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 (QAAs) 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

UDC 005.8:378-0443: 004
DOI: 10.15587/1729-4061.2022.253351

IMPROVING OF THE DECISION-MAKING MODEL IN THE PROCESSES OF EXTERNAL QUALITY ASSURANCE OF HIGHER EDUCATION

Tetiana Fesenko
Corresponding author
Doctor of Technical Sciences, Professor*
E-mail: tetiana.fesenko@nure.ua
Igor Ruban
Doctor of Technical Sciences, Professor, First Vice-Retor*
Kateryna Karpenko
Doctor of Philosophical Science, Professor, Head of Department
Department of Philosophy
Kharkiv National Medical University
Nauky ave., 4, Kharkiv, Ukraine, 61022
Galyna Fesenko
Doctor of Philosophy Sciences, Associate Professor, Professor
Department of History and Cultural Studies**
Andriy Kovalenko
Doctor of Technical Sciences, Professor, Head of Department*
Anatolii Yakunin
PhD, Associate Professor
Department of Higher Mathematics**
Hryhorii Fesenko
PhD, Associate Professor
Department of Machine Repair,
Energy Resources Operation and Labor Protection
Volodymyr Dahl East Ukrainian National University
Tsentralnyi ave, 59-a, Severodonetsk, Ukraine, 93400
*Department of Electronic Computers
Kharkiv National University of Radio Electronics
Nauky ave., 14, Kharkiv, Ukraine, 61166
**O. M. Beketov National University of Urban Economy in Kharkiv
Marshala Bazhanova str., 17, Kharkiv, Ukraine, 61002

Received date 10.01.2021
Accepted date 17.02.2022
Published date 28.02.2022

How to Cite: *Fesenko, T., Ruban, I., Karpenko, K., Fesenko, G., Kovalenko, A., Yakunin, A., Fesenko, H. (2022). Improving of the decision-making model in the processes of external quality assurance of higher education. Eastern-European Journal of Enterprise Technologies, 1 (3 (115)), 74–85. doi: https://doi.org/10.15587/1729-4061.2022.253351*

1. Introduction

In today's globalized world, it is a fact that economic growth is determined not so much by the growth of physical capital and labor as by the stock of knowledge and its rate of growth. At the same time, the latest information and communication technologies have enabled the emergence of knowledge societies, where higher education institutions (HEIs) play a key role. The development of the higher education sector have to become a priority in the most advanced as well as in emerging economies, according to UNESCO recommendations [1, 2].

Higher education systems face challenges to ensure quality. It is known that quality is not a static condition and it needs to be assessed and enhanced regularly. Quality assurance is in most cases encouraged by continuous self-assessment and by seeking some form of external validation. The mechanism for external quality assurance (EQA) is organize

through the creation of independent administrative structures (Quality Assurance Agency, QAA) that commonly function as professional buffer organizations between public authorities and HEIs. National QAAs 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 QAAs 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 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 tools to implement a multi-criteria assessment and its 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 ($w^{(q)}$ i $w^{(sq)}$).

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 – E – 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 $w^{(cn)}$ 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 – E – 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_q and the list of criteria by which the EP will be assessed, $m_q = \overline{1,10}$, 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 ω_i corresponds to 1, and the value of the rejected one corresponds to the value of 0.

Table 1

An example of the selection of criteria for assessing the EP of the first (bachelor's) and second (master's) levels of higher education

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

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 $w^{(c)}$ 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 $w^{(cn)}$ of the weight coefficient of competence correspond to the condition $w_1^{(cn)} + w_2^{(cn)} + w_3^{(cn)} = 1$ and calculated by the formula:

$$w_l^{(cn)} = w_l^{(c)} \Big/ \sum\nolimits_{i=1}^{3} w_l^{(c)}, \quad l = \overline{1,3}, \tag{1}$$

where $w_1^{(c)}$ and $w_1^{(cn)}$ are the input and normalized weight coefficients of the l-th expert's competence, respectively, $l = \overline{1,3}$.

Table 2

An example of the values of the weight coefficients of the academic competence of the EG

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), $w_1^{(c)}$	20	19	14
Normalized weight coefficient of competence, $w_1^{(cn)}$	0.377	0.359	0.264

Then a comparison is made by weighted expert assessments (in whole numbers) of the linguistic scale "*A – B – E – 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 $\overline{x}^{(d)}$ 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:

$$\overline{x}^{(d)} = \sum_{l=1}^{3} w_l^{(cn)} \overline{x}_l^{(d)}, \quad (2)$$

where $\overline{x}_l^{(d)}$ – the corresponding integer discrete boundary value at the suggestion of the l-th expert, $l = \overline{1,3}$.

