comparison and estimation of defined criteria and variants.
3. The choice of the variant with highest indicator of the preference.

Choosing the best way for the decision-maker of applying following criteria:
- **combat ability** (tactical and technical parameters – range, mass, speed, rate of fire, etc.);
- **costs** (particularly the life cycle analysis if the way of achieving determined capability are: procurement, production or modernization);
- **technological possibilities** (technologies making possible achieving the determined capability);
- **availability on the armament and military equipment market**;
- **time** (time horizon the required capability should be achieved and period of its usefulness);
- **logistics** (logistic system able to support the determined capability: the already existing one, the rebuilt one or the newly created one);
- **versatility** (the determined capability necessary for single requirement only or capability which could be applied in different conditions).

Continuing the example of hypothetical capability "crossing water obstacles by mechanized units" – the first step: constructing hierarchical structure of the problem has been presented (fig. 4).

In the presented hierarchical structure 5 criteria have been chosen as a basis to select optimum variant for the Armed Forces. Then we create the matrix of the priority which enables the pairwise comparison of particular criteria.

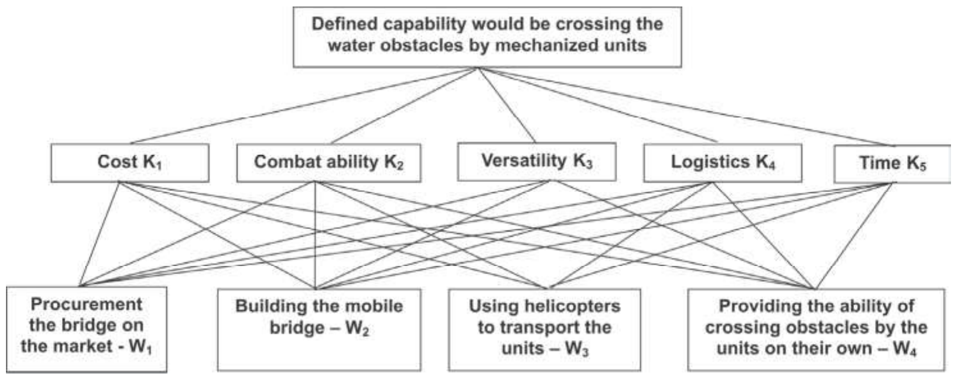

Fig. 4. Hierarchical structure of defined capability

$$A = \begin{vmatrix} 1 & a_{1,2} & \ldots\ldots\ldots & a_{1,j} \\ 1/a_{2,1} & 1 & \ldots\ldots\ldots & 1/a_{2,i} \\ \ldots\ldots & \ldots\ldots & 1 & \ldots\ldots \\ 1/a_{i,1} & a_{i,2} & \ldots\ldots\ldots & 1 \end{vmatrix}, \tag{1}$$

where: $a_{i,j}$ – value of criteria estimation index ($i = j = 1, 2, \ldots, k$); $a_{i,j} = 1/a_{j,i}$ (table 1); k – number of accepted criteria.

Table 1. Values of criteria estimation index

	K_1	K_2	K_3	K_4	K_5
K_1	1	1/3	5	3	5
K_2	3	1	5	3	5
K_3	1/5	1/5	1	1/5	3
K_4	1/3	1/3	5	1	5
K_5	1/5	1/5	1/3	1/5	1

Next step is creation the matrix of preference of particular variants in relation to every criteria (e.g. K_1, K_2, K_3, K_4, K_5).

$$B_{K_i} = \begin{vmatrix} 1 & b_{1,2} & \ldots\ldots\ldots & b_{1,l} \\ 1/b_{2,1} & 1 & \ldots\ldots\ldots & 1/b_{n,2} \\ \ldots\ldots & \ldots\ldots & 1 & \ldots\ldots \\ 1/b_{1,l} & b_{n,2} & \ldots\ldots\ldots & 1 \end{vmatrix}, \tag{2}$$

where: B_{K_i} – matrix of preference of variants in reference to particular criteria i;
$b_{n,l}$ – the values of variant estimation index (n, l = 1, 2,…, m); $b_{n,l} = 1/b_{l,n}$ (tables 2-6);
n – number of variants.

Table 2. Matrix of preference of particular variants in relation to criterion of costs K_1

	W_1	W_2	W_3	W_4
W_1	1	3	5	9
W_2	1/3	1	5	9
W_3	1/5	1/5	1	1/5
W_4	1/9	1/9	5	1

Table 3. Matrix of preference of particular variants in relation to criterion of combat ability K_2

	W_1	W_2	W_3	W_4
W_1	1	3	5	9
W_2	1/3	1	5	9
W_3	1/5	1/5	1	5
W_4	1/9	1/3	1/5	1

Table 4. Matrix of preference of particular variants in relation to criterion of versatility K_3

	W_1	W_2	W_3	W_4
W_1	1	3	3	5
W_2	1/3	1	3	5
W_3	1/3	1/3	1	1/3
W_4	1/5	1/5	3	1

Table 5. Matrix of preference of particular variants in relation to criterion of logistics K_4

	W_1	W_2	W_3	W_4
W_1	1	1/3	1/5	1/5
W_2	3	1	1/5	1/5
W_3	5	5	1/5	1/5
W_4	5	5	5	1

Table 6. Matrix of preference of particular variants in relation to criterion of time K_5

	W_1	W_2	W_3	W_4
W_1	1	3	5	5
W_2	1/3	1	5	5
W_3	1/5	1/5	1	3
W_4	1/5	1/5	1/3	1

Using following functions (3), (4), (5), (6) matrices of values of standardized individual criteria (table 7) and matrices of values of standardized variants in relation to particular criteria (table 8) including ratio weights could be created.

