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METHODS OF CATEGORIZING SAMPLES OF ARMAMENTS AND MILITARY EQUIPMENT ACCORDING TO THE LEVEL OF THEIR MODERNITY

According to the results of the existing approaches analysis to the categorization of samples of armaments and military equipment taking into account the level of their modernity, it was concluded that today such a procedure is carried out on the basis of verbal methods, which is accompanied by the negative influence of the subjective factor. The purpose of the article is to present the results of a method development for categorizing samples of armaments and military equipment according to the level of their modernity based on analytical (formal) decision-making methods. This method is based on the use of the methodological apparatus of the theory of fuzzy sets, as well as on the procedure of fuzzy logical inference using the Mamdani algorithm, which is implemented in the FisPro program. Approbation of the specified method was carried out on the example of the combat tactical aircraft categorizing problem solving.

Keywords: *sample of armaments and military equipment, category of modernity, military-technical level, theory of fuzzy sets, fuzzy logical inference, Mamdani algorithm.*

Introduction

Formulation of the problem. In scientific and popular scientific publications devoted to the issues of troop technical equipment and military formations combat capabilities, such concepts (categories) as "obsolete", "morally obsolete", "modern", "new", "promising" sample of armaments and military equipment (AME) are quite often used.

The analysis of relevant sources of information shows that at this time there are no clearly established interpretations of these concepts, which significantly complicates the definition of AME samples categories.

At the same time, the generally accepted interpretations of the mentioned concepts and the arbitrary procedure of assigning samples of AME to a certain category of their modernity, developed by the authors of publications at their discretion without proper justification, give rise to the urgent scientific task of AME samples categorizing according to the level of their modernity on the basis of analytical decision-making methods to reduce the negative impact of the subjective factor.

Analysis of recent research and publications. In the work [1, p. 210], the promising samples of AME is understood as a development sample, the main tactical and technical characteristics (TTC) of which significantly exceed the characteristics of foreign analogues or there are no analogues.

A new sample means a highly effective sample of AME, created for the first time or created instead of the previous one, and has significantly better quality indicators that fully meet the prospective general technical requirements for 10…15 years ahead and is not inferior to it in terms of TTC, not is inferior to promising foreign analogues and has a significant reserve of technical resource and service life [1, p. 210].

According to the publication [2, p. 186], a modern sample of AME is a sample that is in service, serially produced or modernized, the main TTC of which are not inferior to the characteristics of existing foreign analogues. In [1, p. 211] it is indicated that such a model should fully meet the general technical requirements and tasks of the armed forces for 5…10 years, should not be inferior to the best foreign analogues in terms of quality, and should have a sufficient supply of technical resources and service life.

At the same time in [2, p. 187] suggests combining the concepts of "new" and "modern" within the broader concept of "modern". Also, in the specified source, an outdated sample of AME is considered to be a discontinued sample that has no modernization potential, the main TTC of which are inferior to the characteristics of foreign analogues or, according to [1, p. 211], which finds limited use, does not meet the modern operational-tactical requirements (OTR) of AME and the tasks of the Armed Forces, in terms of quality indicators it is significantly inferior to domestic and foreign analogues of later releases, and has an insignificant reserve of technical resource and service life.

According to [3, p. 376], a morally obsolete sample of AME is a sample that cannot perform tasks according to its functional purpose in new conditions of use for the intended purpose (exploitation) with a level of efficiency (quality) that exceeds the critical (minimum admissible) value, and which cannot be modernized for one reason or another (primarily of a technical-technological and / or technical-economic nature) to raise the level of its perfection to an acceptable level.

It is seen that in the above interpretations of the AME categories, such descriptions of concepts as "significantly superior", "highly effective", "much better", "sufficient reserve", "limited use", "significantly inferior", "negligible reserve", "acceptable level", do not have a clear gradation, which makes the process of assigning a sample of AME to a certain category rather arbitrary with a high degree of uncertainty.

This circumstance makes the verbal assessment of the technical equipment of military formations too "blurred" and makes it difficult to understand the results of the comparison of alternative samples of AME, and reduces confidence in the results obtained.

The purpose of the article is to present the results of the AME samples categorizing method development according to the level of their modernity based on analytical (formal) decision-making methods.

Presenting main material

In well-known publications on this topic, various authors agree that the assignment of AME samples to certain categories according to the level of modernity is directly related to the procedure of comparing them according to the effectiveness of their use for the intended purpose (combat effectiveness) and / or according to their technical excellence (technical level, quality).

