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DECISION SUPPORT SYSTEM IN ASSESSING TECHNICAL DESIGN AND TENDER PURCHASES

A simple method of integrated assessment of quality indicators of various equipment, including the dual-purpose equipment has been represented. The difference relates to the combination of different methods of qualimetry, expert estimations and linguistic utterances.

***Keywords**: dual-purpose equipment, qualimetry, tender, quality, integrated assessment*

Introduction

Applied scientific research, carried out by state order, tends to be ended by making project decisions, which is realized in terms of the tender. In assessing equipment characteristics [1], making a final decision during the tender procurement [2], establishing requirements for the parameters of individual components and modules it is obligatory: *a*) the final decision to be made after a reasonable comparison of several variants; *b*) a choice to be made under the established objective criteria, the best variant; *c*) proposed variants need to be developed by various independent contractors; *d*) assessment of variants should be performed not only by customer but also the third independent contractor. But that is where the problem can appear - how to measure efficiency [3] of different proposed technical, technological, environmental and so on possible solutions, which most frequently have different units of measurement, different scales and do not lend itself to analytic definition as well as can not be objectively compared? In addition, which characteristic, for example, energy efficiency of special transport equipment, can be reflected in the figures, it remains to be seen how significant is this figure, among other performance indicators[4]? Some characteristics can be evaluated by specialists intuitively, based upon personal experience, informal knowledge and therefore, it cannot be measured and principally some characteristics can be calculated, but there is lack of information or takes a long time to do it. It is clear that requirements of design specification can be satisfied with various technical and technological solutions. Certainly, the best design solution is to be determined if the technical requirements are performed equally well in different variants, in the tender [2], for example, for custom machinery, it is estimated involving complex economical indicators, or integrated technical-economic, technical-operational and other indicators [5]. The problem of determining the best design solution is most frequently solved through integrated quality indicators involving methods of analytical and expert evaluation [6, 7], econometric methods [1, 8] and fuzzy logic [9], but the method for determining the indicators especially for objects and dual-purpose systems considerably varies according to the assessment conditions and has subjectivity characteristics[10].

For that reason, the improvement of analysis methods and objective assessment of new technical projects for dual-use goods, as well as its implementation results based on tender procurements is an important and urgent task for the current state of the Ukrainian economy and a prolonged military and political crisis. [11]

Analysis of literary sources

Calculations of the relative economic efficiency of investments are applied when comparing the variants of business and technical decisions, placement of orders on engineered systems and facilities, in solving tasks in accordance with the choice of interchangeable products and services, the introduction of new technology, the development of new or reconstruction of existing enterprises. There is a tested method for evaluation and comparison of different technical solutions. The method of reduced costs [12, 13], in other words, all costs, conditionally reduced to one year of operation.

Various automated Decision Support Systems (DSS), for example, CMMS, CVSS (Computerised Maintenance Management Systems, Computerised Vendor Selection System), BI and BA instruments (Business

Intelligence, Business Analytics) and several others [14] can be used to solve the problem of choice supplier, to evaluate the quality of its offer in the tender procurement. Although, DSS are often not suitable or require adaptation for Ukrainian legislation and under special conditions of tender purchases, therefore are not widely implemented. Furthermore, when dealing with such DSS, there is a risk of information leakage.

Typically, in the various techniques and DSS, the comparative indicator of variants is the minimum of reduced expenditures [12, 13], where the costs are allocated to:

– capital, $K_в$ (equipment purchases, its transportation, construction, installation, checkout, putting into operation). These costs are divided for each year of operation;

– operational costs, $E_в$ (salary for maintenance personnel, costs for electricity, technical maintenance, repairs and overhead costs). These costs are calculated for each year of operation.

Reduced expenditures $E_{пр}$ for each variant, representing the sum of current and capital expenditures (reduced to the same dimension and in accordance with the normative coefficient [15] of effectiveness, are defined as: $E_{пр} = (C_1 + E_н{\cdot}K_1) - (C_2 + E_н{\cdot}K_2)$, где C_1 и C_2 – current expenditures, and K_1 and K_2 – capital expenditures, consequently, for the first and second variants; $E_н$ – the normative coefficient of efficiency of capital investments.

It is understandable that, the best solution would not have a minimum of operational (current) costs, as this variant requires the most large-scale investments.

