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**НАЦИОНАЛЬНОЙ АКАДЕМИИ НАУК
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БАЯНДАМАЛАРЫ **2018 • 4**

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THE DEVELOPMENT OF FUZZY MODELS FOR ANALYSIS OF EDUCATIONAL ACTIVITIES

Abstract. The article presents a model of fuzzy quality management of higher education as the main factor of competitiveness for further integration into the model of intellectual control system of educational activities. The present work is concerned with modeling and monitoring the quality of high education system using fuzzy techniques. Design of controllers using conventional methods for that kind of systems is not easy due to absence of a systematic theory behind it. In such cases, an approach based on the use fuzzy logic for identifying the risks of deterioration of quality teaching and administration based on the input output data have been shown to be attractive. The data obtained as a result of monitoring are presented to the administration of the educational institution for strategic and operational decision-making.

Keywords: fuzzy mathematical model, indicators, fuzzy rules, aggregation, artificial intelligence, prediction, membership functions.

Difficulties in the development of higher education are partly explained not only by the results of internal indicators, but also by the effects of external influences of the labor market. A separate problem of professional training is the lack of an effective system for monitoring its quality and effectiveness. The main difficulty of monitoring the quality of educational services is the weak formalization of many assessments of the quality educational activities and the lack of standard monitoring procedures (which evaluate a standard set of license and accreditation indicators) for the comprehensive assessment. Analysis of the work on the study of factors affecting the quality of university activities is area the theory of fuzzy sets and fuzzy logic with the possibility of the transition from the classical probability models and expert assessments to fuzzy-multiple descriptions.

The fuzzy logic provides a means of converting a linguistic control strategy based on expert knowledge into an automatic control strategy. The ability of fuzzy logic to handle imprecise and inconsistent real-world problems has made it suitable for a wide variety of applications.

To achieve the goal, the following tasks were set:

- identify factors that affect the competitiveness of the educational institution;
- develop a fuzzy model of quality management of educational services;
- implement the developed model on a concrete example;
- evaluate the results and prospects of further research.

Construction of fuzzy model: Description of input and output variables

When constructing a model for assessing the quality of the work university, it is advisable to classify the input variables and, based on it, construct an output tree that defines a system of nested smaller knowledge statements. Thus, the presence of mathematical means of reflecting the fuzziness of the initial information allows us to construct a model adequate to reality, in which a fine-tuning of the fuzzy model is carried out by training it on the basis of experimental data. The final evaluation of the model, showing the quality of the department is indicated by the letter - R (results). R∈ [0.100]. The greater the value of this criterion, the higher the leading positions of the university in the market of educational services.

The main indicators of learning activities that affect competitiveness, and the change of which is described with the help of clear mathematical functions, are quantitative indicators. Denote them by X1, ..., Xn, then the final evaluation of the university model will represent a functional mapping of the form:

$$X = \{X_1, X_2, \dots X_n\} \rightarrow R \in [0,100]$$

For a sufficiently large number of factors, it is convenient to represent them in the form of a hierarchical tree (Figure 1). Elements of a tree are interpreted as follows:

- the root of the tree - the competitiveness of the educational institution (R);
- terminal vertices - partial influencing factors (X_i, i=1..9)
- nonterminal peaks - enlarged influencing factors - (Y_1, Y_2, Y_3, R)

