The peculiarities of external quality assurance processes in the higher education management system are considered. It is noted that the quality of educational programs (EP) of higher education institutions is controlled by quality assurance agencies (QAs) using an accreditation system. The key features of the accreditation process in terms of peer review are identified. The problem of accreditation process management, namely the subjectivity and lack of consistency of expert decisions, is highlighted.

The correlation method was applied to determine the interdependencies in expert assessments (competence, meaningful orientation of judgments, and perception of the linguistic rating scale). The identified types of variables make it possible to explain the existing measure of subjectivity that affects the collective conclusion of experts.

A comprehensive methodology for quantitative evaluation of the EP quality under conditions of uncertainty based on the relative importance of the relevant criteria and subcriteria, as well as the levels of expert competence using the apparatus of fuzzy mathematics, is proposed. A basic model for the formation of a collegial expert opinion on the EP quality has been developed using the example of a system of quality criteria approved by the Ukrainian QAA. Variations in the expert values of the weight coefficients and parameters of fuzzy numbers in the context of the linguistic rating scale (“A – B – E – F”) made it possible to use the means of a computational experiment. The application of this model will allow managers to positively influence the existing ambiguity of the assessment method, which requires being guided by standard criteria and at the same time determining the EP innovativeness. In general, the application of the proposed evaluation tools on the quality of EP allows experts and managers to make decisions at a higher level of academic and managerial culture.

Keywords: quality assurance, higher education, accreditation, peer review, integrated assessment model.
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through the creation of independent administrative structures (Quality Assurance Agency, QAA) that commonly function as professional buffer organizations between public authorities and HEIs. National QAs develop common EQA models in international cooperation, as well as approve quality standards and criteria (for example, in the European Higher Education Area [3]).

However, the activities of QAs are criticized, in particular, due to bureaucratic approaches to the elements of the education quality process, the invalidity of the mechanisms for combating corruption in the academic sphere, etc. [4]. The problem of insufficient correlation of EQA tools with professional qualifications frameworks is also articulated (in particular, in the field of engineering [5], healthcare [6], social sciences [7], art and culture [8]). The focus is on QAA approaches to monitoring and quality control of higher education, especially to the accreditation of educational programs (EP). The accreditation process is currently carried out in line with the general concepts of continuous improvement and total quality management (TQM). However, there is still scientific and practical uncertainty in measuring the quality of academic processes in the HEI, and emphasizes are placed differently in assessing the EP [9]. Given this, there is a scientific and practical need for a better understanding of peer review processes, as well as the search for solutions that can improve existing EQA models. Therefore, studies devoted to the development of tools for managing the EQA process in higher education, namely the improvement of the expert decision-making model, are relevant.

2. Literature review and problem statement

The paper [10] emphasizes the specifics of modern models of quality assurance in terms of achieving a balance between standardized QAA recommendations and the professional judgment of the expert group (EG). An important scientific achievement of the study was the results of sociometric analysis applied in the survey of groups of stakeholders who acted as experts in accreditations. Disagreements in the assessment of the EP between expert conclusions and QAA decisions were identified. In an empirical study [11], the fact that a positive opinion of experts on the EP quality is not always approved by the QAA is confirmed (the deviation is about 25%). However, this study does not contain an analytical development regarding the improvement of the existing EQA process in terms of making expert decisions in order to identify deviations. The ambiguity in the assessment of the EP is also comprehended in [12] using documentary analysis (questionnaires and interviews with the academic community and QAA staff). The results of the analysis showed that the process of accreditation assessment should be improved in the direction of increasing the potential of the involved human resources, mainly through the qualitative selection of reviewers. However, the authors of this study did not propose a specific EQA model. In [13], the evaluation process was analyzed on the basis of an autoethnographic approach and using the theory of symbolic interactionism. The results of contextual analysis of the evaluation of the EP are presented according to two criteria (learning outcomes and human resources) with the appropriate correlation with the stages of the accreditation process and the interactivity of the EG. Emphasis is placed on the need to develop organizational and methodological approaches to ensuring the minimum academic capital in the formation of the EG to evaluate the EP. However, the available studies do not contain developed solutions for the selection of experts (reviewers) for EP accreditation, which would allow educational managers to effectively manage academic capital and minimize disagreements in expert decisions (peer reviews).

The current approaches to the analysis of decision-making processes in EQA systems, presented in [14], are based on the concept of trust management. The decision-making information technology of QAA has been investigated from the point of view of processing symbolic representations of trust in the processes of ensuring the quality of education in the HEI. The empirical part of this research found that dishonesty in reporting information and the application of legal documents have a direct impact on the management processes of EQA in higher education. Quality management is transformed into a purely technical process with a low level of trust between the QAA and the HEI. It focuses primarily on accountability according to clearly defined criteria. The author of this study substantiates the idea that trust should be a component of EQA management models, but leaves open the question of scientific and practical development of such models.

The analytical study [15] summarizes new approaches to assessing the quality of higher education, which take into account the interests of various stakeholder groups and focus on establishing a balance of accountability and improving EQA processes. This makes it possible to form an assessment of the EP that is more fair and trustworthy for stakeholders. The authors of this analytical research left without attention the issue of involving such an important group of stakeholders as students in peer review. This information gap is to some extent filled by the publication [16], where a wide range of functions (from advisory to full experts) outlines the role of students in EQA processes. However, models for the formation of EG that take into account the specifics of students’ academic experience have not yet been developed. There are not also models that provide the minimum amount of “academic capital” in the processes of EQA. Special attention of researchers [17] is focused on the application of the latest approaches to quality management processes that meet the social priorities of the development of higher education (equality, inclusion, diversity). An approach to the implementation of gender monitoring of the HEI management system and a methodology for calculating the gender-sensitive characteristics of the organizational maturity of educational management are proposed. However, the authors of this study do not offer a specific methodology for peer review of the EP quality. Contextual features of the application of gender audit to the management of EP in the field of STEM are defined in the paper [18]. It also presents relevant experimental investigations in HEIs. Nevertheless, this study does not offer tools for identifying expert actions for evaluating the EP quality. The authors [19] developed a logical-structural model for integrating gender criteria into the system of project and program management. This model is useful for application in EP evaluation processes, since the QAA functioning system is project-based. At the same time, it requires the development of appropriate tools for decision makers on the EP quality.

A review of current research has shown that EQA processes are evolving in line with general quality management concepts. The authors [10–15] discuss possible ways to measure the quality of higher education and highlight the causal context of the quality assurance process in HEIs. Particular
attention is paid to the organizational approaches of QAAs to involve different groups of stakeholders in accreditation processes [15–18]. Methodological approaches are being developed to create an information platform for experts, on which their contribution and knowledge will be taken into account and determine the value of their contribution to the EP accreditation process [12, 13, 15, 16, 19]. However, quality management tools applied to higher education remain inaccurate and require the use of fuzzy mathematics. All this points to the feasibility of conducting a study on the development of tools for making expert decisions on assessing the quality of EP using fuzzy set theory.

