При формуванні тактико-технічного завдання на створення зразка озброєння розглядаються не тільки його характеристики за призначенням, а й експлуатаційно-технічні, технологічні, економічні та інші характеристики. Сукупність характеристик визначає військово-технічний рівень зразка озброєння. Звичайно розглядаються варіанти зразка озброєння, які відрізняються сукупністю характеристик. Для порівняльного оцінювання варіантів зразка озброєння за військово-технічним рівнем необхідно застосовувати відповідні методичні положення.

Вирішення завдання – порівняльного оцінювання варіантів зразка озброєння – стало можливим шляхом послідовного вирішення чотирьох задач.

При вирішенні першої задачі здійснена декомпозиція сукупності характеристик зразка озброєння на три рівні: властивості, складові властивостей, показники. Науковим результатом першої задачі є методичний підхід до порівняльного оцінювання варіантів зразка озброєння на підставі урахування важливостей характеристик при ранжируванні варіантів зразка озброєння з використанням методу багатокритеріального аналізу.

При вирішенні другої задачі отримано порядок поетапного експертного оцінювання коефіцієнтів важливостей властивостей, складових властивостей, показників з використанням методу парних порівнянь, що дозволяє урахувати їх вплив на військово-технічний рівень зразка озброєння.

Результатом вирішення третьої задачі дослідження є алгоритм порівняльного оцінювання варіантів зразка озброєння з використанням методу таксономії. Наведений алгоритм дозволяє ранжирувати варіанти зразка озброєння з урахуванням важливості показників, які визначають їх військово-технічний рівень.

Проведення декомпозиції характеристик, застосування методу парних порівнянь для експертного оцінювання їх важливості, методу таксономії дозволило отримати цілісну методику порівняльного оцінювання варіантів зразка озброєння за військово-технічним рівнем.

При вирішенні четвертої задачі дослідження розглянуто порядок застосування розробленої методики на прикладі порівняльного оцінювання військово-технічного рівня варіантів зенітної ракетної системи.

Методика може застосовуватися при обґрунтуванні тактико-технічного завдання на розробку зразків озброєння

Ключові слова: зразок озброєння, військово-технічний рівень, парне порівнювання, метод таксономії, методика порівняльного оцінювання

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DEVISING METHODOLOGICAL PROVISIONS FOR THE COMPARATIVE EVALUATION OF VARIANTS FOR AN ARMAMENT SAMPLE IN TERMS OF MILITARY-TECHNICAL LEVEL

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1. Introduction

Equipping the army with modern weapons is a priority for any country. To replace outdated designs that have exhausted the set resource, more modern means of military activities are used. In this case, the army can be armed by:

– own development and own production of armament;
– armament production by license;
– armament production in cooperation with other countries;
– procurement of weapons.

It is obvious that equipping armed forces with new modern weapons of world quality in sufficient quantities is the primary task of any country. And the developed capacity of a military-industrial complex to provide its own forces with the main types of modern weapons is one of the defining conditions for ensuring independence in the field of security and defense.

It is known that the construction of new armament samples begins with the substantiation of their outline and the development of a tactical-technical task (TTT).

In this case, a certain number of variants for an armament sample is typically considered, which could vary by the structure of design, operational principles, parameters, and so on. When making a decision on designing an armament sample, it is required to choose the rational (best) option based on the results of comparing (ranking) these variants in terms of their military-technical level. Comparison of an armament sample variants employs the indicators that characterize: its possibility to be applied as intended; the cost of development, production, and operation; technological features; compliance with the world level quality, etc.

In practice, it is quite difficult to choose an accepTable variant of the sample considering all the indicators or at least most of them. In this case, the task on comparing the variants of an armament sample in terms of the military-technical level becomes multi-criterial, which requires the development of appropriate methodological provisions.

The requirement to take into consideration many different factors, their significance during comparative estimation of an armament sample variants when making a decision about its construction under conditions of limited resources has defined the practical importance and relevance of the current work.

2. Literature review and problem statement

Typically, armament samples are compared taking into consideration those characteristics that define their application as intended. Thus, only a certain set of tactical-technical characteristics of the specified military objects (mass, dimensions, speed, load capacity, etc.) is taken into consideration in paper [1].

Article [2] describes a procedure for defining the criterion of comparison of efficiency of fire-destruction complexes, which is based on the calculation of the required outfits of firing equipment on the assigned set of targets. In this case, the procedure considers only the probabilities of damage to the complexes of objects based on which the necessary outfits of firing means are determined. The issue on the comprehensive comparison of complexes of fire destruction was not considered.

The methodology of comparative assessment of military formations that considers combat potentials of the means of armed struggle has been proposed in [3]. The influence of the means of support and management on combat potentials of military formations is considered. However, the influence of tactic-technical characteristics (TTC) of means of armed struggle on their combat potentials was not investigated. Therefore, the procedure cannot be used in principle to assess the military-technical level of armament samples.

Paper [4] made an attempt to carry out a comprehensive comparative assessment of both the groups of troops and the samples of weapons and military equipment using a capabilities-based defense planning procedure. For this purpose, the authors proposed one of the methods of regression analysis (a combinatorial method with the limited base of arguments). However, the disadvantage of this approach is the uncontrolled results from calculations, which is very important for understanding cause and effect relations.