Table 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 $\overline{x}$	96	85	64	0
	Right limit value $\overline{x}$	100	95	84	63
Expert proposal 2	Left limit value $\overline{x}$	90	70	50	0
	Right limit value $\overline{x}$	100	89	69	49
Expert proposal 3	Left limit value $\overline{x}$	82	60	35	0
	Right limit value $\overline{x}$	100	81	59	34
Unified 100-point discrete scale	Left limit value $\overline{x}^{(d)}$	90	73	51	0
	Right limit value $\overline{x}^{(d)}$	100	89	72	50
Unified 100-point continuous scale of the EG	Left limit value $\overline{x}$	89.5	72.5	50.5	0
	Right limit value $\overline{x}$	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

$$\overline{x}_{ab} = \left(\overline{x}_a^{(dL)} + \overline{x}_b^{(dR)}\right)/2; \quad (3)$$

$$\overline{x}_{be} = \left(\overline{x}_b^{(dL)} + \overline{x}_e^{(dR)}\right)/2; \quad (4)$$

$$\overline{x}_{ef} = \left(\overline{x}_e^{(dL)} + \overline{x}_f^{(dR)}\right)/2, \quad (5)$$

where $\overline{x}_{ab}$, $\overline{x}_{be}$, $\overline{x}_{ef}$ – the common boundaries of the respective adjacent ranges of the continuous scale; $\overline{x}_a^{(dL)}$, $\overline{x}_b^{(dL)}$, $\overline{x}_e^{(dL)}$, $\overline{x}_f^{(dL)}$ i $\overline{x}_a^{(dR)}$, $\overline{x}_b^{(dR)}$, $\overline{x}_e^{(dR)}$, $\overline{x}_f^{(dR)}$ – 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 $X_\Delta = <a_x, \alpha_x, \beta_x>$ is completely determined by an ordered triple of real numbers – its parameters: a_x – the mode of the fuzzy quantity x, α_x and β_x – the left and right fuzziness coefficients, respectively, and is described by a triangular membership function (Fig. 1):

$$\mu_\Delta(x) = \begin{cases} 0, & x \le a_x - \alpha_x; \\ L(x, a_x, \alpha_x), & a_x - \alpha_x < x < a_x; \\ 1, & x = a_x; \\ R(x, a_x, \beta_x), & a_x < x < a_x + \beta_x; \\ 0, & x \ge a_x + \beta_x; \end{cases} \quad (6)$$

$$L(x,a,b) = \begin{cases} (b - a + x)/b, & b > 0; \\ 0, & b = 0; \end{cases}$$

$$R(x,a,b) = \begin{cases} (a + b - x)/b, & b > 0; \\ 0, & b = 0. \end{cases} \quad (7)$$

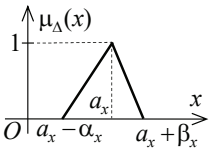

Fig. 1. Graphical representation of a triangular fuzzy number

It is accepted: X_Δ – triangular fuzzy number (fuzzy set, $X_\Delta = \{<x, \mu_\Delta, (x)> | x \in U\}$); x – a specific value of a fuzzy quantity; U – a universal set of a given subject area, in the general case $U = (-\infty; +\infty)$; a_x – the mode (modal value, core, peak) of the fuzzy value x; α_x and β_x – are the left and right fuzziness (blurring) coefficients, respectively, $\alpha_x \ge 0$ and $\beta_x \ge 0$; $\mu_\Delta(x)$ – unimodal membership function of fuzzy quantity x, μ_Δ, $(a_x) = 1$; $L(x, a, b)$ and $R(x, a, b)$ – auxiliary functions of x with parameters a i b, $b \ge 0$. In this case, the interval $(a_{xL}; a_{xR})$, where the membership function is nonzero, serves as a continuous carrier of the fuzzy set X_Δ.

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

$$a_{xL} = \max\{0; a_x - \alpha_x\}; \quad (8)$$

$$a_{xR} = \min\{100; a_x + \beta_x\}. \quad (9)$$

As the fuzzy number X_Δ 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_Δ:

$$D[X_\Delta] = \int_{-\infty}^{+\infty} x^2 \mu_\Delta(x)\,dx \Big/ \int_{-\infty}^{+\infty} \mu_\Delta(x)\,dx - \left(\int_{-\infty}^{+\infty} x \mu_\Delta(x)\,dx \Big/ \int_{-\infty}^{+\infty} \mu_\Delta(x)\,dx\right)^2; \quad (10)$$

$$s_\Delta = \sqrt{D[X_\Delta]}. \quad (11)$$

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:

$$D[X_\Delta] = (1/18)\left(\alpha_x^2 + \alpha_x \beta_x + \beta_x^2\right). \quad (12)$$

Trapezoidal fuzzy interval $X_T = <a_x, b_x, \alpha_x, \beta_x>$ is completely determined by the ordered four of real numbers – its

parameters a_x, b_x, α_x, β_x and is described by a trapezoidal membership function (Fig. 2):

$$\mu_T(x)=\begin{cases}0,\ x\le a_x-\alpha_x;\\ L(x,a_x,\alpha_x),\ a_x-\alpha_x<x<a_x;\\ 1,\ a_x\le x\le b_x;\\ R(x,b_x,\beta_x),\ b_x<x<b_x+\beta_x;\\ 0,\ x\ge b_x+\beta_x.\end{cases} \quad (13)$$

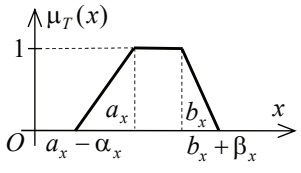

Fig. 2. Graphical representation of a trapezoidal fuzzy interval

It is accepted: X_T – trapezoidal fuzzy interval (fuzzy set $X_T=\{<x, \mu_T, (x)>|x\in U\}$); a_x and b_x – respectively, the left (lower) and right (upper) modal value of the fuzzy quantity x; α_x and β_x – are the left and right fuzziness coefficients, respectively, $\alpha_x\ge 0$ and $\beta_x\ge 0$; $\mu_T(x)$ – a convex membership function of a fuzzy quantity x. In this case, the interval (a_{xL}; a_{xR}), where the membership function is different from zero, serves as the carrier of the fuzzy set X_T.