3. The aim and objectives of the study

The aim of the study is to develop a comprehensive toolkit for the formation and adoption of a collegial decision by an expert group (EG) to assess the EP quality on the use of fuzzy set theory. This will allow QAAs managers to provide experts with effective tools for making an informed, balanced and impartial decision on the EP quality. The proposed decision-making tools will allow in the long term to improve the management culture of the quality of higher education.

To achieve this goal, it is proposed to solve the following tasks:

– to analyze the organizational features of the EQA system in terms of involving groups of experts in the accreditation process and identify expert actions for assessing the EP quality;

– to propose a comprehensive methodology for quantitative assessment of the EP quality under conditions of uncertainty based on the relative importance of the relevant criteria and sub-criteria, as well as the levels of academic competence of experts using fuzzy mathematics.

4. The study materials and methods

Key decisions in the EQA processes are made collectively by the EG. The holistic approach as a holistic perception by experts of the degree of compliance (or non-compliance) of the EP with the QAAs criteria [20] is used to develop a generalized assessment of the EP. Some subcriteria are significantly more significant than others within each criterion, but none of them is decisive importance. The use of fuzzy mathematics tools [21] allows to take into account the importance and “blurring” of each component of the evaluation criterion. The system of criteria and sub-criteria for the assessment of EP can be represented by a multidimensional time series for different indicators.

The participation of experts in the accreditation process is determined by their academic competence and is based on the development of value judgments about the compliance of the EP with the system of standards, criteria and relevant indicators. The use of fuzzy mathematics tools makes it possible to take into account the multilevel academic competence of each of the experts. The correlation analysis was employed to identify significant dependencies of variables in expert assessments. Accounting for all information owned by experts, including subjective, allows the adoption of an objective and balanced collegial decision. Mathematical programming methods are used to quantify and objectify replaceable expert judgments.

Operations research methods were used to support collegial decision-making for the quantitative assessment and objectification of the variables of academic capital, expert judgments in a situation of fuzzy uncertainty. The main idea of fuzzy theory is to replace the characteristic function of the set A, which assigns the value 1 when the element belongs to A, and 0, if it does not belong, the membership function µA, which connects each element with a real number in the interval [0, 1]. The zero degree of membership is understood as non-membership, 1 is understood as full membership in the Boolean sense. Intermediate values reflect the corresponding degree of membership uncertainty, which is interpreted depending on the situation.

The empirical basis of the study is the experience of the authors’ participation in the work of EG in accreditation processes. This led to the formulation of the hypothesis of the existence of correlation variables in the collegial decisions of experts on the EP quality under conditions of uncertainty. The hypothesis was tested using mathematical modeling tools and aimed to assess correlation variables and their optimization under conditions of varying degrees of uncertainty in the initial information. The application of the focus of differentiation in the context of the sub-criteria for assessing the EP quality and taking into account the level of competence of experts allows improving the model of assessing the EP quality.

5. The results of developing a model for forming a collegial decision of the expert group to assess the quality of the educational program

5.1. Analysis of organizational features of involving experts in the process of accreditation of the educational program

The accreditation process for assessing the EP quality involves compliance with the following logic of the EG.

Stage 1. Formation of EG with the indication of the level of its academic competence. The values of the competency weighting factor \( w(c) \) of each expert are established on the basis of academic experience (professor, associate professor, graduate student, master’s degree, bachelor’s degree). There is a need to make the most of the academic experience of experts, taking into account the limited human resources of the EG (usually 3 participants). This is especially important in a situation where the EG includes a higher education applicant, who has much less academic experience than teachers. For example, the Ukrainian QAA does not specify the level of educational experience of students (bachelor, master, postgraduate). Therefore, undergraduate applicants are involved in the evaluation of the EP not only at the bachelor’s level, but also at the master’s and postgraduate level [16].

Each expert has his (her) own vision of comparing a single 100-point scale with the linguistic scale “A – B – E – F”. It is proposed to use the European “ECTS” scale as a means of extrapolation to the subjective systems of assessing experts in order to solve the problem of different approaches of experts to assessment. It is necessary that each of the experts determine their range of points for each term “A”, “B”, “E” and “F”. The resulting rating scales will be used by experts in assessing the EP for each sub-criterion and will correlate expert judgments on a linguistic scale.

9 criteria (48 sub-criteria) are used to assess the EP quality of the first (Bachelor’s) and second (Master’s) levels.
of higher education, and 10 criteria (54 sub-criteria) are used to evaluate the programs of the third (educational and scientific) level by QAAs [20].

Stage 2. Determination by experts of the significance of the criteria and sub-criteria for assessing the EP quality. Each of the experts determines the degree of importance of the criteria and sub-criteria for assessing the EP quality (based on their own academic experience and vision of the EP innovativeness) by setting the values of the weighting coefficients \( w^{(i)}/w^{(l)} \).

Stage 3. Grading by experts according to the criteria and sub-criteria for assessing the EP quality. The EG holds meetings with different focus groups of EP stakeholders, as a rule, during the first two days of the accreditation examination. Each of the experts clarifies and checks the information provided in the self-assessment information and its annexes by means of a survey. Experts give their scores (in the form of fuzzy numbers) for all required sub-criteria on the third day of the accreditation examination (“judgment day”), and also form a personal weighted overall score for each criterion. Experts use operations on fuzzy numbers based on a 100-point scale and determine the appropriate evaluation term on the linguistic scale “A – B – Е – F”, in order to form a personal weighted overall score for the EP quality.

Stage 4. Calculation of EG grades according to the quality criteria of the EP. Experts are determined with the only assessments for the EG for each quality criterion of the EP. The formation of a group-wide weighted score for each criterion is carried out by performing operations with fuzzy numbers based on a 100-point scale. In addition, the normalized weight coefficient of the expert’s academic competence \( w^{(l)} \) is taken into account to calculate the group-wide assessment. Further, the corresponding closest value of each assessment (term) on the linguistic scale “A – B – Е – F” is established on the basis of procedures for comparing fuzzy numbers.

As a result, the EG determines the final overall assessment for all quality criteria of the EP. For example, the Ukrainian QAA [20] uses the final linguistic scale: “Accreditation “exemplary” – “Accreditation” – “Accreditation “conditional (deferred)” – “Refusal of accreditation”.

Stage 5. Preparation of the final report of the EG on the quality assessment of the EP. As a rule, the EG submits a draft report to the QAA on the fifth or seventh working day after the completion of the accreditation examination. The report contains group expert assessments according to the quality criterion of the EP. The assessment of each criterion is accompanied by a thorough explanation of the level of compliance with the EP, citing facts, examples, evidence. The scores given in the draft report and the final report must be identical.

The implementation of the algorithm for performing expert actions to assess the EP quality in specific processes of accreditation examinations requires strict mathematical formalization and the development of a detailed application methodology. The conceptual apparatus of matrix algebra and fuzzy mathematics can adequately reflect the presence of fuzzy terms of a linguistic variable, a complex structural-logical hierarchy of objects of the input concept and ways of their transformation.