When improving or designing new means of armed struggle, study [5] proposed defining the TTC for promising means by methods of extrapolation based on existing means. With this approach, the task is to obtain a functional dependence of the combat potential of a means of armed struggle on relevant TTC. A given problem belongs to the class of extrapolation (interpolation) multidimensional problems. One way to build such a functional dependence is the application of the method of undefined coefficients. The presence of the functional dependence of the combat potential of an armament sample on TTC makes it possible to compare different variants of this sample. However, to build such a dependence, it is necessary to have relevant statistical data based on test results, which is problematic under conditions of resource constraints.

In work [6], comparison of armament samples is carried out based on the ratio of mathematical expectations for the number of weapons at opposing parties at the time of battle, which are determined using the method of dynamics of average (Lanchester equations). In this case, only the intensity of damaging shots flow from armament samples of different types is considered.

The expert method of multi-criteria analysis for the priority choice of systems is considered in work [7]. Comparison of systems is carried out according to the base system. Experts determine the ratings of functions that must be performed by systems, the comparison coefficients to the base system, the coefficient of indicators' significance. The system priority estimation is carried out based on the maximum amount of products of the ratings of functions by the amounts of products of comparison coefficients to the base system by the significance coefficients for indicators. That is, an additive convolution of indicators is used, which is not quite correct when comparing systems or armament samples. In addition, the work does not define what is meant by the base system; the approaches to evaluating the significance of indicators were not considered.

One of the methods for multi-criteria analysis of alternatives is the method MOORA [8]. Analysis of alternatives is carried out in two stages: at the first stage, using the additive convolution of normalized indicators, at the second – based on the distance to a reference point. A prerequisite for the limited practical use of the MOORA method is the lack of a justification for the normalization of natural values for indicators, as well as the lack of a formal mechanism for combining the obtained priority series in order to determine the best alternative [9].

Paper [10] improves the use of the MOORA method (MULTI MOORA), taking into consideration the fuzzy output data. The application of this method for personnel screening was considered. For the case of comparing an armament sample's variants based on the tactical-technical characteristics, using this method is inappropriate.

A comprehensive method for comparing alternatives is suggested in study [11]. The method is based on the use of MACBETH method to determine the weights of criteria and EDAS method for ranking alternatives. The weights of criteria are determined using linear programming, which is quite time-consuming given a large number of criteria. In accordance with the method of EDAS, ranking of alternatives is based on the distances from the mean solution; a comparative assessment of the military-technical level of an armament sample's variants relative to a reference variant is more representative.

In addition to the above article, the attempt to combine characteristics, different by nature, to assess the samples of weapons and military equipment was made in source [12]. In a given example, there is an attempt to combine such characteristics as protection, load capacity, task execution, modularity, maintainability, cost, etc.

Comparative evaluation of weapon samples could be performed based on the cost of damage to a target. For example, considered a benefit of using laser in comparison with a missile system to attack the ammunition of close-action. It is shown that the cost of damage to an ammunition by laser is USD 2,000, and the missile complex “Iron Dome” in Israel from USD 40,000 to 80,000. However, cost characteristics exert only partial influence on the military-technical level of an armament sample.

Analysis of approaches to choosing the rational variant of an armament sample [1–12] reveals the lack of a general scientific and methodical apparatus for solving the set problem. Typically, assessing the importance of characteristics for armament and military equipment employs the approaches defined by the specificity of objects that are compared.

The task is related to the need for quantitative comparative assessment (ranking) of variants of armament samples, which should be considered when compiling TTT for its construction based on many disparate characteristics.

The methods to compare armament samples, described in the above papers, consider only certain characteristics of samples. General methods of multi-criteria analysis, outlined in the studies, require the consideration of patterns in comparing the variants of an armament sample. This refers to the use of a reference variant when comparing the variants of an armament sample and correct accounting for the significance of its many characteristics. Therefore, we can argue that it is expedient, in order to solve the problem, to undertake a research into the development of methodological provisions for the assessment of characteristics’ significance that define the military-technical level of an armament sample and for ranking the variants of its construction.

3. The aim and objectives of the study

The aim of this study is to devise a procedure for comparative evaluation of the armament sample variants based on the totality of characteristics that define its military-technical level.

To accomplish the aim, the following tasks have been set:

– to devise a methodological approach for comparative assessment of the military-technical level of an armament sample’s variants;

– to define the method and a procedure for assessing the significance of characteristics that determine the military-technical level of an armament sample;

– to substantiate the method and define the sequence of comparative estimation of an armament sample’s variants;

– to consider assessing the variants of an intermediate-range anti-aircraft missile system using the devised procedure.

4. Methods and procedure for comparative evaluation of variants of an armament sample

4. 1. Methodological approach to the comparative assessment of the military-technical level of armament samples

When assessing the military-technical level of an armament sample (a complex, a system), the structure of its construction is defined first. Based on the design’s structure, the functions are determined that it must fulfill. The execution of these functions is characterized by appropriate indicators (TTC), which are assigned by TTT on constructing an armament sample. TTT typically contain those characteristics that define the requirements for the application of an armament sample. At the same time, the military-technical level of an armament sample is characterized by features in its development, production, economic costs, compliance with world quality level, etc.