At the same time, it is proposed to determine the category of modernity of AME sample by finding the value of the quality (efficiency) indicator and comparing it with the given values of the selected scale.

At one time, a detailed analysis of the relationship between the concepts of "efficiency" and "quality" in the field of complex technical systems was carried out, the results of which were presented in the article [4, p. 178], based on which, in further studies, a conclusion was made about the expediency and sufficiency of the use for the purposes of comparing samples of AME, in particular military aircraft, their evaluation by the coefficient of military-technical level - a relative indicator of the AME sample quality as a complex technical system of military purpose.

Based on the provisions, as set forth in [4, p. 178…184], effectiveness is understood as an integral determining feature of the of AME sample functioning (application, use) process for its intended purpose, which is objectively expressed by the degree of the target result (useful effect) achievement taking into account resource costs. Most often, financial costs are taken as a fairly general equivalent of various types of resource costs, which are characterized, for example, by an indicator of the AME sample life cycle cost (primarily such components as the cost of production and operation; it is appropriate to compare these cost indicators with beneficial effect) [5, p. 11].

Quality is understood as an objective general characteristic of AME sample, which is expressed through a set of its properties useful from the point of view of the target purpose of such a sample [4, p. 180]. According to [6, p. 3], the quality indicator of the object can be represented by a vector, the components of which are indicators of the properties of the object, essential for its intended use. In this way, a clear distinction is made between the concepts of efficiency as a general defining property of the process of functioning (application, using) of AME sample and quality as a general defining property of the actual sample of AME.

It should be noted that today, as part of the harmonization of national quality standards with European ones, a number of State Standards of Ukraine have been put into effect, in which the term quality is interpreted as "the degree to which the set of its own characteristics meets the requirements" [7, p. 6]. According to the authors, this definition of the concept of "quality" is not quite successful, because it does not reveal the physical meaning of this concept. At the same time, in another valid State Standard of Ukraine, product quality is defined as a set of its characteristics that relate to its ability to satisfy established and anticipated needs [6, p. 3]. It is obvious that even this interpretation is not meaningful enough for its use in the field of AME. Therefore, what is stated below in this scientific article refers to the interpretation of concepts in the edition, which is stated in [4, p. 178…184].

In this way, the effectiveness of AME sample is evaluated for the process of its application as intended, and for the purpose of its evaluation, it is necessary to establish a dynamic relationship between the properties, characteristics or indicators (which are at the same time components of the quality vector) of AME sample, as well as methods and conditions of its application. For such an assessment, it is necessary to carry out field experiments, tests in conditions close to real ones, the use of physical and mathematical (simulation, analytical, etc.) models.

Quality characterizes a sample, as a rule, at the stage of creation, manufacture, selection for equipment, and for its evaluation, a list of defining indicators (TTC) that characterize the technical perfection of the sample, regardless of the methods and conditions of its use, is sufficient.

The relative characteristic of product quality, which is based on a comparison of the indicator values s characterizing the technical excellence of the evaluated products, with the main values of these indicators is the technical level of the products [6, p. 7].

A generalized indicator of the technical level of products is the coefficient of the technical level or, in relation to the branch of AME, the coefficient of the military-technical level (CMTL).

Mathematically, the CMTL is represented as a certain convolution (additive, multiplicative or other) of the determining indicators of the technical perfection (ITP) of AME sample, taking into account the relative importance (weighting coefficients) of such indicators.

Thus, in the well-known methodology for assessing the military-technical level of aviation equipment sample , the calculation of an aircraft CMTL (C_{MTL}) is based on the mathematical apparatus of qualitative assessment of the technical level (quality level) of a complex technical system based on the ratio of the evaluated and base / reference aircraft determining indicators of technical perfection (TTC), taking into account the relative importance of these indicators [8, p. 2]:

$$C_{MTL} = \sum_{k=1}^{M} \sum_{ki=1}^{N_k} d_k g_{ki} \frac{\bar{c}_{ki}}{\bar{c}_{ki}^{баз}}, \qquad (1)$$