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

$$a_{xL}=\max\{0;\ a_x-\alpha_x\}; \quad (14)$$

$$a_{xR}=\min\{100;\ b_x+\beta_x\}. \quad (15)$$

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

$$D[X_T]=\int_0^{100}x^2\mu_T(x)\mathrm{d}x\Big/\int_0^{100}\mu_T(x)\mathrm{d}x-$$
$$-\left(\int_0^{100}x\mu_T(x)\mathrm{d}x\Big/\int_0^{100}\mu_T(x)\mathrm{d}x\right)^2, \quad (16)$$

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 integer ends of the ranges of a single 100-point discrete scale as the lower and upper modal values of each value:

$$b_a=100;\ \ a_f=0;\ \ a_a=\overline{x}_a^{(dL)};$$

$$b_b=\overline{x}_b^{(dR)};\ \ a_b=\overline{x}_b^{(dL)};\ \ b_e=\overline{x}_e^{(dR)};$$

$$a_e=\overline{x}_e^{(dL)};\ \ b_f=\overline{x}_f^{(dR)};\ \ \beta_a=0;\ \ \alpha_f=0. \quad (17)$$

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 $(\overline{x};\ 0.5)$, where $\overline{x}$ – the common limit of two adjacent ranges of a single 100-point continuous scale. Then:

$$\alpha_a=2(a_a-\overline{x}_{ab});\ \ \beta_b=2(\overline{x}_{ab}-b_b);\ \ \alpha_b=2(a_b-\overline{x}_{be});$$

$$\beta_e=2(\overline{x}_{be}-b_e);\ \ \alpha_e=2(a_e-\overline{x}_{ef});\ \ \beta_f=2(\overline{x}_{ef}-b_f). \quad (18)$$

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

An example of the characteristics of the target trapezoidal fuzzy intervals A_T, B_T, E_T, F_T, which correspond to the terms of the linguistic scale "$A-B-E-F$"

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 $\overline{x}$	89.5	72.5	50.5	0
Right boundary value of the transition $\overline{x}$	100	89.5	72.5	50.5
Trapezoidal fuzzy intervals	A_T	B_T	E_T	F_T
Left modal value a_x	90	73	51	0
Right modal value b_x	100	89	72	50
Left fuzziness coefficient α_x	1.0	1.0	1.0	0.0
Right fuzziness coefficient β_x	0.0	1.0	1.0	1.0
Left border of media $a_{xL}=\max\{0;\ a_x-\alpha_x\}$	89	72	50	0
Right border of media $a_{xR}=\min\{100;\ b_x+\beta_x\}$	100.0	90	73	51
Dispersion analogue $D[X_T]$	9.2	24.1	40.4	212.6
Standard deviation analogue, s_T	3.0	4.9	6.4	14.6

The collection and coordination of the relevant expert assessments $w^{(q)}$ (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 $w^{(eqn)}$ and $w^{(qn)}$ must satisfy the conditions $\sum_{i=1}^{m_q}w_{il}^{(eqn)}=1$ i $\sum_{i=1}^{m_q}w_i^{(qn)}=1$ and calculated by the formulas:

$$w_{il}^{(eqn)}=w_{il}^{(q)}\Big/\sum_{i=1}^{m_q}w_{il}^{(q)},\ \ l=\overline{1,3}; \quad (19)$$

$$w_i^{(qn)}=\sum_{l=1}^{3}w_l^{(cn)}w_{il}^{(eqn)},\ \ i=\overline{1,m_q}. \quad (20)$$

It is accepted: $w_{il}^{(q)}$ i $w_{il}^{(eqn)}$ – 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 l-th expert; m_q – the total number of criteria involved, $m_q=\overline{1,10}$; $w_i^{(qn)}$ – generalized normalized weight coefficient of the contribution of the i-th criterion to the generalized assessment of the EP quality. It is accepted that $w_{il}^{(eqn)}=w_{il}^{(q)}=0$, $l=\overline{1,3}$ and $w_i^{(qn)}=0$, if i-th is not included in the list selected for evaluation. An example of the values of the input weight coefficients $w^{(q)}$ according to expert data and their normalized analogies $w_{il}^{(eqn)}$ i $w_i^{(qn)}$, $i=\overline{1,m_q}$, $l=\overline{1,3}$ are calculated is given in Table 5.