It is advisable to consider a set of characteristics that define the military-technical level of an armament sample as the system of characteristics. According to the principles of systems analysis [13], this makes it possible to perform the breakdown (decomposition) of the system of characteristics into elements, in order to better define their influence on the military-technical level of an armament sample. Paper [14] proposed to decompose the characteristics that define the military-technical level of an armament sample into properties, properties’ components, and indicators (Fig. 1).

The properties, properties’ components, and indicators that characterize the military-technical level of an armament sample are determined by using a heuristic method, which is subjective in character. Therefore, performing this task requires the engagement of specialists who have experience in designing similar armament samples, as well as in their operation (application).

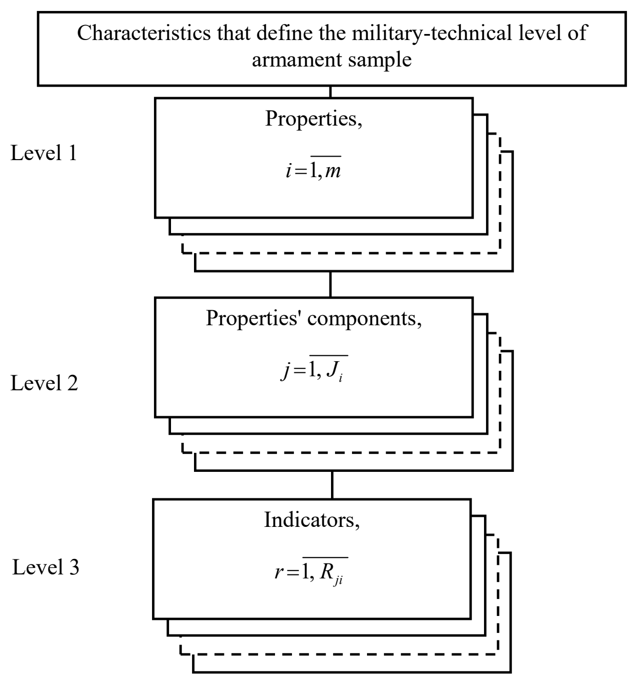

Fig. 1. Decomposition of the system of characteristics into properties, properties’ components, and indicators

The properties that define the military-technical level of an armament sample include: combat, structural, operational-technical, technological, economic, etc. Combat properties directly determine the ability of an armament sample to perform tasks on purpose. According to the type of an armament sample, the components of combat properties could include intelligence, firing and maneuvering capabilities. The properties’ components are characterized by relevant indicators. For example, firing capabilities may be characterized by the range and probability of damage to a target, the average time of shelling the targets, etc.

It is advisable to divide the structural and operational-technical properties into components that are defined by the parameters that characterize the structure of the design of an armament sample, reliability of functioning of its tools, ergonomics and safety of operation, ease of repair and maintenance, etc.

The technological and economic properties include those components that are characterized by the use of custom elements in the production of an armament sample, the degree of unification of its means, the cost of development, production, and maintenance of an armament sample in troops, as well as competitiveness.

The variants of an armament sample, which are meant to be considered during substantiation of TTT to construct it, are compiled by experts.

When determining those indicators that characterize the combat properties of an armament sample's variants, experts shall be guided by the results from previous studies into the feasibility of basic TTC for a sample in line with its purpose.

A possible composition of means in the armament sample variants is determined based on the analysis of the structures of samples similar in purpose.

Reliability indicators for the functioning of an armament sample and its means are defined in advance taking into consideration the element base that is supposed to be uses, reserves in the functioning of separate units, systems, etc. The indicators of maintainability are defined by experts based on the analysis of operation of the similar armament samples.

Conformity of an armament sample, implied to be constructed, to the world quality level is assessed by experts by comparing its characteristics to the characteristics of modern foreign examples.

Technological properties are determined based on the analysis of capacities at enterprises, which are meant to be engaged in the construction of an armament sample, in the production of respective element base, component assemblies and unified units and systems.

The economic cost of constructing an armament sample are estimated approximately, based on the experience of development of local and foreign designs. One could assume that the cost of constructing an armament sample substantially depends on its combat capacities.

When preparing variants for an armament sample, not all indicators could be determined in absolute magnitudes. Part of the indicators is defined in relative magnitudes. To this end, a conditional maximal value for an indicator related to the variants of the sample is taken to be equal to unity, and for the rest of the variants a decrease in it relative to unity is defined.

The impact of characteristics, namely, the properties, their components, and indicators, on the military-technical level of an armament sample differs. Therefore, when comparatively assessing the variants for an armament sample, one must take into consideration the significance (importance) of characteristics.

The final stage of the comparative evaluation of variants for an armament sample is the application, in order to select the rational variant, of a multicriteria method of analysis, using the significance of characteristics that determines its military-technical level.

A structural diagram of the methodical approach to comparative assessment of the military-technical level of variants for an armament sample is shown in Fig. 2.

When analyzing the selected variant of an armament sample, there may emerge the need to refine its characteristics. In this case, it is advisable to repeat comparative evaluation of all variants considering the refined characteristics for the chosen variant of an armament sample.

