FACTA UNIVERSITATIS (NIŠ)
SER.: ELEC. ENERG. vol. 19, no. 3, December 2006, 393-404

Modelling of the Criteria for Measurement and Assessing the Quality of University Education

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Abstract: The paper deals with the application of expert methods and correlation analysis during multi-criterial measurement and assessment of the quality of university education. The paper is founded on the precondition that the quality of university education has to be measured and the quantitative assessments have to be obtained by scalarization of preliminarily defined criteria, which depend on the single indices about quality of training.

The multi-componential criterial functions of indices, the correlation dependences between them, the coefficients of weight have been studied applying the method of expert assessment.

Keywords: Measurement, assessment, quality of training, expert assessment

1 Introduction

The generalized feature, called quality, does not appear as a physical magnitude and in severely metrological understanding it cannot be measured, because there are not the regulated measures about this characteristic. At the same time, on the basis of analogies with the measurement of physical magnitudes, the practical rules for assessing the quality are accepted including quantitative ones.

In [1] the following definition about term measurement is given a combination of actions, which have for an object to determine one value of a given magnitude. In order to determine or measure one magnitude it has to be compared with other known magnitude accepted as a unit of measure.

During measurement and assessment of the quality of training, quality indices can be used as analogues of physical magnitude. In order to assess the quality, it

Manuscript received March 20, 2006.

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is necessary to compare the quality indices of educational product with the quality indices of uniform products accepted as a sample. On the basis of comparison, the conclusion can be drawn about whether the quality indices of object for comparison (the product) are higher or lower and with how much (using some scale). In this way, it is possible to solve the problem for measuring and assessing the quality by means of quality indices [2].

The concepts physical magnitude (or magnitude) and quality index are close, but not identical. The physical magnitude reflects the objective property in the nature, but the quality index information set of data according to which the separate criterion for quality or its complex assessment can be determined.

The quality of training can be controlled and assessed according to three different approaches:

- On the exit where the knowledge, skills, arrangements, values acquired by the students at the time of training are verified (absolute quality assessment).
- Method of added value, at which the difference between the input and output level is sought. From this difference is rated about the effectiveness at the process of training and the quality of educational product.
- About quality is rated indirectly on separate parts, elements and processes, conditions and preconditions, through which the educational process passes. The presumption of this approach is that if all these ones responds at the most to the quality requirements then the quality will possess a high assessment.

The present paper is connected with the third approach. From this point of view, the quality represents a complex multi-measured feature. About its assessment simplified models are worked out accounting for small number of determining components of quality. These models can be reconsidered and improved as new features are included or such ones, which do not carry useful information, are excluded.

In [2] the quality indices are qualified as single (referring to feature) or complex. The complex indices can be composed of single one as functional dependences from them, but they can be a combination (more often occurred variant) of single indices. Depending on the selection of single indices (definitions which are accepted about them), dependences between complex and single indices can be unitar (the single index participates in the forming of one complex only) or matrix when the all complex indices in general case depend on all single ones.

It is possible that the complex indices to be unified in complex ones from higher level. In this way the structure of quality indices is received on several levels (multistorey). During transition towards index from higher level, the quality model

becomes still more complicated until it is brought to one generalized quality index. The complex indices appear criteria for quality which participate with their corresponding coefficients of weight in the complex assessment.

2 Modeling of the Criteria for Quality of Training

2.1 Suggestion about criteria and indices

The criteria (complex indices) for assessing the subject as it is suggested in [3, 4] can be as follows:

1. Purposes and expected results from the educational course (K1).
2. Educational contents of the course (K2).
3. Quality of the teaching and learning (K3).
4. Assistance from lecturers to students (K4).
5. Resources of training (K5).
6. Assessment of the achievement of students (K6).

It can claim that these criteria possess joint comprehensiveness, i.e. taken in a whole they assess the quality, fully enough without to remain uncovered spaces and without separate criteria to repeat already made estimates according to other ones.

They proceed from:

- The understanding that the quality is not final result, which can be measured with difficulty but the features about the process of training according to what it is achieved.
- The structure and design of the subject.
- The conducted examinations of literature sources.

The so suggested points of view about assessments take into account also the criteria of National Agency for Assessment and Accreditation during evaluation of specialities [5]. The quality indices of subject can be as follows:

P1 Conformity of the educational contents on subject with the stated purposes of training and expected results.

P2 Conformity of the educational contents on course with analogous subjects in leading European and Bulgarian Universities.

