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Development of intelligent system to support management decision-making in education

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Abstract—**The article takes a look at an algorithm of decision making in educational management data system based on the Analytic Hierarchy Process. This technique allows to choose the best of the proposed alternatives, the characteristics of which are vectors with heterogeneous individual components including those that are not clearly defined. The architecture of a decision-making support system that implements the proposed algorithm is suggested.**

Keywords- decision support system, Analytic Hierarchy Process, good governance, actor, criterion, pairwise comparison.

I. INTRODUCTION

Timely and well-founded decisions - one of the most important objectives of management activities. The availability of complete, objective and reliable information is a prerequisite for making right decisions and organizing effective management development. In the process of administrative activity some problems are appeared: problems of efficient collecting information receiving, comprehensive information about the control object, timely formation of adequate solutions, which are directed to support positive and weakening negative tendencies as well as the organization of execution of taken decisions [1].

In some cases, making a right decision requires a deep analysis of multi-criteria objective activity. To assist decision makers (DM), the decision support systems are created (DSS). Decision support system - is computer automated systems that are based on the collecting and objective analysis of large amounts of information can influence the selection of optimal action [2].

Specialists in various fields devoted a great number of their works to the problems of improving the effectiveness of manageportant points regarding the preparation of the initial data [3-5]. In this connection, the automated support process of preparation, formation and implementation of management decisions becomes the urgent task. In accordance with the above steps in the management cycle information the analytical decision support requires the implementation of the same functional cycle. Fig. 1 shows a diagram of the functional cycle of decision support.

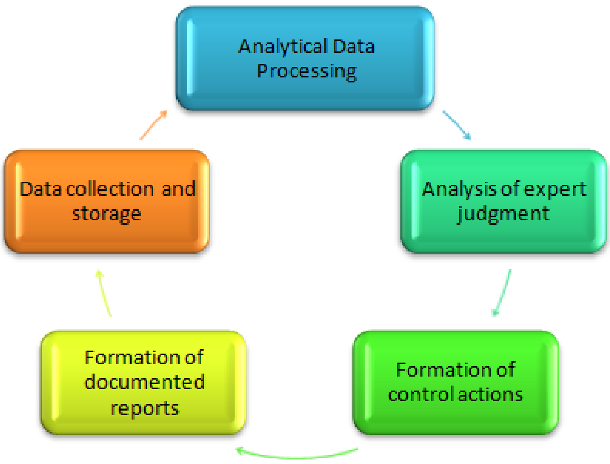

Figure 1. Diagram of the functional cycle of decision support

Modern DSS use different methods of analysis. They are imitation modeling neural networks, expert systems, genetic algorithms, and others. This article is considered one of them - the Analytic Hierarchy Process (AHP) [6]. This method became widely known owing the works of T. Saaty [6,7].

The important feature of the Analytic Hierarchy Process is the possibility of using subjective judgments which do not have any quantitative characteristic and cannot be measured by any devices or may vary depending on the conditions [8].

In the AHP it is possible to determine the most inconsistent data that reveals the least clear areas of problems and organize more thorough consideration of the problem. On the basis of the results the decision is made.

The object of study in this article is the AHP.

The aim of the study is to develop a decision support system in the field of education through the application of the AHP.

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The following tasks were identified as necessary in order to reach the set goal:

- the justification for using the analytical hierarchy process (AHP) in decision support systems (DSS) and in the context of the problem of assessing the quality of education
- the documentation of the algorithmic representation of AHP;
- the development of a functional model of DSS based on AHP;
- the development of an architectural decision for DSS based on AHP;
- the documentation of results of the experimental study.

II. Using The Algorithm Of The Analytic Hierarchy Process In Education Quality Assessment System

The quality of education, the increasing of investments in education is very important for the state and society and it is the main reason for the development of electronic control systems and decision support systems in the field of education. It is clear that educational institutions receive significant benefits from using of the latest achievements in the field of information technology. Implementation of various automated systems can significantly improve the management of the educational process. The development of information decision support system in education will reduce material resources optimally allocate human resources, improve the quality of educational services. With the help of information technology education system and each institution can significantly improve the conditions of its activities [9,10].