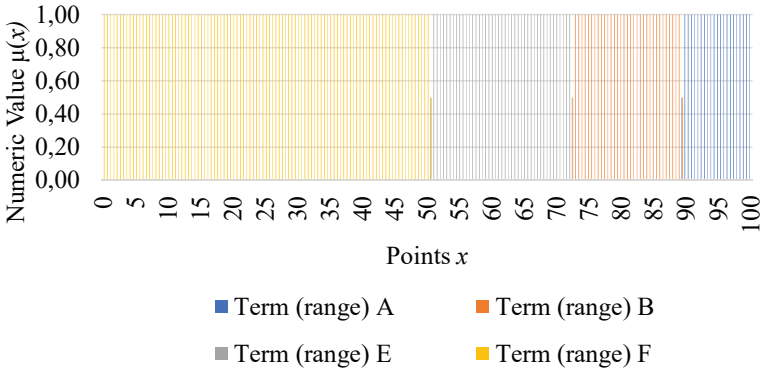

Fig. 3. Membership functions of trapezoidal fuzzy intervals

The collection, coordination of the relevant expert assessments $w^{(sq)}$ (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 $w^{(esqn)}$ and $w^{(sqn)}$ established, which satisfy the conditions $\sum_{j=1}^{k_i} w_{ijl}^{(esqn)} = 1$ and $\sum_{j=1}^{k_i} w_{ij}^{(sqn)} = 1$ and calculated by the formulas:

$$w_{ijl}^{(esqn)} = w_{ijl}^{(sq)} \Big/ \sum_{j=1}^{k_i} w_{ijl}^{(sq)}, \quad l = \overline{1,3}; \tag{21}$$

$$w_{ij}^{(sqn)} = \sum_{l=1}^{3} w_l^{(cn)} w_{ijl}^{(esqn)}, \quad j = \overline{1,k_i}, \quad i = \overline{1,m_q}. \tag{22}$$

It is accepted: $w_{ijl}^{(sq)}$ and $w_{ijl}^{(esqn)}$ – respectively, the input and normalized weight coefficients of the contribution of the j-th subcriterion, 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_i – the number of sub-criteria in the i-th criterion; $w_{ij}^{(sqn)}$ – 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 $w^{(sq)}$ according to expert data and calculated their normalized counterparts $w_{ijl}^{(esqn)}$ and $w_{ij}^{(sqn)}$, $i = \overline{1,m_q}$, $j = \overline{1,k_i}$, $l = \overline{1,3}$.

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 $x_{ijl}^{(0)}$ 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, $i = \overline{1,m_q}$, $j = \overline{1,k_i}$, $l = \overline{1,3}$.

Each initial elementary information block (tuple) X_{ijl} is interpreted as the corresponding fuzzy triangular number $X_{\Delta ijl} = <a_{xijl}, \alpha_{xijl}, \beta_{xijl}>$, whose integer parameters are determined by the formulas:

$$a_{xijl} = x_{ijl}^{(0)};$$

$$\alpha_{xijl} = \min\left\{ \max\left\{ \begin{matrix} x_{ijl}^{(0)} - \overline{x}_a^{(dL)}, \\ -100 \cdot \mathrm{sgn}\left(x_{ijl}^{(0)} - \overline{x}_a^{(dL)}\right) \end{matrix} \right\}, \right.$$

$$\max\left\{x_{ijl}^{(0)} - \overline{x}_b^{(dL)}, -100 \cdot \mathrm{sgn}\left(x_{ijl}^{(0)} - \overline{x}_b^{(dL)}\right)\right\},$$

$$\max\left\{x_{ijl}^{(0)} - \overline{x}_e^{(dL)}, -100 \cdot \mathrm{sgn}\left(x_{ijl}^{(0)} - \overline{x}_e^{(dL)}\right)\right\},$$

$$\left.\max\left\{x_{ijl}^{(0)} - \overline{x}_f^{(dL)}, -100 \cdot \mathrm{sgn}\left(x_{ijl}^{(0)} - \overline{x}_f^{(dL)}\right)\right\}\right\},$$

$$i = \overline{1,m_q}, \quad j = \overline{1,k_i}, \quad l = \overline{1,3}; \tag{23}$$

$$\beta_{xijl} = \min\left\{ \max\left\{ \begin{matrix} \overline{x}_a^{(dR)} - x_{ijl}^{(0)}, \\ -100 \cdot \mathrm{sgn}\left(\overline{x}_a^{(dR)} - x_{ijl}^{(0)}\right) \end{matrix} \right\}, \right.$$

$$\max\left\{\overline{x}_b^{(dR)} - x_{ijl}^{(0)}, -100 \cdot \mathrm{sgn}\left(\overline{x}_b^{(dR)} - x_{ijl}^{(0)}\right)\right\},$$

$$\max\left\{\overline{x}_e^{(dR)} - x_{ijl}^{(0)}, -100 \cdot \mathrm{sgn}\left(\overline{x}_e^{(dR)} - x_{ijl}^{(0)}\right)\right\},$$

$$\left.\max\left\{\overline{x}_f^{(dR)} - x_{ijl}^{(0)}, -100 \cdot \mathrm{sgn}\left(\overline{x}_f^{(dR)} - x_{ijl}^{(0)}\right)\right\}\right\},$$

$$i = \overline{1,m_q}, \quad j = \overline{1,k_i}, \quad l = \overline{1,3}. \tag{24}$$

Table 5

An example of the values of the weight coefficients of the contribution of criteria to the evaluation of the EP quality

Criteria for assessing the EP quality, i	Criteria weighting coefficients						
	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		Generalized normalized weight coefficient, $w_i^{(qn)}$
	Input weight coefficient, $w_{i1}^{(q)}$	Normalized weight coefficient, $w_{i1}^{(eqn)}$	Input weight coefficient, $w_{i2}^{(q)}$	Normalized weight coefficient, $w_{i2}^{(eqn)}$	Input weight coefficient, $w_{i3}^{(q)}$	Normalized weight coefficient, $w_{i3}^{(eqn)}$	
1	70	0.090	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	99	0.127	80	0.110	70	0.101	0.114
7	80	0.102	95	0.130	80	0.115	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
∑	781	1	730	1	695	1	1