P3 Availability and quality of up-to-date and accessible informative educational matters about assistance to learning of students on the subject (textbooks, manuals, notes, teaching tests, publications in Internet).

P4 Position of the material base and technical means used for lectures, laboratory and other practical occupations.

P5 Scientific professional language and practical preparation of the lecturers.

P6 Assistance from lecturers to students during the term (including the dialogue students-lecturers) and their ability to involve the students in educational process.

P7 Methods for teaching on the subject, their adequacy of its character and degree of utilization of up-to-date scientific achievements.

P8 Methods for testing, forming of final assessments and their justice.

P9 Success of students about the subject. The so formulated, indices fulfill the requirements submitted above, i.e.:

- to be explicitly connected with the criteria for quality assessment.
- to have feature measurability.
- to use data, which are serene, actual, valid and understandable.
- to be subjected to processing so that they allow quantitative assessment of the criteria.

2.2 Assessment of the indices and criteria

The measurability of indices can be objective (according to norms or data from administration), but the most often it is expert as the experts answer to five-stage scale from 2 to 6:

Estimate 2 means that according to this index, the necessary preconditions for quality are not formed. In the range of this index there are large disadvantages which have to be eliminated.

Estimate 3 means that according to this index, some preconditions are formed or some results have been achieved but significant improvements can be made.

Estimate 4 means that in this activity there are preconditions and the results, which are evidence about good quality, have been achieved.

Estimate 5 means that in this activity there are many good preconditions and many good results, which are substantial contribution toward an achievement of announced purposes, have been obtained but there are some things to be improved.

Estimate 6 means that this index contributes fully to solution of the assigned tasks and there are not any notes.

Here, an attempt will be made in order to reveal the dependences between criteria and indices. As it is obvious from their formulation, with increasing the possitive assessment of indices the criteria are improved and the quality of subject is raised, i.e. there is directly proportionality between indices and criteria. In is suggested that the dependence is matrix, i.e. in general case which one criterion

$$K_i = f_i(a_{i1}, a_{i2}, \ldots, a_{im}, P_1, P_2, \ldots, P_m) \tag{1}$$

where $(i = \overline{1,n})$, is dependent on all indices $P_j (j = \overline{1,m})$:

$$\begin{aligned} K_1 &= f_1(a_{11}, a_{12}, \ldots, a_{im}, P_1, P_2, \ldots, P_m) \\ K_2 &= f_2(a_{21}, a_{22}, \ldots, a_{2m}, P_1, P_2, \ldots, P_m) \\ &\ldots \\ K_n &= f_n(a_{n1}, a_{n2}, \ldots, a_{nm}, P_1, P_2, \ldots, P_m) \end{aligned} \tag{2}$$

But the indices have different influence on the criteria. Some of them can participate not in the part of criterial functions (they have zero effect). In extreme case it can be reached to *unitar dependence* as one index influence only on one criterion and each criterion has their own indices. This is suggested in some publications [6].

The indices P_{ij} are ordinarily descrete numbers from degree (point) scale according to which is accepted to assess their value. For assessing the indices it is accepted to use customary five-stage six-point system about Bulgarian education from 2 (the most unfavourable value about quality) to 6 (the most favourable value about quality).

From matrix to unitar dependence in all cases it is necessary to determine the coefficients of weight a_{ij}. However, in the two cases they have different influence on the criteria which depends on the character of the same functional dependence and their coefficients of weight. These problems are solved in the next items.

The task is as follows: the criterion depending on the indices as multi-factorial functions from the type $K_i = f_i(a_{i1}, a_{i2}, \ldots, a_{im}, P_1, P_2, \ldots, P_m)$ to be modelled. If the values of criteria $K_1 \div K_6$ are determined according to these models, the complex assessment about quality of the subject Q can be found. For this purpose the coefficients of weight $a_{i1}, a_{i2}, \ldots, a_{im}$ has to be known.

In principle, it can be supposed that a given criterion $K_{ij} = f(P_1, P_2, \ldots, P_m)$ depends on each index in another way (for example, linearly from P_i, quadratically from P_j, logarithmically from P_k, etc.). This is the supposition in [7], where it is assumed that $K_{ij} = f(P_k)$ is extreme curve and its best value stays in the extremum as well the quality is good in this value. For instance, the ratio between reproductive and productive knowledge which the student has to obtain at the time of his/her training, even though it is different about various subjects then it has to be optimum

about each of them. It cannot be required creative skills without reproductively learned basic subject. Simultaneously, without any effort it cannot be reproduced given or absorbed knowledge and principles by the student especially about some engineering subjects he/she must learn himself/herself to apply them. Therefore, the ratio reproductive/productive has optimum value.