5.2. Development of methods for expert evaluation of the quality of the educational program

A multilayer technique for the implementation by the EG of the synthesis of a mathematical model is developed. It is also proposed to form an initial integral assessment of the EP quality for each criterion, which includes five stages.

At the first stage, the total number \( m_i \) and the list of criteria by which the EP will be assessed, \( m_i = 10 \), and the corresponding number of sub-criteria \( k_i \) in each \( i \)-th criterion are determined. It is accepted in Table 1 that the evaluation of \( i \)-th criterion, the value of the choice index \( o_i \) corresponds to 1, and the value of the rejected one corresponds to the value of 0.

| Criteria for assessing the EP quality, \( i \) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|-------------------------------------------|---|---|---|---|---|---|---|---|---|----|
| Selection index, \( o_i \)                | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0  |
| Number of sub-criteria, \( k_i \)         | 4 | 9 | 4 | 5 | 4 | 6 | 7 | 3 | 6 | 0  |

The schedule for conducting accreditation procedures is drawn up taking into account the production capabilities and work style of each expert. The value of the weight coefficient of competence \( w^{(l)} \) for the assessments of each expert is approved. An example of the values of the weight coefficients of academic competence for the composition of the EG is given in Table 2. The normalized values \( w^{(l)} \) of the weight coefficient of competence correspond to the condition \( w^{(l)}/w^{(l)} + w^{(m)}/w^{(m)} = 1 \) and calculated by the formula:

\[
w^{(l)} = w^{(l)} \frac{1}{\sum_{i=1}^{3} w^{(l)}}, \quad l = 1,3,
\]

where \( w^{(l)} and w^{(m)} are the input and normalized weight coefficients of the \( l \)-th expert’s competence, respectively, \( l = 1,3 \).

| Characteristics | Expert 1 – head of the EG (professor) | Expert 2 – member of the EG (associate professor) | Expert 3 – member of the EG (bachelor student) |
|-----------------|-------------------------------------|-----------------------------------------------|-----------------------------------------------|
| Ordinal number in the EG | 1 | 2 | 3 |
| Input weighting factor (tariff category), \( w^{(t)} \) | 20 | 19 | 14 |
| Normalized weight coefficient of competence, \( w^{(l)} \) | 0.377 | 0.359 | 0.264 |

Then a comparison is made by weighted expert assessments (in whole numbers) of the linguistic scale “A – B – Е – F” with a single 100-point scale (in discrete and continuous form) according to Table 3, which shows an example of expert proposals and their agreement. For instance, expert 1 (doctor of science, professor) considers that the EP is valid for the criterion at level “A” when the expert assessment is from 96 to 100 points. At the same time, expert 3 (bachelor applicant) considers that it is acceptable for level “A” if the EP is rated at 82 points or higher.

The basis for establishing such a correspondence is the generally accepted mechanism for reducing the assessment system of the ECTS system. Every integer boundary \( \mathbb{E}^{(l)} \) of the corresponding range \( d \) of a unified 100-point discrete
scale for the weighted positions of experts is defined as the average weighted value of the corresponding limits of the scales proposed by each expert, rounded to integers, according to the formula:

\[ X_{i}^{(e)} = \sum_{i=1}^{3} w^{(e)} x_{i}^{(e)}, \]

where \( X_{i}^{(e)} \) – the corresponding integer discrete boundary value at the suggestion of the \( i \)-th expert, \( i = 1, 3 \).

**An example of comparing the linguistic scale “A – B – E – F” with a single 100-point scale (in discrete and continuous form)**

| Scale | Terms (ranges) |
|-------|---------------|
| Linguistic scale “A – B – E – F” | A | B | E | F |
| Expert proposal 1 | Left limit value \( x \) | 96 | 85 | 64 | 0 |
| | Right limit value \( x \) | 100 | 95 | 84 | 63 |
| Expert proposal 2 | Left limit value \( x \) | 90 | 70 | 50 | 0 |
| | Right limit value \( x \) | 100 | 89 | 72 | 50 |
| Expert proposal 3 | Left limit value \( x \) | 82 | 60 | 35 | 0 |
| | Right limit value \( x \) | 100 | 81 | 59 | 34 |
| Unified 100-point discrete scale | Left limit value \( x \) | 90 | 73 | 51 | 0 |
| | Right limit value \( x \) | 100 | 89 | 72 | 50 |
| Unified 100-point continuous scale of the Eq | Left limit value \( x \) | 89.5 | 72.5 | 50.5 | 0 |
| | Right limit value \( x \) | 100 | 89.5 | 72.5 | 50.5 |

The intermediate limit of each range of a single 100-point continuous scale by weighted positions of experts is determined as the average value of the corresponding adjacent left and right integer boundaries of a single 100-point discrete scale. Then

\[ \bar{x}_{l} = \left( \bar{x}_{l}^{(a)} + \bar{x}_{l}^{(b)} \right) / 2; \]

\[ \bar{x}_{b} = \left( \bar{x}_{b}^{(a)} + \bar{x}_{b}^{(b)} \right) / 2; \]

\[ \bar{x}_{f} = \left( \bar{x}_{f}^{(a)} + \bar{x}_{f}^{(b)} \right) / 2, \]

where \( \bar{x}_{l}, \bar{x}_{b}, \bar{x}_{f} \) – the common boundaries of the respective adjacent ranges of the continuous scale; \( \bar{x}_{l}^{(a)}, \bar{x}_{l}^{(b)}, \bar{x}_{b}^{(a)}, \bar{x}_{b}^{(b)}, \bar{x}_{f}^{(a)}, \bar{x}_{f}^{(b)} \) – left and right boundaries of the corresponding discrete scale ranges.

It is proposed to confine ourselves to the concepts of fuzzy numbers and intervals to describe the fuzzy terms “A”, “B”, “E”, “F” of the linguistic variable “EP quality level” using the apparatus of fuzzy mathematics [21]. The rational choice of fuzzy representation models is important for the efficiency of calculations, since it determines the level of simplicity and convenience of operating with them. It suffices to consider fuzzy numbers and intervals (L-R) of the type [21], since they have a clear geometric interpretation. The implementation of algebraic operations with fuzzy numbers is uncomplicated (accessible) and allows to cover a wide range of real membership functions.