Table 7. Matrices of standardized individual criteria values and their weights

	K_1	K_2	K_3	K_4	K_5
K_1	1	0,33	5	3	5
K_2	3	1	5	3	5
K_3	0,2	0,2	1	0,3	3
K_4	0,33	0,33	5	1	5
K_5	0,2	0,2	0,33	0,2	1
Σ	4,73	2,06	16,33	7,5	19

	K_1	K_2	K_3	K_4	K_5	weight
K_1	0,21	0,16	0,31	0,40	0,26	0,27
K_2	0,63	0,49	0,31	0,40	0,26	0,42
K_3	0,04	0,10	0,06	0,04	0,16	0,08
K_4	0,07	0,16	0,31	0,13	0,26	0,19
K_5	0,04	0,10	0,02	0,03	0,05	0,05
Σ	1	1,00	1,00	1,00	1,00	1,00

$$\overline{a}_{i,j} = \frac{a_{i,j}}{\sum a_j} \text{ for the matrix of criteria priority,} \tag{3}$$

$$\overline{b}_{n,l} = \frac{b_{n,l}}{\sum b_l} \text{ for the matrix of variants,} \tag{4}$$

$$weight_{K_i} = \frac{\overline{a}_{i,j}}{\sum a_i} \text{ for the standardized matrix of criteria priority,} \tag{5}$$

$$weight_{W_i,K_i} = \frac{\overline{b}_{n,l}}{\sum b_l} \text{ for the standardized matrix of variants preference.} \tag{6}$$

Using the following function (7) we calculate indicators of preference for every variants:

$$M_{W_k} = \sum_{k=1}^{m} weight_{W_i,Ki} \bullet weight_{K_i}, \tag{7}$$

$$M_{W_1} = 0,375, \quad M_{W_2} = 0,272, \quad M_{W_3} = 0,11, \quad M_{W_4} = 0,17.$$

The conclusion resulting from the calculated values is that a best way of achieving of defined capability is variant W_1 – **the procurement of the bridge**.

In the next part of this paper the assumption has been made that the result of the carried out analyses is conclusion that the only way of achieving the determined

Table 8. Values of standardized variants in relation to criteria and their weights

	W_1	W_2	W_3	W_4		W_1	W_2	W_3	W_4	weight
W_1	1,00	3,00	5,00	9,00	W_1	0,61	0,70	0,31	0,47	**0,52**
W_2	0,33	1,00	5,00	9,00	W_2	0,20	0,23	0,31	0,47	**0,30**
W_3	0,20	0,20	1,00	0,20	W_3	0,12	0,05	0,06	0,01	**0,06**
W_4	0,11	0,11	5,00	1,00	W_4	0,07	0,03	0,31	0,05	**0,11**
Σ	1,64	4,31	16,00	19,20	Σ	1,00	1,00	1,00	1,00	**1**
	W_1	W_2	W_3	W_4		W_1	W_2	W_3	W_4	weight
W_1	1,00	3,00	5,00	9,00	W_1	0,61	0,66	0,45	0,38	**0,52**
W_2	0,33	1,00	5,00	9,00	W_2	0,20	0,22	0,45	0,38	**0,31**
W_3	0,20	0,20	1,00	5,00	W_3	0,12	0,04	0,09	0,21	**0,12**
W_4	0,11	0,33	0,20	1,00	W_4	0,07	0,07	0,02	0,04	**0,05**
Σ	1,64	4,53	11,20	24,00	Σ	1,00	1,00	1,00	1,00	**1**
	W_1	W_2	W_3	W_4		W_1	W_2	W_3	W_4	weight
W_1	1,00	3,00	3,00	5,00	W_1	0,54	0,66	0,30	0,44	**0,49**
W_2	0,33	1,00	3,00	5,00	W_2	0,18	0,22	0,30	0,44	**0,28**
W_3	0,33	0,33	1,00	0,33	W_3	0,18	0,07	0,10	0,03	**0,09**
W_4	0,20	0,20	3,00	1,00	W_4	0,11	0,04	0,30	0,09	**0,13**
Σ	1,86	4,53	10,00	11,33	Σ	1,00	1,00	1,00	1,00	**1,00**
	W_1	W_2	W_3	W_4		W_1	W_2	W_3	W_4	weight
W_1	1,00	0,33	0,20	0,20	W_1	0,07	0,03	0,04	0,13	**0,07**
W_2	3,00	1,00	0,20	0,20	W_2	0,21	0,09	0,04	0,13	**0,12**
W_3	5,00	5,00	0,20	0,20	W_3	0,36	0,44	0,04	0,13	**0,24**
W_4	5,00	5,00	5,00	1,00	W_4	0,36	0,44	0,89	0,63	**0,58**
Σ	14,00	11,33	5,60	1,60	Σ	1,00	1,00	1,00	1,00	**1,00**
	W_1	W_2	W_3	W_4		W_1	W_2	W_3	W_4	weight
W_1	1,00	3,00	5,00	5,00	W_1	0,58	0,68	0,45	0,36	**0,52**
W_2	0,33	1,00	5,00	5,00	W_2	0,19	0,23	0,45	0,36	**0,31**
W_3	0,20	0,20	1,00	3,00	W_3	0,12	0,05	0,09	0,21	**0,12**
W_4	0,20	0,20	0,20	1,00	W_4	0,12	0,05	0,02	0,07	**0,06**
Σ	1,73	4,40	11,20	14,00	Σ	1,00	1,00	1,00	1,00	**1,00**

