

Mathematical Software For Evaluating And Supporting The Selection Decision On Academic Programs

Zakharova A.A.¹, Lazareva A.N.², Aleksandrov A.A.¹
Yurga Institute of Technology, National Research Tomsk
Polytechnic University (Affiliate)
Yurga, Russia
E-mail: ¹aaz@tpu.ru, ²lazarevanastya@mail.ru

Abstract—The article explains the importance of developing methods and tools in order to provide information support when selection decisions on academic programs are made by individuals. We have developed a model for integrated evaluation of academic programs in view of aims students want to attain and competencies to acquire when entering the profession and building individual careers. The proposed information system provides information interaction among stakeholders and main actors involved in the education market: individuals (prospective students) and educational institutions.

Keywords—individuals, educational institution, academic program, integrated evaluation, fuzzy set, alternatives, information system.

I. INTRODUCTION

Developing a modern and innovative economy is impossible without establishing the relevant system that is committed to educating and training innovation-oriented human resources. With this, it is essential to continually increase knowledge, expertise and skills throughout a professional life of individuals. The modern market of academic services offers a wide variety of academic programs to prospective students for selection. In a tough competitive environment (today already international) educational institutions need to understand the process of how a person makes a decision on the choice of a particular academic program in order to be sure that most in-demand educational services are delivered. Individuals themselves are interested in evaluating academic programs on conditions they make their choice consciously and plan their own professional career profoundly [1]. It is also important for employers to interest potential employees in choosing academic programs considered as the best for them. In this regard, an urgent task is to develop methods for use in a system intended to support decisions in the context of individual academic programs. Certain aspects of this problem are widely discussed by researchers from different countries. Among such aspects are the relation between quality of education and labor market conditions [2], evaluation of academic program quality [3, 4], selection of further training programs based on assessment of professional competence and a level of student's own preferences [5], formulation of criteria for evaluating academic programs [6], formation of an optimal path relative to

individual learning courses (including electronic) [7] and others.

Note that quality and adequacy of decisions made by individuals, when it comes to choosing the right academic program, is determined by the quality of information support in favor of this choice. Thus, it is currently important, when choosing an educational path, to design an information environment and techniques intended for supporting decision-making that provide all parties involved - individuals, educational institutions and employers with tools for evaluating academic programs. It should be noted that this problem is semi-structured, and there are difficulties in its formalization; decisions are made under conditions of high uncertainty in the decision-making environment and information incomplete for analyzing [5]. Therefore, in program evaluating, the decision-making technique under uncertainty should be applied, where methods of expert assessments are supposed as self-sufficient tools or as part of combined methods.

This article offers mathematical software for evaluation, ranking and selection of academic programs offered on the educational market in view of learning needs and competencies necessary to individuals and employers for the purpose of choosing an occupation and building individual careers.

II. ACADEMIC PROGRAM EVALUATION MODEL

When choosing academic programs, individuals are motivated by some factors and considerations, i.e. benefits, advantages and results that they want to get after implementation of their educational paths. Some of these criteria are quantitative (for example, salary) and others are qualitative (for example, in-demand jobs).

Let us formulate basic requirements for an integrated evaluation model intended to support the choice of academic programs:

- 1) Aggregation of various criteria that have different dimensions.
- 2) A universal form of criteria aggregation, i.e. the model can be used for integrated evaluation by a number of individuals.

3) Criterion weights, i.e. the significance of criteria is considered in integrated evaluations.

4) Formalization of fuzzy concepts to ensure the efficient processing of qualitative information on an equal basis with clear quantitative data.

It is proposed to use fuzzy set theory [8] in integrated modeling for evaluating academic programs.

