Advances in Economics, Business and Management Research, volume 128
International Scientific Conference "Far East Con" (ISCFEC 2020)

Use of the Method of the Analysis of Hierarchies in Acceptance of Pedagogical Decisions

M G Koliada[1], T I Bugayova[1], G A Kapranov[2]

[1]Donetsk National University, Donetsk, 283101, Ukraine
[2]Far Eastern Federal University, 692500, Russian Federation

E-mail: kapranovg@mail.ru

Abstract. In pedagogical processes and the phenomena connected with an innuendo, with indistinct and indistinct expression of a processed material, with uncertainty of conditions and the reasons which influence results, and difficulty of their multifactorial analysis, it is necessary to involve such methods of the analysis of hierarchies which would yield the best results in final decision acceptance. From a position of processing of results of alternatives mathematical methods, to the most demonstrative way of their account and smoothing carry a technique of American mathematician Thomas Saaty. Article purpose – to demonstrate, as the method of the analysis of hierarchies for acceptance of pedagogical decisions is used. Among the primary goals which arise thus, two have been allocated: 1) to spend a theoretical substantiation of use of a method of Saaty for objective decision-making in the conditions of hierarchical system of alternatives, and 2) to show on a concrete example realization of this method at the analysis of problems of a pedagogical orientation. There are two principles in acceptance of rational decisions: a principle of sequence and a maximization principle. The first starting position assumes that it is necessary to order set of alternatives from the point of view of preferences of the one who makes the decision. The second, connected with maximization considers cases when a condition of the rational decision is the choice taking into account the maximizing size of criterion function of the one who accepts it. From a position of processing of results of didactic alternatives the most demonstrative way which has received the name «a method of the analysis of hierarchies» has been chosen. A number of typical problems of the pedagogical and educational sphere which decision is most effectively carried out this way is illustrated. As an example, concrete realization of a method of the analysis of hierarchies for a choice of the most productive educational technology is presented. Using such method at a choice of alternatives of the pedagogical decision, possibility to pass or not to consider the return and an interconnection between investigated components and hierarchy levels that minimizes possibility of acceptance of the wrong decision is excluded.

1. Introduction

Problem of Research. In practice acceptance of the pedagogical decision is realized in the conditions of partial uncertainty – incompleteness of the information on corresponding problems, discrepancy of the available information, and sometimes, and in the conditions of total absence of the data about objects of the analysis. Trainees differently perceive world around, and sometimes absolutely inadequately recreate reactions, for example, on teaching and educational actions, being under the influence of personal benefits or erroneous installations and stereotypes, any dependences. In the conditions of constant change of the pedagogical information, a considerable quantity processed given (the facts and the reasons), and sometimes and owing to information chaos, it is very difficult to make correct decisions. The problem of a correct choice of alternatives in the conditions of uncertainty, as a rule, should be reduced to narrowing of their initial set, taking into account their importance and then *the person the making decision* (PMD) receives the highest expected value of the choice.

Acceptance of the pedagogical decision is understood as process of a choice of optimum alternatives in student teaching, for the purpose of achievement of the best training, developing, educational or operating educational effect. Optimum alternatives are understood as preferences which are not always expressed by the greatest or least values, and such which define the best benefits or the greatest efficiency (efficiency) of considered object, educational process and the phenomenon in the circumstances (place) or in concrete conditions [6].

In the classical kind, expected value consists in acceptance of the pedagogical decision that there is a choice of variants of actions when each of them can give some possible results with various probabilities. Rational procedure PMD is reduced to definition of all possible results, to an establishment of their value (positive or negative sides of each choice) and probabilities, and then to multiplication of corresponding values and probabilities and the subsequent addition to receive as a result prospective optimum value [5]. The alternative which it will be thus chosen, and should give the greatest prospective value.

In pedagogical processes and the phenomena connected with an innuendo, with indistinct and indistinct expression of a processed material, with uncertainty of conditions and the reasons which influence results, and difficulty of their multifactorial analysis, it is necessary to involve such methods of the analysis of hierarchies which would yield the best results in final decision acceptance [13; 17].

2. Methodology of research

In works of the Russian scientists questions of the theory of decision-making [10; 11; 14; 15] were considered. In the conditions of uncertainty foreign scientists [9; 18] paid to search of methods of decision-making attention; to a solution of a problem of paradox of a choice of alternatives have devoted the proceedings Sheena S. Iyengar [22] and Mark R. Lepper [23]. Research of scientists goes by the way of revealing of features on "changes" of utility of conditions, instead of on value of conditions and consequently the estimation of corresponding subjective conclusions in decision-making has started to be displaced towards so-called "reference point", with input of function of losses and risk functions. The directions connected with studying of function of utility are a little inherent in acceptance of pedagogical decisions, and the problem of a choice of alternatives in didactic processes and systems is still insufficiently investigated both in theoretical, and in practical aspects [1; 12]. Without attention of researchers there were such important questions as the account of hierarchies [6], use of effective mathematical methods of multiplane comparisons in acceptance of pedagogical decisions.