The following underlies the proposed approach: first, the estimation of significance of those characteristics that define the military-technical level of an armament sample; second, comparative assessment of variants for an armament sample in terms of their military-technical level. It is advisable to consider the methodological provisions for solving these tasks separately.

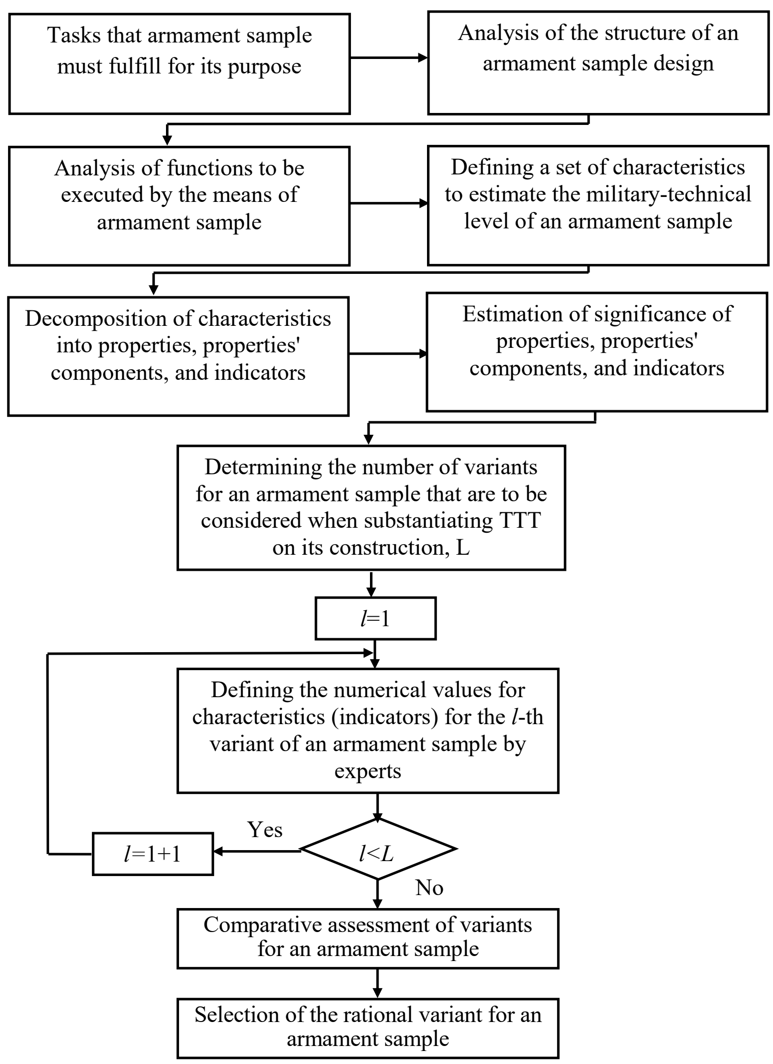

Fig. 2. Structural diagram of the methodical approach to comparative assessment of the military-technical level of variants for an armament sample

4. 2. Evaluation of the significance of characteristics that define the military-technical level of an armament sample

The significance of those characteristics that define the military-technical level of an armament sample should be assessed in three stages based on the levels that correspond to their decomposition in Fig. 1. At the first stage, one estimates coefficients of significance for properties, at the second stage – coefficients of significance for the components of properties, at the third stage – coefficients of significance for indicators considering the first and second stages. In the presence of a large number of alternatives (more than seven), using the ranking methods, direct assessment, sequential comparisons to establish the benefits of alternatives, becomes too time consuming [15, 16]. In this case, it is advisable to use a method of pairwise comparisons [17].

To evaluate the significance of alternatives, experts compile of a matrix of pairwise comparisons using the nine-point Saaty scale [18]. In a given case, the number of matrices of pairwise comparisons, which should by built by experts, is determined based on the decomposition of the system of characteristics in Fig. 1.

It is necessary to build, in order to estimate coefficients of significance, for the properties of an armament sample – a single matrix of pairwise comparisons, for the components of properties – m matrices, for indicators – $\sum_i I_i \left(i=\overline{1,m}\right)$ matrices. The form of the matrix of pairwise comparisons of properties (the first stage at estimating the significance of characteristics) is given in Table 1.

Table 1

Matrix of pairwise comparisons of properties

Properties of armament sample	B_1	B_2	...	B	...	B_m
B_1	1	$\frac{\omega_1}{\omega_2}$	...	$\frac{\omega_1}{\omega_в}$	...	$\frac{\omega_1}{\omega_m}$
B_2	$\frac{\omega_2}{\omega_1}$	1	...	$\frac{\omega_2}{\omega_в}$	...	$\frac{\omega_2}{\omega_m}$
. . .	. . .	. . .	. . .	. . .	. . .	. . .
B	$\frac{\omega_в}{\omega_1}$	$\frac{\omega_в}{\omega_2}$	...	1	...	$\frac{\omega_в}{\omega_m}$
. . .	. . .	. . .	. . .	. . .	. . .	. . .
B_m	$\frac{\omega_m}{\omega_1}$	$\frac{\omega_m}{\omega_2}$	...	$\frac{\omega_m}{\omega_i}$	...	1

The matrix is diagonal, its elements are inversely symmetric relative to the main diagonal. The elements of the matrix are the ratios that determine the preference of one property over another in terms of the impact on the military-technical level of an armament sample.

