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Intelligent Methods for Attestation of Scientific and Teaching Staff. Rasch Model

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Abstract. Introduced in many universities quality management systems suggest the development of appropriate technologies for the assessment of learning results. Unfortunately, some of the real tasks remain outside the scope of the systems due to complexity, non-formalization, unawareness or lack of adequate mathematical models, software and more. Such is the task of attestation of the research and teaching staff, which is being periodically solved in universities. The work proposed model for the formalization of the problem of attestation of scientific and pedagogical staff, based on an adapted version of the one-parameter Rasch model for dichotomic data. The model allows software implementation and help to reduce the subjectivism in evaluating the performance of teachers in universities.

Keywords: attestation of personnel, attestation of scientific-pedagogical staff, one-parameter Rasch model.

I. INTRODUCTION

The world is witnessing the modernization in the field of education related to implementation of information technologies at all stages of the educational process. Implementation of quality management systems education in higher education implies the development of adequate technologies for the modelling and assessment of learning results.

Unfortunately, some of the real tasks remain outside the scope of the systems due to complexity, nonformalization, multicriteria, unawareness or lack of adequate mathematical models, software and more. Attestation is essential and controllable parameter of the educational process. Developing procedures for objective evaluation of the teaching work and ranking of scientific and teaching staff allows for the development of personnel potential, improvement of quality control and compliance with European standards.

Because of these reasons, the development of methods of formalization and models for decision making with objective measurement and evaluation of results of scientific and teaching activity is an important task that after the development of the model and the experiment can be embedded in the quality management system.

II. OBJECTIVES, AND RESEARCH METHODOLOGY DESIGN

Attestation is performed in order to determine compliance of research workers to their positions on the basis of an assessment of their professional activity.

Attestation of personnel is a "systematic procedure to be formally assessed according to the criteria of conformity of the employee's standards of performance in the workplace in this position for a certain period of time" [1].

Attestation is intended to promote the rational use of educational and creative potential of researchers; to improve their professional level; optimization of preparation, selection and appointment of personnel, the possibility of choice in the changes of conditions of remuneration of researchers; strengthening the role of the moral and material interest.

The purpose of attestation is to define the individual ratings and ranking teachers in the structural units of the organization in accordance with their rating.

The rating of a teacher is an individual numeric indicator of the results of scientific and teaching activity of the teacher, obtained by summing ratings on individual criteria. Intuitively it is clear that the criteria are not of the same weight, so it is advisable to introduce weight coefficients of criteria based on expert opinion.

The rating system of evaluation of teachers has clear advantages, some of which are:

- Allows for a quantitative characteristic of the creative and educational potential of the teacher;
- Reduces subjectivity and the role of random factors in the final evaluation;
- Gives you the opportunity to create standards for evaluation;
- Promotes adherence to the same for all conditions to assess;
- Promotes competition in departments;
- Allows differentiation of teachers in accordance with their achievements;

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- Gives the opportunity to diagnose features of the teaching process;
- Allows for the development of software systems monitoring of the scientific and teaching work;
- Allows the accumulation of statistical data and statistical results;
- Promotes adherence to the ethical requirements.

The purpose of this paper is the formalization of the problem and the development of a method of decision making when attestation of scientific and pedagogical workers is performed, to reduce subjectivity and to automate the process.

A.Analysis of the decision-making process for the assessment of scientific and pedagogical staff

Attestation of scientific-teaching staff is carried out periodically in accordance with predetermined criteria. Universities develop specific Regulations for attestation, which are available on their websites [2], [3]. Because research-teaching activities have common characteristics, Regulations of various universities differ insignificantly [4]. Criteria for assessing and ranking personnel are similar.

Attestation of the teaching staff for research units is carried out by a special Commission, head of Department, and sometimes from teachers themselves on the basis of specific criteria.

Analyzing the thought process of the expert in the decision-making process for the evaluation of the teaching staff, can draw some conclusions related to the nature of this process.