Each target criteria of academic programs (integrated evaluation criterion) is proposed as a fuzzy variable $(\alpha_i, X, C(\alpha_i))$, where α_i is the name of fuzzy variable, $X = \{x\}$ is the domain of its definition (basic set), $C(\alpha_i) = \{\mu_{C\alpha_i}(x)/x\}$, $(x \in X)$ is the fuzzy subset of the X set, describing restrictions on possible values of α_i variables, i is the quantity of criteria.

Fuzzy logic membership functions are built using expert data to specify each criterion. In fact, the criterion membership function indicates a degree of compliance of the actual value to the planned in terms of criteria (the desired results after implementing the program).

Evaluating a criterion at a particular point in time is specified as the degree of membership $\mu_{C\alpha_i}(x)$ of the actual value of criterion in the fuzzy set $C(\alpha_i)$.

The convolution of criteria is based on intersection operation of the fuzzy sets.

If there is n of $\alpha_1, \alpha_2, \dots, \alpha_n$ criteria, then the integral estimate IS is determined by the following formula:

$$IS = C(\alpha_1) \cap C(\alpha_2) \cap \dots \cap C(\alpha_n). \quad (1)$$

The intersection operation of fuzzy sets corresponds to the operation *min*, performed on their membership functions

$$\mu_{IS} = \min \mu_{C\alpha_i}(x). \quad (2)$$

The greater the value of membership function μ_{IS} , the higher the value of integral index, the closer the individual academic program to the optimal one.

If criteria have different significance, then a number $w_i \geq 0$ is attributed to each of them (the more significant criterion, the greater w_i is). Then the integral estimate is determined by the formulas:

$$IS = C^{w_1}(\alpha_1) \cap C^{w_2}(\alpha_2) \cap \dots \cap C^{w_n}(\alpha_n);$$

$$w_i \geq 0, i = \overline{1, n};$$

$$\frac{1}{n} \sum_{i=1, n} w_i = 1 \quad (3)$$

The membership function μ_{IS} is defined by:

$$\mu_{IS} = \min_{i=1, n} \mu_{C\alpha_i}^{w_i}(x). \quad (4)$$

Since $\mu_{C\alpha_i}(x) \in [0; 1]$, then the value of academic program integral index is within $[0, 1]$. The closer the value of integral index to 1, the closer the individual academic program to the optimal for the individual, in the context of aims and considerations when entering the profession and choosing a potential career path.

If necessary, the criteria can be categorized into groups, with weights being assigned to them. This allows us to calculate values of integral indices for alternatives according to the groups of criteria, providing additional information for decision making.

III. APPLYING THE INTEGRATED EVALUATION METHOD TO THE PROCESS OF SELECTING ACADEMIC PROGRAMS

When making researches and analyzing preferences of prospective students at Yurga Institute of Technology, Tomsk Polytechnic University Affiliate (YIT TPU) in 2015, we took six most important criteria that determine the choice of a particular academic program. The criteria were combined into 3 groups:

The "Acquired Knowledge" group (a weight of 1.0) includes two criteria:

- "Knowledge" is an amount of theoretical, public and professional knowledge that an individual can acquire in the course of a given program and /or learning path (to be calculated as proportion of competencies needed for the selected professional life and conveyed by the academic program) (a weight of 1.25);
- "Experience" is an amount of practical skills and expertise that can be acquired during the implementation of this academic program (defined as the previous index) (a weight of 0.75);

The "Costs" group includes two criteria (a weight of 0.75):

- "Minimal operating costs" is an estimated amount of financial and material resources that will be needed (in a given period of time) for implementing the program (a weight of 1.1);
- "Cost recovery" is a criterion characterizing a period of time during which earnings resulted from knowledge and experience obtained cover the amount of money spent on the implementation of the academic program (in this case, it is expressed in percentage of cost recovery within 3 years after implementing the academic program) (a weight of 0.9);

The "Potential" group (a weight of 1.25) includes two criteria:

- "Future income" is an estimated amount of income after implementing the academic program (a weight of 1.1)

- "In-Demand Jobs" is a ratio of the number of vacancies that require competences this academic program can offer for the review period to the total number of vacancies on the labor market (a weight of 0.9).