In order to prioritize the properties, one computes the components of natural vector of the matrix by deriving the mean geometric of its rows [18]:

$$\xi_1 = \sqrt[m]{1\times\frac{\omega_1}{\omega_2}\times\cdots\times\frac{\omega_1}{\omega_i}\times\cdots\times\frac{\omega_1}{\omega_m}};$$
$$\xi_2 = \sqrt[m]{\frac{\omega_2}{\omega_1}\times 1\times\cdots\times\frac{\omega_2}{\omega_i}\times\cdots\times\frac{\omega_2}{\omega_m}};$$
$$\cdots\cdots\cdots\cdots \tag{1}$$
$$\xi_в = \sqrt[m]{\frac{\omega_i}{\omega_1}\times\frac{\omega_i}{\omega_2}\times\cdots\times 1\times\cdots\times\frac{\omega_i}{\omega_m}};$$
$$\cdots\cdots\cdots\cdots$$
$$\xi_m = \sqrt[m]{\frac{\omega_m}{\omega_1}\times\frac{\omega_m}{\omega_2}\times\cdots\times\frac{\omega_m}{\omega_j}\times\cdots\times 1}.$$

Matrices of pairwise comparisons are filled by a group of experts. It is believed [19] that the most optimal group in terms of quantity is a group of experts including 10–15 people. The probability of truth of the collective expert view is approximately equal to 0.8 [20].

The mean geometric of the component of natural vector of matrices filled by K experts $\left(k=\overline{1,K}\right)$

$$\xi_i = \sqrt[K]{\prod_k \xi_{ik}}, \tag{2}$$

where ξ_{ik} is the i-th component of natural vector of the matrix that is filled by the k-th expert.

Coefficients of significance for properties a_i are determined from normalizing the magnitudes $\xi_i \left(i=\overline{1,m}\right)$

$$a_i = \frac{\xi_i}{\sum_i \xi_i}; \quad \sum_i a_i = 1. \tag{3}$$

The components of natural vectors of all matrices that must be built by experts are calculated similarly, as well as the priorities of characteristics are defined.

At the second stage of evaluation of the significance of characteristics for each i-th property, one considers $J_i \left(j=\overline{1,J}\right)$ of its constituents. Experts define the priorities for properties' components p_{ji} from the matrices of pairwise comparisons. Coefficients of significance for the properties' components are calculated from formula

$$C_{ji} = a_i\, p_{ji}; \quad i=\overline{1,m}; \quad j=\overline{1,J_i}. \tag{4}$$

At the third stage of evaluation of the significance of characteristics, experts determine priorities for the indicators relative to the components of properties. To obtain the coefficient of significance for the r-th indicator $\left(r=\overline{1,R_{ji}}\right)$ it is necessary to multiply its priority by the factor of significance for the component of the property, which this indicator relies on. The total number of indicators whose significance is assessed by experts is

$$R = \sum_i \sum_j R_{ji}; \quad i=\overline{1,m}; \quad j=\overline{1,J_i}. \tag{5}$$

Thus, the military-technical level of an armament sample is proposed to be defines considering a comprehensive assessment of its combat, structural, operational-technical, technological, economic, and other important groups of characteristics that would make it possible to scientifically substantiate the efficiency of the considered sample of armament and military equipment. It is proposed to account for the relative significance of characteristics for the variants of an armament sample by an expert poll using a method of pairwise comparisons.

4. 3. Determining the sequence of comparative evaluation of variants for an armament sample

An armament sample is characterized by a large number of different indicators (parameters), which in different ways impact its military-technical level. One of the methods of analysis of multi-criteria processes is the method of taxonomy [21], which is specifically intended to study the objects that are characterized by a large number of attributes (parameters). The method makes it possible to rank the variants of an armament sample without constraints for the number of variants and the number of parameters that characterize their military-technical level.

The main element used in the taxonomic method is the so-called taxonomic distance.

A taxonomic distance is determined based on the rules of analytical geometry between the points – indicators for the variants of an armament sample in a multidimensional space. The dimensionality of this space is determined by the number of indicators that characterize the military-technical level of an armament sample. Each variant of an armament sample is given its specific position in the multidimensional space of indicators.

The taxonomy method procedure is based on the classification of indicators to stimulants and destimulators. Attributes (indicators) that contribute to an increase in the military-technical level of an armament sample are typically assigned in taxonomy to the class of stimulants, while those attributes (indicators) that reduce the growth – to the class of destimulators.