However, the indices can be defined so that with increasing of their values according to accepted point system the quality is improved. In this case, it concerns multi-factorial monotone increasing functions. Thus, with such statement an important part of the entropy about this problem has been cleared off.

The conducted analysis points that the influence of indices on the criteria has to be proportional. Then, it can be used some type of averaging.

The simpliest one is *arithmetic averaging*, i.e.:

$$Y = c_1x_1 + c_2x_2 + \cdots + c_nx_n = \sum_{i=1}^{n} c_ix_i \tag{3}$$

where c_i are normalized coefficients of weight

$$\sum_{i=1}^{n} c_i = 1 \tag{4}$$

When the arithmetic averaging is applied on the dependences of criteria from indices (1) it is obtained:

$$\begin{aligned}
K_1 &= a_{11}P_1 + a_{12}P_2 + a_{13}P_3 + a_{14}P_4 + a_{15}P_5 + a_{16}P_6 + a_{17}P_7 + a_{18}P_8 + a_{19}P_9 \\
K_2 &= a_{21}P_1 + a_{22}P_2 + a_{23}P_3 + a_{24}P_4 + a_{25}P_5 + a_{26}P_6 + a_{27}P_7 + a_{28}P_8 + a_{29}P_9 \\
K_3 &= a_{31}P_1 + a_{32}P_2 + a_{33}P_3 + a_{34}P_4 + a_{35}P_5 + a_{36}P_6 + a_{37}P_7 + a_{38}P_8 + a_{39}P_9 \\
K_4 &= a_{41}P_1 + a_{42}P_2 + a_{43}P_3 + a_{44}P_4 + a_{45}P_5 + a_{46}P_6 + a_{47}P_7 + a_{48}P_8 + a_{49}P_9 \\
K_5 &= a_{51}P_1 + a_{52}P_2 + a_{53}P_3 + a_{54}P_4 + a_{55}P_5 + a_{56}P_6 + a_{57}P_7 + a_{58}P_8 + a_{59}P_9 \\
K_6 &= a_{61}P_1 + a_{62}P_2 + a_{63}P_3 + a_{64}P_4 + a_{65}P_5 + a_{66}P_6 + a_{67}P_7 + a_{68}P_8 + a_{69}P_9
\end{aligned} \tag{5}$$

In the same way, it is obtained about the *complex quantitative assessment of quality* of the subject, i.e.:

$$Q = k_1K_1 + k_2K_2 + k_3K_3 + k_4K_4 + k_5K_5 + k_6K_6 \tag{6}$$

The worth of this mathematical model is its simplicity and logicality. The model is applicable when the influence of each factors is linear-proportional to its coefficient of weight.

In various publications, other methods for averaging are suggested, i.e. quadratic-mean, harmonic or geometric. Irrespective of the applied methods, the final assessment is given by the experts or the most commonly by the body authorized to estimate the subject. In a series of higher schools, this is the commission on Faculty

level with participation of the student representatives, and somewhere also of the main employers. It is an organ, which accepts a solution for final assessment of the criterion. Furthermore, this organ is authorized and competent about substance of assessment as well as it can: specify the contradictions between data, apply triangulative method and reach a decision about the final assessment, as it is described in [8].

2.3 Methods for determining the coefficients of weight

Here, only the expert methods, which are based on the subjective estimates of separate specialists about examined problem, have been considered. It is recommended they to be at least 7, to be competent and high-qualified in the sphere of quality of the university education. In the specialized literature the algorithms about exact determination of the expert staff, according to which estimates their averaged values are found, have been given.

Further down, the methods are determined, in the way of putting the question and processing the results from consultation with the experts.

2.3.1 Methods of weighed arithmetic-mean expert assessment

A stage scale about significance of criteria (indices) in the complex assessment $\overline{q}$ is selected. The questions are posed toward the experts about their appraisal what is the significance according to this scale about the corresponding criterion (index). The results obtained are grouped in sets of the equal assessments using the known formula:

$$\overline{q} = \frac{\sum\limits_{i=2}^{6} n_i A_i}{\sum\limits_{i=2}^{6} n_i} \tag{7}$$

where A_i is the extent of connectivity (the power of influence) according to five-stage scale ($i \in (2,3,4,5,6)$) between the criterion and total assessment of quality, but ni is the number of cases, in which the experts have pointed this stage.