Based on expert estimations, membership functions of these indices were built (presented in Tables 1-6). For example, a fuzzy variable α_i was defined for the "knowledge" criterion within a range of definition [0, 100] %. "Knowledge" in percentage is expressed as a ratio of the amount of competencies offered by the academic program, meeting an employer's requirements, to the total amount of competencies the employer requires. The membership function (see Table 1) is based on expert data. If higher demands are not specified relative to accuracy of membership function, it is possible to use models to formalize the expert knowledge presented in [9] for its construction.

TABLE I. FUZZY VARIABLES α_i DEFINED FOR "KNOWLEDGE" CRITERION

Knowledge, %	0	25	50	80	90	100
$\mu_{c_{\alpha_i}}(x)$	0	0,15	0,35	0,89	0,95	1

TABLE II. FUZZY VARIABLES α_i DEFINED FOR "MINIMAL OPERATING COSTS" CRITERION

Minimal operating costs, thousand RUR	0	13	20	36,5	42,5	80
$\mu_{c_{\alpha_i}}(x)$	1	0,75	0,70	0,55	0,32	0

TABLE III. FUZZY VARIABLES α_i DEFINED FOR "EXPERIENCE" CRITERION

Experience, %	0	50	60	75	100
$\mu_{c_{\alpha_i}}(x)$	0	0,52	0,65	0,85	1

TABLE IV. FUZZY VARIABLES α_i DEFINED FOR "COST RECOVERY" CRITERION

Cost Recovery, %	0	30	50	87	100
$\mu_{c_{\alpha_i}}(x)$	0	0,1	0,25	0,93	1

TABLE V. FUZZY VARIABLES α_i DEFINED FOR "FUTURE INCOME" CRITERION

Future Income, thousand RUR	0	40
$\mu_{c_{\alpha_i}}(x)$	0	1

TABLE VI. FUZZY VARIABLES α_i DEFINED FOR "IN-DEMAND JOBS" CRITERION

In-Demand Jobs, %	0	100
$\mu_{c_{\alpha_i}}(x)$	0	1

With the help of an expert survey, the values of criterion-based indices were defined for several academic program alternatives A_i (shown in Table 7), where

A_1 - Applied Informatics, Bachelor's degree course, full-time, YIT TPU;

A_2 - Applied Informatics, Bachelor's degree course, full-time, Kemerovo State University (KemSU);

A_3 - Economics, Bachelor's degree course, full-time, YIT TPU;

A_4 - Economics, Bachelor's degree course, full-time, KemSU;

A_5 - Software and Management Information Systems, Bachelor's degree course, full-time, Tomsk State University (TSU);

A_6 - Fundamental Computer Science and Information Technology, Bachelor's degree course, full-time, TSU;

A_7 - Applied Mathematics and Informatics, Bachelor's degree course, full-time, Institute of Physics and Technology Tomsk Polytechnic University (TPU);

A_8 - Applied Mathematics and Informatics, Bachelor's degree course, full-time, Institute of Cybernetics TPU;

A_9 - Informatics and Computer Science, Bachelor's degree course, full-time, Institute of Cybernetics TPU;

A_{10} - Applied Informatics, Bachelor's degree course, full-time, TSU;

A_{11} - Software Engineering, Bachelor's degree course, full-time, TSU.

Table 8 shows the values of membership functions calculated for each value of criterion given in Table 7.

Using formulas (1-4) we determined the values of integral index with and without weights of significance criteria. The integral indices are given in Table 9.

When choosing the first course alternative (Applied Informatics, Bachelor's degree course, full-time, YIT TPU), the integral index is the highest. Thus this academic program is regarded by a given individual as the closest to the desired. The integral indices calculated according to groups provide educational institutions with additional information needed for decision-making. Values of integral indices (in general and in groups) relating to academic programs can be used by educational institutions' heads to conclude how academic programs meet the requirements of prospective students.