The high level of uncertainty in the task of accreditation examination of the EP and the short time frame for its implementation is taken into account. Therefore, it is better to limit ourselves to triangular fuzzy numbers and trapezoidal fuzzy intervals from a computational point of view. A triangular fuzzy number \( X_{\alpha, \beta} = \{a_{\alpha}, a_{\beta}, \beta\} \) is completely determined by an ordered triple of real numbers – its parameters: \( a_{\alpha} \) – the mode of the fuzzy quantity \( x \); \( a_{\alpha}, \beta \) – the left and right fuzziness coefficients, respectively, and is described by a triangular membership function (Fig. 1):

\[ L(x, a_{\alpha}, a_{\beta}) = \left\{ \begin{array}{ll}
0, & x < a_{\alpha} - \alpha; \\
1, & x = a_{\alpha}; \\
R(x, a_{\beta}), & a_{\alpha} < x < a_{\alpha} + \beta; \\
0, & x \geq a_{\alpha} + \beta;
\end{array} \right. \]

\[ \mu_{x}(x) = \left\{ \begin{array}{ll}
0, & x \leq a_{\alpha} - \alpha; \\
L(x, a_{\alpha}, a_{\beta}), & a_{\alpha} - \alpha < x < a_{\alpha}; \\
1, & x = a_{\alpha}; \\
R(x, a_{\beta}), & a_{\alpha} < x < a_{\alpha} + \beta; \\
0, & x \geq a_{\alpha} + \beta;
\end{array} \right. \]

where \( \alpha, \beta \geq 0 \) and \( \theta \geq 0 \). \( \mu_{x}(x) \) – unimodal membership function of fuzzy quantity \( x \), \( L(x, a, b) \) and \( R(x, a, b) \) – auxiliary functions of \( x \) with parameters \( a, b \), respectively, where the membership function is nonzero, serves as a continuous carrier of the fuzzy set \( X_{\Delta} \).

Additionally, given the limitations of the continuous scoring scale \([0; 100]\), it is necessary to put:

\[ a_{\Delta, l} = \max \{0, a_{\alpha} - \alpha\}; \]

\[ a_{\Delta, u} = \min \{100; a_{\alpha} + \beta\}. \]

As the fuzzy number \( X_{\Delta} \) is compact (blurred), according to [22], it is possible to take an analog of the dispersion \( D[X_{\Delta}] \) of a random variable and analog of the root-mean-square deviation \( s_{x} \):

\[ D[X_{\Delta}] = \int_{-\infty}^{\infty} x^{2} \mu_{x}(x) dx / \int_{-\infty}^{\infty} \mu_{x}(x) dx - \int_{-\infty}^{\infty} \mu_{x}(x) dx / \int_{-\infty}^{\infty} \mu_{x}(x) dx \]

\[ s_{x} = \sqrt{D[X_{\Delta}]} \]

After substituting the membership function (6), (7) into the last relation and performing analytical calculations, a simple calculation formula for \( D[X_{\Delta}] \) can be obtained:

\[ D[X_{\Delta}] = (1/18) (a_{\alpha}^{2} + a_{\beta}^{2} + \beta^{2}). \]

Trapezoidal fuzzy interval \( X_{\Delta} = \{a_{\alpha}, b_{\alpha}, a_{\beta}, b_{\beta}\} \) is completely determined by the ordered four of real numbers – its
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\[ \mu_c(x) = \begin{cases} 
0, & x \leq a_s - \alpha_s; \\
L(x, a_s, \alpha_s), & a_s - \alpha_s < x < a_s; \\
1, & a_s \leq x \leq b_s; \\
R(x, b_s, \beta_s), & b_s < x < b_s + \beta_s; \\
0, & x \geq b_s + \beta_s.
\end{cases} \]

(13)

\[ \begin{align*}
\alpha_s &= 2(a_s - \bar{x}_a); \\
\beta_s &= 2(\bar{x}_a - b_s); \\
\alpha_e &= 2(a_e - \bar{x}_a); \\
\beta_e &= 2(\bar{x}_e - b_e).
\end{align*} \]

(18)

It is accepted: \( X_f \) – trapezoidal fuzzy interval (fuzzy set \( X_f = \{ x \mid \mu(x) > 0, x \in U \} \); \( a_s \) and \( b_s \) – respectively, the left (lower) and right (upper) modal value of the fuzzy quantity \( x \); \( \alpha_s \) and \( \beta_s \) – are the left and right fuzziness coefficients, respectively, \( \alpha_s \geq 0 \) and \( \beta_s \geq 0 \); \( \mu(x) \) – a convex membership function of a fuzzy quantity \( x \). In this case, the interval \((a_s, b_s)\), where the membership function is different from zero, serves as the carrier of the fuzzy set \( X_f \).

In this study, the parameters of trapezoidal intervals are considered integral and limited. The continuous scoring scale \([0; 100]\) is taken into account, and additionally adopted:

\[ a_s = \max \{0; a_s - \alpha_s\}; \]

(14)

\[ a_s = \min \{100; b_s + \beta_s\}. \]

(15)

The measure of compactness (blurring) of the fuzzy interval \( X_f \) can also be an analogue of the dispersion \( D[X_f] \) of a random variable and an analogue of the standard deviation \( s_v \) where \( s_v = \sqrt{D[X_f]} \). However, \( D[X_f] \) is easier to calculate not by a cumbersome analytical expression, but directly by the formula:

\[ D[X_f] = \int_0^{100} x^2 \mu_c(x) \, dx / \int_0^{100} \mu_c(x) \, dx - \left( \int_0^{100} x \mu_c(x) \, dx / \int_0^{100} \mu_c(x) \, dx \right)^2, \]

(16)

using the trapezoidal method for numerical integration [22]. In the discretization step by points, it is sufficient to take \( h = 0.5 \).

Each term “A”, “B”, “E”, “F” corresponds to the target trapezoidal fuzzy interval \( A_T, B_T, E_T, F_T \). It is proposed to take the corresponding interval ends of the ranges of a single 100-point discrete scale as the lower and upper modal values of each value:

\[ b_s = 100; \ \alpha_s = 0; \ \alpha_a = \bar{x}_a; \]

\[ b_s = \bar{x}_a; \ \beta_s = 1; \ \beta_a = \bar{x}_a; \]

\[ a_s = \bar{x}_a; \ \alpha_e = \bar{x}_a; \ \beta_e = 0; \ \alpha_e = 0. \]

(17)

It is natural to determine nonzero fuzziness coefficients from the condition that the graphs of two adjacent membership functions pass through the corresponding common transition point \((\bar{x}, 0.5)\), where \( \bar{x} \) – the common limit of two adjacent ranges of a single 100-point continuous scale. Then:

\[ \alpha_s = 2(\bar{x}_s - \bar{x}_a); \]

\[ \beta_s = 2(\bar{x}_a - b_s); \]

\[ \alpha_e = 2(\bar{x}_a - \bar{x}_e); \]

\[ \beta_e = 2(\bar{x}_e - b_e). \]

The calculated values of the parameters of the target trapezoidal fuzzy intervals \( A_T, B_T, E_T, F_T \) are presented in Table 5. The carriers of the formed fuzzy sets have a non-empty section, as can be seen from Table 4 and Fig. 3. The list of all criteria for assessing the EP quality is also agreed upon at the first stage.