capability is procurement a new armament or military equipment. In such case the next step is specifying expected (or standard) parameters of the armament and military equipment and then analyzing the market of potential producers and suppliers which would be able to meet the requirements of the parameters. This appears the final result of the stage 3.

The fourth stage seems to be the most extended part of acquisition process connected with the selection of armament and military equipment (fig. 5). As a result of this stage the final choice is carried out which enables achievement of the determined capability and subsequently the possibility of national defense system and armed forces to respond the previously specified threats.

An important element of this stage is analysis of parameters characterizing the armament and military equipment (fig. 6). Following characteristics should be the subject of the analysis:

– tactical and technical parameters (e.g. the range, the mass, the speed, etc.);

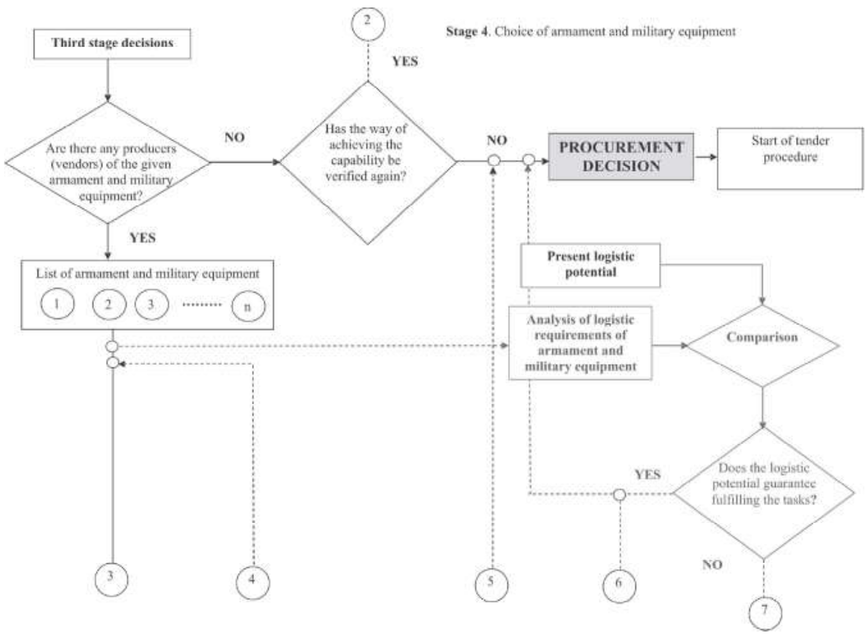

Fig. 5. Beginning the stage of choice of a system

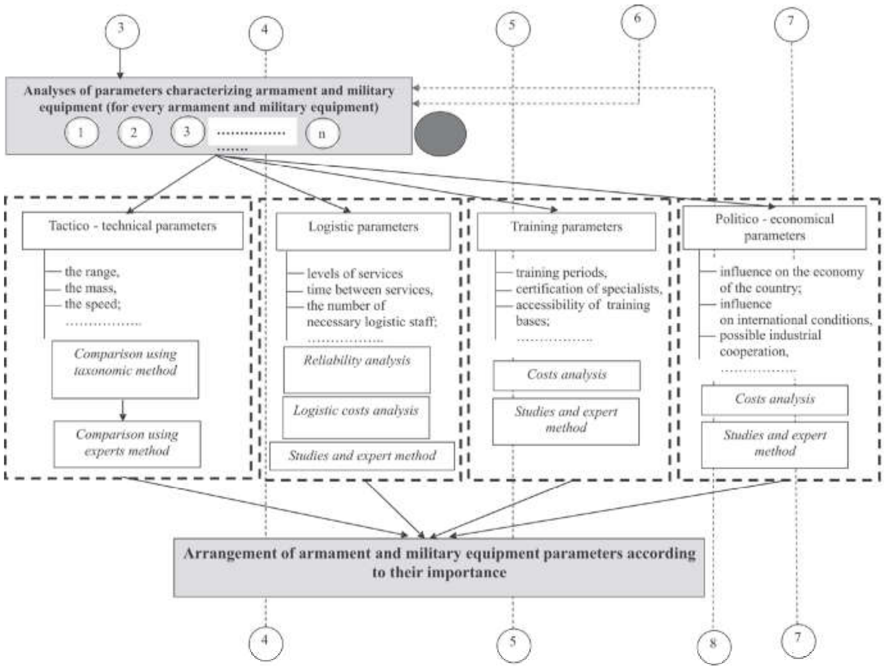

Fig. 6. Analysis of armament and military equipment characteristics

- logistic parameters (e.g. levels of services, time between services, volumes of supplies connected with the wearing of system components, the number of necessary logistic staff etc.);
- economic and political parameters (e.g. influence on the economy of the country, influence on international conditions, possible industrial cooperation, etc.);
- training (e.g. training periods, accessibility of training bases, certification of specialists, etc.).