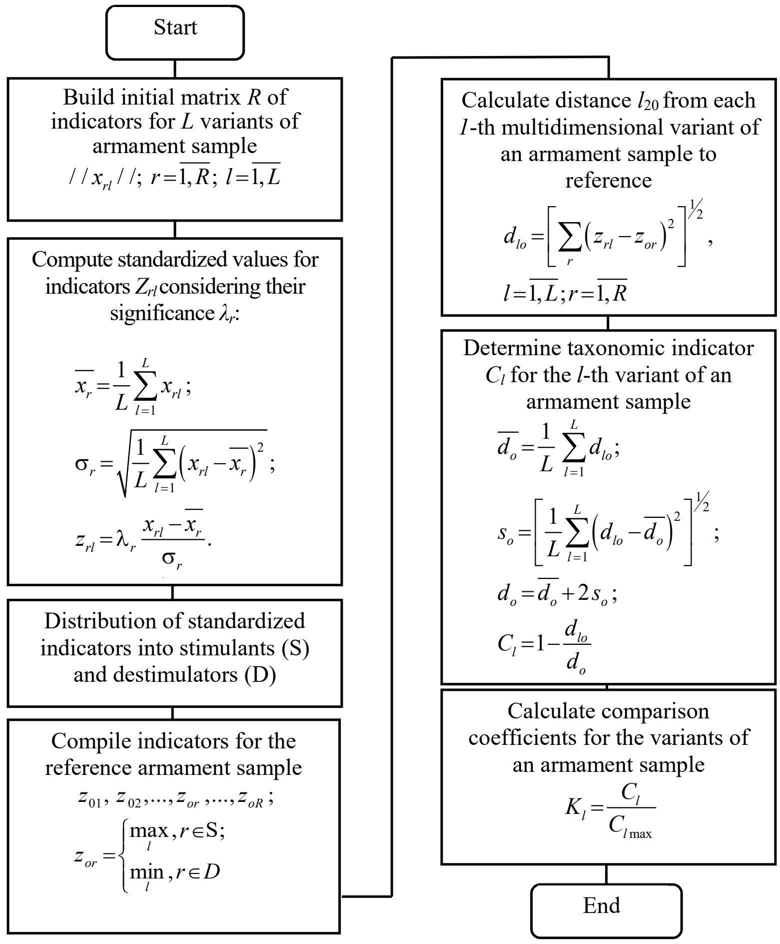

Fig. 3. Structural diagram of the algorithm for comparative assessment of variants for an armament sample using the method of taxonomy

The concept of the ideal, or reference, armament sample is introduced to create a model for the general indicator of the military-technical level of an armament sample. Such an armament sample is matched by the maximum values for indicators –stimulants, and the minimal values for indicators – destimulators. The military-technical level of variants for an armament sample is estimated based on the taxonomic distances relative to the reference armament sample.

The initial data for comparative assessment of the military-technical level of variants for an armament sample are the indicators and their coefficients of significance.

Structural diagram of the algorithm for comparative assessment of variants for an armament sample using the method of taxonomy is shown in Fig. 3.

Taxonomic indicator C_l characterizes the degree to which the l-th variant of an armament sample is close to reference. The closer indicator C_l to unity, the higher the military-technical level of the l-th variant of an armament sample. For the variant of an armament sample with a maximum value for taxonomic indicator $C_{l\max}$ the comparison coefficient K_l=1.

The implementation of decomposition of characteristics, the application of a method of pairwise comparisons for assessing their significance, the use of a taxonomy method, have made it possible to devise a comprehensive methodology for the comparative assessment of variants for an armament sample in terms of military-technical level.

5. Example of assessing the variants of a medium-range anti-aircraft missile system

According to the methodological approach shown in Fig. 2, one needs first to define the structure of design of the anti-aircraft missile system (AMS). It follows from the analysis of existing AMS and the anti-aircraft missiles [22–25] that the most common structure is the design of AMS the type of C-300 (Fig. 4); it is advisable to accept it for the research.

When substantiating TTT on the construction of AMS, 5 variants of the system are considered that differ in their characteristics. It is necessary to determine the rational variant of AMS in terms of military-technical level.

The set of characteristics (properties, components, properties) is given in Table 2.

The coefficients of significance for properties derived by experts are:

a_1=0,48; a_2=0,25; a_3=0,27.

Priorities for the properties' components p_{ji} are equal to:

p_{11}=0,19; p_{21}=0,36; p_{31}=0,35; p_{41}=0,10;

p_{12}=0,32; p_{22}=0,52; p_{32}=0,16;

p_{13}=0,23; p_{23}=0,24; p_{33}=0,53.