Table 4

| Scale | Terms (ranges) |
|-------|----------------|
| Linguistic scale “A – B – E – F” | A | B | E | F |
| Unified 100 point continuous scale | A | B | E | F |
| Left transition value limit \( \bar{x} \) | 89.5 | 72.3 | 50.5 | 0 |
| Right boundary value of the transition \( \bar{x} \) | 100 | 89.5 | 72.5 | 50.5 |
| Trapezoidal fuzzy intervals | \( A_T \) | \( B_T \) | \( E_T \) | \( F_T \) |
| Left modal value \( \alpha_a \) | 90 | 73 | 51 | 0 |
| Right modal value \( \beta_a \) | 100 | 89 | 72 | 50 |
| Fuzziness coefficient \( \alpha_e \) | 1.0 | 1.0 | 1.0 | 0.0 |
| Fuzziness coefficient \( \beta_e \) | 0.0 | 1.0 | 1.0 | 1.0 |
| Left border of media \( \alpha_a = \max \{0; a_s - \alpha_s\} \) | 89 | 72 | 50 | 0 |
| Right border of media \( \alpha_a = \min \{100; b_s + \beta_s\} \) | 100.0 | 90 | 73 | 51 |
| Dispersion analogue \( D[X_f] \) | 9.2 | 24.1 | 40.4 | 212.6 |
| Standard deviation analogue, \( s_f \) | 3.0 | 4.9 | 6.4 | 14.6 |

The collection and coordination of the relevant expert assessments \( w^{(i)} \) (according to a single 100-point scale) and the weight coefficients of all criteria is carried out at the second stage to determine the importance of each of the criteria for assessing the EP quality. The weighted generalized values of the normalized weight coefficients \( w^{(i)} \) and \( w^{(i)} \) must satisfy the conditions \( \sum_i w^{(i)} = 1 \) and \( \sum_i w^{(i)} = 1 \) and calculated by the formulas:

\[ w^{(i)} = \frac{w^{(i)}}{\sum_i w^{(i)}}, \]

(19)

\[ w^{(i)} = \frac{\sum_i w^{(i)} w^{(i)}}{\sum_i w^{(i)}}, \]

(20)

It is accepted: \( w^{(i)} \) and \( w^{(i)} \) respectively, the input and normalized weight coefficients of the contribution of the \( i \)-th criterion to the generalized assessment of the EP quality from the position of the \( i \)-th expert; \( n \) – the total number of criteria involved, \( m = \frac{1}{10}; \) \( w^{(i)} \) – generalized normalized weight coefficient of the contribution of the \( i \)-th criterion to the generalized assessment of the EP quality. It is accepted that \( w^{(i)} = 0 \) and \( w^{(i)} = 0 \) if \( i \)-th is not included in the list selected for evaluation. An example of the values of the input weight coefficients \( w^{(i)} \) according to expert data and their normalized analogues \( w^{(i)} \) and \( w^{(i)} \), \( i = 1, m \), \( l = 1, 3 \) are calculated in Table 5.
At the third stage, each of the experts gives scores for all criteria and sub-criteria of the EP quality, guided by an agreed single 100-point discrete scale. Further, each expert forms a personal weighted total score for each criterion.

The input information of the expert evaluation of the EP quality is represented by a three-dimensional array $X$, each element of $X_{ijl}^{(q)}$, which is an integer score of the EP quality by the $l$-th expert according to the $j$-th sub-criterion, which is part of the $i$-th criterion, $i = 1, \ldots, 5$, $j = 1, \ldots, 3$.

Each initial elementary information block (tuple) $X_{ijl}^{(q)}$ is interpreted as the corresponding fuzzy triangular number $X_{ijl}^{(q)} = \langle a_{ijl}, b_{ijl}, c_{ijl} \rangle$, whose integer parameters are determined by the formulas:

$$a_{ijl} = X_{ijl}^{(q)};$$

$$\alpha_{ijl} = \min \left[ \max \left\{ \frac{X_{ijl}^{(0)} - X_{ijl}^{(d)}}{100}, 0 \right\}, 1 \right] - 100 \cdot \text{sgn} \left( X_{ijl}^{(0)} - X_{ijl}^{(d)} \right),$$

$$\beta_{ijl} = \min \left[ \max \left\{ \frac{X_{ijl}^{(d)} - X_{ijl}^{(0)}}{100}, 0 \right\}, 1 \right] - 100 \cdot \text{sgn} \left( X_{ijl}^{(d)} - X_{ijl}^{(0)} \right).$$

Each expert evaluates the three-dimensional array $X$, which in turn is a three-dimensional fuzzy number $X^{(q)} = \langle A_{ijl}^{(q)}, B_{ijl}^{(q)}, C_{ijl}^{(q)} \rangle$.

The collection, coordination of the relevant expert assessments $w_{ijl}^{(q)}$ (on a single 100-point scale) of the coefficients of importance of all its sub-criteria is carried out within the framework of each $i$-th criterion for assessing the EP quality. The weighted generalized values of the normalized (within the corresponding criterion) weight coefficients $w_{ijl}^{(q)(n)}$ and $w_{ijl}^{(q)(n)(q)}$ established, which satisfy the conditions $\sum_{j=1}^{3} w_{ijl}^{(q)(n)} = 1$ and $\sum_{j=1}^{3} w_{ijl}^{(q)(n)(q)} = 1$ and calculated by the formulas:

$$w_{ijl}^{(q)(n)} = \frac{w_{ijl}^{(q)}}{\sum_{j=1}^{3} w_{ijl}^{(q)}, \ l = 1, 3};$$

$$w_{ijl}^{(q)(n)(q)} = \sum_{j=1}^{3} w_{ijl}^{(q)(n)(q)}, \ j = 1, 3, i = 1, m_i, l = 1, 3. \ (21)$$

It is accepted: $w_{ijl}^{(q)}$ and $w_{ijl}^{(q)(n)}$ – respectively, the input and normalized weight coefficients of the contribution of the $j$-th sub-criterion, which is part of the $i$-th criterion, to the generalized quality assessment for this $i$-th criterion from the position of the $l$-th expert; $k_j$ – the number of sub-criteria in the $i$-th criterion; $w_{ijl}^{(q)(n)}$ – the generalized normalized weight coefficient of the contribution of the $j$-th sub-criterion, which is part of the $i$-th criterion, to the generalized quality assessment for this $i$-th criterion. Table 6 shows an example of the values of the input weight coefficients $w_{ijl}^{(q)}$ according to expert data and calculated their normalized counterparts $w_{ijl}^{(q)(n)}$ and $w_{ijl}^{(q)(n)(q)}$, $i = 1, m_i, j = 1, 3, l = 1, 3$. 