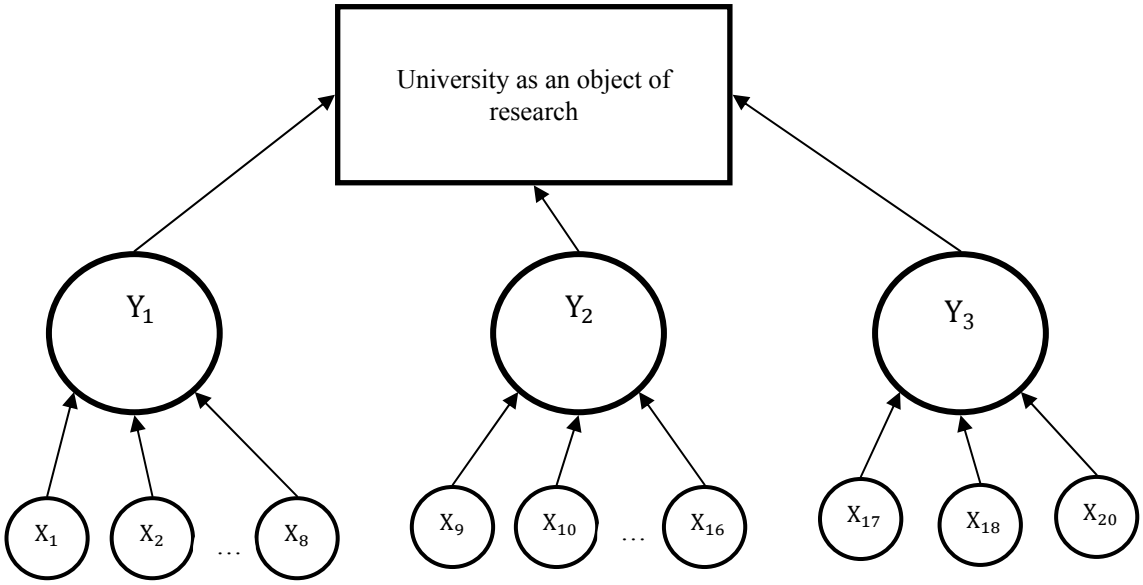

Figure 1 – a hierarchical representation of university activities

Table 1 – description of indicators

Symbol	Description of indicators
Y_1	Educational-methodical work
X_1	Active educational programs in English
X_2	Active joint educational programs or dual diploma programs
X_3	Position of the specialty in the QS ranking by areas (directions) of preparation
X_4	Proportion of employed graduates
X_5	Specialties of VOUD, the average score for which is more than 60% of the maximum points
X_6	The level of the teaching staff
X_7	Increase (in%) of the number of students compared to the previous year (1% above the threshold level of 5%)
X_8	Average assessment of teachers through the questionnaires of students
Y_2	Research work
X_9	The number of articles published in English-language scientific journals of KazNU together with authors from the far abroad with the Index of Hirsch at least 3 in the Scopus database
X_{10}	The number of articles published in English in the series of the Bulletin of KazNU named after al-Farabi
X_{11}	The number of articles published in scientific journals, recommended by KKSON and the journal "Aikap"
X_{12}	Number of security documents received
X_{13}	The volume of research funding from industry, business and other development institutions (household contracts), mln.tg
X_{14}	The volume of grant, program-targeted financing of scientific research, mln. Tenge
X_{15}	The number of articles (students, undergraduates and doctoral students) published in the journals indexed in Scopus
X_{16}	Number of created student start-up companies
Y_3	Social and educational work
X_{17}	Organization of educational events in the framework of innovative projects (Ainalady nrlandir, Greenkampus, 100 kitap, Cult of a healthy body, etc.)
X_{18}	The volume of student scholarships established by graduates and university partners, mln.tg
X_{19}	Number of students-winners of creative competitions, sports competitions
X_{20}	Number of image publications about the achievements of KazNU

As an algorithm for fuzzy logic inference, the Mamdani algorithm [2] is used. At the first stage, the base of rules of fuzzy inference systems is formed. A set of rules was generated based on possible combinations of fuzzy statements in the premises and conclusions of the rules, according to which the maximum number of rules in the database is determined by the following ratio: $N = N_{x_1} \cdot N_{x_2} \cdot \ldots \cdot N_{x_m} \cdot N_y$, where $N_{x_1} \cdot N_{x_2} \cdot \ldots \cdot N_{x_m} \cdot N_y$, – number of membership functions for specifying input and output variables [3]. Since the initially formed rules base is redundant - with the same assumptions and different conclusions, the set of rules was optimized on the basis of expert information, resulting in the formation of a base of 27 rules. Expert fuzzy knowledge bases are given in Table 3. Elements of antecedents of fuzzy rules are related by the logical operation AND, the weight coefficients of each of the rules are equal to 1.

Table 2 – Translation from a quantitative index to a fuzzy parameters

Indicators		Fuzzy parameters		
		low	middle	high
X_1	Active educational programs in English	Absent	1≤x<3	More than x≥3
X_2	Active joint educational programs or dual diploma programs	Absent	1≤x<3	More than x≥3
X_3	Position of the specialty in the QS ranking by areas (directions) of preparation	More than x>50	10<=x<50	less than x< 10%
X_4	Proportion of employed graduates	Less than x<50	50≤x<75%	More than x≥ 75%
X_5	Specialties of VOUD, the average score for which is more than 60% of the maximum points	Less than x<30	30≤x<60%	More than x≥60
X_6	The level of the teaching staff	Less than x<75	75≤x<90%	More than x≥90
X_7	Increase (in%) of the number of students compared to the previous year (1% above the threshold level of 5%)	Less than x<10%	10≤x<15%	More than x≥15
X_8	Average assessment of teachers through the questionnaires of students (score)	Less than x<2	2≤x<4	More than x≥4

