

*Представлена параметрична модель прогнозування та оцінки рівня якості навчальних закладів (НЗ), яка враховує багаторівневу структуру процесів, набір параметрів впливу на процеси і функцію розрахунку рівня якості процесів на основі початкових ресурсів. Запропоновані 10 ступенів реальної оцінки рівня якості процесів, що дозволило проводити порівняння реальних показників якості НЗ з прогнозними і виявляти проблемні процеси. Запропоновані рішення дозволять проводити проактивне управління розподілом ресурсів НЗ та забезпечити якість надання освітніх послуг в НЗ*

*Ключові слова: навчальні заклади, оцінка якості, проактивне управління, прогнозування якості, параметрична модель*

*Представлена параметрическая модель прогнозирования и оценки уровня качества учебных заведений (УЗ), которая учитывает многоуровневую структуру процессов, набор параметров влияния на процессы и функцию расчета уровня качества процессов на основе начальных ресурсов. Предложены 10 степеней реальной оценки уровня качества процессов, что позволило проводить сравнение реальных показателей качества УЗ с прогнозными и выявлять проблемные процессы. Предложенные решения позволят проводить проактивное управление распределением ресурсов УЗ и обеспечить качество предоставления образовательных услуг в УЗ*

*Ключевые слова: учебные заведения, оценка качества, проактивное управление, прогнозирование качества, параметрическая модель*

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# DEVELOPMENT OF PARAMETRIC MODEL OF PREDICTION AND EVALUATION OF THE QUALITY LEVEL OF EDUCATIONAL INSTITUTIONS

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## 1. Introduction

The quality of educational activity for the institutions of Ukraine today is a key factor in its entering the European space of educational institutions, which requires the painstaking work of the initiation of internal quality system into educational institutions (EI).

However, the efficiency of functioning of the quality system, and hence the quality of educational services, depends on how carefully it will be conceived and built. Among various approaches to the formation of quality assurance systems, the most common is the international standard ISO of 9001 Series, which is widespread among European EI. This standard allows improving the system of management of EI, adapting it to new socio-economic conditions, increasing the competitiveness of EI, as well as contributing to the increase in quality of the graduates.

However, the implementation of the ISO 9001 quality standard needs adaptation of its provisions to the conditions of EI in Ukraine, namely the conditions of limited resources.

Under these conditions, the quality of EI is largely determined by the efficiency of resource planning and implementation of preventive and corrective actions to improve the processes of EI.

Thus, in educational institutions there is a problem of rational resource allocation among the processes different by their functionality under condition of their limitation. To solve this problem, we propose to predict the quality level of the work of an educational institution, depending on the allocation of initial resources based on the developed parametric model. Such approach creates conditions for proactive management of the allocation of resources in order to ensure the quality of educational services in EI.

A parametric model of an institution is built with consideration of international standards of quality management and a process-oriented approach to the activities of EI. The basis of it is a multilevel and multifactorial structure of the processes sorted by the levels of sequence of their execution [1]. The level of quality of the initial resources and other processes affect the quality of each process.

The proposed parametric model should help authorities of educational institutions to develop quality management in line with the international standards.

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## 2. Literature review and problem statement

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Under conditions of competition, a consumer expects to receive not only fulfillment of his/her requirements to the services/products offered by organizations but also puts forward certain requirements to the quality of processes in organizations and institutions [2]. That is why the international community proposes rational approaches not only to the evaluation of quality of services/products but also to the evaluation of the processes that ensure this quality [3]. A methodological base of standards of the ISO 9001 series is the approach of total quality management (Total Quality Management – TQM) [4]. The standards are set in the form of requirements and general recommendations in which the description of models is missing, with the help of which those mechanisms and methods can be implemented in the form of unique projects. Developers of the standards rely on the initiative and creativity of the performers who would use requirements and recommendations of the standards under their specific conditions [5].

The development of educational projects to improve the quality and efficiency in the work of educational institutions today is reflected in many studies. But they address either the basic principles of the concept of formation of educational space [6] or specific approaches to the organization of educational processes in colleges and universities [7] or the design of criteria for the management of innovative projects in universities and colleges [8]. These studies are aimed at separate parts in achieving the quality of education in Ukraine.

But the formation of quality of a particular educational institute is linked not only to the development of general principles, classification and improvement of separate structural parts of quality management, but also to the creation of a properly functioning model of EI including structural features and tasks concerning quality of work as a whole and its particular processes [9]. An analysis of particular processes of educational institutions, for example: technical support and maintenance [10], group emotional intelligence of students [11], extended means of evaluation of students' abilities [12], impact of duration of educational process on the quality of educational process, director's discipline requirements and organizational unity among teachers [13], is constantly updated with methods and models that may be used for the evaluation of particular processes and their components for educational institution [14].

Standardization and certification of the processes of quality management of education in higher education allows unifying general evaluation of all processes of EI as a whole but different studies of influential factors on these processes could be used to evaluate quality level of particular processes [15]. It is important to distinguish the key factors of influence on quality level from many supporting factors [16]. There are a small number of key factors used for the evaluation of quality but they provide for basic weight of this evaluation.

The constant dynamics of changes in legislation, market requirements and other factors are explored in a model of systems dynamics as a base for building a tool of process

monitoring of the quality of educational projects [17]. The study addresses the problem of resource allocation among different processes on the example of time allocation among academic disciplines.