In Higher School of Transport an inquiry examination has been made about the opinion of 22 members of the Commission for Assessing the Quality, Deans, Heads of department, lecturers and public figures in higher education.

The results are shown in Table 1 and are systematized in Pareto diagram in Fig.1.

In the column “Arithmetic averaging” the calculation is made about influence of the criteria in the total assessment of quality. After normalizing of these values so that they to give an answer to the requirements of equation (4), the coefficients

Table 1. Criteria about assessment and coefficients of weight at arithmetic averaging.

Criteria	Number of assessments in five-stage scale					Arithmetic averaging	Coefficients of weight	
	2	3	4	5	6			
Purposes and expected results from the educational course (K_1)	1	1	2	9	9	5.0909	k_1	0.171
Educational contents of the course (K_2)	1	1	2	4	14	5.3182	k_2	0.184
Quality of the teaching and learning (K_3)	0	1	2	3	16	5.5455	k_3	0.196
Assistance from lecturers to students (K_4)	1	3	5	8	5	4.5909	k_4	0.144
Resources of training (K_5)	1	0	5	10	6	4.9091	k_5	0.161
Assessment of the achievement of students (K_6)	0	2	9	7	4	4.5909	k_6	0.144

of weight about the criteria in total assessment (the last column in the table) have been obtained.

The opinion of experts about the first three criteria is rather unanimous. Especially, it is underlined about second and third criterion (k_2 and k_3), which has the biggest significance according to them, i.e. the highest value of five-stage scale. The opinions about the fifth criterion are with lower variance.

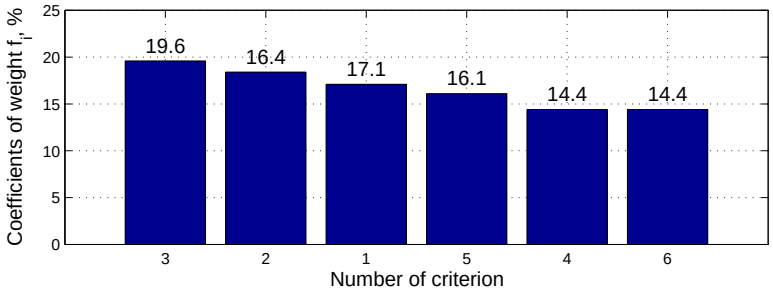

Fig. 1. Pareto diagram about the coefficients of weight obtained according to the method of weighed arithmetic-mean expert assessment.

At such found values of the coefficients of significance the equation of global assessment of the quality of subject can be also written depending on the value of criteria, according to which the quality of training on the subject to be estimated.

$$Q = 0.171K_1 + 0.184K_2 + 0.196K_3 + 0.144K_4 + 0.161K_5 + 0.144K_6 \qquad (8)$$

More precise estimate of the experts' competency requires their self-assessment and mutual assessment moreover, about each criterion according to which the estimate is in store for making. After averaging the opinion of everyone for everyone, their singly competency acquires normalized values which are accounted for as

particular coefficients of competency about estimated criterion. At this stage of examination the experts are supposed as equally-competent.

2.3.2 Method of expert assessment by means of ranging

According to methods presented in [9], the experts arrange on priority (on significance, power of influence) each of the criteria. Hence, in compliance with its own seeing every expert about each of the criterion. In this way at m criteria the m ranks is received, in each of which according to personal opinion of the expert every criterion K_i can fall. Ranging of 6th criteria made by 7 independent expert is shown in Table 2 (matrix of ranks). After calculating the coefficients of weight the agreement in the opinion of experts is assessed as the coefficient of concordation w_k is computed according to the method of rank correlation.

Table 2. Criteria about evaluation and coefficients of weight at method of expert assessment.

Expert Criterion	E_1	E_2	E_3	E_4	E_5	E_6	E_7	$\sum_{j=1}^{n} a_{ij}$	Δ_j	Δ_j^2	V_j	k_j
Purposes and expected results from the educational course (K_1)	3	2	4	3	3	4	2	21	−3.5	12.25	0.6	0,2
Educational contents of the course (K_2)	2	3	1	2	2	2	3	15	−9.5	90.25	0.771	0.257
Quality of the teaching and learning (K_3)	1	1	2	1	1	1	1	8	−16.5	272.25	0.971	0.323
Assistance from lecturers to students (K_4)	5	4	3	4	4	3	6	29	4.5	20.25	0.372	0.124
Resources of training (K_5)	6	6	5	6	5	5	4	37	12.5	156.25	0.143	0.048
Assessment of the achievement of students (K_6)	4	5	6	5	6	6	5	37	12.5	156.25	0.143	0.048
									$\sum$	707.5	3	1

The matrix of ranks is filled in as the estimates of experts are carried in as well as Δ_j, V_j and the values coefficients of weight k_j are calculated:

$$\Delta_j = \sum_{j=1}^{m} a_{ij} - S_m \tag{9}$$

where Δ_j is a deviation of the sum of weights about each criterion from the mean sum of all weights S_m;

$$S_m = \frac{1}{2}(m+1)n \tag{10}$$

where m is the number of criteria, but n - number of experts.