At the same time, considering the practical importance in use of well-founded techniques in acceptance of pedagogical decisions, absence of a theoretical substantiation and practical introduction of new constructive systems of the analysis of hierarchies, article theme has been selected: "*Use of the method of the analysis of hierarchies in acceptance of pedagogical decisions*".

This theme of research is very *actual* not only for the research assistants who are taking up the problems of administrative decisions in educational sphere and for post-graduate students of pedagogical specialties, investigating didactic processes and the phenomena from the scientific point of view, but also for ordinary teachers-researchers who constantly face problems of acceptance of optimum pedagogical decisions from the methodical point of view. We hope that substantial disclosing of this problem becomes powerful theoretic-practical help in their professional work.

Article purpose – to demonstrate, as the method of the analysis of hierarchies of Thomas Saaty for acceptance of pedagogical decisions is used.

Among the primary **goals** which arise thus, two have been allocated: 1) to spend a theoretical substantiation of use of a method of Saaty for objective decision-making in the conditions of hierarchical system of alternatives, and 2) to show on a concrete example realization of this method at the analysis of problems of a pedagogical orientation.

Theoretical bases in acceptance of rational decisions. There are two principles in acceptance of rational decisions: *a principle of sequence and a maximization principle*. The first starting position assumes that it is necessary to order set of alternatives *from the point of view of preferences* of the one who makes the decision. The second, connected with *maximization* considers cases when a condition of the rational decision is the choice taking into account the maximizing size of criterion function of the one who accepts it.

At the present stage of development of the theory of decision-making the third principle connected *with uncertainty of psychological component* PMD comes into force also [8]. The matter is that the person accepting the responsible final decision has a struggle between a self-estimation and self-checking. The inadequate self-estimation is shown in an antagonism between two basic tendencies – *increase of level of claims* (that is, this person, as well as all sane people, wishes to make the maximum success) and *decrease in level of claims* (it tries to avoid failure). The psychological factor of responsibility enters "game", to be exact in struggle against desire of the greatest efficiency (benefit), under condition of unpredictability of result of a choice, especially when on a game there are very big rates (in business – probability of very big monetary losses (thousand and hundred thousand dollars), in pedagogic – huge responsibility for the trainees, connected with them and danger of death).

As specified U. Kozeletsky [8], there are two base scientific theories of decision-making: *the theory of acceptance of rational decisions* and *the psychological theory of decision-making*. The matter is that ability to make the decision depends on individual psychological features of the person [6; 21], and first of all, from its way of thinking. Thus distinguish convergent and divergent thinking.

The *thinking convergent type* is directed on search of a uniform best solution of a problem or on search of the unique right answer on the brought attention to the question. Such thinking to aspire to exclude uncertainty as tries to focus attention to the main alternatives conducting to reception of the effective decision.

Thinking of divergent type (from the Latin divergere – to disperse) it is aimed at search of answers of a problem through finding a considerable quantity of variants of its decision. It is shown in ability to flexible search of various alternatives and reception of set of the decisions possessing likelihood character that is necessary in research activity, but risky in student teaching.

The psychological component of a choice of alternatives is defined by specific features making the decision, thus, especially an important point remains it person the painted experience and its actual motivational condition at the moment of decision acceptance [24].

If to consider acceptance of pedagogical decisions it is necessary to consider not only purely educational and educational advantages and benefits, psychological features of the person confirming such decisions, but also its moral relation in choice situations, its ethical estimation of the chosen alternatives, – their conformity to universal values, moral standards, traditions and national interests. The person, the making pedagogical decision should consider interrelation of training-educational behavior of the trainee with its personal requirements, cultural wealth, religious installations, with its level of culture and good breeding. To all told the account of alternatives (factors) of teaching and educational activity which are connected with mutual relations between trainees is added, and also between trainees and teachers, and influence of one party on another thus is necessarily considered.

Considering such variety of factors which are necessary for considering for acceptance of the correct decision, we focus our attention only on decision-making *from the point of view of preferences* of the person accepting it. From a position of processing of results of alternatives mathematical methods, to the most demonstrative way of their account and smoothing, also carry a technique of Saaty [7].

Instrument and Procedures. The way developed by American mathematician Thomas Saaty, name "*a method of the analysis of hierarchies*" more often. It is more well-founded means of the decision it is a lot of criterion problems in difficult conditions with the hierarchical structures including both perceived, and intangible factors, than the approaches based on the linear logic. The matter is that applying the deductive logic, researchers pass a difficult way of construction of carefully intelligent logic chains in the form of conclusions only that as a result, relying on only one intuition, to unite various consequences together. Thus, such approach based on logic steps, not always leads to the best decision as possibility of acceptance of compromises between the factors lying in different places of these chains of logic thinking can be thus lost.