Table 6

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, i	Sub-criteria for assessing the EP quality, j	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		Generalized normalized weight coefficient, $w_{ij}^{(sqn)}$
		Input weight coefficient, $w_{ij1}^{(sq)}$	Normalized weight coefficient, $w_{ij1}^{(esqn)}$	Input weight coefficient, $w_{ij2}^{(sq)}$	Normalized weight coefficient, $w_{ij2}^{(esqn)}$	Input weight coefficient, $w_{ij3}^{(sq)}$	Normalized weight coefficient, $w_{ij3}^{(esqn)}$	
1	1	75	0.218	90	0.269	99	0.296	0.257
	2	90	0.262	85	0.254	80	0.240	0.253
	3	99	0.288	80	0.239	75	0.225	0.254
	4	80	0.233	80	0.239	80	0.240	0.237
	∑	344	1	335	1	334	1	1
2	1	60	0.083	85	0.119	80	0.117	0.105
	2	99	0.137	90	0.126	90	0.131	0.132
	3	99	0.137	95	0.133	80	0.117	0.130
	4	85	0.118	80	0.112	85	0.124	0.117
	5	99	0.137	85	0.119	80	0.117	0.125
	6	80	0.111	75	0.105	65	0.095	0.104
	7	80	0.111	90	0.126	70	0.102	0.114
	8	70	0.097	55	0.077	70	0.102	0.091
	9	50	0.069	60	0.084	65	0.095	0.081
	∑	722	1	715	1	685	1	1
3	1	70	0.250	80	0.267	90	0.269	0.261
	2	90	0.321	85	0.283	75	0.224	0.282
	3	70	0.250	75	0.250	90	0.269	0.255
	4	50	0.179	60	0.200	80	0.239	0.202
	∑	280	1	300	1	335	1	1
4	1	75	0.176	85	0.205	80	0.213	0.196
	2	80	0.188	70	0.169	80	0.213	0.188
	3	90	0.212	90	0.217	70	0.187	0.207
	4	95	0.224	90	0.217	70	0.187	0.211
	5	85	0.200	80	0.193	75	0.200	0.197
	∑	425	1	415	1	375	1	1
5	1	85	0.246	75	0.227	70	0.250	0.240
	2	90	0.261	80	0.242	70	0.250	0.251
	3	80	0.232	90	0.273	80	0.286	0.261
	4	90	0.261	85	0.258	60	0.214	0.247
	∑	345	1	330	1	280	1	1
6	1	99	0.194	95	0.186	80	0.178	0.187
	2	80	0.157	85	0.167	70	0.156	0.160
	3	90	0.177	85	0.167	85	0.189	0.176
	4	95	0.187	85	0.167	80	0.178	0.177
	5	70	0.138	80	0.157	65	0.144	0.146
	6	75	0.147	80	0.157	70	0.156	0.153
	∑	509	1	510	1	450	1	1
7	1	95	0.200	90	0.189	80	0.157	0.185
	2	80	0.168	80	0.168	90	0.176	0.171
	3	70	0.147	70	0.147	90	0.176	0.155
	4	70	0.147	75	0.158	90	0.176	0.159
	5	75	0.158	80	0.168	80	0.157	0.161
	6	85	0.179	80	0.168	80	0.157	0.169
	∑	475	1	475	1	510	1	1

Continuation of Table 6

8	1	90	0.118	90	0.137	85	0.147	0.132
	2	85	0.147	70	0.137	75	0.183	0.153
	3	90	0.167	85	0.157	80	0.138	0.155
	4	85	0.176	85	0.186	75	0.147	0.172
	5	70	0.108	70	0.137	70	0.110	0.119
	6	70	0.118	65	0.108	70	0.128	0.117
	7	85	0.167	85	0.137	75	0.147	0.151
	∑	510	1	510	1	545	1	1
9	1	70	0.292	75	0.326	70	0.318	0.311
	2	80	0.333	70	0.304	80	0.364	0.331
	3	90	0.375	85	0.370	70	0.318	0.358
	∑	240	1	230	1	220	1	1
10	not applicable							

In this case, the incoming integer estimate $x_{ijl}^{(0)}$ is taken as the mode of the triangular fuzzy number $X_{\Delta ijl}$, and its carrier is the corresponding range of a single 100-point discrete scale. The weighted total score for the i-th criterion, corresponding to the position of the l-th expert, is formed as a weighted triangular fuzzy number $Y_{\Delta il}=<a_{yil}, \alpha_{yil}, \beta_{yil}>$ with integer parameters, which are calculated from the ratios that use the rules of operations on fuzzy numbers [21] with rounding of the final result to integer values:

$$a_{yil}=\sum_{j=1}^{k_i} w_{ijl}^{(esqn)} a_{xil},\quad \alpha_{yil}=\sum_{j=1}^{k_i} w_{ijl}^{(esqn)} \alpha_{xil},$$

$$\beta_{yil}=\sum_{j=1}^{k_i} w_{ijl}^{(esqn)} \beta_{xil},\quad i=\overline{1,m_q},\quad l=\overline{1,3}. \qquad (25)$$