In order to improve the adequacy of the results of initial information to find effective solutions it is proposed to use algorithms based on AHP, which represent the original data in the ratio scale, allowing using all basic mathematical and statistical operations [11]. On the basis of proposed algorithms the present background information is investigated and used in multicriteria problems with mutual requirements for a distributed computer system to support the formation and selection of complex collective decisions. The effective structure for storing this information is devised.

Using AHP is conditioned by the problems:

- the hierarchical structure of the problems of evaluation (assessment objects - assessment criteria - experts - consumers);
- the structure of the indicators and evaluation of their composition (quantity and quality);
- the necessity of using expert estimates of specialists at all levels of education quality assessment;
- the complexity of the selection of optimal management decisions by the education authorities at different levels.

III. The Algorithmic Representation of the Analytical Hierarchy Process

The purpose of the Analytic Hierarchy Process – the justification of a choice made from proposed alternatives, the characteristics of which are vectors with heterogeneous individual components including those that are not clearly defined.

The essence of the Analytic Hierarchy Process is the step-by-step solution of the following specific interrelated problems:

- construction of the hierarchical structure of indicators (signs);

- evaluation of the significance of individual private indicators for each level of the hierarchy;

- comparison between the available alternatives and the choice of the best one [8].

As result a relative degree (intensity) should be expressed of the interaction between the different elements in the hierarchy. The Analytic Hierarchy Process includes procedures for the synthesis of multiple judgments based on the results of pairwise comparison which can then be expressed numerically; priority evaluation (importance) of criteria (specific indicators) as well as the evaluation of alternative solutions and the choice of the best solution. The obtained result values are grades on a ratio scale which in turn correspond to rigorous grades.

The source material based on which the decision-maker can obtain a sufficient, clear and precise idea of the superiority of one element over another is intuition and subjective assessment despite the fact that the judgments and their intensity characterize the expression of inner feelings and inclinations specific experts. Judgments expand the borders of communication, fastening elements that are present on certain and specific levels of the hierarchy.

The Analytic Hierarchy Process includes the following stages the significance of which is different for different tasks and situations [12]:

Stage 1. Description of the problem and identification of research objectives.

Stage 2. Construction of the hierarchy, beginning from the top (targets - from a management perspective), through intermediate levels (criteria on which subsequent levels depend on) to the lowest level (which typically is a list of alternatives).

Stage 3. The construction of the matrix elements of the influence of the upper (previous) on the elements of the lower(next) level (for each of the lower levels) - one matrix for each element on top of the level. In a complete and simple hierarchy any element effects on each adjacent element on the upper level. The elements of each level are compared with each other regarding the extent of their effect on the adjacent elements of upper levels and get a square matrix of judgments. Real hierarchical structures are very rarely complete and simple hierarchies and, in some cases, it is useful to decompose them into sublevels. Pairwise comparisons are made in terms of determining the degree of dominance (preference) of one

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element over another which then can be expressed in whole numbers. And if element A dominates element B, the cell corresponding to row A and column B is filled with a whole number, and the cell corresponding to row B and column A is filled with an inverse number (fraction).

Stage 4. To obtain a matrix in step 3 n (n-1) / 2 judgments (pairwise comparisons) are required. The result of step 3 (comparison of the importance of the effect of the elements on adjacent elements of the previous level) is the set of square matrices N_1, N_2, …, N_k with elements (a_{ij}, i, j = 1, 2,…, n), wherein k is the number of elements of the previous hierarchy level and n is the number of elements of the next level of the hierarchy.