As specified T. Saaty, its approach is deprived these lacks, and itself "the method of the analysis of hierarchies is the closed logic design providing by means of simple rules the analysis of challenges in all their variety and leading to the best answer. Besides, method application allows including in hierarchy all available for the researcher on a considered problem of knowledge and imagination. It, from my point of view, is the balanced way of the decision of a difficult problem: to leave mathematics idle time and to allow riches of structure to bear burden of complexity" [16, P. 3].

Examples of typical problems of a pedagogical reality. Let's illustrate typical problems which can be solved, using a method of the analysis of hierarchy's concrete examples from student teaching:

– A choice from a set of alternatives, for example *a choice of system of training, a choice of pedagogical technology, a choice of a method of training* and etc.;

– *Realization of a freedom in choosing of the student* based on positions of individually-focused system of training: 1) selection of disciplines (special courses); 2) selection of educational modules; 3) selection of substantial units of educational modules; 4) a choice of variants of sequence studying of educational modules; 5) a choice of methods of training; 6) use of various educational technologies 7) a choice of forms of carrying out of employment; 8) a choice of a way of carrying out of employment; 9) a choice of various systems of training; 10) a choice of rate of carrying out of employment; 11) alternative in definition of time of carrying out of employment; 12) alternative in a choice of time of carrying out of consultation; 13) alternative in a choice of the teacher on discipline; 14) alternative of a choice of the tutor [4, c. P. 244];

– *The generalized analysis and distribution of educational and information resources* under the scheme: "efficiency of employment – expenses for its preparation", "quality of knowledge of trainees – time for their mastering", "efficiency of pedagogical technology – cost on its realization" and etc.;

– *Planning and any search of compromises* in educational and educational processes;

– *An estimation of any quality of educational objects*, for example certification of pedagogical workers or coordination of educational services of educational institution;

– *Researches of a demand of this or that speciality* of the higher (average) professional educational institution in the market of educational services;

– *Definition of optimum cost for training* on a contract basis, by comparison of the prices for the analogues similar to estimated object.

For example, modern student teaching offers more than fifty various didactic technologies reflecting the current trends and directions of a development of education. Presence so a considerable quantity of the alternative information brings an attention to the question on a reliable and well-founded choice of those ways of activity which are adequate to the developed pedagogical conditions the researcher (teacher).

Data Analysis. In educational practice often it is necessary to make decisions, generalizing the data of many groups of researchers according to any in advance chosen criterion. It can be paired comparisons of opinions in relation to some characteristic (didactic object) or comparisons of sights of persons about their relation to various acts of trainees [19]. As a rule, return sizes of these estimations provide in the expedient image a certain key to association of group judgments of interrogated authoritative people (the name experts). For example, if the group of pedagogical experts has to agree with opinion that one of considered technologies of training is more effective in relation to other similar educational technology, for example, in 3 times then this second technology should be in 1/3 times to be more productive, than the first.

The method of the analysis of hierarchies allows considering solutions of a problem of pedagogical conflicts in group of the trainees having different interests and values [20; 25]. For example, in the conflict between two subgroups of trainees in each of them it is necessary to use four hierarchies for an estimation both real performance of the problem put by the teacher, and imaginary, that is reaction emotionally-perceived by participants, and also valuable cost of this problem for both parties of the conflict. The Teacher-intermediary should use these eight hierarchies plus to construct four more own to find the compromise which is pulling together interests of the parties of these subgroups of trainees. In each case performance of the problem put by the teacher and its valuable cost are considered in common, and relations between each subgroup of the reached positive shifts and negative defects (failures) in points of their contact of interests are simultaneously considered. It is clear that all it in aggregate influences acceptance of the final decision for an estimation of the general relative advantages of alternatives of a conflict situation in students collective.

3. Results of research

Findings of own vector for streamlining of priorities of decision-making. Thomas Saaty so described the main theoretical feature of the method. “The theory reflects that is represented a natural course of human thinking. Facing set of the controllable or uncontrollable elements reflecting a difficult situation, the reason unites them in groups according to distribution of some properties between elements. Our model allows repeating the given process in such a manner that groups, or are faster general properties defining them, are considered as elements of a following level of system. These elements, in turn, can be grouped according to other set of properties, creating elements of one more, higher level and so until the unique element - top which frequently can be identified with the decision-making process purpose” [16, P. 3].

In a general view the method of the analysis of hierarchies of Saaty consists in the following. At first by means of experts *find the numbers of the comparison* reflecting at comparison the reached consent in opinions among themselves, then them *write down in the table* (matrix), and then find *own vector with the greatest value*. This own vector also provides streamlining of priorities, and its concrete *value is a measure of a coordination of judgments*.