Based on the study and analysis of materials of domestic and foreign scientists [4, 5, 6, 7] on the development of assessments of the quality of educational services authors made the following conclusions regarding the methodological principles that are necessary take into account when developing a rating:

- the principle of systemic nature, which requires both the interconnection of indicators in the model, so that this connection makes sense.
- the principle of complexity, which means that the model should display various aspects of the educational activity of the institution.
- principle of normative model. Its application in the model is based on the fact that

growth rates of indicators characterizing various aspects of educational the activities of the institution are in a certain relationship with each other. Wherein it should be noted that the objective of the normative model is to achieve state of the educational institution, which for him is the most optimal.

Developed by the authors in this study, the methodology of analyzing and evaluating the quality of educational services, these principles implements, taking into account various aspects (options) of educational activities, such as the quality of teaching, the quality of students' learning and profitability, and the social-educational work of educational activities.

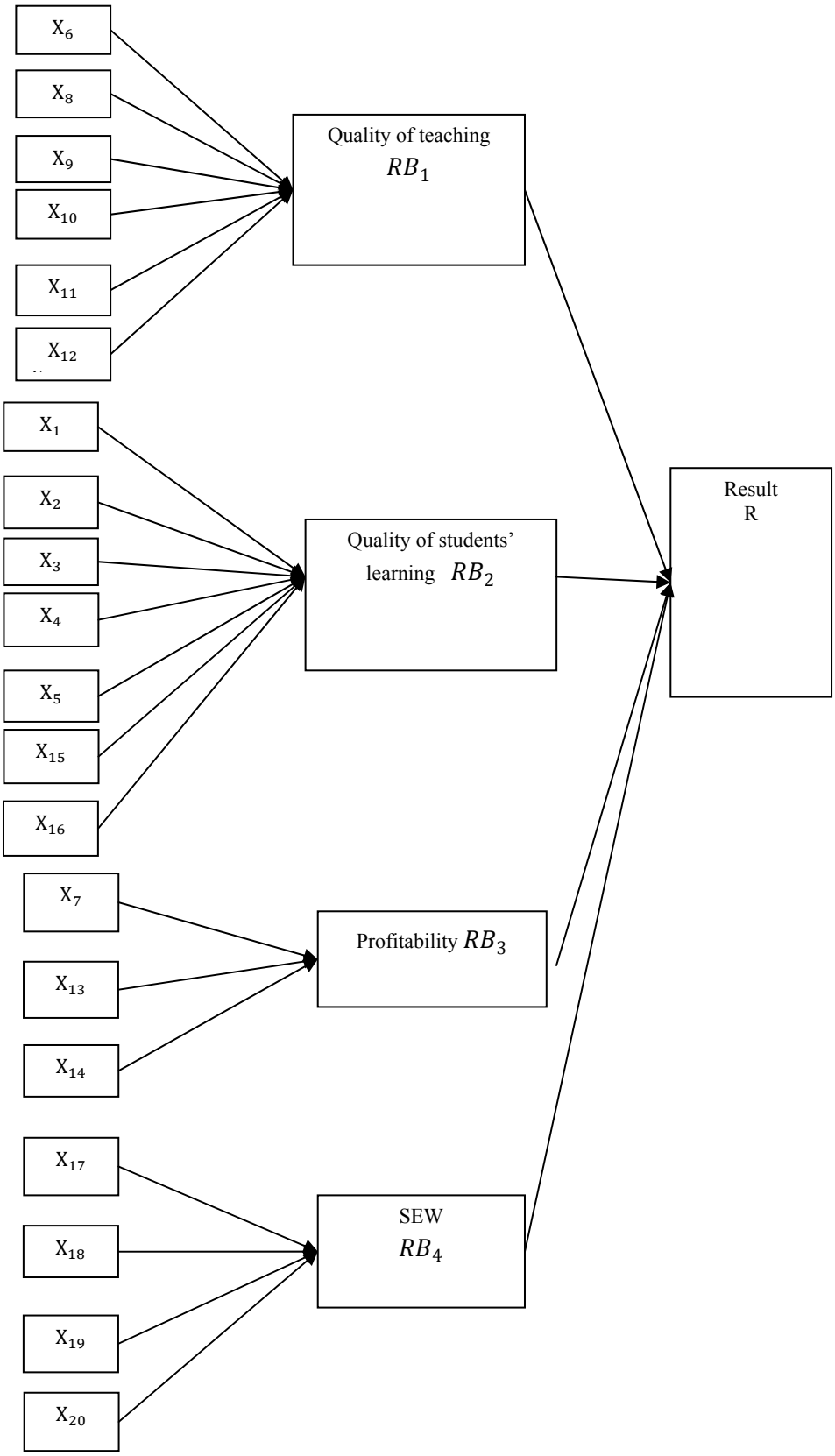

Figure 2 – A new method of indicators' classification

Based on suggested new method of classification of university indicators (figure 2) , we can make a fuzzy rule for the integrated value of R in the table 3.