In analysis of every of the presented group of characteristics different research methods could be used both qualitative and quantitative. For example to asses the tactical-technical characteristics we can use the taxonomic method. This method makes possible comparisons of basic characteristics of analyzed armament and military equipment (or group) with expected characteristics (or standards) and on this basis the best armament and military equipment could be defined.

In the example explaining the third stage the best way of achieving the defined capability: "crossing water obstacles" has been procurement of new bridge. The analysis of modern solutions, concepts and prototypes has shown that two systems of modern bridges are presently preferred [3]:

- the folding system (the possibility of overcoming vertical obstacles e.g. pipelines, etc.);
- the sliding system (providing of the short profile during the arrangement on the obstacle).

The taxonomic method facilitates the choice of best type and structure the bridge. This method is particularity useful when features of the system are difficult to measure or sizes characterizing the system are measured in different units. The methods base is the assumption on the additivity which means that the global value of the object could be calculated as the sum of partial values.

The result of application the taxonomic method has been the choice of bridge, which adjustment to the anticipated tasks could be defined by following parameters: spread of bay, maximum speed of moving on the roads, the time of assembling of the bay, mass of the bridge (table 9).

Table 9. Values of features of evaluated mobile assault bridges

The feature – *i* Type of the bridge – *n*	Spread of the bay [m]	Maximum speed of moving on the roads [kph]	Time of assembling of the bay [min]	Mass of the bridge [mg]
Folding-bridge on the wheeled chassis CNIM PAR 70	19,5	80	6	35
Folding-bridge on the chassis with caterpillar BR 90	26	60	3	60,5

table 9 – continuation

Sliding bridge on the caterpillar chassis WHAB	26	72,4	5	68,7
Sliding bridge on the wheeled chassis PTA 10x10 LEGUAN	27	100	10	53

It results from the presented table that the spread of bay and the maximum speed of moving on the roads are stimulants – i.e. parameters for which high values are required, whilst the time of assembling of the bay and the mass of the bridge are destimulants – i.e. parameters of required lower values. In order to introduce the homogeneity of measures of particular features the standardization has been done according to the function:

$$\tilde{C}_{in} = \frac{C_{in} - C_i}{S_i} \quad \text{for } i = 1, 2, ..., \mathrm{I}; \ \text{for } n = 1, 2, \ldots, \mathrm{N}, \tag{8}$$

where: I – the number of features accepted to the estimation of bridges;
N – the number of evaluated bridges;
$\tilde{C}_{in}$ – standardized value of the feature number i for bridge number n;
C_{in} – the value of feature number i of bridge number n;
C_i – the expected value of feature number i:

$$C_i = \frac{1}{N}\sum_{n=1}^{N} C_{in}, \tag{9}$$

S_i – the standard deviation of feature number i:

$$S_i = \sqrt{\frac{1}{N}\sum_{n=1}^{N}\left(C_{in} - C_i\right)^2}. \tag{10}$$

According to the above-dependences standardized values of particular features of evaluated bridges are placed in the table 10 (lines 1-4).

Table 10. Standardized values of features of mobile assault bridges

Lp.	[n] \ [i]	1	2	3	4
1	1	–1,716	0,131	0	–1,550
2	2	0,460	–1,247	–1,177	0,498
3	3	0,460	–0,393	–0,392	1,157
4	4	0,795	1,508	1,569	–0,104
5	Standard solution – M_w	0,795	1,508	–1,177	–1,550

Next step is the choice of the so called standard solution M_w, i.e. the abstract object formed by the list of best values of features (C_{0i}) from the list of all the features of bridges (values for the standard-bridge are placed in the last line of the table 10).

$$C_{0i} = \begin{cases} \min \tilde{C}_{in}, & if \quad C_{in} \text{ is destimulant} \\ \max \tilde{C}_{in}, & if \quad C_{in} \text{ is stimulant.} \end{cases} \tag{11}$$

Then the dispersions between standardized values of features and standard features are calculated according to the function:

$$\delta_{ni} = \left(C_{0i} - \tilde{C}_{ni}\right)^2 \quad \text{for } i = 1, 2,..., I;\ n = 1, 2,..., N. \tag{12}$$

Next step is calculation of the "distance" between the values of the features of considered bridges and the ones of standard-solution according to the function:

$$d_{on} = \sqrt{\sum_{i}^{I} \alpha_i * \delta_{ni}}, \tag{13}$$

where α_i – the coefficient of weight for the feature number i (equal weights = 1 have been accepted).
Values of the "distance" calculated for particular bridges are:

$$d_{01} = 3{,}096;\ d_{02} = 3{,}449;\ d_{03} = 3{,}416;\ d_{04} = 3{,}103.$$

The taxonomic method permits also to calculate the global estimate of the mobile assault bridges – related to the interval [0; 1]. The expected value and the variance of "distance" is calculated according to the function:

$$\overline{d}_0 = \frac{1}{N}\sum_{n=1}^{N} d_{0n}, \tag{14}$$

$$D_0^2 = \frac{1}{N}\sum_{n=1}^{N}\left(d_{0n} - \overline{d}_0\right)^2. \tag{15}$$

Then the final values are calculated according to the function:

$$d_0^* = \overline{d}_0 + 3\sqrt{D_0^2}. \tag{16}$$

For the considered case these values are:

$$\overline{d}_0 = 3,266;\ D_0^2 = 0,028;\ d_0 = 3,767.$$

The global estimate of the bridge is calculated according to the function:

$$\chi_n = 1 - \frac{d_{0n}}{d_0^*}. \tag{17}$$

These are:

$$\chi_1 = 0{,}178; \quad \chi_2 = 0{,}084; \quad \chi_3 = 0{,}093; \quad \chi_4 = 0{,}176.$$

The result of the analysis is that the highest estimate has been attributed to the sliding bridge on the wheeled chassis.