where d_k – is the weighting factor of the k-th functional subsystem of the aircraft, which is evaluated, such that: $\sum_{k=1}^{M} d_k = 1$; g_{ki} – the weighting factor of the i-th ITP (TTC) of the k-th functional subsystem of the aircraft, which is evaluated as: $\sum_{ki=1}^{N_k} g_{ki} = 1$; M – the number of functional subsystems of the evaluated aircraft; N_k – the number of determining ITP (TTC) of the k-th functional subsystem of the evaluated aircraft; $\bar{c}_{ki}, \bar{c}_{ki}^{base}$ – the given values of the i-th ITP (TTC) of the k-th functional subsystem of the evaluated and base aircraft, respectively, are such that:

$$\bar{c}_{ki}(\bar{c}_{ki}^{base}) = \begin{cases} X_{ki}(X_{ki}^{base}), & \text{if an increase in the } i\text{-th ITP (TTC) of the } k\text{-th functional subsystem of the aircraft corresponds to an increase in its technical perfection;} \\ \dfrac{1}{X_{ki}}\left(\dfrac{1}{X_{ki}^{base}}\right), & \text{if the increase in the } i\text{-th ITP (TTC) of the } k\text{-th functional subsystem of the aircraft corresponds to a decrease in its technical perfection.} \end{cases}$$

X_{ki}, X_{ki}^{base} – natural values of the i-th ITP (TTC) of the k-th functional subsystem of the evaluated and base aircraft, respectively.

Evaluation (calculation) of the CMLT in order to determine the category of modernity of AME sample involves the following stages:

selection of a base sample (as a base sample, it is proposed to accept the sample that represents advanced scientific and technical achievements in the development of this type of technology, which has the most favorable values of the ITP);

selection of the most significant (determining), from the point of view of influence on the quality of the sample, ITP (TTC);

determination of the weighting coefficients of such ITP (TTC);

determination of the values of these ITP (TTC) for the base and evaluated samples;

comparison of the obtained values of ITP (TTC) of the evaluated and base samples;

determination of the modernity category of AME sample by finding the value of CMTL (1) and comparing it with the given values of the selected scale.

As can be seen, the presented procedure is a comparison of alternatives based on a number of indicators with weights. As a result, an additive convolution is obtained, which is often called a “weighted sum”. Analogues of such a convolution are methods of “norm vectors”, Hermeyer, “multiplicative”, “exponentiation method” and others, which take into account the levels of confidence in the convolution, the degree of compensation of various indicators, professional qualities of experts and so on. The choice of the type of convolution is subjective and does not contain proof that a certain type is better than another [9, p. 29].

In addition to this shortcoming, the implementation of most of the specified stages of evaluation of the CMTL includes the use of expert evaluations: when choosing the most significant indicators, weights, base sample, scale values. This may be the reason that the special selection of experts and influence on their opinion will lead to unreliable results. At the same time, the opinion of experts does not always coincide with the opinion of the final instance - the decision-maker (DM), moreover, they may not even know about the meaning of weights, scales, etc.

It is also known that every convolution using weights is not completely correct [10, p. 67]. This is due to the fact that the weights, as a rule, are selected based on the combination of the indicators specific values for the compared alternatives. When changing the combinations of these values, the weights also change. So, if a limit is reached at a given stage of science and technology development, experts often assign less weight to it compared to an indicator that has the potential for improvement. In addition, shortcomings in one indicator can easily be compensated by advantages in another. It is also worth considering that many indicators are correlated, which also reduces the probability of the conducted assessment.

Another shortcoming of expert weighted assessments is related to the fact that initially, experts select a subset of the most significant (determining) indicators from a set of indicators. At the same time, this procedure very often leads to the fact that in the selected subset there are indicators whose differences in weights are insignificant (because only the most important ones remained). Therefore, the resulting quality assessment slightly depends on the specific values of these weights.

It should also be noted that for assessing the relative importance of indicators, the method of analyzing hierarchies is often used, which is attractive for the simplicity of expert pairwise comparison and the ease of processing the results. However, a number of authors prove that this method is not correct due to the violation of the measurment theory. Thus, point (rank) evaluations of a pairwise comparison, which belong to an ordinal (qualitative) scale, are converted into quantitative scales (ratio, etc.) using arithmetic operations that are unacceptable for an ordinal scale. An analysis of the shortcomings of this method with examples of unreliable results obtained with its use is given in [11, p. 8…13]. Thus, the solution of the considered vector (multi-criteria) evaluation problem using different convolutions with weights, despite its attractiveness, is not correct. In this connection, further search for approaches to its solution is expedient.

Given the previous considerations, the following main requirements can be put forward for this approach: absence of weights, minimal number of heuristic procedures, taking into account the advantages of DM.