For this purpose, at first define a scale of priorities. Let two conditional elements of comparison are set, we will designate them through the Roman figures *I* and *II*. Then, if:

– *I*-й and *II* th elements are equally important among themselves then in a comparison cell bring 1;
– *I*-й the element slightly is more important, than *II* th, – bring 3;
– *I*-й the element is much more important than *II* th, – bring 5;
– *I*-й *II* th obviously is more important, – bring 8;
– *I*-й *II* th is much more important, – bring 12.

It would be possible to choose to (think up) and other scale of priorities of elements, all depends on them, so-called “importance scales”, that is comparative distinctions in importance “weight”.

At comparison of the same element with itself establish the equal importance, therefore in a table cell on crossing of elements of the same line number and a column always bring only 1, therefore the main diagonal of the table always consists only of sequence of units. Cells top (from “an individual” diagonal) fill table parts according to the rule resulted above, and the cells placed symmetrically of this diagonal in (the bottom part of the table) fill with corresponding return sizes of initial elements of comparison, for our case it: 1 1/3, 1/5 1/8, 1/12.

Let's disassemble a concrete example.

Let symbols T_1, T_2, T_3 and T_4 designate conditional names of educational technologies which can be applied to effective training of pupils or students. The estimation is made by the expert in which role one of skilled teachers who in the professional work already many long years used all four pedagogical technologies acts. It, for example, ask: “how much pedagogical technology T_2 is more productive in comparison with technology T_3?”. He answers on above considered scale through weight numbers of comparison of efficiency of considered technologies, and results brings in a corresponding cage of the table (in our case, a cage on crossing of a line T_2 and column T_3).

After the announcement of five remained estimations of the expert, and also entering of their return sizes in cells of all table, we will receive a matrix of paired comparisons for four lines and four columns (table 1 see).

Table 1. A matrix of paired comparisons.

	T_1	T_2	T_3	T_4
T_1	1	5	8	12
T_2	1/5	1	3	8
T_3	1/8	1/3	1	3
T_4	1/12	1/8	1/3	1

On this matrix it is possible to calculate a vector of priorities. In mathematical terms it is calculation of main own vector which after normalization becomes a vector of priorities. For reception of an analytical estimation of this vector use next four ways (are considered as increase in accuracy of estimations) [16, P. 24]:

1. To summarize elements every line and to normalize division of each sum into the sum of all elements; the sum of the received results will be equal to unit. The first element the total a vector will be a priority of the first object, the second – the second object and etc.
2. To summarize elements of each column and to receive return sizes of these sums. To normalize them so that their sum equaled to unit, to divide each return size into the sum of all return sizes.
3. To divide elements of each column into the sum of elements of this column (i.e. to normalize a column), then to combine elements of each received line and to divide this sum into number of elements of a line. It is averaging process on the normalized columns.
4. To increase n elements every line and to take a root n th degrees. To normalize the received numbers.

We use the *first way*. For this purpose we summarize lines of this matrix, – we receive a column (26.000; 12.200; 4.458, 1.542), then we will combine its elements and we will receive a component of this vector which is equal in our case 44.2. Having divided everyone to a vector component into this number, we will receive written down in the form of a line (0.588; 0.276; 0.101; 0.035) a vector-column relative priority educational technologies T_1, T_2, T_3 and T_4 accordingly.

The *second way* gives the sum of columns of this matrix in the form of a vector-line: (1,408; 6,458; 12,333; 24,000). Its each element is transformed into return size (0.710; 0.155; 0.082; 0.042), and after normalization it become such: (0.718; 0.157; 0.082; 0.042).

Using the *third way*, we normalize each column (for this purpose we put components and we divide each of them into this sum) and we receive a matrix:

0.710059	0.774194	0.648649	0.5
0.142012	0.154839	0.243243	0.333333
0.088757	0.051613	0.081081	0.125
0.059172	0.019355	0.027027	0.041667

We summarize lines also we will receive a vector-column (2.633; 0.873; 0.346; 0.147) which after division into dimension of columns 4 allows receiving a vector-column of priorities (0.658; 0.218; 0.087; 0.037).

Using the *fourth way*, we will multiply all elements every line and we will take a root of *4*th degree. We will receive a new vector-column of priorities (0.650; 0.206; 0.083; 0.034).

The most exact decision of this problem can be received by matrix erection in any way big degrees and divisions of the sum of each line into a total sum of elements of a matrix.

Comparing all four results, we will notice that accuracy raises from the first to a way to the last, however calculations simultaneously become complicated. If the matrix is coordinated, in all four cases vectors of priorities will be identical. In case of inconsistency the best approach can be received only by means of last way.