The method of experts could be the supplement of the described above method which could confirm the choice of the best solution (but only in the area of tactical-technical characteristics) [3, 8].

After the choice of type of bridge as a result of the applied taxonomic method next step could be an attempt of the exact estimation of different variants using the method of experts. It is based on the experience of persons evaluating the military equipment (in this case the mobile assault bridges). The accessible source-information on the evaluated equipment and the professional knowledge of experts are important. Important elements of the method are: definition of evaluation factors and establishing preferences of weights applied in estimation of variants of the mobile bridge. Essence of the method consists in exchange of different ideas and experiences of experts and on making the list of possible estimations and then verification of their reality and practical usefulness by the producer of the estimation activity.

In application of expert method to the choice of the variant of the bridge following criteria have been accepted:

- performance characteristics:
  - traction (road and field mobility, the access to the site of assembling or disassembling of the bay) requirements – [w_1];
  - tactical (carrying capacity of the bay, spread, width, time of assembling, possibility of train and air transportation) requirements – [w_2];
  - durability, reliability and servicing facility (maintainability) – [w_3];
- possibilities and limitations of prototype:
  - necessary time of building – [w_4];
  - cost of the prototype – [w_5].

Thus five factors (w_1-w_5) have been obtained through comparative estimation which makes possible the choice of variant of the bridge. The four-degree scale of estimates has been assumed:

2 – the factor does not fulfill expectations,
3 – the factor fulfills it expectation on minimum level,
4 – the factor fulfills most of expectations,
5 – the factor fulfills all expectations.

The final estimation was calculated basing on the function:

$$O_j = \frac{\sum_{i=1}^{5} p_i w_{ij}}{5}, \tag{18}$$

where: O_j – the final estimate for j variant ($1 \le j \le 6$);
$w_{i,j}$ – the estimate of factor i for variant j;
p_i – weight coefficient for factor I assumed: $0{,}5 \le p_i \le 2$ and $\sum_{i=1}^{5} p_i = 5$.

Following variants of the bridge have been accepted basing on analyses of world solutions:

- slide bay I (slided forward) – transported on the multiaxial vehicle, consisting of two semibays of united with each other;
- folding bay transported on the multiaxial vehicle – with bridge-layers manipulator in back part of the vehicle;
- slide bay I (slided backward), transported on the semitrailer;
- folding bay transported on the semitrailer with bridge-layers manipulator in the back semitrailer;
- slide bay II (slided forward), consisting of two bys transported on the multiaxial vehicle;
- slide bay II (slided backward) as above, transported on the semitrailer.

The averaged estimations are presented in the table 11. Deserves attention comparatively low estimates for traction characteristics, which suggests to turn careful attention on this when working out the chosen solution. In the last column of the table there are final estimates O_j for particular variants assuming that all weights $p_i = 1$. For such case the highest estimate receives the variant No. 4 (the folding bay installed on semitrailer). It is important however to notice, that no variant received the final estimation 4 – meaning fulfillment of the most of the expectations.

Table 11. Averaged results of estimates for particular variants and the final estimation for $p_j = 1$

Lp. (j)	Variant	Useful feature			Characteristics of working out prototype		Final estimation O_j
		W_1	W_2	W_3	W_4	W_5	
1	Special vehicle with folding bay	3,2	3,2	4,5	3,2	3,0	3,42
2	Special vehicle with slide bay I	3,2	3,9	3,5	3,1	2,5	3,24
3	Tractor with the semitrailer and slide bay I	3,37	3,8	3,7	3,4	3,0	3,455
4	Tractor with the semitrailer and folding bay	3,37	3,2	4,3	4,2	4,5	3,915

table 11 – continuation

5	Special vehicle with slide bay II	3,2	4,6	3,4	3,0	2,0	3,24
6	Tractor with the semitrailer and the slide bay II	3,2	4,5	3,4	3,2	3,0	3,46

In following tables (12-13) results for different weights p_i have been presented. In the table 12 final estimations have been presented assuming following weight coefficients: $p_1 = 1$; $p_2 = 2$; $p_3 = 1$; $p_4 = 0{,}5$; $p_5 = 0{,}5$. Using such coefficients p_i the tactical – technical values are stressed. In the table 13 the estimations for the following set of weights: $p_1 = 1{,}3$; $p_2 = 0{,}8$; $p_3 = 1{,}3$; $p_4 = 1$; $p_5 = 0{,}6$ have been presented. This set of weight – coefficients prefers the variant which would be able to be quickly implemented for the needs of peace time operations, such as:

- disaster relief and terrorists attacks;
- the training of forces and support of exercises for the NATO units.

