Technology of Computer Monitoring of the Quality of Educational Process

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Abstract: This research aimed at developing operational assessment tool to minimize the university risk background with the purpose to raise the quality of the educational process. The original mathematical approach is proposed as a means to solve the problem of assuring the quality of education. The method of modified risk thermometer and binary fuzzy relations composition were used as the basic methods of sociological monitoring data analysis to measure the satisfaction of students with educational process. The method of modified risk thermometer identifies the risk background of the educational process, defined by the Key Risk Indicators. The method of fuzzy analysis allows to consider and minimize the existing uncertainty of the educational process and risk background. It is shown on the example that if the university risk background is of high degree, it necessitates taking the complex of management decisions to improve the situation with the risk background. The theoretical significance of the research is in development of the methodology of educational computer monitoring. The application of this methodology raises satisfaction of students and teachers with educational process, objectivity of management decisions and their implementation into educational process in order to normalize the risk temperature, which is the practical significance of the research. The degree of this condition corresponding to the normal one is defined at the next stage and needs taking further management decisions. The described methodology is a universal and efficient tool to revaluate the activity of not only universities but also of any company at risk as well as to organize the process of risk management in social and economic systems.

1 INTRODUCTION

The sociological research into universities' competition for top positioning in global and national rankings demonstrates the growing demand for the ways to monitor the university performance [1, 2, 3, 4]. According to B. Williamson, the findings of the recent sociological research conducted in the United Kingdom raise 'two critical points': the traditional judgement made by experts and professionals is substituted with numerical data, and the people's understanding of the notions ‚good university' and ‚good course' is changing due to the rankings' results [5]. So, literature suggests that most attention has focused on monitoring as an instrument to improve the performance of an organisation, that Lucas H., Greely M. and Roelen K. define as 'higher frequency data collection or reporting, often using information and communication technologies, to strengthen current programme performance or to inform policy and the practice (design, scale and scope) of future service delivery' [6]. Any monitoring system aims to deal with stability and availability [7], that is why, it needs to be reliable and efficient.

One of the monitored parameters to measure the university's performance is the quality of the educational process. It needs monitoring not only for measuring progress and growth but also for negative trends and risks, which is understood as ‚the effect of uncertainty on objectives resulted in a deviation from the expected — positive and/or negative and is often expressed in terms of a combination of the consequences of an event (including changes in circumstances or knowledge) and the associated likelihood of occurrence‘ [8]. Birkinshaw J., and Jenkins H. define risk as ‘the potentially negative impact arising from a future event <…> that can be calculated as a product of the probability of the future event happening and the scale of loss associated with that event‘[9].

In order to measure and manage the risks of the educational process the qualitative and quantitative criteria need to be identified [10]. These criteria, which could serve as an operational risk management tool, are called key risk indicators. Young J. underlines that a risk indicator ‘becomes key when it tracks a risk exposure, which could have a major influence on the organisation‘[11].

Multilevel monitoring is an efficient social technology for managing the quality of professional education [12] in conditions of dynamically changing educational standards, developing new technologies, resources and forms of teaching resulted from globalization and internationalization. The university authorities also change forms and methods of management to make the university competitive. They need new ways of information collection and processing. The ongoing innovations in dynamic assessment of changes make social monitoring the efficient tool for universities’ top and middle management. Monitoring helps not only detect changes, but also evaluate the results of managerial decisions [13].

The latest Federal state educational standards in Russia call for internal and external assessment of the quality of education [4]. Monitoring and operational one-time research allow to work out the methodology of development and objective assessment of the quality of teaching and learning within any university professional program on the principles of competence-based approach [15, 16]. It necessitates the research and development of mathematical model of computer monitoring of education with the purpose to minimize educational risks.

The sociological research conducted at Siberian State University of Telecommunications and Information Science defined the quality of education as a social category which has the following characteristics [17]:

- it defines conditions and efficiency of educational process in society, its meeting the needs and expectations of the society for learners’ social, personal and professional competences;

it is measured by the complex of indicators characterizing various parameters of university performance, which provide the development of learners’ competences: curriculum, forms and methods of teaching, facilities, staff. The data were collected by the risk thermometer method, which is considered to be one of the effective tools to measure risk background of social and economic system and make the first approximation to identify organizational risk background.