Stage 5. After the conduction of pairwise comparisons for the elements of adjacent levels (a set of matrices) the weight coefficients of the arcs should be calculated. For each of the matrices N_i is defined as a normalized vector of local priorities with the following components (1):

$$\sqrt[n]{\prod_{l=1}^{n} a_{jl}} = a_j \tag{1}$$

wherein n is the dimension of the matrix; a_{ji} the element of the j row of the matrix. Thus, the N_i matrix is associated with vector $\boldsymbol{a_i}$.

The normalization of components is carried out by dividing each component of the vector $\boldsymbol{a_i}$ by the sum of all components of this vector (2):

$$b_j = \frac{a_j}{\sum_j a_j} \tag{2}$$

Normalized vector $\boldsymbol{b_i}$ corresponds to the weight coefficient of arcs connecting the i element of the previous level with all elements of the next level. If we introduce the influence matrix of elements of the lower-level on the elements of the previous level B_l, where l is the number of levels of the hierarchy, the vectors $\boldsymbol{b_i}$ will be its columns.

Stage 6. After receiving the data (processing N_i judgments matrices with formulas (1) and (2)) its consistency should determine. The degree of consistency for each matrix is calculated approximately as follows: each column of the judgments matrix is added up, and the sum of the first column is multiplied by the value of the first component of the normalized vector of priorities, the amount of the second column, by the second component, and so on. The resulting numbers are added together and a size is obtained (3):

$$\lambda_{\max} = \sum_{i=1}^{n} \left(b_j \sum_{j=1}^{n} a_{ji} \right) \tag{3}$$

Using the deviation of $\lambda_{\max}$ from n the conformity index(CI) is obtained, comparing that with the corresponding mean values for random elements obtained for conformity relation (CR). (Details to obtain estimates of consistency are given below).

Stage 7. Steps 3, 4, 5 and 6 are conducted at all levels of the hierarchy.

Stage 8. A phased evaluation is performed of the weight coefficients of the elements of each of the subsequent levels of the hierarchy (4):

$$C_i = C_{i-1} \cdot B_i, \tag{4}$$

wherein $\boldsymbol{C_{i-1}}$ is the vector of weight coefficients of elements of the previous level, and B_i is the matrix of influences of the elements of the lower-level and the elements of the previous level consisting of vectors derived from the formula (2); i is the number of the hierarchy level.

Stage 9. Consistency throughout the hierarchy can be found by multiplying each conformity index by priority of the relevant criterion and summing the resulting numbers. Then the result is divided by the expression of the same type but with a random conformity index, the size of each respective weighted priorities matrix. The acceptable result is considered with a conformity of about 10% or less. Alternatively, the quality of the judgments should be improved by changing the way following which the questions are asked during the pairwise comparisons. If this does not help to improve the consistency, it is likely that the problem should be more precisely structured, i.e. to group similar items for more meaningful criteria. This will require the return to step 2, although only the questionable part of the hierarchy may require review.

IV. The Functional Model Of Decision Support System

The proposed method of supporting the processes of preparation, formation and implementation of administrative decisions is based on the methodology of the system analysis technology of structural analysis and design.

Fig. 2 shows a contextual diagram technique to support the processes of preparation, formation and implementation of management decisions.

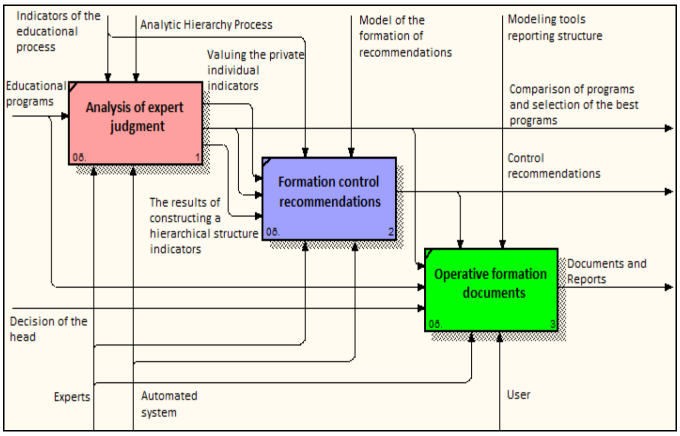

Figure 2. Diagram methods of decision-making on the basis of the AHP

Support for the preparation of management decisions implemented by using AHP, based on the procedure of synthesis of multiple judgments based on the results of paired

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comparisons, priority assessment criteria, as well as the evaluation of alternative solutions and finding the best of them.