The Hellinger distance $H[X_1, X_2]$ 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 $S_{\Delta i}=<a_{si}, \alpha_{si}, \beta_{si}>$ 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:

$$H^2[X_1,X_2]=1-$$
$$-\int_0^{100}\sqrt{\mu_1(x)\cdot\mu_2(x)}\,dx\Big/\sqrt{\int_0^{100}\mu_1(x)dx\cdot\int_0^{100}\mu_2(x)dx}. \qquad (26)$$

The only evaluation for the expert group of the EP quality S_{AFi} 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 $S_{\Delta i}$. The correspondence of the calculated trapezoidal fuzzy interval from the target set $\{A_T, B_T, E_T, F_T\}$ 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]:

$$a_{si}=\sum_{l=1}^{3} w_l^{(cn)} a_{yil},\quad \alpha_{si}=\sum_{l=1}^{3} w_l^{(cn)} \alpha_{yil},$$

$$\beta_{si}=\sum_{l=1}^{3} w_l^{(cn)} \beta_{yil},\quad i=\overline{1,m_q},\quad l=\overline{1,3}. \qquad (27)$$

$$I_1=\begin{cases}0, \exists i: i\in\{1,...,m_q\}, S_{AFi}=F;\\ 1, \text{otherwise};\end{cases} \qquad (28)$$

$$I_2=\begin{cases}0, \exists i,j,k: i,j,k\in\{1,...,m_q\}, i\neq j, i\neq k, j\neq k,\\ S_{AFi}=E\wedge S_{AFj}=E\wedge S_{AFk}=E;\\ 1, \text{otherwise};\end{cases} \qquad (29)$$

$$I_3=\begin{cases}0, \exists i: i\in\{1,...,m_q\}, S_{AFi}=E;\\ 1, \text{otherwise};\end{cases} \qquad (30)$$

$$I_4=\begin{cases}1, \exists i,j: i,j\in\{1,...,m_q\}; i,j\neq\{2,6,8\}, i\neq j,\\ S_{AFk}=A, k\in\{2,6,8,i,j\};\\ 0, \text{otherwise};\end{cases} \qquad (31)$$

$$I_5=\begin{cases}1, \exists i: i\in\{1,...,m_q\}, i\neq\{2,6,8,10\},\\ S_{AFk}=A, k\in\{2,6,8,10,i\};\\ 0, \text{otherwise}.\end{cases} \qquad (32)$$

Then the final overall assessment of the EP quality S_V is determined by the number of the corresponding variant V (term) of the final linguistic scale according to the formula:

$$V=4-I_1I_2\left(1+I_3\left(1+(3-r)I_4+(r-2)I_5\right)\right), \qquad (33)$$

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 $x_{ijl}^{(0)}$ and calculated the initial values of the parame-

ters and blur characteristics of the corresponding triangular fuzzy numbers $X_{\Delta ijl}=<a_{xijl}, \alpha_{xijl}, \beta_{xijl}>$, $Y_{\Delta il}=<a_{yil}, \alpha_{yil}, \beta_{yil}>$ i $S_{\Delta i}=<a_{si}, \alpha_{si}, \beta_{si}>$, $i=\overline{1,m_q}$, $j=\overline{1,k_i}$, $l=\overline{1,3}$.

Table 7

An example of the values of the input expert estimates $x_{ijl}^{(0)}$ 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, $X_{\Delta ijl}$, $Y_{\Delta il}$ or $S_{\Delta i}$				
			Modal value, a	Left fuzziness coefficient, α, α	Right fuzziness coefficient, α, β	Dispersion analog	Mean quadratic deviation analog
Expert 1 – academic staff, head of the EG							
1	1	75	75	2	14	12.7	3.6
	2	70	70	19	2	22.4	4.7
	3	80	80	7	9	10.7	3.3
	4	80	80	7	9	10.7	3.3
Triangular number $Y_{\Delta il}$:			76	9	8	12.1	3.5
...	...		...	...	...	...	...
Expert group							
1	Triangular number $S_{\Delta i}$:		76	9	8	12.1	3.5
2	Triangular number $S_{\Delta i}$:		80	7	8	9.4	3.1
...	...		...	...	...	...	...
7	Triangular number $S_{\Delta i}$:		73	8	10	13.6	3.7
...	...		...	...	...	...	...
10	not applicable						

Table 8 shows an example of the values of the proximity functional $H^2[X_1, X_2]$, calculated for each pair of "initial triangular fuzzy number – target trapezoidal fuzzy interval" in the context of the quality criteria of the EP. The proximity functional is calculated for each l-th expert, $l=\overline{1,3}$ and the expert group as a whole. The correspondence of the obtained values of the weighted total score of the EP quality(target trapezoidal fuzzy interval) to a certain term of the linguistic scale for each i-th criterion, $i=\overline{1,m_q}$ is further established.

Table 9 shows the approximate minimum values of the proximity functional $H^2[X_1, X_2]$ corresponding to each l-th expert, and the expert group as a whole, of the pair "initial triangular fuzzy number – target trapezoidal fuzzy interval" for the overall score of the EP quality for each i-th criterion, $i=\overline{1,m_q}$.