### Table 5

| Criteria for assessing the EP quality, $i$ | Criteria weighting coefficients | Generalized normalized weight coefficient, $w_{ijl}^{(q)(n)(q)}$ |
|----------------------------------------|--------------------------------|----------------------------------|
| **Input weight coefficient, $w_{ijl}^{(q)}$** | **Normalized weight coefficient, $w_{ijl}^{(q)(n)}$** | **Normalized weight coefficient, $w_{ijl}^{(q)(n)(q)}$** |
| Expert 1 – academic staff, head of the EG | Expert 2 – academic staff, member of the EG | Expert 3 – higher education applicant, member of the EG |
|----------------------------------------|--------------------------------|----------------------------------|
| Input weight coefficient, $w_{ijl}^{(q)}$ | Normalized weight coefficient, $w_{ijl}^{(q)(n)}$ | Normalized weight coefficient, $w_{ijl}^{(q)(n)(q)}$ |
| 1 | 70 | 0.990 | 60 | 0.082 | 75 | 0.108 | 0.092 |
| 2 | 99 | 0.127 | 85 | 0.116 | 85 | 0.122 | 0.122 |
| 3 | 65 | 0.083 | 70 | 0.096 | 85 | 0.122 | 0.098 |
| 4 | 99 | 0.127 | 90 | 0.123 | 85 | 0.122 | 0.124 |
| 5 | 85 | 0.109 | 95 | 0.130 | 85 | 0.122 | 0.120 |
| 6 | 89 | 0.127 | 80 | 0.110 | 70 | 0.101 | 0.114 |
| 7 | 80 | 0.102 | 95 | 0.130 | 80 | 0.105 | 0.116 |
| 8 | 99 | 0.127 | 80 | 0.110 | 70 | 0.101 | 0.114 |
| 9 | 85 | 0.109 | 75 | 0.103 | 60 | 0.086 | 0.101 |
| 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| $\Sigma$ | 781 | 1 | 730 | 1 | 695 | 1 | 1 |
An example of the values of the weight coefficients of the contribution of the sub-criteria included in the corresponding criterion to the generalized quality assessment for this criterion

| Criteria for assessing the EP quality, j | Sub-criteria for assessing the EP quality, i | Sub-criteria weighting coefficients within the corresponding quality criterion of the EP |  |
|----------------------------------------|------------------------------------------|-----------------------------------------------|---|
|                                       | Expert 1 – academic staff, head of the EG | Expert 2 – academic staff, member of the EG | Expert 3 – higher education applicant, member of the EG |
|                                       | Input weight coefficient, $w_{ij}^{(q)}$ | Normalized weight coefficient, $w_{ij}^{(q, norm)}$ | Input weight coefficient, $w_{ij}^{(q, norm)}$ | Normalized weight coefficient, $w_{ij}^{(q, norm)}$ | Generalized normalized weight coefficient, $w_{ij}^{(q, norm, gen)}$ |
| 1                                      | 75 0.218 90 0.269 99 0.296 0.257         | 2                                      | 90 0.262 85 0.254 80 0.240 0.253 |
|                                        | 99 0.288 80 0.239 75 0.225 0.254         | 3                                      | 80 0.233 80 0.239 80 0.240 0.237 |
|                                        | 344 1 335 1 334 1 1                      | 4                                      | 60 0.083 85 0.119 80 0.117 0.105 |
|                                        | 99 0.137 90 0.126 90 0.131 0.132         | 5                                      | 99 0.137 95 0.133 80 0.117 0.130 |
|                                        | 99 0.137 95 0.133 80 0.117 0.130         | 6                                      | 85 0.118 80 0.112 85 0.124 0.117 |
|                                        | 80 0.111 75 0.105 65 0.095 0.104         | 7                                      | 80 0.111 90 0.126 70 0.102 0.114 |
|                                        | 70 0.097 55 0.077 70 0.102 0.091         | 8                                      | 50 0.069 60 0.084 65 0.095 0.081 |
|                                        | 722 1 715 1 685 1 1                      | 9                                      | 60 0.250 80 0.267 90 0.269 0.261 |
| 2                                      | 75 0.176 85 0.205 80 0.213 0.196         | 1                                      | 90 0.321 85 0.283 75 0.224 0.282 |
|                                        | 80 0.188 70 0.169 80 0.213 0.188         | 2                                      | 90 0.250 75 0.250 90 0.269 0.255 |
|                                        | 90 0.212 90 0.217 70 0.187 0.207         | 3                                      | 95 0.224 90 0.217 70 0.187 0.211 |
|                                        | 95 0.200 80 0.193 75 0.200 0.197         | 4                                      | 50 0.179 60 0.200 80 0.239 0.202 |
|                                        | 280 1 300 1 335 1 1                      | 5                                      | 75 0.176 85 0.205 80 0.213 0.196 |
|                                        | 80 0.188 70 0.169 80 0.213 0.188         | 6                                      | 85 0.250 75 0.250 90 0.269 0.261 |
|                                        | 90 0.261 80 0.242 70 0.250 0.251         | 7                                      | 90 0.261 80 0.258 80 0.214 0.247 |
|                                        | 320 1 415 1 375 1 1                      | 8                                      | 99 0.194 95 0.186 80 0.178 0.187 |
|                                        | 99 0.194 95 0.186 80 0.178 0.187         | 1                                      | 85 0.261 75 0.237 80 0.250 0.240 |
|                                        | 80 0.157 85 0.167 70 0.156 0.160         | 2                                      | 90 0.250 80 0.242 70 0.250 0.251 |
|                                        | 90 0.177 85 0.167 85 0.189 0.176         | 3                                      | 95 0.187 85 0.167 80 0.178 0.177 |
|                                        | 95 0.187 85 0.167 80 0.178 0.177         | 4                                      | 70 0.138 80 0.157 70 0.156 0.153 |
|                                        | 70 0.147 80 0.157 70 0.156 0.153         | 5                                      | 75 0.158 80 0.168 80 0.157 0.161 |
|                                        | 509 1 510 1 450 1 1                      | 6                                      | 85 0.179 80 0.168 80 0.157 0.169 |
| 3                                      | 95 0.200 90 0.189 80 0.157 0.185         | 7                                      | 475 1 475 1 510 1 1                      |
Continuation of Table 6

|   |  1  |  2  |  3  |  4  |  5  |  6  |  7  |  8  |  9  | 10 |
|---|-----|-----|-----|-----|-----|-----|-----|-----|-----|----|
|   |  90 |  85 |  90 |  85 |  70 |  70 |  85 |  85 |  75 |  1 |
|   |  0.118 | 0.147 | 0.167 | 0.176 | 0.108 | 0.118 | 0.167 | 0.167 | 0.137 | 0.137 |
|   |  90 |  70 |  85 |  85 |  70 |  65 |  85 |  85 |  75 | 1 |
|   |  0.118 | 0.157 | 0.186 | 0.137 | 0.108 | 0.136 | 0.137 | 0.137 | 0.110 | 0.116 |
|   |  0.292 | 0.186 | 0.085 | 0.108 | 0.326 | 0.137 | 0.167 | 0.167 | 0.110 | 0.116 |
|   |  0.326 | 0.186 | 0.137 | 0.110 | 0.304 | 0.137 | 0.147 | 0.147 | 0.110 | 0.116 |
|   |  0.304 | 0.157 | 0.137 | 0.104 | 0.370 | 0.137 | 0.147 | 0.147 | 0.110 | 0.116 |
|   |  0.370 | 0.186 | 0.137 | 0.104 | 0.364 | 0.137 | 0.147 | 0.147 | 0.110 | 0.116 |
|   |  0.364 | 0.157 | 0.137 | 0.104 | 0.331 | 0.137 | 0.147 | 0.147 | 0.110 | 0.116 |
|   |  0.331 | 0.186 | 0.137 | 0.104 | 0.331 | 0.137 | 0.147 | 0.147 | 0.110 | 0.116 |

In this case, the incoming integer estimate \( x_{\text{in}}^{(i)} \) is taken as the corresponding closest value of each assessment (term) of the final linguistic scale according to the formula:

\[
H^I[X_k, X_l] = 4 - I_k I_l \left( 1 + I_k (1 + (3 - r) I_k + (r - 2) I_l) \right),
\]

where \( r = 2 \) – EP of the first (bachelor’s) or second (master’s) level (criterion 10 is not applied); \( r = 3 \) – EP of the third (scientific) level (criterion 10 is applied).