Specifically, a number of years is determined for special means of transportation for which capital expenditures are reduced to. If the short term is determined, these capital expenditures turn out to be very considerable and can become economically unviable or practically unfulfilled. However, if we take the life cycle costs (lifetime) of specialized machinery or special transport vehicles, and it can be measured for marine or autotransport dual-purpose vehicles during the decade, it shows the capital expenditures are significantly being reduced.

Several approaches for quantitative assessment of quality design solutions[16] have been developed by qualimetric methods [1]. The following principles [18] were used for dual-purpose vehicles, for instance, [17].

1. Quality [19] – is a set of only those properties of vehicle, which are associated with the result, but not with the incurred expenses, which are visible during the vehicle's operation in accordance with its intended purpose (ISO 9000-9004, ISO 8402).

2. All properties of vehicle can be measured by absolute indicator property Q_i ($i = 1, \ldots, n$, where n – the number of properties of assessed vehicle). The obtained indicator values is expressed in specific units for each property, whereas the analytical and expert methods [6, 7], classical metrology methods are used for measurement. Out properties forming the quality indicator, organize hierarchical structure – the properties tree [20].

3. Normative *payback period* (T) – is the time required to recover the investment costs. However, the payback period may not be taken into account for transport equipment and dual-purpose technology considering that the payback period of various variants of transport equipment serves as a tool for implementing state policy.

Short payback periods stimulate rapid increase in production but require considerable investment attraction. Long payback periods are used in sustainable and planned development of the industry, such as the Sea and River Fleet, the Armed Forces of Ukraine (AFU), [3], as well as for the technology of long-term operation. They are typical of conditions of market economy development, economic instability, demonstration of federalization, aggressive behavior of other states. In such difficult circumstances, the capital owner can even take chance of great costs, but only with a short payback period, guaranteed by the state. The new solution to be competitive in the global market must not only meet the requirements established by the technical design specifications, but also correspond to the current state of science and technology development as well as currently have the best operational and environmental characteristics and so on. If the project is a production, then the concept of its service life and operation includes the following production issues such as: materials consumption, unification, manufacturability, etc.), export opportunities for future products (patentability), some features (dual-purpose production), which do not comply with the concept of operation of the finished product, utilization and so forth.

Note that when it comes to a complex instrument, mechanism, dual-purpose vehicle, as the goods of production, therefore it is necessary to take into account the specific properties, which are visible during its technical operation. Technical operation – is a part of the operation, including transportation, storage, technical maintenance and repair of the product. In such a case, exploitation is taken to mean the stage of the product life cycle, on which is implemented, maintained and restored its quality (GOST 25866-83).

Therefore, various methods of qualimetry, which are the part of econometrics [21] and studies the methods of complex and quantitative assessment (products of labor, objects, processes, etc.) are used to evaluate operational, eco-economic and other indicators.

Consequently, it can be concluded that comprehensive, integrated indicator should be used in assessing technical projects and at the tender procurement. Moreover, it should be applied not only when using metrological measurement methods and econometrics methods [1, 21], as well as in combination with non-analytical, expert [7, 22] methods.

Objective, task, subject and topic of research study

The objective of the research is to prove the possibility of using the individual components of Decision Support Systems (integrated indicators) used for the final assessment of various competing technical and technological projects (mainly - dual-use goods and special transportation means), as well as during subsequent tender purchases, aimed at implementing selected solutions.

The task of the research is to improve the calculation methodology of the integrated indicators, assessing the quality of projects, products, equipment or tender offers, based on the use of additive qualimetry methods and expert estimations.

The subject of the research are the processes and quality assessment procedures as well as making decisions in solving the expert and tender tasks for the projects and equipment of double and special purpose.

The topic of the research are the calculation methods of integrated quality indicators of the projects, products, equipment, or tender offers of double and / or special purpose.

The basic material

If a competing variant (the project tender offer, equipment, etc.) has not only reduced operating expenditures as well as increased technical parameters and characteristics such as productivity, cargo capacity, reliability, universality, environmental friendliness etc., in this case, the payback period *T* of capital expenditures will be considerably reduced. Usually, the reduced expenditures (*ПВ*) are calculated by the example:

$$ПВ = E_в + \frac{K_в}{T} . \tag{1}$$

It is clear that the variant will win, which has the lowest value of the reduced expenditures and the highest "quality".