The development of administrative decisions is made by recommendations based on selecting the best of the proposed alternatives. Support for the implementation of administrative decisions is performed by operative reports and organizational and administrative documentation based on modeling of information structure of the document [14].

V. The Experimental Study Of The Application Of APH To The Problems In The Management Of The Educational System

A. General description of the experimental study

For the pilot study ways to improve the quality of educational services using the method of hierarchy were examined.

This structure has an aim - improving the quality of educational services. The primary factors that contribute to achieving this goal are legal, economic, technical, technological and social. This set of factors is the second level in the hierarchy problem. The third level displays secondary factors (actors) that have a direct impact on the primary factors. Actors include leadership, public education standards, financing, educational institution, human resources, research and innovation. Each of these actors is motivated by their goals. The set of actors is the fourth level of the hierarchy. At the lowest level options (alternatives) are presented; programs aimed at the achievement of the global goal.

B. Software implementation of the experimental study

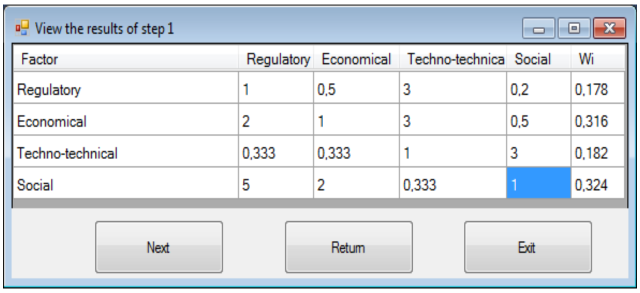
The following programs are to be considered and may significantly affect the quality of education. The first program (P1) is aimed at improving the regulatory framework in the field of education; the second program (P2) is determined by the necessity of the development of science; the third program (P3) aims to equip educational institutions with modern information technology and infrastructure development; the fourth program (P4) - cooperation with research centres, not exclusive with domestic; the fifth program (P5) is aimed at increasing financial and investment support for education.

Thus, from this set of programs aimed at improving the quality of education it is necessary to identify the most important and relevant for today. The scale presented in Table 1 will be the scale of the relative importance during paired comparisons.

TABLE I. The Hierarchy Of Expert Comparisons Of Relations Between Factors

Relative Importance	Definition	Explanation
0	Not Comparable	Expert has a hard time comparing
1	Equal Importance	Equal contribution of both in achieving goal
3	Moderate superiority of one over another	Experience and judgement give a moderate superiority of one over the other
5	Substantial superiority of one over another	Experience and judgement give a substantial superiority of one over the other
7	Significant superiority of one over another	One is considered significantly superior over the other and is considered generally superior
9	Very strong superiority	The strong superiority of one over the other is clearly evident
2,4,6,8	Intermediate solutions between two adjacent judgements	Applied in the case of a compromise

The evaluation of the agreement between experts in the matrix of pairwise comparisons on factors, actors and the global objective in this case does not exceed the recommended values (no more than 10%). The hierarchical structure of decision support system is shown in Fig. 5. The first step is evaluation of the impact factors of the second level to improve the quality of educational services. The result of this comparison is shown in Fig 3.