Taking into account the above, it appears that the formal methods application for the correct solution of the AME samples categorizing problem according to the level of modernity is in principle impossible. This is due to the fact that it is weakly formalized and has significant uncertainty in the content of the raw data and the procedure for processing it. In this connection, it is proposed to use fuzzy set theory (FST), which is a generalization of classical set theory, including in the case of various physical, linguistic, and other uncertain factors presence.

The theoretical and applied aspects of FST application of are described in numerous works, in particular in [12…16], and therefore will not be considered in detail, except for the most general basics, which are necessary for the presentation of the specifics of the application of the methodological apparatus in relation to the problem being solved.

Taking into account the provisions of FST, it is first necessary to define linguistic variables and construct membership functions. In the considered case, such variables are “indicator levels” (for example, an indicator of the military-technical level of an aircraft) with linguistic values, for example, “low”, “medium” and “high”. The scope of determining these values is the actual range of the indicator change.

To construct membership functions of the specified variable, researchers can use different approaches based on the analysis of available information and trends in indicator changes. That is, they have the right to directly impose this variable and determine its form based on the results of a survey of the DM. At the same time, the DM survey itself can be conducted once for a significant period of time (for example, for the duration of the State-Targeted Defense Program for the Development of AME for a certain period).

This is related to the patterns of changes in indicators over time, which grow (decrease) mainly in an evolutionary, smooth manner. In rare cases, when new effects, principles, laws, and breakthrough technical solutions are discovered, the change takes place in a revolutionary, abruptly. For example, for a combat tactical aircraft, such a jump occurs during the transition to a new generation. But such transitions are quite rare, and therefore the constructed membership function can be used for a long time.

Intervals of the value of a linguistic variable, as a rule, overlap, which reflects the property of a person (DM, expert) to “think not with numbers, but with concepts” [13, p. 59].

Speaking about the form of the membership function curve, it should be noted that a large number of their forms are used - symmetric and asymmetric Gaussian, sigmoidal, harmonic, polynomial, and others. However, with a small amount of available information, it is recommended to use the simplest membership functions consisting of rectilinear sections (so-called piecewise linear - triangular, trapezoidal) [13, p. 73…77]. Finding their parameters requires much less information compared to other membership functions. At the same time, the high accuracy of calculations with their use is noted even with a shortage of initial data.

The specified functions must be constructed for all selected most important (determining) indicators of AME samples and then make the transition from them to the function of belonging to the “outdated”, “modern”, “promising” categories.

The transition from “levels of indicators” to the function of belonging to categories is carried out with the help of production rules (rules of logic, logical rules, implications). Each production rule consists of one or more premises and a conclusion. If there are several parcels, they are connected by a logical “AND”.

In its general form, the production rule has the following form:

IF *condition* [AND *condition* …], THEN *the conclusion*, where the condition and conclusion are fuzzy statements.

Within the framework of specific task consideration, a complete set of rules forms a base of IF-THEN type logic rules, which is formed by specialists (experts) of the subject area in the form of a set of fuzzy production rules of the P type (a case for two conditions):

P1: if $a \in A1$ and $b \in B1$, then $c \in C1$,

P2: if $a \in A2$ and $b \in B2$, then $c \in C2$,

…

Pn: if $a \in An$ and $b \in Bn$, then $c \in Cn$,

where *a, b* are input variables (names for known data values), *c* is an output variable (name for data values to be calculated); *A, B, C* are membership functions defined for *a, b, c*, respectively.

As the experience of applying the FST shows, the task of such rules (implications) does not cause difficulties and is based on intuitive representations of DM. At the same time, such intuitive implications successfully replace abstract scales [16, p. 34].

There are several algorithms of fuzzy inference, according to which separate membership functions of fuzzy input parameters are transformed into a general membership function of a fuzzy output value: Mamdani, Tsukamoto, Sugeno, and Larsen. The results of these algorithms comparison show that the estimates obtained by the algorithms of Mamdani and Larsen are closest to the estimates obtained by the main method of multi-criteria utility MAUT, which is taken as a reference [17, p. 48].

Currently, the Mamdani algorithm is the most common, which is most often used in fuzzy modeling problems [18, p. 202; 19, p. 40], it was chosen to solve this task.

On the basis of the obtained membership function of the output variable, a defuzzification operation is performed in order to obtain a clear quantitative value of the original linguistic variable.