Table 3 – expert fuzzy knowledge bases for the integrated result R

№	RB1	RB2	RB3	RB4	R
1	Low	Low	Low	Low	Low
2	Low	Low	Middle	Low	Low
3	Low	Low	High	Low	Low
4	Low	Middle	Low	Low	Low
5	Low	High	Low	Middle	High
6	Low	Middle	Middle	LOW	Low
7	Low	Middle	High	Middle	Middle
8	Low	High	Middle	High	Low
9	Low	High	High	High	Low
10	Middle	Low	Low	High	Low
11	Middle	Low	Middle	Middle	Middle
12	Middle	Low	High	Middle	Middle
13	Middle	Middle	Low	Low	Middle
14	Middle	Middle	Middle	Middle	Middle
15	Middle	Middle	High	Middle	Middle
16	Middle	High	Low	Low	Middle
17	Middle	High	Middle	High	High
18	Middle	High	High	High	High
19	High	Low	Low	Low	Low
20	High	Low	Middle	Low	Low
21	High	Low	High	Low	Low
22	High	Middle	Low	Middle	Middle
23	High	Middle	Middle	Middle	Middle
24	High	Middle	High	High	High
25	High	High	Low	Low	Middle
26	High	High	Middle	High	High
27	High	High	High	High	High

Expertise determines the priority of the above blocks of indicators, based on the interests of the evaluating entity.

Based on the preferences of the interested party, ranking of the scores on the blocks of indicators is made, that is

$$RB_1 > RB_2 > RB_3 > RB_4$$

where RB_i– Quality assessment for one of the above four blocks of indicators; > – the preference of the previous block of the indicator before the next one.

Table 4 – Weights of each blocks of indicators

№	Indicator Block	weight μ_i
1	Quality of students' learning	0,5
2	Quality of teaching	0,3
3	Profitability	0,15
4	Social and educational work	0,05

For the analyzed university, the value of its rating will be determined by the formula:

$$R = \mu_1 * RB_1 + \mu_2 * RB_2 + \mu_3 * RB_3 + \mu_3 * RB_3$$

Where R – university rating; μ – weight index; RB_i– quality assessment by groups of indicators.

Table 5 - Classification of rating ratings of educational institutions:

State	Value of rating
High	85≤R≤100
Middle	65<R<85
Low	0≤R≤65

The membership functions for input variables were constructed using the method of statistical processing of expert information, and for the output variable-based on the paired comparisons method [4]. In the construction, the following piecewise linear membership functions were used-triangular, and trapezoidal, which are depicted in Fig. 3.

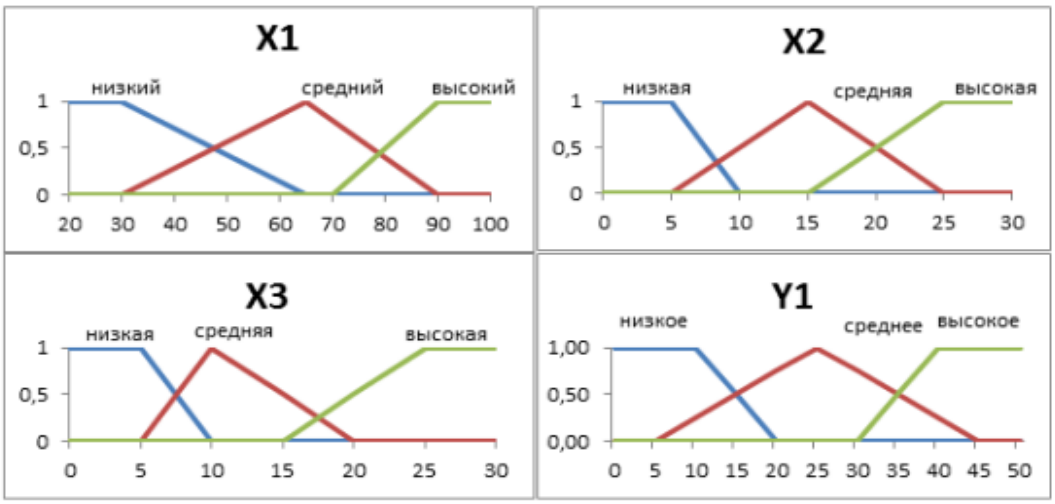

Figure 2 – Membership functions of linguistic variables

With the help of aggregation, the degrees of truth of the conditions of each of the rules of fuzzy products were determined, and paired fuzzy logical operations (min-conjunction and max-disjunction) were used. Those rules, the degree of the truth of the conditions of which is different from zero, are considered active and are used for further calculations.