Quality is not only the whole complex of the properties and characteristics of the products or services, which give them the ability to meet the conditional and prospective consumers' needs, but also is a set of object properties that are evident in the process of consumption, operation, usage, object implementation and describes the positive and negative results achieved in these conditions. Separately, the quality does not assess the expenditures for production and consumption. [19]

It may be considered that dual-purpose production are determined by quality factors such as: factors of project; materials, raw material, semi-finished products; works; observance of project; norms and standards. Notwithstanding, these factors not equally have an impact on the quality of new or renovated transportation means, such as dual-purpose vehicles. The most important quality, up to 80% of overall weight is the quality of manufacturing design solution. This is due to the fact that the latest components (quality of materials, works, observance of norms, etc.) are easily controlled by the customer.

While assessing properties, it is possible to apply scales [23]: ratio scale ("how many times"); interval scale ("how much"); ordinal scale (information about what is of better quality, but not how much better or how many times better it is); nominal scale. Although, to compare the different properties measured on different scales, it is convenient to use relative dimensionless quality indicator K_i [18, 22]. This index reflects the degree of approximation of absolute indicator of property Q_i to the benchmark Q_i^{em} and defective index $Q_i^{бр}$, characterizing the highest and lowest levels of assessment.

The relative indicator is described by conjugacy with $K_i = f(Q_i, Q_i^{ет}, Q_i^{бр})$ which is standardized by the function [18, 22] in the case of using qualimetric methods:

$$K_i = \frac{Q_i - Q_i^{бр}}{Q_i^{ет} - Q_i^{бр}}. \quad (2)$$

We use [22] dimensionless coefficients of weight properties G_i to compare selected tree properties of individual indicators according to relative importance, and have $0 < G_i < 1$, a $\sum_{i=1}^{n} G_i = 1$. Weight coefficients can be determined with the involvement of various expert, analytical methods and its combinations.

In general, quantitative assessment of quality is expressed by quality indicator [19]:

$$Кjя = φ(Ki, Gi, Kje), \quad (3)$$

where K_{je} – efficiency coefficient of j object ($0 \le K_{je} \le 1$).

For example, the function φ (K_i, G_i, K_{je}) can be expressed by polynomials, posynomials, averages and all that. Commonly, the quality indicator can be expressed by the simplified formula:

$$K_{jя} = K_{je} \cdot \sum_{i=1}^{n} K_i \cdot G_i. \quad (4)$$

Except for the quality of technical project or special equipment, it is necessary to take into account the expenditures for its creation, production and consumption (usage, operation), the overall expenditures (for example, the reduced expenditures). That is why, the integrated quality indicator, value determination of which is based on the same principles is used instead of the quality indicator (4). We will determine the procedure to be followed while assessing the possible solutions and tender procurements.

Construction of tree properties. Quality assessments depend on the properties indicators, a set of which forms the quality model of assessed object: under one set of indicators, the 1_{st} vehicle will be better in quality than the 2_d vehicle, but under a different set of indicators, on the contrary, the 2_d vehicle is better than the 1_{st} one. It is clear that, the set of indicators against which the quality is assessed, must be unambiguous, ordered and decomposed into the properties tree. Comparing by quality several variants of the object (product, project) of one type, those properties are excluded from consideration, which are equally expressed in comparable variants. In other words, assessment results are interpreted as if they are expressed in ratio scale [23]. It provides information not only on how much each variant differs in quality from the other, but how many times the difference appears. In this case, quality assessments can be expressed by ordinal scale and provide information about what of better quality (but not how much better).

Determination of reference values and defective values of indicators properties. Reference values of indicators are taken in this manner.

1. Some objects-analogues are selected in relation to the assessed object and some of the objects are determined by the best quality.
2. Determination of indicators of individual properties of the best object are taken as reference values.
3. The best for the whole complex of these analogue values of indicators of each property are defined for selected objects-analogues. These values are taken as reference values.

In [1, 21] it has been proved that use of objects-analogues can result in errors and that determination of reference values must be the following: the value needs to be selected of the best in the world (at the time of quality assessment) the indicator values of corresponding properties. This relates to the defective factors as well (the worst, intolerable) performance properties.