Table 2

Properties, properties' components, and indicators

Titles of properties, properties' components, and indicators	Indicator No., r	Indicator priority	Significance coefficient, λ_r	Values of indicators for AMS variants					"+" –stimulant, "–" – destimulator
				1	2	3	4	5	
Combat capabilities (i=1)									
Reconnaissance capabilities (j=1)									
Detection range of typical target, km	1	0.50	0.045	280	300	290	270	260	+
Lower limit of the airspace, m	2	0.33	0.030	150	100	200	100	100	–
Upper limit of the airspace, km	3	0.17	0.015	30	35	30	30	30	+
Parameters for the destruction zone of AMS (j=2)									
Range of a typical target destruction, km	4	0.42	0.073	80	90	85	80	75	+
Lower limit of the zone of destruction, m	5	0.41	0.071	50	30	30	50	50	–
Upper limit of the zone of destruction, km	6	0.17	0.029	28	30	28	25	25	+
Capabilities to destroy and shell targets (j=3)									
Probability of a typical target destruction	7	0.50	0.85	0.75	0.8	0.7	0.7	0.7	+
Average time in shelling a target, C	8	0.25	0.042	80	90	85	80	75	–
Number of targeted channels at AMS	9	0.25	0.042	4	6	4	4	6	+
Maneuvering capabilities (j=4)									
Time to take the position, min.	10	0.34	0.016	18	20	18	15	15	–
Time to leave the position, min.	11	0.16	0.008	16	18	16	14	14	–
Time to get ready for combat work, min.	12	0.50	0.024	12	10	12	15	15	–
Structural and operational-technical properties (i=2)									
Structural characteristics (j=1)									
Number of AMS as part of AMS	13	0.46	0.037	3	4	3	4	3	+
Number of combat means as part of AMS	14	0.28	0.023	47	62	47	62	47	–
The number of facilities maintenance and support as part of AMS	15	0.26	0.021	21	28	21	28	21	–
Reliability (j=2)									
Probability of non-failure operation	16	0.51	0.066	0.88	0.91	0.85	0.87	0.84	+
Average lifespan of means, P	17	0.18	0.023	20	18	20	21	22	+
Coefficient of combat readiness	18	0.31	0.040	0.76	0.78	0.8	0.79	0.82	+
Ergonomics, maintainability, and safety of operation (j=3)									
Ergonomics indicator	19	0.23	0.009	0.8	0.9	1.0	0.95	0.85	+
Maintainability indicator	20	0.24	0.010	0.85	1.0	0.9	0.85	0.8	+
Degree of safety of operation	21	0.53	0.021	0.95	1.0	0.98	0.97	0.96	+
Competitiveness, efficiency, and technological properties (i=3)									
Compliance with the global level (j=1)									
Compliance with modern principles of systems design	22	0.25	0.015	0.85	0.9	1.0	0.8	0.9	+
Compliance with modern technologies	23	0.27	0.017	0.8	1.0	0.9	0.7	0.85	+
Competitiveness	24	0.48	0.030	0.7	09	0.75	0.8	1.0	+
Unification (j=2)									
Degree of unification of elements	25	0.28	0.018	0.6	0.7	0.6	0.7	0.8	+
Degree of utilizing own components	26	0.30	0.019	0.85	0.95	1.0	0.85	0.75	+
Degree of usage of own elements base	27	0.42	0.028	0.9	1.0	0.8	0.7	0.8	+
Economic costs (j=3)									
Costs of AMS development	28	0.45	0.064	0.9	1.0	0.85	0.75	0.8	–
Cost of production	29	0.32	0.046	0.9	0.95	0.95	1.0	0.85	–
Cost of maintenance in troops	30	0.23	0.033	0.7	1.0	0.7	0.9	0.7	–

The results from calculations of coefficients of significance helped establish the results for the significance coefficients of properties' components, given in Table 3.

Thus, the military-technical level of AMS under design is affected to the greatest degree by the parameters for AMS zone of destruction, the capabilities to destroy and shell targets, and economic costs. The lowest impact on the military-technical level of AMS, as evidenced by the results from expert assessment, is exerted by maneuvering capabilities, ergonomics, maintainability and operational safety. The obtained results concerning the significance of the properties' components do not contradict the purpose of AMS, whose task is to destroy the means of air attack from the enemy.

Priorities for the indicators regarding the components of properties obtained by experts at the third stage of assessment of the significance of the characteristics, as well as the results from determining the significance coefficients for indicators, are given in Table 2.

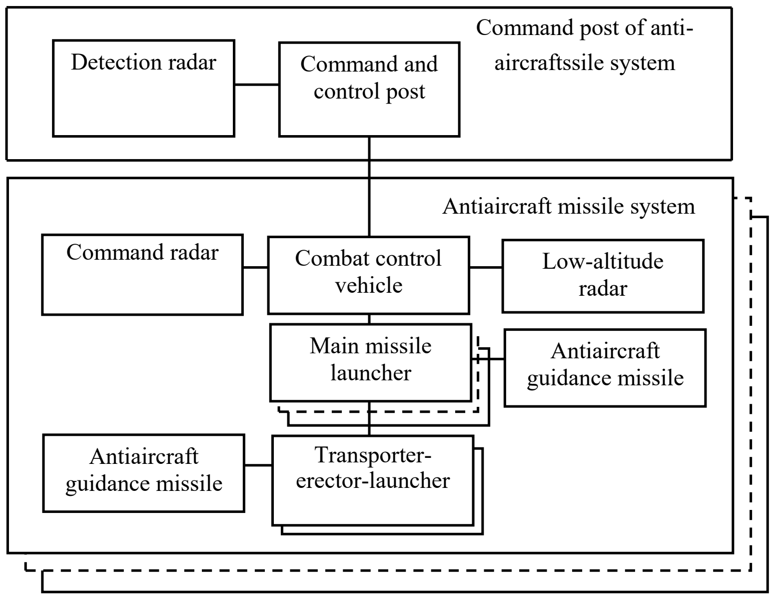

Fig. 4. Generalized structure of AMS design

TTT on its design (Fig. 2). The quality of the performed procedure affects the rational correlation among the characteristics of system properties, which affects the efficiency of functioning of the armament sample as intended, taking into consideration the cost of a life cycle of the sample of weapons and military equipment. As an example, a procedure of the methodical approach was applied to compare variants of medium-range anti-aircraft missile systems. To this end, in accordance with the methodological approach, we have defined the structure in order to construct an anti-aircraft missile system (Fig. 4).