IV. SOFTWARE FOR EVALUATING ACADEMIC PROGRAMS

In Figure 1 there is a flow chart showing the process of decision-making to support individuals (prospective students) in the selecting process relating to academic programs offered on labour market. Separate sections in this chart, in fact, represent main functions of the developed information system.

Features of the proposed flow chart:

1) A record is kept of competencies offered on the market of educational services in the context of requirements stated in the Federal State Education Standards (FSSES), occupational standards, standards of educational institutions, as well as separate knowledge, abilities and skills. With this, competencies formed at different levels and requirements of various market participants can be taken into account.

TABLE VII. CRITERION-BASED VALUES IN SELECTING INDIVIDUAL ACADEMIC PROGRAMS

Criterion-based values in selecting individual academic programs	Results										
	A ₁	A ₂	A ₃	A ₄	A ₅	A ₆	A ₇	A ₈	A ₉	A ₁₀	A ₁₁
Knowledge, %	89	86	89	85	85	86	90	90	92	88	87
Experience, %	76	77	76	75	78	76	84	84	80	76	77
Minimum operating costs, thousand RUR	37,3	41,16	37,3	41,16	38,75	38,75	39,45	39,45	65,95	38,75	38,75
Cost recovery, %	89	87	89	86	88	88	92	92	86	88	88
Future Income, thousand RUR	25	25	25	24	23	21	26	26	30	25	27
In-Demand Jobs, %	50	51	25	24	48	44	52	52	55	50	52

TABLE VIII. ESTIMATED VALUES IN SELECTING INDIVIDUAL ACADEMIC PROGRAMS

Estimated Values in selecting individual academic programs	Results										
	A ₁	A ₂	A ₃	A ₄	A ₅	A ₆	A ₇	A ₈	A ₉	A ₁₀	A ₁₁
Knowledge, %	0,94	0,93	0,94	0,92	0,92	0,93	0,95	0,95	0,96	0,94	0,93
Experience, %	0,86	0,86	0,86	0,85	0,87	0,86	0,90	0,90	0,88	0,86	0,86
Minimum operating costs, thousand RUR	0,29	0,20	0,29	0,26	0,28	0,28	0,27	0,27	0,1	0,28	0,28
Cost recovery, %	0,94	0,93	0,94	0,91	0,94	0,94	0,96	0,96	0,91	0,94	0,94
Future Income, thousand RUR	0,63	0,63	0,63	0,61	0,58	0,53	0,65	0,65	0,75	0,63	0,68
In-Demand Jobs, %	0,51	0,51	0,26	0,25	0,49	0,45	0,52	0,52	0,55	0,51	0,52

TABLE IX. ESTIMATED VALUES IN SELECTING INDIVIDUAL ACADEMIC PROGRAMS

Alternatives	Integral Index Value with Equal Significance of Criteria	Integral Index Value with weights of criteria	Integral Index Value according to groups			Integral Index Value with weights of criteria and groups
			Knowledge	Potential	Costs	
A ₁	0,29	0,26	0,89	0,55	0,26	0,36
A ₂	0,20	0,17	0,89	0,55	0,17	0,27
A ₃	0,26	0,26	0,89	0,30	0,26	0,22
A ₄	0,25	0,23	0,89	0,29	0,23	0,21
A ₅	0,28	0,25	0,90	0,53	0,25	0,35
A ₆	0,28	0,25	0,89	0,49	0,25	0,35
A ₇	0,27	0,24	0,92	0,56	0,24	0,34
A ₈	0,27	0,24	0,92	0,56	0,24	0,34
A ₉	0,10	0,08	0,91	0,58	0,08	0,15
A ₁₀	0,28	0,25	0,89	0,55	0,25	0,35
A ₁₁	0,28	0,25	0,89	0,56	0,25	0,35

2) A record is kept of competencies offered on the market of educational services in the context of requirements stated in the Federal State Education Standards (FSES), occupational standards, standards of educational institutions, as well as separate knowledge, abilities and skills. With this, competencies formed at different levels and requirements of various market participants can be taken into account.