Determination of indicators properties. Commonly, linguistic expression of gradation of values of absolute properties, otherwise speaking, vague (fuzzy [9]) expression is used instead of digital expression gradation in methods for quality assessment. For example, a five-grade scale: excellent, good, satisfactory, unsatisfactory, fail. Though, due to small discreteness of gradations the relative error of assessments is 20%. To reduce the margin of errors, it is necessary to increase the number of gradations, but not in all sizes, but particularly those, which are within the psychological capabilities of man (expert, specialist). If the object, the vehicle, the transportation device of special purposes, dangerous vehicle, etc. are estimated, then the scale can be more rigid and demanding to positive evaluations. Clearly, the gradations can be sufficiently flexible and vary according to the requirements of the final product or project.

It is proved that the best number of gradations should be up to 20 for psychological and mental-logic capabilities of highly qualified expert. A good outcome could be achieved if 100-percent scale with gradations is used, for example 5% or 10%. However, in our opinion, at the beginning and at the end of this scale it is necessary to use smaller gradation (5%), while larger gradation (10%) should be used in the middle of the scale. It applies to those properties, the indicators of which are impossible, difficult or undesirable to use normal physical units.

[18, 22] doesn't show how to convert the linguistic, fuzzy experts' assessments into single-digit and numerical. A well-known Harrington's scale [24] is proposed to be used for assessing linguistic indicators made by experts (excellent, good, qualitative, almost possible etc. with smaller indicators at the beginning and at the end of the scale). A well-know method for each indicator can be easily implemented for Harrington's scale - to use dimensionless (relative, normalized) scale on a certain range. The scale of Harrington is formed by means of the expression $y(x)$:

$$y(x) = e –E, \qquad (5)$$

where $E = e^{-x}$ – a function to determine linguistic variable.

This scale is of the same type for all merged indicators, allowing them to compare. Despite the fact that the assessment result is heavily dependent on the source information about private indicators, on determination accuracy of generalizing characteristics and properties and the experts' qualifications, then this scale is universal and easily adaptable to experts' linguistic utterances [25].

Source information is normalized on the range {0, ..., 1} or {0% ... 100%} and partial indicators (assessment, Tab. 1, Fig. 1) are normalized as well. Thus, it is possible to easily establish finer gradations at the beginning and at the end of the scale, where the function (5) is the most sensitive to the change of linguistic variable *x*.

Table 1

Possible assessment on the scale of Harrington

Range inside of Harrington's scale	Expert's assessment
1,00 – 0,80	Excellent
0,80 – 0,63	Good
0,63 – 0,37	Satisfactory
0,37 – 0,20	Bad
0,20 – 0,00	Very bad

Here is the method to assess the technical design, which can be used in the common Decision Support System in evaluating and comparing different projects variants, as well as at the tender procurement proceeding.

Define the indicator for assessing the quality of the hypothetical construction project of dual-purpose vehicle. The objective is to continue to carry out tender procurements, therefore we use the described method and experts' assessment of indicators properties and execute several mandatory phases, which almost completely exclude the subjective component of evaluation [5, 10].

We show the calculation only for one object (project, vehicle, solutions, technology), or rather for $K_{1я}$, according to (4), j=1. Clearly, that the calculations of the other indicators of alternate solutions ($K_{2я}$, $K_{3я}$, …, $K_{jя}$) are carried out in a similar way but the best solution is determined by comparing the coefficients

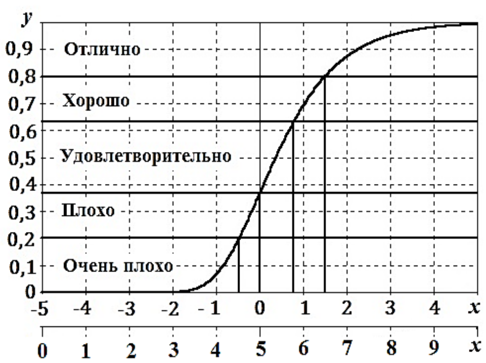

Fig. 1. Variant of graphical representation of Harrington scale

Stage 1. Expert evaluation. Objective assessment of individual components of the project quality depends on personal qualities, speciality, experts' experience:

- experts should have the authority, seniority and experience;
- the number of experts should be from 7 to 10 people;
- the representatives of different professions, services, research areas and so on must be among the experts.

Stage 2. Determination of characteristic quality indicators. Indicators and its number is determined by the customer. It is essential to aim for determining the most characteristic indicators and to avoid its too large number.