For an estimation of the coordination reflecting proportionality of preferences of experts, enter special size λ_{max} which name the *maximum* or *main own value*. **The more close this size λ_{max} to number of**

objects or action kinds in a matrix n, the is considered, the result is more coordinated. The deviation from a coordination can be expressed in size of relations ($\lambda_{max} - n)/(n - 1$) which we name a *co-ordination index* (CI).

Also enter one more size which names the *relation coordination's* (RC) through which define acceptability or a deviation of the received result. **If value of RC, smaller or equal 0.10, is considered result comprehensible**. It define through, a *so-called casual* index (SI) which count through casually generated sample in matrixes to 500 elements. So for matrixes no more than *15 x 15* average values of SI have following sizes (table 2):

Table 2. Average values of casual indexes.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

Let's illustrate for our example the approached calculations CI, for a finding of main own value λ_{max}. We take the initial table and a column-vector calculated in the third way. We will increase our matrix by this vector of priorities (0.658; 0.218; 0.087; 0.037) (it can be executed in program Excel). We will receive a new vector-column (2.885; 0.904; 0.352; 0.147).

Let's divide elements of this vector into corresponding components of an initial third vector, we will receive (4.382; 4.141; 4.065; 4.151), and result we will average. We will receive size 4.151, whence we will find CI = (4.151 – 4) / 3 = 0.050. For that definition, this result is how much good, we will divide it into corresponding value of size of SI = 0.90. The relation of a coordination 0,05 / 0.90 = 0.056 that is less than size 0.10, hence, the received result received in the third way is comprehensible (it should be left).

4. Discussion

Realization of a method of Saaty in a choice of the most productive educational technology. Now we will disassemble a concrete example of application of a method of Saaty in acceptance of the pedagogical decision. For this purpose we will solve a problem on a choice of the best technology of training.

The analysis of four educational technologies about their efficiency has been carried out. For comparison of their efficiency five main characteristics have been chosen: 1) *degree of achievement of the end result* which is partially defined through level of uncertainty of result of training (for brevity we will designate it ***End result***); 2) *level of the organization of trainees* which first of all is connected with presence and quality of feedback between those who trains also those who is trained (***Organization of trainees***); 3) *level of interaction of trainees with the teacher (teacher),* expressed through degree of attraction of pupils (students) to employment of informative activity and support of this interest (***Interaction with the teacher***) . This characteristic is shown in the form of face-to-face or individual mode of study more often. 4) *level of interaction of pupils (students) with the tutorials*, expressed through quality of interaction of the trainee with tutorials (***Interaction with tutorials***). This characteristic shows degree of mastering of a material to pupils (the student) at its interaction not with the teacher, and with a tutorial [16, P. 252]; 5) *the level of diagnostics* expressed through quality of revealing not only an initial condition training (instruction), and the reasons of misunderstanding or backlog in the course of training (learning) (***Diagnostics***).

Let's remind that the educational technology is a system of ways, receptions and the steps which sequence of performance provides a training statement of the problem, and activity is presented procedure, that is as the certain system of the actions providing guaranteed result [2, P. 163].

Our hierarchical system consists of two levels which elements are grouped at first sight in two untied sets. But at detailed research it appears that components of each set nevertheless are under influence each other and, in turn, influence elements of other level, and, they in each group of hierarchy are independent sizes (figure 1).

Our problem consisted in at first to carry out the analysis ***without feedback, and then with its account and then to spend comparison of result***s. The constructed model of a pedagogical reality on the basis of model of hierarchies of Saaty gives the chance to consider possible return correlations which at usual decision-making, a bowl of all are ignored. This problem uneasy, and without application of mathematical calculations practically it is not realized.

It is considered that such hierarchical system taking into account feedback between elements gives the chance to reproduce a primary reality of existence of system, or as speak, the form of its coordination and the organization taking into account streamlining by the most rational way.

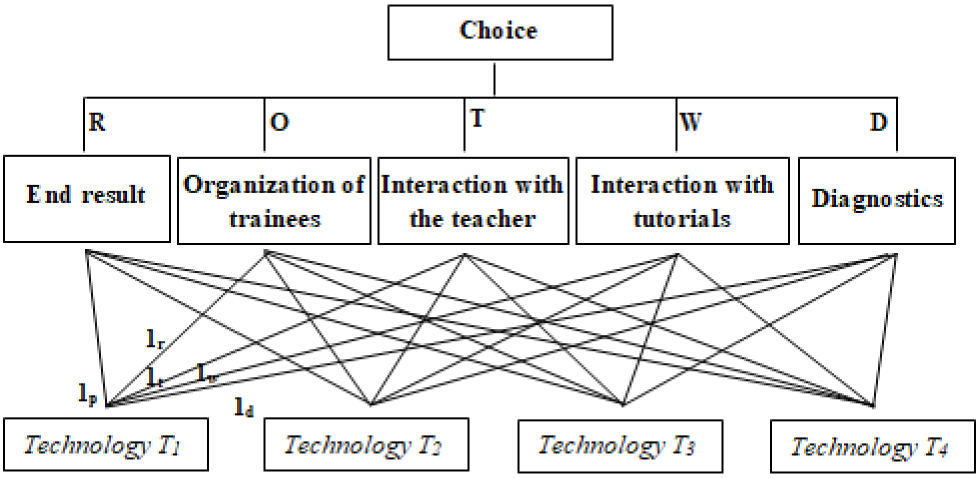

Figure 1. Hierarchy of system for decision-making of a choice of a variant of educational technology.