The monitoring literature analysis demonstrates that various methodological approaches are used for monitoring consumers’ satisfaction with goods and services. Such approaches, methods and techniques include «SERVQUAL», «SERVPERF», «INDSERV», CSM, weighted estimate method, discrepancies analysis method [18]. However, with the aim to analyze not only students’ and teachers’ satisfaction with educational process, but also its riskiness, we have chosen the risk thermometer method as a model-measuring approach of risk management. Without well-developed corporate culture of risk management any organization uses ‘primitive’ methods of risk management like risk mapping, risk calculator, risk radar, and risk thermometer. The risk thermometer method allows defining the risk background of an organization at a first approximation. Moreover, its application does not require from the user any special risk management knowledge and skills, which might be considered the advantage of the method. This is due to the fact that the risk thermometer method is based on carrying survey data to the integral indicator, which can be interpreted as the risk temperature of a company, with survey questionnaire items implicitly indicating company’s risks and being not specific for risk management.

2 FORMAL DESCRIPTION OF THE RISK THERMOMETER

Being the formalization of a survey procedure [19], the risk thermometer method leads the statistically processed survey results from a questionnaire to the integral indicator:

$$T = \sum_{i=1}^{n} \sum_{j=1}^{m} k_{ij}^{l} x_{ij}, \ l = \overline{1, p},$$

where x_{ij} – variable of *j*-th respondent’s answer to *i*-th item of the questionnaire: $x_{ij} = 1$, if respondent gave *i*-th answer to *j*-th question, $x_{ij} = 0$ – vice versa; k_{ij}^{l} – risk value of *j*-th answer to *i*-th question; *l* – index of the object risk condition, *p* – number of such conditions.

Risk coefficients k^l are expertly set and serve as a norm coefficient leading integral results to temperature indicators: $k^l = \frac{T_l}{n},\ l = \overline{1,p}.$ For example, when analyzing if some system meets the requirements, it is possible to see the following temperature conditions T_l:

- normal $T_1 = 36{,}6\,°C$ – full compliance;
- fever $T_2 = 38\,°C$ – partial compliance;
- hazardous $T_3 = 42\,°C$ – full inadequacy.

As far as the research of a complex system requires a complicated questionnaire structure its items are grouped according to some value-based criteria (block 1). The received groups are considered to be the target factors, rational and purposeful actions aimed at adjusting the researched system to normal conditions meeting the standard requirements (see Table 1). The baseline study [17] worked out the students' questionnaire including 79 items addressed to the learners and aimed to receive qualitative assessment of satisfaction according to five-grade scale shown in Table 1.

Table1: Risk thermometer to monitor the quality of educational process.

Satisfaction assessment		Risk temperature	
Score	Verbal	°C	Verbal
5	To a full degree	36,6	Normal
4	To a degree	37,2	Subfebrile
3	To a moderate degree	38,0	Feverish
2	To some degree	39,5	Critical
1	To no degree	42,0	Hazardous

The questionnaire items were organized into eight groups (see Table 2), which can be considered as satisfaction indicators characterizing its specific aspects and correlating with the goals of educational program risk temperature measurement. In fact, the questionnaire reflects the organizational values being at risk and allows to analyze if they meet the requirements of the Federal State Educational Standard.

The questionnaire serves as baseline data for the risk-management model. The group of questions to the faculty is interpreted as value-based criteria, rational and purposeful actions aimed at adjusting the researched system to normal conditions meeting the standard requirements.

Table 2: Groups of program satisfaction indicators.