Table 7 shows an example of input quality assessments of the EP \( x_{\text{in}}^{(i)} \) and calculated the initial values of the parameter correspondences of the calculated trapezoidal fuzzy interval from the target set \( \{ A_F, B_F, E_F \} \) to a certain evaluation term on the linguistic scale \( "A - B - E - F" \) is determined further.

Choice indices are introduced for the mathematical formalization of the procedure for determining the final overall assessment of the EP within the final linguistic scale "Accreditation exemplary" – "Accreditation" – "Accreditation conditional (deferred)" – "Refusal of accreditation" [20]:

\[
a_u = \sum_{\ell=1}^{3} w_{\ell}^{(u)} a_{\ell}, \quad a_{\ell} = \sum_{i=1}^{k} \mu_{\ell}(x) a_{\ell}, \quad \beta_{\ell} = \sum_{i=1}^{k} \mu_{\ell}^{(u)}(x) \beta_{\ell}, \quad \ell = 1,3.
\]

The Hellinger distance \( H[\mu_i, \mu_j] \) as a criterion for the difference (proximity) of the laws of distribution of random variables is widely used in problems of classification and pattern recognition [23]. This takes into account not only the distance between their average values and the distribution of deviations of values from the average, characterized by the values of the dispersion, but the difference between the distributions as a whole.

At the fourth stage, the experts discuss the results of the accreditation examination, form a weighted total score for each criterion that is common for the expert group, using operations on fuzzy numbers based on a 100-point scale. Then the corresponding closest value of each assessment (term) is established according to the linguistic scale "A – B – E – F". The only final overall assessment of the EP for the expert group on the final linguistic scale is further found according to the methodology [20]. The scale provides four possible options for the final conclusion.

The only weighted total score for the expert group according to the i-th criterion is formed in the form of a weighted triangular fuzzy number \( S_{Ai} = \langle a_{Ai}, \beta_{Ai}, \mu_{Ai} \rangle \), with integer parameters, which are calculated by ratios using the rules of operations on fuzzy numbers [21] with rounding of the final result to integer values:

\[
H^I[X_k, X_l] = 1 - \frac{\int_0^{100} \mu_k(x) \mu_l(x) dx}{\int_0^{100} \mu_k(x) dx \int_0^{100} \mu_l(x) dx}. \quad (26)
\]

The only evaluation for the expert group of the EP quality \( S_{Ai} \) according to the i-th criterion on the linguistic scale "A – B – E – F" is determined by the nearest neighbor method as the closest to the triangular fuzzy number \( S_{Ai} \). The correspondence of the calculated trapezoidal fuzzy interval from the target set \( \{ A_F, B_F, E_F \} \) to a certain evaluation term on the linguistic scale "A – B – E – F" is determined further.
Control processes

and blur characteristics of the corresponding triangular fuzzy numbers $X_{ijl}=(a_{ijl}, \alpha_{ijl}, \beta_{ijl})$, $Y_{ijl}=(a_{ijl}, \alpha_{ijl}, \beta_{ijl})$ and $S_{ijl}=(a_{ijl}, \alpha_{ijl}, \beta_{ijl})$, $i=1, m_i$, $j=1, l$, $l=1, 3$.

Table 7

An example of the values of the input expert estimates $x^0_{ij}$ of the quality level of the EP and the calculated output parameters and blur characteristics of the corresponding triangular fuzzy numbers

| Criteria for assessing the EP quality, $i$ | Sub-criteria for assessing the EP quality, $j$ | Evaluation by an expert of the quality level of the EP | Initial triangular fuzzy number, $X_{ijl}$ | Modal value, $a$ | Left fuzziness coefficient, $\alpha$ | Right fuzziness coefficient, $\beta$ | Dispersion analog | Mean quadratic deviation analog |
|-------------------------------------------|-----------------------------------------------|-----------------------------------------------|---------------------------------|----------------|----------------|----------------|----------------|----------------|
| Expert 1 – academic staff, head of the EG | 1 | 75 | 75 | 14 | 2 | 12.7 | 3.6 | ... | ... | ... | ... | ... |
| | 2 | 70 | 70 | 19 | 2 | 22.4 | 4.7 | ... | ... | ... | ... | ... |
| | 3 | 80 | 80 | 17 | 9 | 10.7 | 3.3 | ... | ... | ... | ... | ... |
| | 4 | 80 | 80 | 17 | 9 | 10.7 | 3.3 | ... | ... | ... | ... | ... |
| Triangular number $Y_{ijl}$ | 76 | 9 | 8 | 12.1 | 3.5 | ... | ... | ... | ... | ... | ... | ... |
| Expert group | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 1 | Triangular number $S_{ijl}$ | 76 | 9 | 8 | 12.1 | 3.5 | ... | ... | ... | ... | ... | ... | ... | ... |
| 2 | Triangular number $S_{ijl}$ | 80 | 7 | 8 | 9.4 | 3.1 | ... | ... | ... | ... | ... | ... | ... | ... |
| ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 7 | Triangular number $S_{ijl}$ | 73 | 8 | 10 | 13.6 | 3.7 | ... | ... | ... | ... | ... | ... | ... | ... |
| ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 10 | not applicable | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |

Table 8 shows an example of the values of the proximity functional $H^2[X_i, X_j]$, calculated for each pair of “initial triangular fuzzy number – target trapezoidal fuzzy interval” in the context of the quality criteria of the EP

| Expert, $i$ | Criteria for assessing the EP quality, $i$ | Linguistic scale |
|-------------|-----------------------------------------------|----------------|
| Expert 1 – academic staff, head of the EG | 1 | 1.00 | 0.29 | 0.79 | 1.00 |
| | 9 | 1.00 | 0.15 | 0.97 | 1.00 |
| Expert 2 – academic staff, member of the EG | 1 | 1.00 | 0.50 | 0.58 | 1.00 |
| | 9 | 0.76 | 0.33 | 1.00 | 1.00 |
| Expert 3 – higher education applicant, member of the EG | 1 | 1.00 | 0.09 | 1.00 | 1.00 |
| | 9 | 1.00 | 0.09 | 1.00 | 1.00 |