Table 12. Averaged results of estimates for particular variants and the final estimation for: $p_1 = 1$; $p_2 = 2$; $p_3 = 1$; $p_4 = 0{,}5$; $p_5 = 0{,}5$

Lp. (j)	Variant	Useful feature			Characteristics of working out prototype		Final estimation O_j
		$P_1 * W_1$	$P_2 * W_2$	$P_3 * W_3$	$P_4 * W_4$	$P_5 * W_5$	
1	Special vehicle with folding bay	3,2	6,4	4,5	1,6	1,5	3,44
2	Special vehicle with slide bay I	3,2	7,8	3,5	1,55	1,25	3,46
3	Tractor with the semitrailer and slide bay I	3,37	7,6	3,7	1,7	1,5	3,575
4	Tractor with the semitrailer and folding bay	3,37	6,4	4,3	2,1	2,25	3,685
5	Special vehicle with slide bay II	3,2	9,2	3,4	1,5	1,0	3,66
6	Tractor with the semitrailer and the slide bay II	3,2	9	3,4	1,6	1,5	3,74

Table 13. Averaged results of estimates for particular variants and the final estimation for: $p_1 = 1{,}3$; $p_2 = 0{,}8$; $p_3 = 1{,}3$; $p_4 = 1$; $p_5 = 0{,}6$

Lp. (*j*)	Variant	Useful feature			Characteristics of working out prototype		Final estimation O_j
		$P_1 * W_1$	$P_2 * W_2$	$P_3 * W_3$	$P_4 * W_4$	$P_5 * W_5$	
1	Special vehicle with folding bay	4,16	2,56	5,85	3,2	1,8	3,514
2	Special vehicle with slide bay I	4,16	3,12	4,55	3,1	1,5	3,286
3	Tractor with the semitrailer and slide bay I	4,387	3,04	4,81	3,4	1,8	3,487
4	Tractor with the semitrailer and folding bay	4,387	2,56	5,59	4,2	2,7	3,889
5	Special vehicle with slide bay II	4,16	3,68	4,42	3	1,2	3,292
6	Tractor with the semitrailer and the slide bay II	4,16	3,6	4,42	3,2	1,8	3,436

In the table 14 averaged final estimates have been presented for individual weights p_i as well as the final estimate and the ranking of variants.

Table 14. The averaged final estimate

Lp. (*j*)	Variant	Indirect estimates			Final estimate
		O_1	O_2	O_3	
1	Special vehicle with folding bay	3,915	3,685	3,887	3,829
2	Special vehicle with slide bay I	3,46	3,74	3,436	3,545
3	Tractor with the semitrailer and the span advanced I	3,455	3,575	3,487	3,506
4	Tractor with the semitrailer and slide bay I	3,42	3,44	3,514	3,458
5	Special vehicle with slide bay II	3,24	3,66	3,292	3,397
6	Tractor with the semitrailer and the slide bay II	3,24	3,46	3,286	3,329

The accomplished analysis, based on the proposed method of experts – enables on the objective estimation of every variant of the bridge and the choice of optimum solution. The carried out additional analysis indicates that the variant the "folding bay transported on the semitrailer" from the user's needs point of view and also from the point of views of executive possibilities is the optimum one and consequently it could be recommended for decision-maker.

The presented methodology can be also applied to other types of the armament and military equipment.

In such way we could also make analyses and comparisons of the remaining groups of characteristics for the considered armament and military equipment using of coarse the adequate research methods for the given group of characteristics. Then the groups of characteristics should be ordered according to the weights of importance (fig. 7). The purpose of analyses and arrangements of parameters is not only the choice of armament and military equipment but also choice of the producer or supplier which offers the best conditions of the contract [8]. This is particularly significant when economic-political characteristics are the most important ones.