As an example, the following list is proposed.

1. Patentability – is the number of technical and technological solutions protected by patents (customer, contractor, industry or state) and its coverage of the proposed scientific and technological solutions in the project.
2. Energy efficiency of vehicle.
3. Material consumption in both qualitative and quantitative terms especially for scarce materials (precious and non-ferrous metals, rare-earth elements, etc.).
4. Manufacturability of vehicle – the degree of unification of separate components, availability of appropriate technologies in production, or conversely, the need for the creation of innovative technology.
5. Coverage of vehicle, the process of its operation or designing of modern information technologies (*IT*).
6. Reliability, or rather the ability to work out the normalized terms of exploitation with the minimum of downtime and repairs.
7. Environmental friendliness, specifically, the environmental impact at all stages of the life cycle.
8. Ergonomics, aesthetics, that is the maximum approaching to physio-logical control capabilities and aesthetic preferences of the person.
9. Functionality – namely, in the product (design, vehicle, etc.) everything should be adapted to perform the main goal and there is nothing superfluous, too difficult, and so on.

Further, in the calculations, we use the number of indicators (1-9) to represent the weight coefficients, G_i, of absolute and relative indicators properties Q_i and K_i.

Stage 3. Weight determination of quality indicators.

For example, 7 experts (Eg.1 ..., Eg.7) should fill his column in the table (Tab. 2), and write down the criterion number from 9 to 1 against each indicator. These actions are conducted by experts using (5). Figure 9 corresponds to the most important indicator, while 1 – to the least significant.

Table 2

Weights indicators of properties (vehicle, project, solution)

Indicator	Ranking of indicators							Sum of ratings	Weight, G_i
	***Eg.* 1**	***Eg.* 2**	***Eg.* 3**	***Eg.* 4**	***Eg.* 5**	***Eg.* 6**	***Eg.* 7**		
1. Patentability	1	5	4	**8**	3	**8**	5	34	0,108
2. Energy efficiency	4	**7**	8	5	4	5	**9**	42	0,133
3. Material consumption	2	**9**	1	1	**7**	2	3	25	0,080
4. Manufacturability	**7**	6	5	3	1	**9**	4	35	0,111
5. *IT*- Tecnhnologies	5	4	**9**	2	6	4	1	31	0,098
6. Reliability	**9**	1	3	4	**9**	3	**7**	36	0,114
7. Environmental friendliness	6	3	6	6	5	6	2	34	0,108
8. Ergonomics	3	2	**7**	**9**	**8**	1	**8**	38	0,121
9. Functionality	**8**	**8**	**2**	**7**	2	**7**	6	40	0,127
Sum	45	45	45	45	45	45	45	**315**	**1**

Table 2 shows that energy efficiency (42 points), functionality (40 points), ergonomics (38 points) and reliability (36 points) are at the first places in importance. Then, manufacturability (35 points), environmental friendliness and patent purity (34 points) tend to be given preference. IT technologies (31 points) and material consumption (25 points) are at the very lowest. Most importantly, that each of the indicators obtained specific weight coefficient, using the expression (5, which reflects a generalized representation of experts.

Stage 4. Absolute indicators. Each of the experts forms the absolute indicators in relation to some imaginary sample. Here is the problem of determining a benchmark indicators of properties Q_{iem}. It is not recommended to choose the biggest of indicators that is in the table as a benchmark in qualimetry theory. An absolute indicator of the best world level is advisable to be chosen as the benchmark.

If we take the reference values for each of the indicators 100%, then the normalized indicators K_i by the expression (2) will be lower, compared with certain world standards. Defective factor $Q_i^{бр}$ should be taken as the lowest possible indicator. Calculate absolute indicators of properties Q_i as arithmetic mean value of experts.