There are several methods of defuzzification, the most common is the method of the center of gravity or the centroid method [18, p. 197]. According to the centroid method, the exact value of the output variable is determined as the coordinate of gravity center of this variable membership function curve according to the formula:

$$c_0 = \frac{\int_Q c \times \mu_\Sigma(c)}{\int_Q \mu_\Sigma(c)} \qquad (2)$$

Thus, the proposed method of categorization of AME samples includes the sequential implementation of the following stages:

formation of a list of defining ITP (TTC);

fuzzification (introduction of fuzziness) – construction of membership functions for defining ITP (TTC), that is, their representation in the form of membership functions as fuzzy numbers;

logical inference – composition of membership functions of determining ITP (TTC) in accordance with the basic rules of IF - THEN logic and the rules of fuzzy mathematics;

defuzzification - bringing the original parameter “category of AME sample” to clarity.

The membership function $\mu_A(x)$ – is a non-probabilistic subjective measure of vagueness, which is determined heuristically based on objective information about the degree of correspondence of the element *x* to the concept, which is formalized by the fuzzy set *A*. Unlike the probability measure, which is an estimate of stochastic uncertainty, which deals with the ambiguity of the occurrence of some event at different points in time, the fuzzy measure is a numerical estimate of linguistic uncertainty, which is related to the ambiguity and vagueness of the categories of human thinking. When constructing the membership function $\mu_A(x)$ with a fuzzy set *A*, some property, sign or attribute *Y* is associated, which characterizes some set of objects *X*. The more a specific object $x\ (x \in X)$ has the property Y, the closer the corresponding value is to unity $\mu_A(x)$. If the element $x\ (x \in X)$ clearly has the property *Y*, then $\mu_A(x) = 1$, and if $x\ (x \in X)$ clearly has no property Y, then $\mu_A(x) = 0$ [18, p. 37].

We will consider the practical application of the above method on the illustrative example of solving the problem of categorizing combat tactical aircraft.

The definition of the category of aircraft modernity is performed according to the presented method using the FisPro program, which allows to automate the fuzzy inference procedures according to known algorithms (in this method, according to the Mamdani algorithm). The choice of the FisPro program was due to its sufficient functionality to solve the given task and its free distribution on the Internet [20].

For an illustrative example, the following minimally necessary list of indicators that determine the level of combat tactical aircraft modernity was established:

the degree of compliance of the aircraft with the accepted OTR (V);

coefficient of aircraft military-technical level (C_{MTL});

the specific remainder of the aircraft resource (R_{SPS}).

The degree of aircraft compliance with the accepted OTR is calculated as a percentage ratio of requirement number that the OTR sample meets, to the total number of requirements from the full list of accepted OTR, taking into account the importance of each requirement group s [21, p. 81].

The CMTL, which is a comprehensive indicator of aircraft technical perfection (quality) as a complex technical system for military purposes, is calculated according to the above-mentioned method [8, p. 1…17]. At the same time, a hypothetical multifunctional fighter is taken as a basic (reference) sample, which has ITP (TTC) at the level of the latest world achievements in the field of military aircraft construction. For example, the effective scattering area in the frontal projection is no more than 0.01 m2, the number of air targets fired at the same time is at least 8, the number of ground (surface) targets fired at the same time is at least 2, the level of automation of crew support during flight (combat) operations tasks - not less than 50 %, supersonic cruising speed in the non-thrust mode of operation of the aircraft's power plant, combat load - not less than 13,500 kg, the number of weapons suspension nodes - not less than 15, etc.

The specific remainder of the aircraft resource is calculated as a percentage ratio of the available remaining resource to the aircraft assigned resource, which characterizes the degree of complex technical system life potential exhaustion. However, at the same time, it should be taken into account that the intended resource of the aircraft, as a rule, can be extended by restoring the technical condition of its design critical elements. This indicator also indirectly characterizes the modernization potential of the aircraft in view of the expediency of spending funds on its modernization and the remainder of the period of its service life until the moment of decommissioning.

Linguistic categories are assigned to each of the specified parameters - “low”, “medium”, “high”. So, for example, for indicator V, a low level of OTR compliance corresponds to a value that does not exceed 50 %, an average level - about 80 %, and a high level – 100 %.

The membership functions of the specified indicators of combat tactical aircraft modernity with the indication of the linguistic levels of these indicators (“low”, “medium”, “high”) in the FisPro program are presented in Fig. 1.