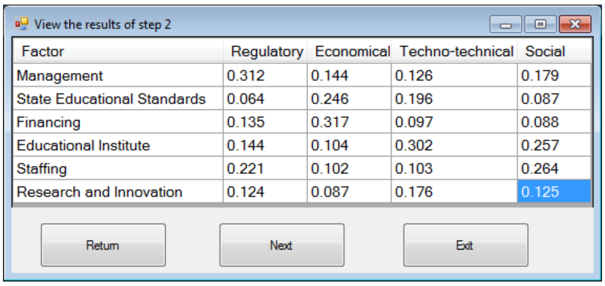
Factor	Regulatory	Economical	Techno-technica	Social	Wi
Regulatory	1	0,5	3	0,2	0,178
Economical	2	1	3	0,5	0,316
Techno-technical	0,333	0,333	1	3	0,182
Social	5	2	0,333	1	0,324

Figure 3. Table of paired comparisons to determine the degree of influence of factors on the level of education

In Fig. 4 W_i represents eigenvector comparisons.

At the second stage a pairwise comparison is made of the actors with respect to each factor, i.e. the degree of influence of the factors of the third level on the factors of the second level is investigated.

Fig. 4 shows the results of the comparison.



Factor	Regulatory	Economical	Techno-technical	Social
Management	0.312	0.144	0.126	0.179
State Educational Standards	0.064	0.246	0.196	0.087
Financing	0.135	0.317	0.097	0.088
Educational Institute	0.144	0.104	0.302	0.257
Staffing	0.221	0.102	0.103	0.264
Research and Innovation	0.124	0.087	0.176	0.125

Figure 4. Windows with eigenvectors of the matrices of pairwise comparisons of actors with respect to each factor

Table with the name of aims is shown in Fig. 6.

Since each of the actors is motivated by a specific set of goals, it is necessary to prioritize these local goals and this is solved through pairwise comparison of the purposes of all actors. As a result, we obtain the eigenvectors of comparison. Eigenvectors are presented in Fig. 7.

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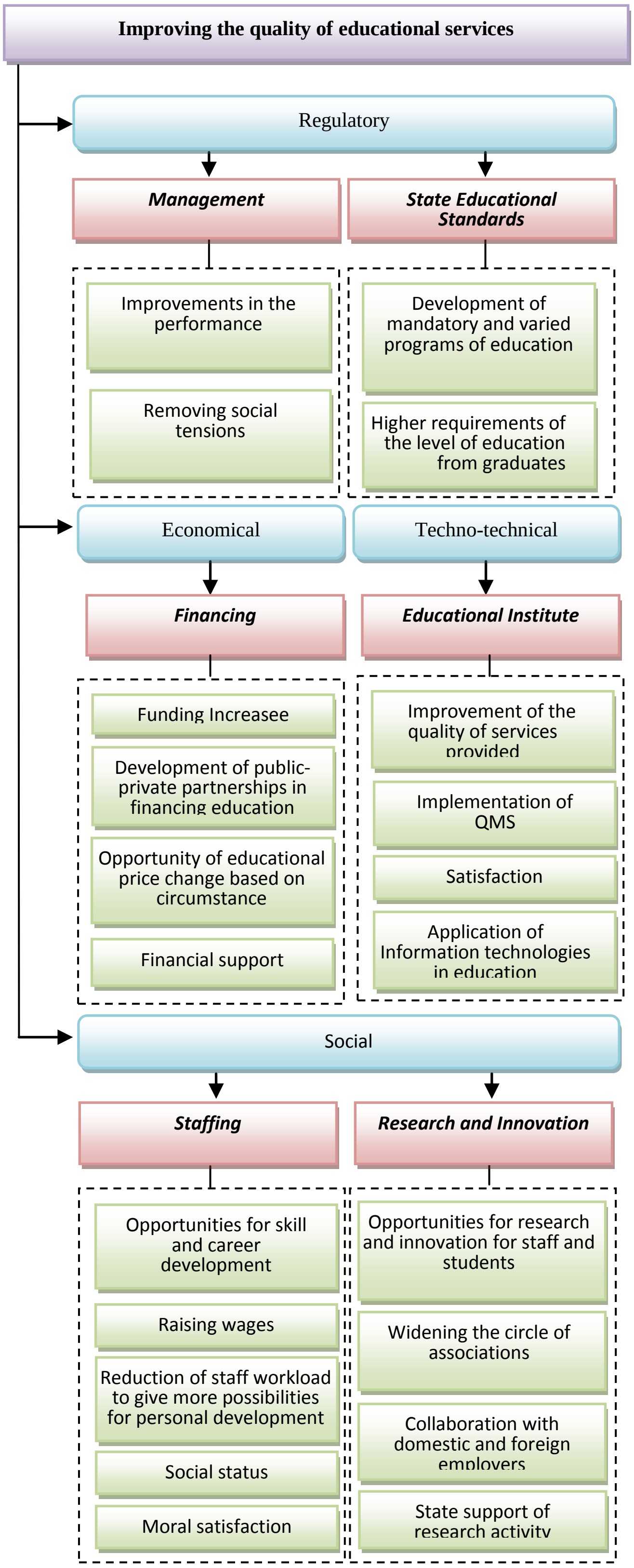