3) A record is kept of academic programs according to the occupational classifications (specialties) compiled in different times, and using cross-references helps in identifying specialties in various versions, codes and names. A particular academic program describes competences a student is supposed to acquire, time schedules, forms and conditions for its implementation.

4) A panel of experts is involved to evaluate and assess conditions, quality, performance and other characteristics of a particular academic program, experts opinions are processed in order to rank academic programs against the evaluation criteria selected.

5) Academic programs are selected with regard to prospective students' aims, their requirements to competencies needed and ratings of academic programs.

The developed information system performs the following functions:

- Record keeping of educational institutions, including information such as short and full names, ownership, addresses, phones, faxes, institution types, names of rectors.

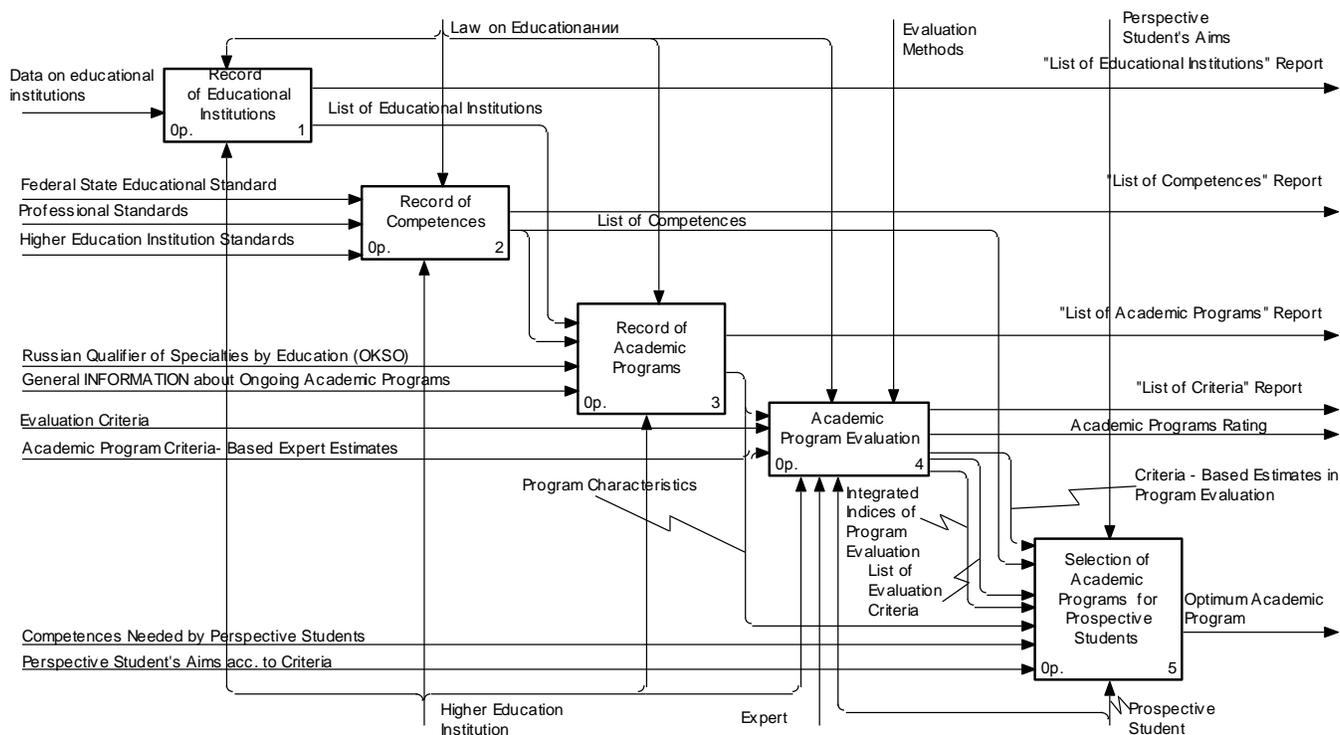


Fig. 1. Schematic decision support system for selecting academic programs by individuals