Activation of subcontracts in fuzzy rules of products is carried out by the method of min-activation, accumulation of conclusions-by combining fuzzy sets, defuzzification of output variables by the method of the center of gravity.

Model of fuzzy quality management of educational services is built on the basis of expert knowledge, therefore, it is necessary to train the model on experimental data to ensure reliable results, and to assess the adequacy of the model constructed. To learn the fuzzy model, 100 pairs of experimental data "inputs-output" were used. The parameters of the term membership functions were adjusted in such a way that the root-mean-square error was minimal [5].

The center of gravity (CoG, COG, Cent of Gravity) or centroid area is calculated by the formula:

$$y = \frac{\int_{Min}^{Max} x \cdot \mu(x)dx}{\int_{Min}^{Max} \mu(x)dx},$$

Where y is the the result of defuzzification; x is the variable corresponding to the output linguistic variable W; $\mu(x)$ - the fuzzy set belonging to the output variable w after the accumulation step; Min and Max are the left and right points of the interval of the carrier of the fuzzy set of the considered

output variable w. In defuzzification by the center of gravity method, the usual (not fuzzy) value of the output variable is equal to the abscissa of the center of gravity of the area bounded by the curve of the membership function of the corresponding output variable.

Results

The developed model allows predicting the indicator of the quality of educational services. The constructed model will allow the university administration to determine the corresponding values of the influencing factors with the purpose of providing the necessary level of quality of educational services, thereby providing for itself a leading position with high competition.

The prospect of further research is the development of a fuzzy model using the Matlab environment, as well as increasing the level of complexity of the model with the addition of such factors as the quality of information technology, the quality of patents, textbooks and the quality of educational programs and the further integration of university management into the model.

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ЖОҒАРҒЫ ОҚУ ОРНЫНЫҢ САПАСЫН ТАЛДАЙТЫН ФАЗЗИ МОДЕЛІН ҚҰРАСТЫРУ

Аннотация. Берілген мақалада жоғарғы оқу орнының білім беру сапасын талдайтын нақты емес фаззи моделі құрастырылған. Бұл модель жүйенің сапасын бақылауға көмектеседі. Қарастырылатын жүйені сипаттайтын кіріс және шығыс параметрлер жөнінде мағлұматтың толықтай болмауына байланысты, жоғарғы оқу орнының жұмысын модельдеу күрделі есептердің бірі болып саналады. Бұндай есептерде нақты емес фаззи моделін қолдану есептің шешімі болуы әбден ықтимал. Модельді бақылау нәтижесінде алынған деректер жоғарғы оқу орнының басшылығына беріледі.

Түйін сөздер: нақты емес фаззи моделі, көрсеткіштер, фаззи ережелері, агрегациялау, жасанды интеллект, жорамалдау, мүшелік функциясы.

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РАЗРАБОТКА НЕЧЕТКОЙ МОДЕЛИ ДЛЯ АНАЛИЗА ОБРАЗОВАТЕЛЬНОЙ ДЕЯТЕЛЬНОСТИ

Аннотация. В статье разработана модель нечеткого управления качеством высшего образования как основного фактора конкурентоспособности для дальнейшего использования и интеграции в модель интеллектуального управления учебной деятельностью. Настоящая работа посвящена моделированию и мониторингу качества системы высшего образования с использованием нечетких методов. Построение модели университетской деятельностью является одним из сложных задач из-за отсутствия полных знаний о входных и выходных параметрах. В таких случаях подход, основанный на использовании нечеткой логики, для определения рисков ухудшения качества обучения и администрирования является адекватным и самым подходящим. Данные, полученные в результате мониторинга, будут представлены руководству учебного заведения для принятия стратегических и оперативных решений.

Ключевые слова: нечеткая математическая модель, показатели, базы нечетких правил, агрегирование, искусственный интеллект, прогнозирование, функция принадлежности.

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