Figure 5. Choice hierarchy of alternative programs

View of aims

№	Aim
Aim №1	Improvements in the performance
Aim №2	Removing social tensions
Aim №3	Development of mandatory and varied programs of education
Aim №4	Higher requirements of the level of education from graduates
Aim №5	Funding Increasee
Aim №6	Development of public-private partnerships in financing education
Aim №7	Opportunity of educational price change based on circumstance
Aim №8	Financial support of research
Aim №9	Improvement of the quality of services provided
Aim №10	Implementation of QMS
Aim №11	Satisfaction with material and technical base
Aim №12	Implementation of modern educational technologies
Aim №13	Application of Information technologies in education
Aim №14	Opportunities for skill and career development
Aim №15	Raising wages
Aim №16	Reduction of staff workload to give more possibilities for personal development
Aim №17	Social status
Aim №18	Moral satisfaction
Aim №19	Opportunities for research and innovation for staff and students
Aim №20	Widening the circle of association and partnership of national institutes with leading universities - domestic and foreign
Aim №21	Collaboration with domestic and foreign employers
Aim №22	State support of research activity

Figure 6. Table with the name of aims

View the results of step 4

Aim	Manageme	State Educationa Standards	Financing	Educationa Institute	Staffing	Research and Innovation
Aim №1	0.25	-	-	-	-	-
Aim №2	0.75	-	-	-	-	-
Aim №3	-	0.25	-	-	-	-
Aim №4	-	0.75	-	-	-	-
Aim №5	-	-	0,172	-	-	-
Aim №6	-	-	0,121	-	-	-
Aim №7	-	-	0,354	-	-	-
Aim №8	-	-	0,354	-	-	-
Aim №9	-	-	-	0,426	-	-
Aim №10	-	-	-	0,151	-	-
Aim №11	-	-	-	0,254	-	-
Aim №12	-	-	-	0,108	-	-
Aim №13	-	-	-	0,061	-	-
Aim №14	-	-	-	-	0,306	-
Aim №15	-	-	-	-	0,404	-
Aim №16	-	-	-	-	0,102	-
Aim №17	-	-	-	-	0,052	-
Aim №18	-	-	-	-	0,135	-
Aim №19	-	-	-	-	-	0,488
Aim №20	-	-	-	-	-	0,248
Aim №21	-	-	-	-	-	0,175
Aim №22	-	-	-	-	-	0,089

Figure 7. Eigenvector of the matrix of pairwise comparisons of the purposes of all actors

Once priorities have been identified the purposes of actors need to find a degree of importance in relation to the factors affecting the quality of education. This estimate is obtained by multiplying the eigenvectors of the actors with respect to each factor of the third level by the eigenvector obtained for the second level. The result of this multiplication is shown in Fig. 8.