In spite of the fact that at us only two levels of hierarchy, all the same a parity of its highest level, proceeding from interaction with lower level, states more exact estimation, than if we simply considered direct dependence only elements at these levels. Experts who deeply investigate interaction of components of hierarchical systems, say that persons who use such methods, in essence "evade from direct comparison big and small" [26; 27]. Thus they specify that systems happen to simple hierarchy – *linear*, that is ascending from one level of elements to the next level, and – *nonlinear* when the top level can be both in a leading position in relation to the bottom level, and in the subordinated condition.

Our hierarchical system just also concerns compositions of the second class. In drawing by capital letters (R, O, T, W, D) five main characteristics which as a matter of fact and are criteria in a choice of the best variant of educational technology are shown. For each such technology in figures with indexes communications with these characteristics (for example, for the first technology are below shown: 1_r, 1_o, 1_t, 1_w, 1_d), all 20 communications (figure 1 see) are.

At first experts estimate indicators of comparison of characteristics educational technologies with each other (table 3), and then compare technologies concerning these five characteristics (table 4).

Table 3. Comparison of characteristics of educational technology concerning its general efficiency.

	End result	**Organization of trainees**	**Interaction with the teacher**	**Interaction with tutorials**	**Diagnostics**
End result	1	8	8	12	5
Organization of trainees	0.125	1	0.333	0.083	1
Interaction with the teacher	0.125	3	1	3	5
Interaction with tutorials	0.083	12	0.333	1	5
Diagnostics	0.2	1	0.2	0.2	1

Let's calculate a vector of priorities of table 3. Using the third way (see above) we range its elements. For this purpose we summarize columns of this table, and then we will find each component of a new matrix a method of division of an initial element for the sum of a corresponding column. As a result we will receive a matrix:

0.652	0.320	0.811	0.737	0.294
0.082	0.040	0.034	0.005	0.059
0.082	0.120	0.101	0.184	0.294
0.054	0.480	0.034	0.061	0.294
0.130	0.040	0.020	0.012	0.059

Let's combine in the lines its elements (we will find a total sum every line), and again we summarize components of the received vector-column. Then each component of this vector-column we will divide into their sum, – we will receive a definitive vector-column (0.570; 0.044; 0.158; 0.187; 0.041).

Now, initial given tab. 3 we will increase by the received vector-column. For this purpose we will use function =MMULTIP () programs Excel (with input in the form of simultaneous pressing of keys *Ctrl+Shift+Enter*), and we will build a new vector-column, but already with the account normal: (4.638; 0.225; 1.129; 1.025; 0.268). Again its each element we will divide into an initial vector-column (0.570; 0.044; 0.158; 0.187; 0.041), also we will receive a column (8.144; 5.069; 7.138; 5.483; 6.532) at which average value is equal 6.473.

So, the vector of priorities of the initial table turns out equal (0.570; 0.044; 0.158; 0.187; 0.041), and own value corresponding to it λ_{max} = 6.473 that is far enough from value in case of a coordination, equal 5 (dimensions of table 3); CI=0.368 and RC=0.368/1.12=0,389 (value 1.12 for tables *5 x 5* see) that also is great enough in comparison with 0.10.

For comparison of educational technologies within the limits of each of five characteristics we will use following tables (table 4 see).

Table 4. Comparison of educational technologies concerning five characteristics.

End result	**T_1**	**T_2**	**T_3**	**T_4**	**Organization of trainees**	**T_1**	**T_2**	**T_3**	**T_4**
T_1	1	12	8	5	**T_1**	1	5	1	3
T_2	0.083	1	0.333	8	**T_2**	0.2	1	0.2	0.333
T_3	0.125	3	1	0.2	**T_3**	1	5	1	0.125
T_4	0.2	0.125	5	1	**T_4**	0.333	3	8	1

Interaction with the teacher	**T_1**	**T_2**	**T_3**	**T_4**	**Interaction with tutorials**	**T_1**	**T_2**	**T_3**	**T_4**
T_1	1	0.333	12	8	**T_1**	1	0.2	8	12
T_2	3	1	0.2	5	**T_2**	5	1	0.125	0.125
T_3	0.083	5	1	0.125	**T_3**	0.125	8	1	0.333
T_4	0.125	0.2	8	1	**T_4**	0.083	8	3	1

Diagnostics	T_1	T_2	T_3	T_4
T_1	1	1	1	1
T_2	1	1	1	1
T_3	1	1	1	1
T_4	1	1	1	1

For comparison of four educational technologies under the characteristic the *End result* (table 4-1 see), we will find (the same third way) values of a vector-column of priorities (0.591; 0.177; 0.090; 0.142), the main own value, an index of a coordination and size of the relation of a coordination, accordingly: λ_{max} = 7.022, CI=1.007 and RC=1.119.