Table 3

Indicators of properties for one version of the project design

Indicator	Absolute indicators of properties							Summed up indicators			
	Eg.1	Eg.2	Eg.3	Eg.4	Eg.5	Eg.6	Eg.7	Q_i	Q_i^{em}	$Q_i^{бр}$	K_i
1. Patentability	40	35	60	45	45	50	70	49,3	100	40	0,155
2. Energy efficiency	65	60	55	70	60	50	80	62,8	100	50	0,256
3. Material consumption	55	60	60	70	55	65	65	61,4	100	50	0,228
4. Manufacturability	40	45	55	65	60	55	45	52,1	100	40	0,202
5. IT-Tecnhnologies	40	50	55	50	40	45	50	47,1	100	40	0,118
6. Reliability	55	50	55	55	60	65	60	57,1	100	50	0,142
7. Environmental friendliness	50	45	55	40	60	55	40	49,2	100	40	0,153
8. Ergonomics	50	55	60	45	55	70	60	56,4	100	45	0,207
9. Functionality	55	75	70	65	65	65	60	65,0	100	50	0,300

According to the Table 4 absolute indicators of properties Q_i, experts for this project are mostly satisfied with functionality (K_i = 0,30), energy efficiency (0,256) and мaterial consumption (0,228), and the least of all satisfied with environmental friendliness and reliability of decision.

It is clear that the indicators only for one version are given in the example (table 3). Really, the tables need to be filled out for several variants of possible solutions and so that, the columns with different variants for each of the properties would stay close by - for a visual comparison of all variants.

Table 4

Ranking of relative indicator K_i of project properties

Number of indicator	Indicator	Ki	Rank
9	Functionality	0,300	1
2	Energy efficiency	0,256	2
3	Material consumption	0,228	3
4	Manufacturability	0,202	4
8	Ergonomics	0,207	5
1	Patentability	0,155	6
7	Environmental friendliness	0,153	7
6	Reliability	0,142	8
5	IT-Tecnhnologies	0,118	9

Now, according to the expression (4), the resulting evaluation can be determined – the overall quality coefficient of the estimated project. Due to the fact that we do not have information about saving individual properties of projects in time, so the expression (4) is simplified (K_{je} = 1) to:

$$K_{jя} = 1 \cdot \sum_{i=1}^{n} K_i \cdot G_i. \qquad (6)$$

With the help of (6) we obtain the quality coefficient of the first project $K_{1я} \approx 0{,}2$. In particular, the project, which is estimated (Tables 2, 3 and 4), only corresponds to 20% of the world's best models (standard Q_i^{em} = 100 %). Conclusions can be drawn about the best or the worst of them only after calculating the quality coefficients of other projects.

Conclusions

1. *The represented method has been tested on one of the auto-repair enterprises Air Defense Gun and when designing the universal dual-purpose ship. The method has given the opportunity for: a) formulation of the results-oriented instructions for developers, designers, repair and maintenance services to further improve the individual indicators of proposed decisions, b) election of the best, with several variants for the purchase of equipment, components and materials.*

2. *The possibility of using heterogeneous integrated indicators, formulated by experts in decision support systems has been shown on the basis of the given calculation methodology. The described method is supposed to be used in such decision support systems as well as during the tender procurement, where specific evaluation of the technical and technological projects, dual- purpose goods, special vehicles are used.*

3. *An example of the integrated assessment of the project quality of hypothetical dual-purpose vehicle has been given. The difference represented from well-known methods lies in the improvement of the calculation procedure of heterogeneous integrated indicators, assessing the quality of projects, products, equipment, tender offers, which is based on the use of additive methods of qualimetry, expert estimations and linguistic utterances.*

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ПОДДЕРЖКА ПРИНЯТИЯ РЕШЕНИЙ ПРИ ОЦЕНКЕ ТЕХНИЧЕСКИХ ПРОЕКТОВ И ТЕНДЕРНЫХ ЗАКУПКАХ

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Представлена простая методика интегрированной оценки показателей качества различного оборудования, в том числе – двойного назначения. Отличие заключено в сочетании различных методов квалиметрии, экспертных оценок и лингвистических высказываний.

Ключевые слова: *оборудование двойного назначения, квалиметрия, тендер, качество, интегральная оценка*.

ПІДТРИМКА ПРИЙНЯТТЯ РІШЕНЬ ПРИ ОЦІНЮВАННІ ТЕХНІЧНИХ ПРОЕКТІВ ТА ТЕНДЕРНИХ ЗАКУПІВЛЯХ

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Представлена проста методика інтегрованої оцінки показників якості різного устаткування, у тому числі – подвійного призначення. Відмінність полягає у поєднанні різних методів кваліметрії, експертних оцінок і лінгвістичних висловлювань.

Ключові слова: *обладнання подвійного призначення, кваліметрія, тендер, якість, інтегральна оцінка*.