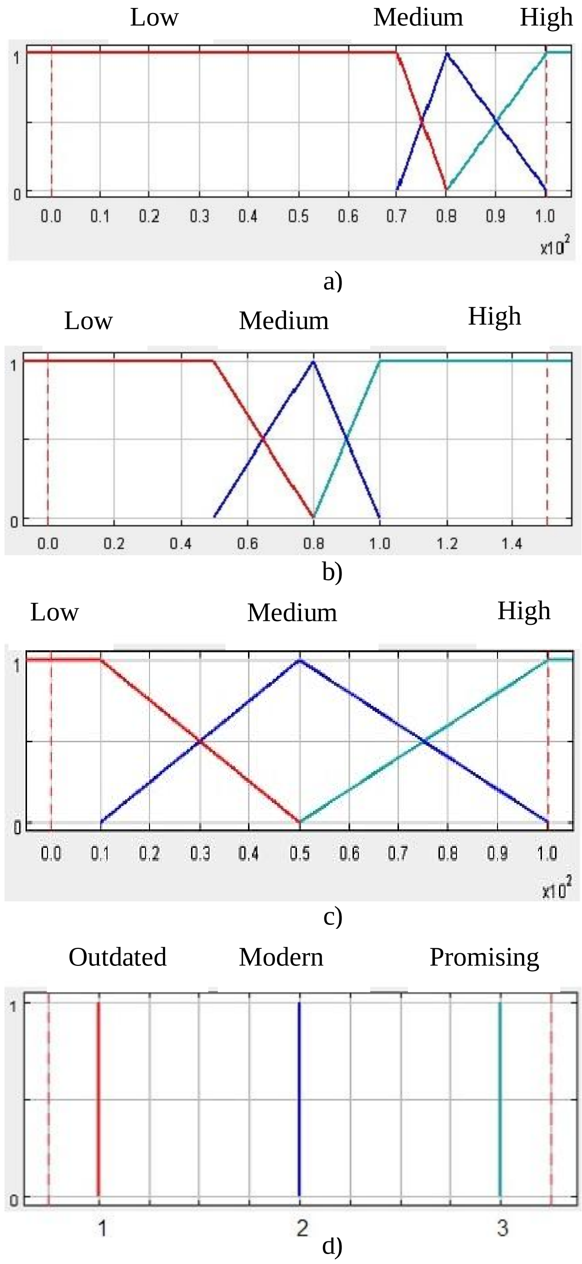

Fig. 1. Functions of belonging to indicators of the modernity of combat tactical aircraft and categories of the sample: the degree of compliance of the aircraft with the adopted of OTR (a); CMTL of the aircraft (b); the specific remainder of the aircraft resource (c); sample categories (d).

Source: developed by the authors based on data [20].

The base of active IF-THEN logic rules for the process of categorizing combat tactical aircraft according to the level of modernity for three inputs (indicators) consists of 27 rules (implications). The view of the window of the FisPro program with the specified rule base is presented in Fig. 2.

Rules

Rules Display

Rule	Active	IF V	AND CMTL	AND R	THEN Category of modernity
1	✓	Low	Low	Low	1
2	✓	Low	Low	Medium	1
3	✓	Low	Low	High	1
4	✓	Low	Medium	Low	1
5	✓	Low	Medium	Medium	1
6	✓	Low	Medium	High	2
7	✓	Low	High	Low	2
8	✓	Low	High	Medium	2
9	✓	Low	High	High	2
10	✓	Medium	Low	Low	1
11	✓	Medium	Low	Medium	1
12	✓	Medium	Low	High	2
13	✓	Medium	Medium	Low	2
14	✓	Medium	Medium	Medium	2
15	✓	Medium	Medium	High	2
16	✓	Medium	High	Low	2
17	✓	Medium	High	Medium	2
18	✓	Medium	High	High	2
19	✓	High	Low	Low	2
20	✓	High	Low	Medium	2
21	✓	High	Low	High	2
22	✓	High	Medium	Low	2
23	✓	High	Medium	Medium	3
24	✓	High	Medium	High	3
25	✓	High	High	Low	2
26	✓	High	High	Medium	3
27	✓	High	High	High	3

Fig. 2. Base of active IF-THEN logic rules for the process of categorizing combat tactical aircraft according to the level of modernity.
Source: developed by the authors based on data [20].

The input data (indicator values) and the results of determining the modernity categories of some combat tactical aircraft are presented in the Table 1.