For comparison of four educational technologies under the characteristic the *Organization of trainees* (table 4-2 see), accordingly: a vector-column of priorities (0.380; 0.061; 0.219; 0.339), λ_{max} = 5.320, CI=0,440 and RC=0.489.

Under the characteristic *Interaction with the teacher* (table 4-3 see): a vector-column of priorities (0.355; 0.307; 0.210; 0.127), λ_{max} = 10.380, CI=2.126 and RC=2.363.

Under the characteristic *Interaction with tutorials* (table 4-4 see): a vector-column of priorities (0.431; 0.221; 0.148; 0.200), λ_{max} = 11.567, CI=2.529 and RC=2.810.

Under the characteristic *Diagnostics* (table 4-5 see): a vector-column of priorities (0,250; 0.250; 0.250; 0.250), λ_{max} = 4.000, CI=0.000 and RC=0.000.

Having written down values of vectors of priorities in the form of lines, we will receive table 5.

Table 5. Comparison of characteristics of four educational technologies.

	End result	Organization of trainees	Interaction with the teacher	Interaction with tutorials	Diagnostic
T_1	0.591	0.381	0.355	0.431	0.250
T_2	0.177	0.061	0.307	0.221	0.250
T_3	0.090	0.219	0.210	0.148	0.250
T_4	0.142	0.339	0.127	0.200	0.250

The general estimation of educational technology T_1 pays off under the formula:

$T_1 = R * 1_r + O * 1_o + T * 1_t + W * 1_w + D * 1_d$,

For educational technology T_2:

$T_2 = R * 2_r + O * 2_o + T * 2_t + W * 2_w + D * 2_d$,

For technology T_3:

$T_3 = R * 3_r + O * 3_o + T * 3_t + W * 3_w + D * 3_d$,

For T_4:

$T_4 = R * 4_r + O * 4_o + T * 4_t + W * 2_w + D * 4_d$.

In another way it would be possible to receive the general ranging of characteristics of educational technologies if to increase table 5 matrixes on the right by the transposed vector-line of scales of characteristics (0.570; 0.044; 0.158; 0.187; 0.041). This same what to weigh each of received above five own vectors a priority of the corresponding characteristic and then to combine (that it is admissible at independence of characteristics). It is As a result had:

T_1=0.500; T_2=0.203; T_3=0.132; T_4=0.163,

Where the priority of educational technologies T_3 and T_4 has exchanged in places.

We will be convinced of it, having looked at a vector-column of priorities for the third way (see previous point):

T_1=0.658; T_2=0.218; T_3=0.087; T_4=0.037.

Resume: the most productive remained the first, behind it there is the second, then - the fourth, and, at last, (from everything, it less productive) – the third technology.

As we see, in relation to an initial choice of the alternatives, the third educational technology has appeared the worst on efficiency.

5. Conclusions

Application of mathematical approaches in acceptance of pedagogical decisions on the basis of hierarchies on Thomas Saaty method gives the objective end result. Such hierarchies are steady and flexible. Stability is shown in the sense that at small changes, the small effect is caused also, and flexibility is found out that addition of new communications to well structured hierarchy does not destroy its characteristics. These qualitative features of hierarchies of pedagogical systems bear high stability at computing processing of the didactic data, realized through multiplane comparisons. Using such method at a choice of alternatives of the pedagogical decision, possibility to pass or not to consider the return and an interconnection between investigated components and hierarchy levels that minimizes possibility of acceptance of the wrong decision is excluded.

Data processing of pedagogical research (experiment) on the basis of the analysis of hierarchies considers not only linear mutual relations between levels of hierarchies, but also difficult nonlinear correlations and transitions which at intuitive level basically it is impossible to consider. Process of a choice of optimum alternatives in student teaching on the basis of a method of Saaty once again confirms D. I. Mendeleyev words which has told: «the Science begins there where start to measure». To these words it is possible to add: «And there, where receive objective result in decision-making». Penetration into pedagogic of information-mathematical methods is one of indicators of its maturity.