Analysis of the decision-making process for the assessment of scientific and pedagogical staff shows that:

- The selection of criteria is carried out by experts and is highly dependent on their experience, professionalism and competence;
- In real problems the criteria are set linguistically. The process of interpretation is accompanied by inaccuracies, ambiguity, due to the subjective interpretation of the experts;
- Examination and ranking of scientific-pedagogical personnel produced by the fuzzy relations between evaluations by fuzzy criteria specified in the linguistic scales;
- In the process of ranking resources it is necessary to substitute the vector assessment by a scalar one by means of convolution of quantitative or qualitative assessment on the basis of preset criteria.

From this it follows that the task of evaluation of the teaching staff belongs to the class of multi-criteria, non-formalized tasks. The decision-making process is characterized by subjectivity, which does not allow to apply the well-known classical methods and theory model of decision making and management. Therefore, to formalize and to solve this problem, it is appropriate to use the Rasch model, which allows modelling the process of decision making and convolution of multi-criteria evaluation in the numerical rating.

B.Formalization of the problem of evaluation of the scientific and teaching staff

Assume that the latent variable <teacher's efficiency> is evaluated. For its assessment we use criteria that represent the latent variables of the lower rank, which are easier to evaluate.

Let's:

D = discrete (for example: {bad, good, excellent}, {meets the criteria, does not meet the criteria}, {0, 1} etc.) or continuous (in intervals, e.g. [0, 1], [1, 10] etc.) set of diagnosis;

$P = \{p_1, p_2, ... p_k\}$ is the discrete set of teachers subject to attestation;

$C = \{C_1, C_2, ...C_m\}$ is the discrete set of expert-defined evaluation criteria;

$A = \|a_{ij}\|$, i=1,2, ... n, j=1,2,...m is the matrix containing the assessment results; $a_{ij} \in L_j$ - assessment of teacher by i expert in accordance with the criterion C_j;

L_j – discrete or continuous scale of assessments according to the C_j- criterion, j = 1, 2, … m;

In practice, for estimating, the easiest method is to use the same scale for assessment according to different criteria, i.e. $L_1 = L_2 = ... = L_n = L$, for example in a dichotomic scale L = {Yes, No} ≡ {0,1}.

For best adequacy to the linguistic model of the decision-making process for the evaluation of the teaching staff it is possible to consider it as a problem of diagnostics of the form <P, C, L, A, D> with the following formulation: for each teacher $p_i \in P$, to determine the diagnosis $d \in D$ on the basis of results A by criteria C defined in the scale L.

Formally, this means to find an injective map

$\Omega: P \rightarrow D$

of a set of personnel, subject to certification to the diagnosis set D in which each element $pi \in P$ is matched to exactly one element $d \in D$.

To obtain Ω we will apply the Rasch model for dichotomous data.

C.Modification of one-parameter Rasch model for calculating the teachers rating

The Rasch model is designed to assess test results. It establishes the correspondence between monitored test results and two sets of latent (hidden, immeasurable directly) properties associated with the difficulty of test and the preparation of students [5].

For the application of the Rasch model, we assume that the professional activity of the teacher and complexity of criteria are evaluation parameters, which allow for an objective assessment. This assumption is not contrary to actual practice, which is confirmed by the following considerations:

- One criterion is more complex than another if the probability of meeting it is smaller, regardless of the teacher, which is estimated;

- A more effective teacher will meet more fully the criteria with arbitrary complexity, compared to the more ineffective one;
- The more effective the teacher is, the higher he will be evaluated, regardless of the Commission
- The same teacher will be evaluated in roughly equal measure from different (but equal in competence) Commissions;
- One and the same Attestation Commission will evaluate higher the highly effective teacher and lower the less effective one;
- Repeated evaluation of different teachers from different commissions may differ because of unavoidable measurement errors, but not due to the differences in competences of the Commissions.