Table 1

Input data and results of combat tactical aircraft categorization according to the level of modernity

Name the plane	Categorization indicators			Category of modern aircraft
	V*, %	CMTL**, unit	R_{SPS}, %	
MiG-29 (product 9.13)	71	0,28	48***	outdated
JAS-39E Gripen	93	0,67	100	modern
F-15EX Eagle II	94	0,84	100	modern
F-35A Lightning II	95	0,96	100	promising

Notes to the table. 1.
* – compliance with the operational-tactical requirements for a multi-purpose tactical aviation aircraft, which were adopted by the General Staff of the Armed Forces of Ukraine as of June 18, 2021, was evaluated;
** – as a basic (reference) sample, a hypothetical multi-functional fighter was taken, which has ITP (TTC) at the level of the latest world achievements in the field of military aircraft construction;
*** - data on the remaining resource of the "youngest" MiG-29 aircraft fleet of the Air Force of the Armed Forces of Ukraine were used for the calculation.

Source: developed by the authors

The reliability of the obtained results of the combat tactical aircraft categorization according to the level of modernity, presented in the table. 1, is confirmed, among other things, by the fact that they do not contradict the generally accepted division of these aircraft into certain of their generations: 4, 4+, 5.

After constructing the presented "fuzzy" methodology with the help of membership functions and implications, it is possible to enter specific numerical values of the selected most important indicators of the modernity of technology samples as input data and obtain their modernity categories at the output.

Conclusions

It should be noted that procedures based on FST, despite their expected "inaccuracy", "vagueness", "uncertainty", are widely used not only in making quantitative, fairly accurate, decisions [16, p. 11], but also in control systems for various technical objects and technological processes: starting from household appliances and ending with the equipment of oil refineries [19, p. 4].

Thus, the presented technique allows to formalize the process of categorization of AME sample according to the level of modernity, thereby reducing the negative impact of subjective factors inherent in heuristic methods and increasing the reliability of assessments.

Directions for further research. Further research on the development of the methodological base for categorizing samples of AME according to the level of modernity should be focused on expanding the list of modernity indicators taken into account and substantiating the appearance of their membership functions.

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МЕТОДИКА КАТЕГОРУВАННЯ ЗРАЗКІВ ОЗБРОЄННЯ ТА ВІЙСЬКОВОЇ ТЕХНІКИ ЗА РІВНЕМ ЇХ СУЧАСНОСТІ

С.В. Кубарь, О.Є. Мавренков, С.В. Матвійчук

За результатами аналізу існуючих підходів до тлумачення та використання таких понять як “застарілий”, “морально застарілий”, “сучасний”, “новий”, “перспективний” по відношенню до зразків озброєння й військової техніки зроблено висновок про те, що на сьогодні таке категорування здійснюється на основі вербальних методів, що робить оцінку технічної оснащеності військових формувань надто “розмитою” та ускладнює розуміння результатів порівняння альтернативних зразків озброєння й військової техніки, знижує довіру до отримуваних результатів.

Відсутність загальноприйнятих тлумачень зазначених понять та довільна процедура віднесення зразків озброєння й військової техніки до певної категорії їх сучасності, що здійснюється авторами публікацій на свій розсуд без належного обґрунтування, породжують актуальну наукову задачу категорування зразків озброєння й військової техніки за рівнем їх сучасності на основі аналітичних (формальних) методів прийняття рішень з метою зменшення негативного впливу суб’єктивного фактору.

Метою статті є представлення результатів розроблення методики категорування зразків озброєння та військової техніки за рівнем їх сучасності на основі аналітичних (формальних) методів прийняття рішень.

Авторами показано, що віднесення зразка ОВТ до певної категорії сучасності тільки за показником його військово-технічного рівня є необхідною, але недостатньою умовою вирішення зазначеного наукового завдання, оскільки категорія сучасності зразка ОВТ є поняттям багатокритерійним.

Представлена методика базується на використанні методологічного апарату теорії нечітких множин, а в її основу покладається процедура нечіткого логічного виводу з використанням алгоритму Мамдані, що реалізована в програмі FisPro.

Апробацію зазначеної методики представлено на прикладі вирішення задачі категорування бойових тактичних літаків.

Ключові слова: зразок озброєння та військової техніки, категорія сучасності, військово-технічний рівень, теорія нечітких множин, нечіткий логічний вивід, алгоритм Мамдані.