Groups of questions in students' questionnaire	Objects of risk	Complex satisfaction factor
1 Degree of your satisfaction with learning	Processes	Satisfaction with different learning activities
2 Degree of your satisfaction with teaching	Personnel	Satisfaction with teachers' work
3 Degree of your satisfaction with organization of the learning process	Processes	Satisfaction with organization of the learning process
4 Degree of your satisfaction with university facilities	Systems	Satisfaction with university facilities
5 Degree of your satisfaction with the quality of university services	Services	Satisfaction with the quality of university services
6 Degree of your satisfaction with extracurricular activity	Reputation	Satisfaction with extracurricular activity
7 Degree of your satisfaction with information support of curricular and extracurricular processes	Processes	Satisfaction with information support of curricular and extracurricular processes
8 Degree of your satisfaction with studying at university in general	Reputation	Satisfaction with studying at university in general

The differential (partial) risk temperature (T^s) with reference to aggregate satisfactory data group (its efficiency q=8) is defined in the following way:

$$T^s = \frac{n}{n^s}\sum_{i=1}^{n^s}\sum_{j=1}^{m} k_{ij}^l x_{ij},\ l = \overline{1,p},\ s = \overline{1,q}. \qquad (1)$$

The calculated temperature data are to some degree fuzzily uncertain due to the specificity of the risk thermometer method. Uncertain temperature parameters of the risk thermometer cannot ensure high validity of assessment. Even border risk thermometer values in Table 1 cannot be considered fairly reliable because they represent experts' assessment influenced by subjectivity. In terms of risk thermometer method the researched object behavior within the interval between the borders remains uncertain to some degree. It is advisable to formalize such regions of uncertainty by fuzzy numbers, and conduct temperature data processing in a fuzzy form.

Multiple studies, including research into education [20-24], demonstrate the efficiency of fuzzy logics for solving the problems of educational management. The most complete set of the fuzzy data analysis methods and their application to management is represented in [20]. Laal M. proves the appropriateness of the fuzzy educational data analysis and application of the fuzzy propositions for the formalized assessment of results [22].

That is why, their further processing is necessary to fulfill by means of fuzzification on the basis of membership function. In this research the membership function is defined by the experts' opinion (authors of the article) with reference to linguistic scale (Figure1). For the usability of the model and with consideration of fuzzy mode of educational control [22-24], in particular, the research of the similar fuzzy model [24], z-shaped and s-shaped membership functions were used for border linguistic terms and trapezium-shaped membership functions within the interval of uncertainty. Taking into consideration the inviability of any system (both real and artificial) at hazardous temperatures it was decided to confine the MF to four levels, understanding them as linguistic terms of fuzzification procedure: N – Normal, AN – Above the Normal, H – High, Cr – Critical.

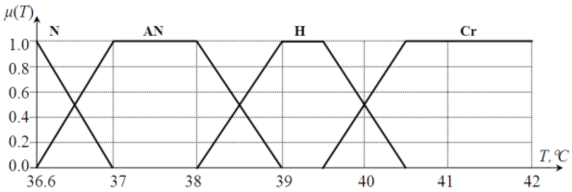

Figure 1: Membership functions of linguistic variable "Fuzzy risk temperature".

3 THE FUZZY TECHNOLOGY OF MONITORING THE RISK BACKGROUND OF A UNIVERSITY EDUCATIONAL PROCESS

The risk background monitoring was carried out with the system of aggregate data called key risk indicators [25, 26]. In this research, they are target factors $c_j \in C$, $j = \overline{1,q}$, which are indicators to identify characteristic risk events $r_i \in R$, $i = \overline{1,n_r}$. The matrix of $n_r \times q$ size defines the correlation of the target factors and risks, and can be considered the binary fuzzy ratio $RC = \{\langle r_i, c_j \rangle, \mu_{RC} \langle r_i, c_j \rangle\}$. The next stage of the risk management process is the execution of the composition binary fuzzy ratio:

$$R_T = RC \otimes C_T, \qquad (2)$$

where RC-binary fuzzy ratio, containing reference fuzzy data about risk matching key risk indicators (see Table 3), C_T - binary fuzzy ratio, contained fuzzified assessment of the differential risk temperature (1) for key risk indicator $c_j \in C$ by assessment of the level $l_k \in TL$ $(k = \overline{1,4})$ in the form of linguistic terms in accordance with membership function 'Fuzzy risk temperature' graphically represented in Figure 1.

Table 3: Frequency characteristics of risk identification.