References

[1] Glushko I V, Zueva T M 2018 Monitoring of quality of educational activity in high school : teoretiko-legal and practical aspects Perspektivy *Nauki i Obrazovanija* **4(34)** 26–32 DOI: 10.32744/pse

[2] Kodzhaspirova G M 2008 Pedagogic in schemes, tables and basic abstracts *Moscow: Ajras-press* 256

[3] Kozeletsky U 1979 Psychological theory of decisions *Moscow: Progress* 504

[4] Koliada M G 2012 Theoretical and methodical bases of vocational training of the future experts in protection of the information and to management of information security: the dissertation of the doctor of pedagogical sciences: 13.00.04 – the theory and a vocational training technique (Lugansk) 563

[5] Koliada M G, Bugayova T I 2015 Pedagogical Forecasting in Computer Intellectual Systems : Manual *M. : Publishing House "Rusyns"* 380 DOI: 10.15216/978-5-4365-0435-3 https://www.book.ru/book/918701/view

[6] Koliada M G, Bugayova T I 2018 Realization of Ideas of Artificial Intelligence for the Finding of Hierarchy of Motives of Training. Informatics and Education Informatics and Education **10** 12–19 DOI: 10.32517/0234-0453-2018-33-10-12-19

[7] Koliada M G, Bugayova T I, Reviakina O G, & Belykh S I 2019 Implementation of ideas of computational pedagogy in the selection of forms of education based on the Markovian model of hierarchies *Perspectives of Science and Education* **38(2)** 413-427 DOI: 10.32744/pse.2019.2.31

[8] Koliada M G, Bugayova T I, Reviakina E G, Belykh S I, Kapranov G A 2019 Effective Management of the Interaction of Sports Team Members by Using Artificial Intelligence Ideas Human. Sport. Medicine vol 19 **1** 72–79 DOI: 10.14529/hsm190110

[9] Leman E L 1979 Check of statistical hypotheses *Moscow: Science* 408

[10] Litvak B G 1996 Expert estimations and decision-making *Moscow: Patent* 271

[11] Litvak B G 2004 Working out of the administrative decision *Moscow: Business* 392

[12] Mitin A I 2018 Training in Group Decision Making in Situational Training Centers Psychological-Educational Studies vol 10 3 84–98 DOI: 10.17759/psyedu.2018100308

[13] Nuriyev N K, Starygina S D, Gibadullina E A 2016 Didactic Engineering : Designing New

Generation Learning Systems Integratsiya obrazovaniya *Integration of Education* **3(20)** 393–406 DOI: 10.15507/1991-9468.084.020.201603.393-406

[14] Orlov A I 2005 Decision-making The theory and methods of working out of administrative decisions *Moscow: MarT* 496

[15] Orlov A I 2006 Theory of decision-making: the textbook *Moscow: Examination* 573

[16] Saaty T 1993 Decision-making. A method of the analysis of hierarchies *Moscow: Radio and communication* 278 p

[17] Smirnov S A 2001 Pedagogic: pedagogical theories, systems, technologies *Moscow: Academy* 512

[18] Abraham W 1945 Sequential Tests of Statistical Hypotheses Annals of Mathematical *Statistics* vol 16 **2** 117–186

[19] Baker R S 2014 Educational Data Mining and Learning Analytics Learning *Analytics* 61–75 DOI: 10.1007/978-1-4614-3305-7_4. https://www.researchgate.net/publication/278660799_Educational_Data_Mining_and_Learning_Analytics

[20] Dutt A A 2017 Systematic Review on Educational Data Mining vol 5 15991–16005 DOI: 10.1109/ACCESS.2017.2654247 http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7820050&isnumber=7859429

[21] Evans B M 2015 Informing programs to improve interpersonal coach behaviours: a systematic review using the RE-AIM framework *The British Journal of Sports Medicine* **49(13)** 871–877 DOI: 10.1136/bjsports-2015-094634

[22] Iyengar S 2010 The Art of Choosing *New York: Twelve* 352

[23] Lepper Mark R 2005 Theory by the numbers? Some concerns about meta-analysis as a theoretical tool Applied Cognitive *Psychology* **8** 1–12

[24] Piaw C Y 2012 Effects of computer-based testing on test performance and testing motivation Computers in Human Behavior vol 28 1580–1586 DOI: 10.1016/j.chb.2012.03.020

[25] Romero C 2010 Educational Data Mining: A Review of the State of the Art IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews) **40(6)** 601–618 doi:10.1109/tsmcc.2010.2053532 https://www.researchgate.net/publication/224160756_Educational_Data_Mining_A_Review_of_the_State_of_the_Art

[26] Simon H A 1962 The Architecture of Complexity Proc. Amer. Philosophical Soc. vol 106 467–481

[27] Whyte L L, Wilson A G, Wilson D 1969 Hierarchical Structures *American Elsevier* (New York)