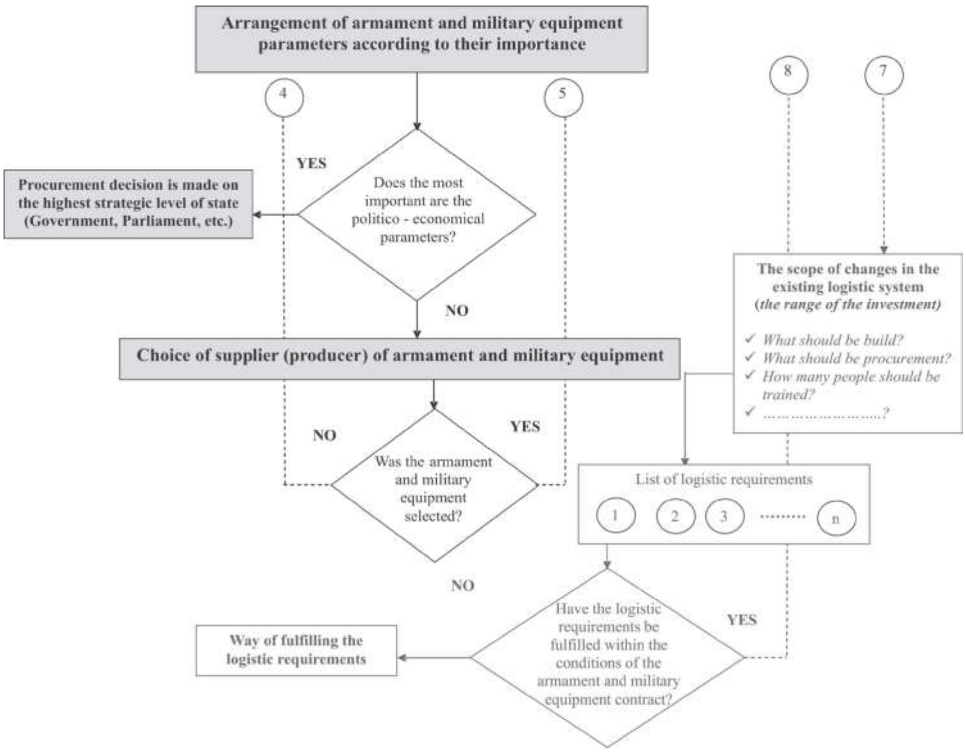

Fig. 7. Choice of supplier or producer of the armament and military equipment

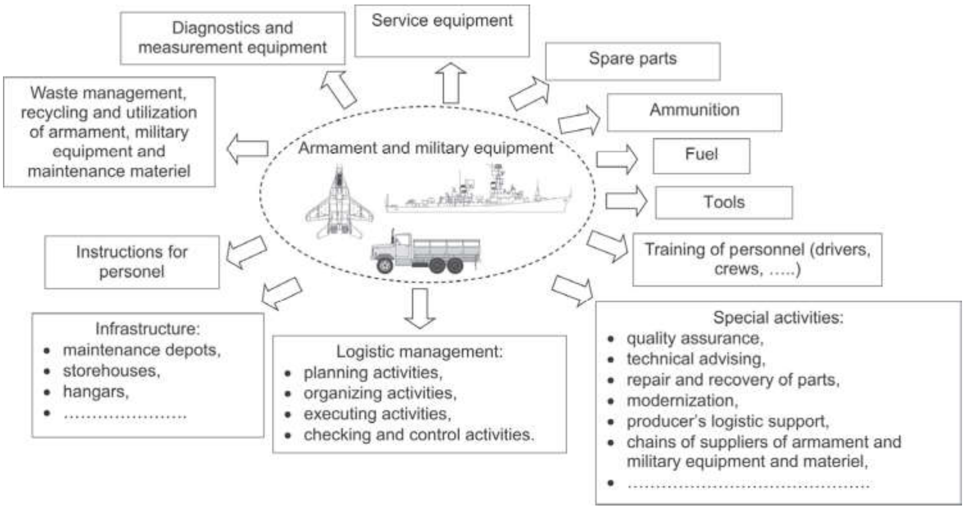

Fig. 8. Logistic requirements of armament and military equipment

In this case the decision on signing the contract and procurement of the armament and military equipment is made in general by the highest authorities of the state (Government, Parliament, etc.).

The result of the choice strongly influences the requirements for logistic system [9]. One should remember that most of armament and military equipment are technical devices or technical systems with determined principles and needs for maintenance, servicing, supply, storage etc. Those are often very specific technical requirements not fulfilling of which could make the devices useless. Generally the requirements of armament and military equipment system could be divided into operational and logistic groups. The first is connected with possible variants of usage of the armament and military equipment on the battlefield, the second – with the ability of accomplishing the task and maintaining the armament and military equipment in the state of readiness.

The intensity of using the armament and military equipment and operations in which the system is employed could influence changes of the demand for logistic resources. This concerns e.g.: number of services, number of delivered resources of materiel and number of logistic personnel [4, 5, 6]. Logistic requirements of armament and military equipment have been presented in figure 8. Logistic requirements of armament and military equipment strongly influence the size, structure and principles of functioning of its logistic system. It is connected with the continuous changes of the system status and needs resulting from the influence of many factors. These changes may be deliberate and precisely defined but may also occur in stochastic ways [9].

This implies the necessity of preplanning, storage and maintaining of adequate supplies. Therefore important is the possession of information on real requirements of supplies and possible size of consumption. Information on the logistic requirements of analyzed armament and military equipment should be compared with the already existing potential of the logistic system (fig. 5).

The result of the comparison would be the list of requirements which the logistic system should fulfill to achieve the capability of initiating and maintaining the armament and military equipment.

Often fulfilling at least the part of the requirements by the supplier or producer is possible but it should be earlier precisely defined and included in the contract.

3. Outline method of optimization the logistic system's contribution to weapons system combat capability

This method has been presented for the first time in [5]. The following three general assumptions are essential for the method:

1. Logistic potential is one of the fundamental components of combat capability. It enables functioning of forces during the peacetime and war and determines necessary material and energy flows for particular elements of forces structure (for particular weapons systems) as well as furnishing logistic services for them.
2. Quantitative evaluation of both combat capability and logistic potential is possible as well as the level (percentage) of logistic potential's contribution to the combat capability.
3. The estimation of the required and the already existing logistic potential does not change the fact that the value of the first one may be a random value which may occur different from the estimated one.

In optimization of the logistic potential contribution to combat capability – the quantitative evaluations of deficiency and surplus of the logistic potential would be necessary.