Identified risks	Key risk indicator category (see Table 2)							
	1	2	3	4	5	6	7	8
1 Risk of knowledge obsolence	0,70	0,50	0,00	0,14	0,00	0,00	0,83	0,45
2 Mismatching of the stakeholders interests	0,53	0,50	0,00	0,14	0,00	0,00	0,67	0,36
3 Technical system malfunctioning	0,23	0,38	0,75	1,00	0,00	0,20	0,83	0,64
4 Risk of the key personnel dependence	0,27	0,25	0,75	1,00	1,00	1,00	1,00	0,45
5 Personnel depletion	0,17	0,25	0,00	0,14	0,00	0,40	0,17	0,64
6 Stagnation of research	0,60	0,50	0,00	0,00	0,00	0,00	0,33	0,73
7 Devaluation of personnel creativity	0,30	0,63	0,00	0,57	0,11	0,00	0,33	0,45
8 Lack of identity and uniqueness	0,37	0,88	0,75	1,00	1,00	1,00	1,00	1,00

The explicit quantitative assessment of i-th risk r_i can be received by defuzzification of the method of center of gravity for the one-point set:

$$P_{r_i} = \frac{1}{\sum_{k=1}^{4} r_{ik}} \sum_{k=1}^{4} \left(r_{ik} \cdot b_{ik}\right),$$

where r_{ik} is the element of binary fuzzy ratio R_T corresponding k-th term $k = \overline{1, 4}$; b_{ik} - the explicit value of the corresponding element of baseline set of factors *TF*, defined on the basis of membership function 'Fuzzy risk assessment' graphically represented in Figure 2 according to the scale in Table 4.

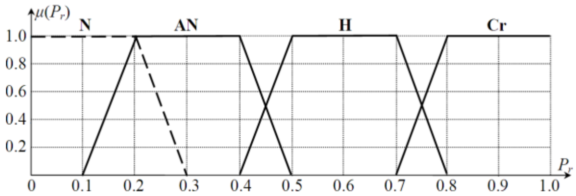

Figure 2: Membership functions of linguistic variable "Fuzzy risk assessment".

Table 4: The scale for fuzzy assessment risk probability [15].

Notion	Rank	Interpretation of risk probability	
N	1	Remote probability	$P_r < 0.20$
AN	2	Mean probability	$P_r \in [0.20, 0.50)$
H	3	High probability	$P_r \in [0.50, 0.75)$
Cr	4	Very high probability	$P_r \geq 0.75$

4 THE RISK ASSESSMENT ON THE BASIS OF THE QUESTIONNAIRE DATA

There were 392 respondents in the survey conducted at Siberian State University of Telecommunications and Information Science by means of questionnaire mentioned in part 2. The total number of data received in the form of qualitative assessments given in answers to 79 questions amounted to 30 thousand elements of data. Moreover, the questionnaire traditionally used as a part of university accreditation in the Russian federation [7] was given to teachers, because teachers as well as students are the key players in educational systems and their satisfaction characterizes the quality of the educational process of the university. The distribution of the received assessment according to the scale is represented in Figure 3.

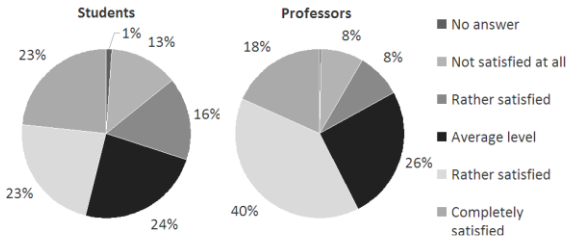

Figure 3: The structure of satisfaction assessment by the university students and professors.

According to the method of transformation assessment grades into temperature data shown in Table 1 and (1), the following risk temperature assessments of the university educational process given by students and teachers were received (Figure 4). It is worth noting that the received data demonstrate high consistency, for example, students' variation coefficient is 1,78%, and teachers' – 2,13%. In students' graph: 1 is studying; 2 – teaching; 3 – organization of educational process; 4 – facilities; 5 – quality of services; 6 – extracurricular activities; 7 – information support; 8 – integral risk temperature. In teachers' graph 1 is facilities and resources; 2 – educational process organization; 3 – working conditions; 4 – integral risk temperature.