The results of calculating the initial values of Y_{AFil} and S_{AFi} on the linguistic scale "$A-B-E-F$" of a weighted overall assessment of the EP quality for each i-th criterion are shown in Table 10. The resulting terms of the linguistic scale are presented both for each l-th expert, $l=\overline{1,3}$, and for the expert group as a whole.

Further, the value of the choice indices I_p, $p=\overline{1,5}$, is calculated using (28)–(33), and the overall assessment of the EP S_V on the final linguistic scale is determined (Table 11).

Thus, based on the results of the EP accreditation examination, the expert group came to a common decision on conditional (deferred) accreditation of the educational program.

Table 8

An example of the values of the proximity functional $H^2[X_1, X_2]$, calculated for each pair of "initial triangular fuzzy number – target trapezoidal fuzzy interval" in the context of the quality criteria of the EP

Expert, l	Criteria for assessing the EP quality, i	Linguistic scale			
		A	B	E	F
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	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 9

An example of the minimum values of the proximity functional $H^2[X_1, X_2]$ for the overall score of the EP quality for each i-th criterion, $i=\overline{1,m_q}$, corresponding to each l-th expert, $l=\overline{1,3}$, and the expert group as a whole

Expert, min-$H^2[X_1, X_2]$	Criteria for assessing the EP quality, i									
	1	2	3	4	5	6	7	8	9	10
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	0.09	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 10

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

Expert, Y_{AFil}, S_{AFi}	Criteria for assessing the EP quality, i									
	1	2	3	4	5	6	7	8	9	10
Expert 1	B	B	B	B	E	E	B	E	B	–
Expert 2	B	B	B	B	B	B	E	E	B	–
Expert 3	B	B	B	B	B	B	B	B	B	–
Expert group	B	B	B	B	B	B	B	E	B	–

Table 11

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

EP level, r	Choice indices, I_p					Variant (term), V	Value, S_V
	I_1	I_2	I_3	I_4	I_5		
2	1	1	0	0	0	3	conditional (deferred) accreditation

At the *fifth stage*, the EG records the weighted overall scores for each S_{AFi} (according to the linguistic scale "$A-B-E-F$") 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 "$A-B-E-F$", 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 ($\varpi^{(cn)}$) will depend on the number of EPs that experts evaluate simultaneously. So, for the evaluation of one EP, the expert group usually consists of three people $\left(l=\overline{1,3}\right)$, and for two EP («cartoon») – four people $\left(l=\overline{1,4}\right)$. Higher education level of the EP will determine the procedure for normalizing the values of the weight coefficients of the importance of the EP quality criteria (m_q). All QAAs criteria (m_q=10) will be applied for the EP of the third (educational and scientific) level, and for the EP of other levels – nine QAAs criteria (m_q=9).

Such an author's heritage opens up the possibility of more accurately and reasonably assessing the EP quality than the accepted approach (linguistically described, without taking into account the share of individual competence and personal vision of the expert). The use of mathematical tools (1)–(33) makes it possible to formalize the adoption of a coordinated group decision under conditions of varying degrees of certainty of the initial information. The proposed mathematical apparatus serves as an initial base, which can be supplemented, developed in accordance with the transformation of the conditions for conducting an accreditation examination, the number of experts in the EG, as well as the EP innovativeness.

The application of the developed analytical tools will be useful in the project activities of QAAs responsible for the implementation of effective EP accreditation procedures. The use of the method of making an agreed decision on the assessment of the quality of higher education institutions as a tool of self-assessment will contribute to the functioning of internal systems for ensuring the quality of education. At the same time, the author's approach requires further scientific and practical development both in the direction of working with specific data and the possibility of using information analytical systems.

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 QAAs 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 QAAs 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 QAAs 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 QAAs 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 ("$A-B-E-F$"). 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.