Next, to be able to assess the significance of characteristics, by using the method of pairwise comparisons we have decomposed a the sample of weapons and military equipment into properties, properties' components, and indicators (Fig. 1). Accordingly, the results of the distribution for a medium range AMS are given in Table 2.

A staged assessment of coefficients of significance: properties; properties' components; indicators, taking into consideration preceding stages (Table 1), has made it possible to take into consideration different characteristics for an armament sample in the assessment of the military-technical level of its variants. For a medium-range AMS, a comparative assessment is given in Table 3.

Thus, a special feature of the devised procedure, when compared with others, is the staged determination of the significance coefficients for different characteristics, which predetermine the military-technical level of an armament sample (1) to (5).

A taxonomic indicator (Fig. 3) is used to compare the variants for an armament sample in terms of the military-technical level. A given taxonomic indicator describes the degree to which a variant of an armament sample is close to reference. The closer the indicator to unity, the higher the military-technical level of an armament sample's variant.

Table 3

Assessment of significance of the properties' components

No. of property, i	No. of component of property, j	Titles of properties' components	Assessment of significance of property components
1	1	Reconnaissance capabilities	0.091
1	2	Parameters for AMS destruction zone	0.173
1	3	Capabilities to destroy and shell targets	0.168
1	4	Maneuvering capabilities	0.048
2	1	Structural characteristics	0.08
2	2	Reliability	0.13
2	3	Ergonomics, maintainability, operation safety	0.04
3	1	Compliance with global level	0.062
3	2	Unification	0.065
3	3	Economic cost	0.143

Based on the results of calculations using the algorithm shown in Fig. 3, the values for the taxonomic indicator for the examined variants of AMS are equal to:

$$C_1=0{,}183;\ C_2=0{,}366;\ C_3=0{,}265;\ C_4=0{,}146;\ C_5=0{,}066.$$

Hence, the best option in terms of the military-technical level is the second variant of AMS (C_2).

Therefore, the proposed approach for determining a rational variant of AMS has demonstrated sufficient sensitivity in the assessment of anti-aircraft missile systems similar in the military-technical level. That makes it possible to uniquely determine the most rational variant of AMS assembly.

6. Discussion of results from studying the military-technical level of variants for an armament sample

The result of our research is the development of methodological provisions for the assessment of a technical-military level of variants for an armament sample. Typically, this procedure of assessment is conducted when substantiating

The methodology devised was used for the assessment of the military-technical level of AMS variants. The results from calculations indicate that, based on the results of comparison of the variants for constructing a medium-range AMS, the best option in terms of the military-technical level was the second variant of AMS. The results of our research testify to that the military-technical level of AMS is greatly affected by the following: parameters for the zone of destruction of AMS targets, the capabilities to destroy and shell targets, economic costs of the development, production, and maintenance of AMS in troops.

Limitations and assumptions in the proposed methodological provisions are mostly related to determining the quantitative values for indicators that characterize the military-technical level of variants for an armament sample. When defining the indicators, one should take into consideration the possibilities to ensure combat characteristics for an armament sample, as well as other characteristics that are predetermined by the capabilities of a military-industrial complex to design and manufacture an armament sample.

On the other hand, the limitations that must be accounted for in the application of the developed procedure are predetermined by the experts' application of the Saaty scale when performing pairwise comparisons of characteristics, that is, when constructing matrices of pairwise comparisons. When using the Saaty scale, it is not recommended to compare more than 9 factors. That must be considered in the decomposition of the system of characteristics that define the military-technical level of an armament sample.

The drawback of the current study is focusing the decomposition of system of characteristics mostly on the assessment of the military-technical level of artillery, rocket, anti-aircraft missile complexes and systems. When evaluating military-technical level of other armament samples, it is necessary to adjust the principles of decomposition of the system of characteristics, in particular, to consider other properties and their components. The current study could be advanced by applying, in order to determine the significance of characteristics for an armament sample, other methods of expert assessment, specifically the Delphi method, and by comparing the results obtained using that method and the method of pairwise comparisons.

7. Conclusions

1. The devised methodological approach to comparative assessment of the military-technical level of variants for an armament sample is based on the decomposition of its characteristics, determining the coefficients of significance for characteristics, and using them when ranking the variants of an armament sample. That has made it possible to obtain a coherent methodology for comparative assessment of variants for an armament sample, meant for design, in terms of a military-technical level.

2. Decomposition of the armament sample' characteristics is based on properties, components of the properties, and indicators. This makes it possible to consistently execute a staged expert assessment of the significance of characteristics for an armament sample, namely the properties, the properties' components, and indicators, using the method of pairwise comparisons.

3. A comparative assessment of the variant of an armament sample in terms of its military-technical level based on our procedure employs the method of taxonomy, which has no constraints for the number of indicators that are considered when comparing. The significance of indicators in the reported algorithm for using a taxonomy method is take into consideration at their standardization.

4. By using the procedure reported in the current work, we have performed a comparative assessment of possible variants for AMS. It has been shown that the greatest influence on the military-technical level of AMS is exerted by the parameters for a zone of destruction by AMS, the capabilities to destroy and shell targets, economic costs of the development, production, and maintenance of AMS in troops.

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