Paraphrasing the Rasch model, we can assume that the probability P that a tutor with the efficiency of S to satisfy the criterion of complexity T gives the formula:

$$P(S,T) = \frac{S}{S+T} \qquad (1)$$

The function P(S, T) is called the success function, and the variables S and T are latent variables. If we introduce the following notation:

A = LN(S), S = EXP(A)

B = LN(T), T = EXP(B)

for P we get:

$$P(S,T) = \frac{EXP(A)}{EXP(A)+EXP(B)} = \frac{1}{1+EXP(B-A)} \qquad (2)$$

The resulting equation is called the basic logistic model of Rasch. Formula (2) shows that the probability of success depends only on the difference B - A, for which the Rasch model is one-parameter. The model parameters A and B characterize the effectiveness of the teacher and the complexity of the criteria and are measured in logit. If A = B = 1 logit, P = 0.5, what semantically means that the probability a standard teacher will meet the standard criteria - 0.5. If the effectiveness of a teacher is very much higher than the complexity of the criteria ($B - A \rightarrow -\infty$), the probability of satisfaction $P \rightarrow 1$. In the case that the effectiveness of a teacher is far less than the degree of difficulty of the criteria ($B - A \rightarrow \infty$), the probability of satisfaction $P \rightarrow 0$.

D. Choice of criteria

We expect to evaluate teachers' rating by pre-selected criteria (indicator variables), which are grouped into categories, with different weights. Correct use of the Rasch model requires that the criteria meet the following requirements:

- Transparency – the criteria should be clear and understandable to teachers and experts;
- Unambiguousness - reduce the possibility of subjective interpretation, the use of unitary assessment {Yes, No};
- Criteria are simple, without logical connections "and, or, not" and without complications due to the use of modifiers, qualificators and quantificators;
- Different criteria do not depend on each other;
- Expert evaluations are independent from each other;
- One-dimension of space – the criteria selected in such a way that they measure the same variable, namely the quality of the teachers work. Analysis of the results of the practical use of Rasch models in the evaluation of the results of the test exams in the United States and Russia [4], shows that this is one of the requirements which are difficult to meet;
- Different criteria must have a high discriminatory ability, which is achieved due to the location of their increasing complexity. This assumes that the teacher who met the requirement of this criterion (received a score of 1) very likely has satisfied all previous, relatively lighter criteria. And vice versa, if they have not satisfied this criterion, the probability to satisfy the next is very small. Most criteria used in practice do not satisfy this requirement, regardless of the lengthy pre-selection and experiments. Evaluation of the discrimination ability of criteria can be achieved only after their practical use.
- All criteria are divided into categories;
- Criteria from different categories affect differently the formulation of final evaluation, i.e. we are aware of the presence of weights, which can be selected by expert assessments.
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III. RESULTS AND DISCUSSION

To demonstrate the operability of the Rasch model to calculate the rating of the teaching staff, an Excel spreadsheet (Table I) is used [6]. The rating of a particular teacher we calculate in the following order:

1. Each member of the Commission (expert) assesses a given teacher by pre-selected criteria in the dichotomic scale L = {0, 1}. As a result of expert evaluation, we obtain A matrix with the dimensions n x m (n is the number of experts, m is the number of criteria) and the elements a_{ij} equal to 1 if the teacher satisfied the requirements of the j-th criterion, and zero otherwise.
2. We calculate the primary ball b_i, i = 1, 2, ... n of the tutor, obtained from the estimation of the i-th expert. Primary ball we call the sum of the matrix elements in the rows modified by the weight of the criteria.
3. Calculate the parameters p_i , i=1, 2, ...n by the formula:

$$p_i = \frac{b_i}{maximalball} \quad (3)$$

4. Ignore the extreme ball in the following way:
   - if $b_i = 0$, set $p_i = \varepsilon$;
   - if b_i is equal to the max ball, set $p_i = 1 - \varepsilon$,

where ε is a small enough number, for example ε = 0,001.