Expert group

| Expert group | Criteria for assessing the EP quality, $i$ | Linguistic scale |
|--------------|-----------------------------------------------|----------------|
| 1 | 1.00 | 0.27 | 0.78 | 1.00 |
| 2 | 1.00 | 0.15 | 1.00 | 1.00 |
| 3 | 1.00 | 0.23 | 0.84 | 1.00 |
| 4 | 1.00 | 0.24 | 0.85 | 1.00 |
| 5 | 1.00 | 0.36 | 0.73 | 1.00 |
| 6 | 1.00 | 0.32 | 0.76 | 1.00 |
| 7 | 1.00 | 0.40 | 0.64 | 1.00 |
| 8 | 1.00 | 0.67 | 0.21 | 1.00 |
| 9 | 1.00 | 0.15 | 1.00 | 1.00 |
| 10 | not applicable | ... | ... | ... | ... |

Table 8

An example of the values of the proximity functional $H^2[X_i, X_j]$ for the overall score of the EP quality for each $i$-th criterion, $p=1, m_i$, corresponding to each $i$-th expert, $l=1, 3$, and the expert group as a whole

| Expert, $i$ | Criteria for assessing the EP quality, $i$ | Linguistic scale |
|-------------|-----------------------------------------------|----------------|
| Expert 1 | 0.29 | 0.12 | 0.22 | 0.09 | 0.24 | 0.41 | 0.19 | 0.11 | 0.15 |
| Expert 2 | 0.50 | 0.12 | 0.22 | 0.27 | 0.18 | 0.13 | 0.44 | 0.21 | 0.33 |
| Expert 3 | 0.69 | 0.12 | 0.24 | 0.40 | 0.34 | 0.13 | 0.41 | 0.29 | 0.09 |
| Expert group | 0.27 | 0.15 | 0.23 | 0.24 | 0.36 | 0.32 | 0.40 | 0.21 | 0.15 |

Table 9

An example of the initial values of $Y_{ijl}$ and $S_{ijl}$, according to the linguistic scale “A – B – E – F” of a weighted overall assessment of the EP quality for each $i$-th criterion

| Expert, $i$ | Criteria for assessing the EP quality, $i$ | Linguistic scale |
|-------------|-----------------------------------------------|----------------|
| Expert 1 | B | B | B | B | E | B | E | B | B |
| Expert 2 | B | B | B | B | B | E | B | E | B |
| Expert 3 | B | B | B | B | B | B | B | B | B |
| Expert group | B | B | B | B | B | B | B | B | B |

Table 10

An example of the values of the choice indices $I_p$, $p=1, 5$, and the corresponding final overall assessment of the EP $S_I$ according to the final linguistic scale for the EP of the second level

| EP level, $r$ | Choice indices, $I_p$ | Variant (term), $l$ | Value, $S_I$ | Conditional (deferred) accreditation |
|--------------|-----------------------|-------------------|--------------|----------------------------------|
| 2 | 1 | 1 | 0 | 0 | 3 | conditional (deferred) accreditation |
At the fifth stage, the EG records the weighted overall scores for each $S_{i,j}$ (according to the linguistic scale “A – В – Е – F”) and the overall score of the EP $S_V$ (according to the final linguistic scale) in its report.

6. Discussion of the results of decision-making modeling during the examination of the educational program

The developed methodology for making an agreed expert decision should become an important tool for improving the procedure for conducting an accreditation examination. The use of the linguistic scale “A – В – Е – F”, compared with a single 100-point scale (in discrete and continuous form), in combination with the weight coefficients of “expert competence” allows to digitize and generalize the EG assessment in terms of the EP quality. At the same time, within the framework of fuzzy reflection, both the individual vision of the expert and the degree of its competence (based on the scale of the tariff scale of academic staff) are taken into account. The normalization of the values of the weighting coefficients of competence (according to the scale of the tariff of the EP quality. At the same time, within the framework of an individual assessment scale, the level of the EP innovativeness.

The correct use of the proposed approach presupposes the virtue of each of the experts and the consistency of their actions. Each expert carries out a personal accreditation study within the framework of an individual assessment scale, rejecting external influences, and presents them to the EG (during intragroup discussions) as “input data” in the form of tables of the accepted form. There may be (deliberate or accidental) gaps in the cells when filling out tabular forms by an expert, as well as a violation of the rules of ethics (the advantage of subjectivity over objectivity). This situation will result in the output being individual numerical values of criteria scores and weights outside of their agreed upon ranges. The proposed methodology for expert assessment of the EP quality allows to timely identify inconsistencies and eliminate them at the appropriate stages of the joint work of the EG. Technical errors that need to be eliminated can also be detected when controlling the input data of computational procedures. The proposed toolkit makes it possible to identify errors and fix the individual inclinations of experts, which will contribute to the convergence of their approaches to accreditation assessment and the growth of professional competence.

The empirical base for further research should be the reports of the EG on the accreditation of EPs in certain specialties and (or) branches of knowledge. This, in turn, requires a detailed analysis of the content of the “substantiation of the level of compliance with the criterion” and the degree of its argumentation by the EG. A promising direction of relevant scientific research can be the consistent application of the apparatus of fuzzy logic, as well as the development of an appropriate software product.

The systematic implementation of the proposed tools for making an agreed collegial decision will allow the EG to take into account the level of academic competence of each expert and his (her) individual expert judgment on the quality level of the EP. The experience gained in applying the proposed decision-making methodology will allow QAA to implement advisory and information activities and benchmarking of local higher education quality systems.

7. Conclusions

1. The organizational features of the EQA system were analyzed in terms of attaching the assessment teams by QAA in the EP accreditation process. Expert actions are identified, and a five-stage logic of the EP quality assessment process is described. It was established that experts with different academic and professional experience are involved in the accreditation processes. This requires QAA to make judgments about the consensus in the collective opinion of the EP quality.

The formation of an agreed expert collegial decision on the evaluation of the EP quality is presented in the interdependence of three variables: the level of academic competence; experts’ perception of the linguistic scale of assessments; value judgments about the compliance of the EP with the quality criteria. The identified types of variables make it possible to explain the existing measure of subjectivity that affects the collective conclusion of experts. This methodological approach makes it possible to form a collegial assessment of the EP quality in accordance with the QAA requirements and the principles of academic culture.

2. A comprehensive methodology for quantitative assessment of the EP quality under conditions of uncertainty is proposed. This methodology was developed taking into account the use of fuzzy mathematics and takes into account the relative importance of criteria and sub-criteria, as well as the levels of competence of experts.

The basic mathematical model for the formation of a collegial peer review on the EP quality according to the system of QAA criteria has been developed. This model provides for variations of expert values of weight coefficients (competence of experts; criteria and sub-criteria for assessing the EP quality) and parameters of fuzzy numbers in the context of the linguistic rating scale (“A – В – Е – F”). Many expert values allow the use of computational experimentation tools.
to identify ways to improve expert decision-making and avoid contradictions and excessive subjectivity.

The application of this model will allow QAAs to take into account the ambiguity of the evaluation method, when, on the one hand, it is necessary to follow the standards, and on the other hand, to make a peer review of the quality of EP with the determination of its innovation. The developed toolkit can be used in higher education for both program and institutional accreditation. In addition, the proposed model can be used by HEIs in the process of self-assessment of the EP quality from the point of view of different groups of stakeholders. In general, the use of the proposed evaluation tools for the EP quality allows experts and managers to make decisions at a higher level of academic and managerial culture.

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