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View the results of step 5

Actors	W2	W3	W4	W5	W1	S
Management	0,312	0,144	0,126	0,179	-	0,182
State Educational Standards	0,064	0,246	0,196	0,087	0,178	0,153
Financing	0,135	0,317	0,097	0,088	0,316	0,170
Educational Institute	0,144	0,104	0,302	0,257	0,182	0,197
Staffing	0,221	0,102	0,103	0,264	-	0,176
Research and Innovation	0,124	0,087	0,176	0,125	0,324	0,122

Next

Return

Exit

Figure 8. The Extent To Which Actors Influence Primary Factors

As can be seen from fig.8 the primary factors are affected more by educational institutions and management and staffing so we can only use these three actors for the balance of the script. During the next stage the most important goal of these three actors are determined. the results of this phase are displayed in the program window Excel. Fig.9 shows the values of the vectors of priority objectives of each actor.

	Vectors of actor priorities				
	Importance	**Vector of actor's aim**	**S_i**	**maxS_i**	**S_in**
Management	**S**	**W_6**			
	0,182	0,25	0,136	0,045	
		0,75	0,045	0,136	0,309
Educational Institute	**S**	**W_8**			
	0,197	0,426	0,0839		0,103
		0,151	0,0297	0,0839	
		0,254	0,05		0,190
		0,108	0,0213	0,0500	
		0,061	0,0121		0,113
Staffing	**S**	**W_9**			
	0,176	0,306	0,0539		0,122
		0,404	0,0711	0,0539	
		0,102	0,018		0,161
		0,052	0,0092	0,0711	
		0,135	0,0238		

Figure 9. Vectors Of Actor Priorities

wherein S_i are vectors of actor priorities, max S_i - the maximum value of the priority vector (two from each target vector), Sin - normalized value max S_i.

C. The results of the experiment.

Thus, we found that for the most influential management objectives are improvement of education and the removal of social tensions at educational institutions - increasing the quality of services and the needs of satisfaction with the material and technical base and training opportunities and wage increases for the staff. At the final stage of the priorities defined by the vector of alternatives with respect to the most important goals of actors. Fig.10 summarizes the results obtained.

View the results of step 7

Aims of actors	Program 1	Program 2	Program 3	Program 4	Program 5
Improvements in the performance	0,145	0,243	0,112	0,062	0,438
Removing social tensions	0,088	0,392	0,247	0,069	0,203
Improvement of the quality of services provided	0,053	0,392	0,215	0,092	0,247
Satisfaction with material and technical base	0,115	0,093	0,364	0,059	0,369
Opportunities for skill and career development	0,090	0,129	0,072	0,486	0,222
Raising wages	0,244	0,102	0,103	0,070	0,481

Figure 10. Vectors of priorities of alternatives with respect to the main objectives of actors

Next the vector-priority alternatives relative to the target must be determined of the entire hierarchy for which it is necessary to multiply the eigenvectors of priorities of alternatives with respect to the objectives of actors and the normalized value of the vector of priorities of the purposes of the actors. The results are shown in Fig. 11.

Results of analysis

Program	Weight coefficie
Improving of the regulatory framework	0.128
Development of science	0.233
Equipment of modern information technology and infrastructure development of educational institutions	0.168
Development of collaboration with domestic and foreign research centers	0.121
Increasing financial and investment support	0.350

Figure 11. Vectors of priorities of alternatives regarding the purpose of the hierarchy

Figure 11 shows that the greatest weight - 0.35 belongs to the software aimed at increasing financial and investment support for the educational system.

VI. CONCLUSION

This is to say that the use of the analytical hierarchy process can effectively solve the problems of decision-making in the intelligent systems of education management. This article justifies the use of pf AHP in decision support systems and in the context of the problem of assessing the quality of education. This article also documents the algorithmic representation of AHP, shows a developed functional model as well as an architectural decision for the DSS based on APH and documents the results of the experimental study.

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