The risk temperature, calculated by the (1) for every key risk indicator is shown in Figure 4 where its fuzzified values correlated with the MF defined by the experts (Figure 1).

The given example demonstrates that the identified risk background requires taking management decisions to reduce the risk background up to the optimal level (N - according to the scale in Table 5). As a result of such decisions the key risk indicator will become normal.

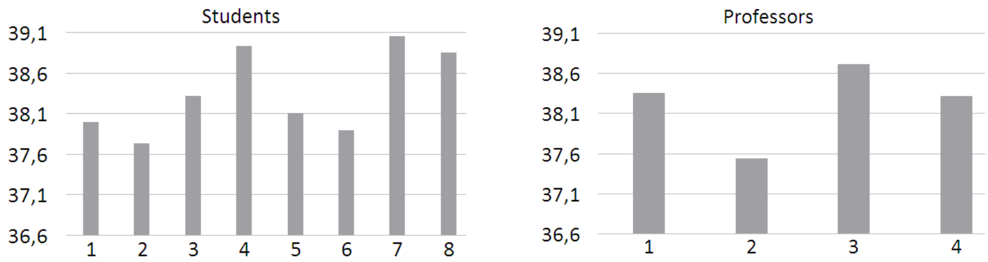

Figure 4: Risk temperature of the university students' and teachers' satisfaction.

Table 5: Temperature characteristics of satisfaction indicators.

Indicators group (key risk indicator category)	Indicators number	Risk temperature				
		T, °C	N	AN	H	Cr
Satisfaction with different learning activities	30	37,99	0,00	1,00	0,00	0,00
Satisfaction with teachers' work	7	37,73	0,00	1,00	0,00	0,00
Satisfaction with organization of the learning process	4	38,31	0,00	0,69	0,62	0,00
Satisfaction with university facilities	7	38,93	0,00	0,07	1,00	0,00
Satisfaction with the quality of university services	9	38,10	0,00	0,90	0,20	0,00
Satisfaction with extracurricular activity	5	37,89	0,00	1,00	0,00	0,00
Satisfaction with information support of curricular and extracurricular processes	6	39,05	0,00	0,00	1,00	0,00
Satisfaction with studying at university in general	11	38,85	0,00	0,15	1,00	0,00

Table 6: Educational process risk assessment.

Identified risks	Fuzzy characteristics				Risk probability
	N	AN	H	Cr	
1 Risk of knowledge obsolence	0,00	0,14	0,00	0,00	0,30
2 Mismatching of the stakeholders interests	0,00	0,14	0,00	0,00	0,30
3 Technical system malfunctioning	0,00	0,64	0,20	0,00	0,37
4 Risk of the key personnel dependence	0,25	0,45	0,25	0,25	0,43
5 Personnel depletion	0,00	0,14	0,17	0,00	0,46
6 Stagnation of research	0,00	0,07	0,00	0,00	0,30
7 Devaluation of personnel creativity	0,00	0,33	0,00	0,00	0,30
8 Lack of identity and uniqueness	0,37	0,75	0,37	0,37	0,41

5 CONCLUSIONS

The new idea of organizing social monitoring of the quality of university educational process as the assessment by the key players of educational relations – students and teachers has been discussed in the article. The method of representation of assessment grades as the university risk background characteristics by means of fuzzy composition allows to calculate probability measures for educational process risks.

The pilot testing of the described approach was done on the basis of processing data of the pilot sociological research through the survey of students and teachers of Siberian State University of Telecommunications and Information Science. The received assessment grades of satisfaction with different aspects of the educational process demonstrated at the moment of the survey its mean level, and transformation of the grades by means of risk thermometer into temperature indicator showed fever and risk background on the 'satisfaction' segment of data, which requires taking management decisions. It should be emphasized that random combinations of the grades demonstrate high degree of uniformity (variation coefficient does not exceed 3% in average), which proves the validity of the received results.

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