About the concrete expert assessment $S_m = 24.5$

$$V_j = \frac{n \times m - \sum_{j=1}^{m} a_{ij}}{n(m-1)} \tag{11}$$

The calculation itself of the coefficients of weight is accomplished by means of

$$k_j = \frac{V_j}{\sum_{j=1}^{m} V_j} \tag{12}$$

at which the condition (4) has to be performed.

In Fig.2 the values of the coefficients of weight in Pareto diagram are systematized.

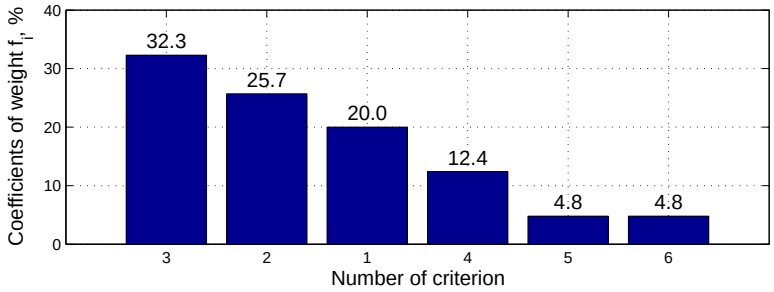

Fig. 2. Pareto diagram about coefficients of weight obtained according to the method of expert assessment.

In order to determine the authenticity and reliability of the assessment, which is given by the expert, the coefficient of concordation has been calculated - about it the values from zero (at fully disagreement) to a unit (at fully agreement).

$$w_k = \frac{S_\Delta}{n^2(m^3 - m)} \tag{13}$$

where w_k is the coefficient of concordation,

$$S_\Delta = 12 \sum_{j=1}^{m} \Delta_j^2 \tag{14}$$

where S_Δ is the sum of deviations. About the coefficient of concordation calculated according to (14), it is received $w_k = 0.825$, which points good agreement of opinions of the experts. If the agreement of opinions is unsatisfactory, the methods for its increase are sought. If it is impossible the utilization of Delphy method is suggested, at which through anonymity, multi-stage and control - lower variance of their opinion can be achieved.

In Fig.3 the diagram of scattering about the values of coefficients of weight, which are obtained by means of the arithmetic averaging also according to the method of expert assessment, has been presented. The ranging of criteria is in decreasing order (the most important criterion - $K-3$ is the first on the x-axis) in conformity with the results obtained according to the method of expert assessment.

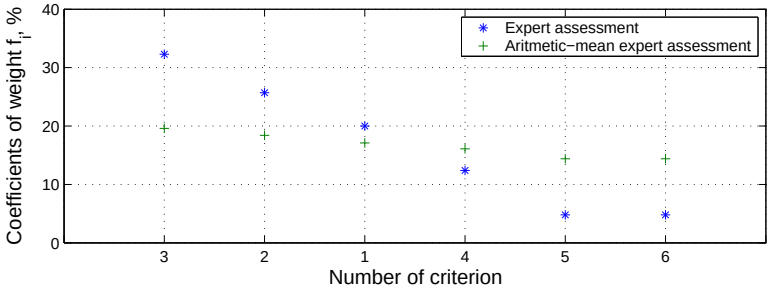

Fig. 3. Diagram of the scattering.

3 Conclusion

The quality measurement of university education and the receiving of quantitative estimates about its assessment is one of the necessary preconditions for successful management and quality improvement as a whole. At modelling of the criteria for measuring and assessing the quality, it is necessary a suitable method for forming the coefficients of weight to be selected. It is obvious from submitted examinations that the two methods are applicable as the tendencies at receiving the coefficients of weight according to the method of weighed arithmetic-mean expert assessment and the method of expert assessment by means of ranging is identical. When the assessments are close according to the method of "weighed arithmetic-mean", the close values about coefficients of weight are obtained. Using the method of expert assessment by means of ranging, especially if the joined ranks are missing, more distinct outlining of the significant criteria has been received.

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