- Record keeping of competencies. A list of professional competencies is formed on the basis of competences prescribed in FSES and academic programs.
- Record keeping of academic programs, including the following information: names, subject groups, an educational institution offering the programs, modes of study, levels of education, learning time, cost, qualifications, competences offered by programs.
- Evaluation of academic programs. Alternative programs are evaluated by experts, using the integrated model presented in section 2.
- Selection of academic programs by prospective students. For the purpose of competences desirable for a prospective student, a relevant specialty is recommended, and a number of educational institutions are listed according to aims of the prospective student against the criteria specified. The optimum training program is selected on the basis of integral index values.

The developed information system provides the information interaction between two main educational service stakeholders: individuals (prospective students) and educational institutions. The proposed by the authors system offers decision support schemes and mathematical tools to support the selection decision on academic programs based on expert methods. Testing the system using test data showed that the proposed mathematical model and software allows you to solve the research problem.

CONCLUSION

The study proved the relevance and importance of developing the information environment and decision support techniques as to the choice of an educational path, with this information environment providing all parties involved - individuals, educational institutions and employers with tools for evaluating academic programs.

The information system developed is able to organize interaction of educational institutions and individuals in order to evaluate and support the choice of academic programs. Using the integrated model to evaluate alternative academic programs on the basis of fuzzy sets allows us to formalize the expert information and information about individual preferences expressed in a qualitative form, what is important when making decisions in uncertain environments with information incomplete and inaccurate for analyzing. The results obtained by calculating integral indices are important not only for individuals but also educational institutions; because these results make it possible to judge how academic programs comply with the learning needs of prospective students.

REFERENCES

- [1] A. Urintsov, V. Dik, N. Dneprovskaya, "Individual Learning Trajectories as a Key Educational Tool in the Information Society," SMART DIGITAL FUTURES, vol. 262, pp. 652-656
- [2] D. Boccanfuso, A. Larouche, M. Trandafir, "Quality of Higher Education and the Labor Market in Developing Countries: Evidence from an Education Reform in Senegal," World development vol. 74, pp. 412-424.

- [3] M. Dyrenfurth, M. Murphy, G. Bertoline, "Quality indicators for engineering & technology education," ASEE Annual Conference and Exposition, Conference Proceedings, 2010, pp. 48
- [4] I.Chen, J.Chen, F. Padró, "Critical quality indicators of higher education," Total Quality Management and Business Excellence, 10 June 2015, pp. 17
- [5] S. Ivashnova, "The model of projection of a fuzzy individual professional educational trajectory," New Educational Review, vol. 40, Issue 2, pp. 69-80, 28 August 2015
- [6] G. Barani, F. Azma, S. Seyyedrezai, "Quality indicators of hidden curriculum in centers of higher education," Procedia - Social and Behavioral Sciences, vol. 30, pp. 1657-1661, 2011.
- [7] Y. Yang, P. Chuang, C. Huang, T. Hou, C Yang, "An efficient adaptive fuzzy learning diagnosis method for e-Learning," Journal of Internet Technology, vol. 16, Issue 3, pp. 391-401, 2015.
- [8] L.A. Zadeh, "Fuzzy sets," Information and Control, vol. 8, Issue 3, 1965, pp. 338-353.
- [9] A A Zakharova, V V Ostanin. "Formalization model of expert knowledge about a technical index level of engineering products," IOP Conf. Ser.: Mater. Sci. Eng. 91 012070, 2015