5. The initial approximation of the effectiveness of the teacher according to the assessment of the i-th expert we determine by the formula:

$$A_i = LN\left(\frac{p_i}{1-p_i}\right), i = 1,2,...n \quad (4)$$

6. We calculate the primary ball c_j, j = 1, 2, ... m of the criteria, obtained by adding the grades in the columns modified by the weight of the criteria.

Table I
Attestation of scientific and pedagogical staff. Rasch model

Criteria / Attestation Commission	A set of criteria 1 weight=1						A set of criteria 2 weight=2				A set of criteria 3 weight=2						A set of criteria 4 weight=3							A set of criteria 5 weight=3			Primary ball bi	p_i	Ai = LN(pi/(1-pi)) in logits	Criteria complexity
Criteria (Rating indicator)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26				
Expert 1	1	1	1	0	1	1	1	0	1	1	0	1	1	1	0	0	1	1	0	0	1	0	0	1	0	0	29	0,408	-0,37037	
Expert 2	1	1	1	1	0	1	1	1	1	0	1	1	0	0	0	1	1	0	1	1	1	0	1	0	0	0	32	0,451	-0,19783	
Expert 3	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	0	0	1	0	40	0,563	0,25489	
Expert 4	1	1	0	1	1	1	0	1	0	1	0	1	1	1	1	1	1	1	1	1	1	0	0	1	1	0	40	0,563	0,25489	
Expert 5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	53	0,746	1,07992	
Primary ball cj	5	5	4	4	4	4	8	8	8	8	6	10	8	8	6	8	15	12	12	9	12	6	6	9	9	0				
p_j	0,999	0,999	0,800	0,800	0,800	0,800	0,800	0,800	0,800	0,800	0,600	0,999	0,800	0,800	0,600	0,800	0,999	0,800	0,800	0,600	0,800	0,400	0,400	0,600	0,600	0,001				
B_j=LN((1-p_j) p_j) in logits	-6,907	-6,907	-1,386	-1,386	-1,386	-1,386	-1,386	-1,386	-1,386	-1,386	-0,405	-6,907	-1,386	-1,386	-0,405	-1,386	-6,907	-1,386	-1,386	-0,405	-1,386	0,405	0,405	-0,405	-0,405	6,907				-0,582321
Teachers' rating																													0,20430	

7. Calculate p_j , j=1, 2, …m by the formula:

$$p_j = \frac{c_j}{maximal\ ball} \quad (5)$$

If $c_j = 0$, set $p_j = \varepsilon$; if c_j is equal to the max ball, set $p_j = 1 - \varepsilon$.

8. Calculate the initial values of the criteria complexity by the formula:

$$B_j = LN\left(\frac{1-p_j}{p_j}\right), j = 1,2,...m \quad (6)$$

9. Find average values:

$$\overline{A} = \frac{1}{n}\sum_{i=1}^{n} A_i \text{ (Teachers' rating)} \quad (7)$$

$$\overline{B} = \frac{1}{m}\sum_{j=1}^{m} B_j \text{ (Criteria complexity)} \quad (8)$$

This can be used as initial approximations of teachers' rating and criteria complexity.

The table above demonstrates the calculations. The data used are examples.

As the table shows, the estimates are in the range from -6.907 to 6.907 with an accuracy of five decimal places. Criteria complexity is -0.582321 and teachers' rating is 0.20430.

Thus it is possible to evaluate and rank all teachers.

IV. CONCLUSION

The one-parameter Rasch model can be used to assess the scientific and teaching staff in the universities. The results are obtained in logits. No need to be transformed to a different scale, as ranking of the teaching staff may be made on the basis of evaluation in logits.

The nonlinearity of the model encourages good teachers and punishes the inefficient ones, which corresponds to the mind-set of the University leadership.

Practical use of the Rasch model is accompanied by many difficulties arising from its probabilistic character, and can lead to misinterpretation of results. The difficulties are associated with the fulfilment of all necessary conditions for the application of the model rather than its software implementation [7].

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