References

1. Martin, M. A., Uvalic-Trumbic, S. (2021). A New Generation of External Quality Assurance: Dynamics of change and innovative approaches. New trends in higher education. Paris: UNESCO, International Institute for Educational Planning, 112. Available at: https://unesdoc.unesco.org/ark:/48223/pf0000377497/PDF/377497eng.pdf.multi
2. Martin, M., Parikh, S. (2017). Quality management in higher education: developments and drivers: results from an international survey. Paris: UNESCO, International Institute for Educational Planning, 99. Available at: https://unesdoc.unesco.org/ark:/48223/pf0000260226/PDF/260226eng.pdf.multi
3. Standards and Guidelines for Quality Assurance in the European Higher Education Area (ESG) (2015). Brussels: EURASHE, 32. Available at: https://www.enqa.eu/wp-content/uploads/2015/11/ESG_2015.pdf
4. Nabaho, L., Turyasingura, W. (2019). Battling Academic Corruption in Higher Education: Does External Quality Assurance (EQA) Offer a Ray of Hope? Higher Learning Research Communications, 9 (1). doi: https://doi.org/10.18870/hlrc.v9i1.449
5. Augusti, G., Birch, J., Payzin, E. (2011). EUR-ACE: A System of Accreditation of Engineering Programmes Allowing National Variants. INQAAHE Conference. Madrid. Available at: https://www.inqaahe.org/sites/default/files/pictures/EUR_ACE%20a%20System%20of%20Accreditation%20of%20Engineering%20Programmes_Giuliano%20Augusti_Jim%20Birch_A%20Erbil%20Payzin.pdf
6. Karpenko, K., Magapu, V. V. A. (2018). Gender factors in education. Gender policy of cities: History and Modern : abstract V international Scientific Conference, Kharkiv, March 15–16, 2018. Kharkiv : O. M. Beketov NUUEK, 6, 156-158. https://eprints.kname.edu.ua/51547/1/ilovepdf_com-156-158.pdf
7. Accreditation Agency in Health and Social Sciences. Available at: https://ahpgs.de/en/welcome-to-the-ahpgs/
8. Pletsan, K., Fesenko, G., Mazepa, T., Syrotynska, N., Moskaljova, A., Osaula, V. (2021). Training of future managers of the culture sphere. AD ALTA: Journal of Interdisciplinary Research, 11/02-XXII, 17–20. Available at: http://www.magnanimitas.cz/ADALTA/110222/papers/A_03.pdf
9. Papanthymou, A., Darra, M. (2017). Quality Management in Higher Education: Review and Perspectives. Higher Education Studies, 7 (3), 132. doi: https://doi.org/10.5539/hes.v7n3p132
10. Langfeldt, L., Stensaker, B., Harvey, L., Huisman, J., Westerheijden, D. F. (2009). The role of peer review in Norwegian quality assurance: potential consequences for excellence and diversity. Higher Education, 59 (4), 391–405. doi: https://doi.org/10.1007/s10734-009-9255-4
11. Moser, M., Treskova, S. (2020). Deviations between Accreditation Recommendations of Expert Panels and Final Decisions of the German Accreditation Council. Thematic analysis. Bayreuth: ACQUIN, 13. Available at: https://www.acquin.org/wp-content/uploads/2021/01/Accreditation-Decisons_-Deviations-between-Accredition-Council-and-Accreditation-Reccommendation-of-Expert-Panels.pdf
12. Chiyevo Garwe, E. (2018). The Role of International and Regional Quality Assurance Bodies. Higher Education Research, 3 (1), 15. doi: https://doi.org/10.11648/j.her.20180301.14
13. Rubio-Arostegui, J. A. (2017). Expertpanel accreditation evaluationpractices: an autoethnographic case study of the Community of Madrid. Annual Review. Debats. Revista de Cultura, Poder i Societat, 2, 151–162. doi: https://doi.org/10.28939/iam.debats-en.2017-11
14. Abebe, R. T. (2021). Trust Between Quality Assurance Agencies and Higher Education Institutions and its Implications for Quality Management Models. Tampere: Tampere University, 381. Available at: http://urn.fi/URN:ISBN:978-952-03-1869-7
15. Ransom, T., Knepler, E., Zapata-Gietl, C. (2018). New Approaches to Judging Quality in Higher Education. Profiles of Emerging Methods. Apart From Traditional Accreditation. Washington: Council for Higher Education Accreditation, 32. Available at: https://files.eric.ed.gov/fulltext/ED588479.pdf
16. European, Ukrainian and Kazakh policies, strategies and practices of quality assurance in higher education: Case Study (2021). Available at: http://web.elth.ucv.ro/eduqas/wp-content/uploads/sites/2/2021/07/R1.-Case-study.pdf
17. Fesenko, G. G., Shakhov, A. V., Fesenko, T. G., Yakunin, A. V. (2020). Monitoring of the educational management system by the gender maturity evaluation models (case study of Ukrainian universities). Bulletin of NTU "KhPI". Series: Strategic Management, Portfolio, Program and Project Management, 1, 68–77. doi: https://doi.org/10.20998/2413-3000.2020.1.10
18. Fesenko, T., Shakhov, A., Fesenko, G. (2017). Modeling of maturity of gender-oriented project management office. Eastern-European Journal of Enterprise Technologies, 5 (3 (89)), 30–38. doi: 10.15587/1729-4061.2017.110286.
19. Fesenko, T., Fesenko, G. (2017). Developing gender maturity models of project and program management system. Eastern-European Journal of Enterprise Technologies, 1 (3 (85)), 46–55. doi: https://doi.org/10.15587/1729-4061.2017.28031
20. Rekomendatsiyi shchodo zastosuvannia kryteriyiv otsiniuvannia yakosti osvitnoi prohramy (2020). Kyiv: Orion, 66. Available at: https://naqa.gov.ua/wp-content/uploads/2020/12/Рекомендації-щодо-застосування-критеріїв-оцінювання-якості-ОП.pdf
21. Pegat, A. (2013). Nechetkoe modelirovanie i upravlenie. Moscow: BINOM. Laboratoriya znaniy, 798. Available at: https://rucont.ru/file.ashx?guid=48250170-6d18-4467-a884-f4dd019d1f57
22. Danylevskyi, M. P., Yakunin, A. V., Kuznetsova, H. A. (2012). Elementy obchysliuvalnoi matematyky. Kharkiv: KhNAMH, 156. Available at: https://eprints.kname.edu.ua/24617/1/2009%2070Л%20печ%20ЕОМ_для_ОіА_ВМ2_10_один_файлом.PDF
23. Richards, J. A., Jia, X. (2006). Remote Sensing Digital Image Analysis. Springer, 439. doi: https://doi.org/10.1007/3-540-29711-1