Within the simple additive approach to the calculations (the value of combat capability is the direct sum or weighted sum of its component potentials' values) the optimization criterion could be the following function evaluating the results of non-balanced requirements and capabilities (19).

$$F(x) = |r - ax| P(r)[k \frac{1 - \operatorname{sgn}(r - ax)}{2} + \frac{1}{w} \frac{1 + \operatorname{sgn}(r - ax)}{2}], \tag{19}$$

where: a – the value of combat capability;
x – optimized contribution (percentage) of the logistic potential to a;

r – required value of participation (percentage) of the logistic potential in a, which may occur with probability $P(r)$;
k, l – the proportionality coefficients relatively for surplus and deficiency of the logistic potential;
w – the equivalency coefficient of the non-logistic and logistic potentials.

The function (1) fulfills following structural assumptions:

1) The value of the function increases proportionally to the increases of surplus and deficiency of the logistic potential.
2) The proportionality coefficients in the case of surplus k and in the case of deficiency l should differ it means: the function $F(x)$ should differentiate the "weights" of surplus and deficiency.
3) The value of the function equals zero in the case of balancing requirements and possibilities of the logistic system.
4) The value of the function changes proportionally to $P(r)$ – the probability of occurring the requirement r (in the case, when r is discrete random value) or proportionally to the density $\varphi(r)$, when r is continuous random variable.
5) The proportionality coefficient l (in the case of deficiency) is "weighed" by the coefficient w, which expresses the equivalence of non-logistic and logistic potential (e.g. what amount of the logistic potential is equivalent to one unit of measure of non-logistic potential).

Let x_{min}, x_{max} denote the limitations imposed on the lowest and the highest admissible participation of the logistic potential in combat capability. The optimization problem would consist in finding the optimum value x^* of participation (percentage) of logistic potential in combat capability which minimizes the criterion – function $F(x)$ in the interval $[x_{min}, x_{max}]$.

One of the fundamental problems in calculating the logistic potential is distinguishing its components and building the mathematical model which reflects the way the components form the entity. The essence of the model consists in:

- construction of the function (or functional) the arguments of which are particular components of the logistic potential,
- the method of standardization the components in order to eliminate the influence of different units of measure (transforming the absolute values of the components into the relative ones),
- the determined measures of particular components,
- the method of determining the weights of particular components.

The components of the logistic potential constitute certain hierarchical arrangement – there are groups of components, subgroups etc. For instance on the top level one may distinguish: human potential, materiel potential, technical potential, organizational potential, logistics management command and control potential. On the lowest level the group of components of e.g. materiel potential may be divided into the subgroups according to the classes of supply, whilst the group of the components of human potential – into the subgroups of particular categories of logistic specialists etc.

Construction of the synthetic index L of the logistic potential should express the influence of particular components, It could be defined as following function or functional (20):

$$L = f\,(H, M, T, O, C), \tag{20}$$

where: H – human potential,
M – materiel potential,
T – technical potential,
O – organizational potential,
C – logistic management, command and control potential.

The component potentials: H, M, T, O, C should be calculated according to the standardized taxonomical formulae. The arguments of the formulae should be the lowest level components of particular potentials H, M, T, O, C with weight coefficients reflecting the role of the given component in shaping the higher level potential. The lower level components of H, M, T, O, C could be distinguished according to the fundamental logistic functions (supply, maintenance and repair, services, movement and transportation, medical support, infrastructure), related both to territorial and organic aspects of military logistics [5, 7].

4. Conclusions

In the paper methodology proposals of conducting analyses facilitating decision making on particular stages of armament and military equipment selection and – in effect – choice of the optimum multicriterial solutions have been presented. Presented analysis makes possible with the objective estimation of chosen variants and the choice of optimum solution of armament and military equipment for the fulfillment of many criteria, eg. tactical-technical requirements. The methodology made the important tool in the decision-making about acquisition of military systems fulfilling world standards.

It is difficult to find in literature comprehensive studies in this area. Presented considerations could be the basis only for further discussions and in effect working out tools facilitating decision making in acquisition processes. One of the tools could be the outlined method of optimization the logistic system contribution to weapons system combat capability. The role of the logistic potential in combat capability should be precisely defined qualitatively and determined quantitatively. The quantitative representation of the potential is particularly important for diagnostic, decision making and planning purposes. Calculating logistic potential needs working out mathematical models representing the inner structure of the potential itself and its components as well as their relations with environment. The assumptions should be also precisely determined placing the potential within the national and alliance logistic systems capabilities. In solving the optimization problem of finding the optimum participation of logistic potential in combat capability the criterion function evaluating the balance of requirements and possibilities should be adopted. The limitations imposed on the lowest and the highest admissible participation could represent relatively the financial and operational views of the decision-makers.

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Streszczenie. Głównym tematem artykułu jest problematyka wyboru metodologii oceny technologicznych rozwiązań dla bezpieczeństwa narodowego. Przeanalizowane zostały kryteria i opcje wyboru broni i uzbrojenia w celu optymalizacji potencjału militarnego. Wybór odpowiedniej metodologii jest niezbędny dla spełnienia wymagań wojskowych związanych z taktyką, technologią oraz innymi potrzebami współczesnych wojsk w różnorodnych działaniach. Metodologia jest podstawowym narzędziem w procesie decyzyjnym wyboru systemów wojskowych odpowiadających standardom światowym. Ze względu na brak literatury przedmiotu przedstawione rozważania mogłyby być podstawą dalszej dyskusji nad zagadnieniem.