A significant assistance to every educational institution in Ukraine in the process of entering a global system of economic principles and quality standards should be provided by the development of information system of management of the quality of educational institution on the basis of the international standards ISO. Authors of article [18] argue that the development of information system should be linked to business processes. In order to meet the requirements of the ISO standards, the information system should be flexible in terms of its constant updating and improvement and this requires certain "universality" of its modules [15]. The creation of such an information system requires the development of appropriate models which would consider the proposed requirements.

Thus, an analysis of the literary sources demonstrated that in order to implement quality standards in EI, the proposed model must take into account: basic provisions of these standards, the main business processes of EI and the allocation of involved resources for these processes. It enabled us to propose a parametric model of evaluation and prediction of the quality level of educational institution with regard to the international standards of quality management and a process-oriented approach to the activities of EI.

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## 3. The purpose and objectives of the study

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The purpose of the study is the development of model for prediction and evaluation of the quality level of the processes of educational institution and its work as a whole based on the multilevel and multifactorial structure of processes.

To achieve this goal, the following tasks were formulated:

- to analyze existing groups of processes according to the standards of project management and recommendations to use the system of quality management in educational institutions to create the multilevel structure of processes on their basis;
- to define the structure and parameters of the parametric model of predicting the level of quality of the work of EI;
- to conduct expert assessment of threshold values and weights of impact of the parameters on the processes with the analysis of sufficient quality and quantity of experts for evaluation and calculation of consistency in the experts' estimates and indicators of their weight;
- to develop the degrees of assessment of the quality of work of the processes, as well as to design verbal evaluation for each process on their basis.

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## 4. Research methods for building a parametric model

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The basis to build the structure of the processes in a parametric model for educational institutions was formed by the standard of project management [19], the requirements to the quality management system and recommendations to use the ISO 9001 standard in education [2]. Despite the fact that these standards and directives do not define specific processes and their influence on each other, their application made it possible to construct a parametric model of the prediction and evaluation of quality of educational institutions,

which defines the structure of EI processes and parameters that affect them.

According to the standard of project management, the analogue of levels is the groups of processes by the following list: initiation, planning, execution, monitoring and control, finish [19]. According to the instructions of DSTU on the ISO standards application, the institution of higher education appoints appropriate group for control: analysis of education needs, education design, education development, education provision, assessment of education, developing the structure of professors and lecturers, the operation of libraries, workshops and laboratories [2].

An important chosen method of research into identifying parameters of influence of certain processes on other processes is the expert assessment of the weight of influence of some processes on other processes [20]. This evaluation enabled us to identify not only the list of parameters but their threshold values and impact weight.

The evaluation of quantitative composition of experts may be determined based on the studies of statistic and heuristic approaches. For the research, a statistical method is chosen, which also has two options of research:

- using the results of applied statistical analysis, experts are selected to the group whose answers give the optimal value by the chosen criterion of quality of clustering, for example, minimum r.m.s. deviation in their answers in the test interview from the arithmetic mean of their group evaluation;
- using the results of the theory of probability of generating a random value, in particular from the Chebyshev inequality [21].

The second method was chosen for the analysis because the experts' assessments correspond to the samples of random values from the theory of probability.

For the analysis of the quality of expert evaluation, different methods were analyzed [20] and the method was chosen of evaluation of vector of competence of experts based on the minimization of deviation of the individual judgment of an expert from the average result of the group. This method of evaluation allows obtaining data on the competence of experts based on information about their a priori assessments of alternative choice. The results can be obtained also from test examples or results of participation of experts in earlier examinations.

For the analysis of consistency of the experts judgments, the method of statistical analysis was selected using the calculation of concordance coefficients, evaluation of the level of alignment of experts opinions by the Margolin and Harrington scale and significance of evaluations by the Pearson criterion.

**5. Description of the structure and properties of the parametric model for predicting the quality level of work of an enterprise**

In the course of analysis and comparison of the groups of processes according to the standard of project management and the standard of Ukraine according to the instructions for the application of the ISO quality standards in education, 19 processes, divided by 7 levels, were selected for the parametric model (Table 1).

The structure of the parametric model is created based on the levels of processes, which are predetermined by a

sequence of processes execution when creating a new project of educational institution.

**Table 1**  
The levels of processes of the parametric model in comparison with the recommendations of project management and the instruction of DSTU for institutions in higher education

Recommendation of project management	DSTU instructions for HEI	Levels of processes of the parametric model	Processes of the parametric model
Initiation	Analysis of needs in studying	1. Analysis	1. External links 2. Publicity and public relations
Planning	Design of studies	2. Projecting	3. Development of plans and programs for studies 4. Economic design 5. Quality management system
	Developing of studies and structure of staff	3. Planning	6. Documentation planning 7. Planning of material procuring 8. Planning of staff management
Implementation and management	Studies provision	4. Support	9. Technical support 10. Maintenance support 11. Information support
		5. Management	12. Documentation management 13. Organization of students enrollment 14. Studies process management 15. Staff management
	Functioning of libraries and laboratories	6. Implementation	16. Studies 17. Scientific activity 18. Educational activities
Monitoring	Study assessment	7. Analysis	19. Analysis of indicators. Reporting

**5. 1. Initial parameters**

To create a parametric model of prediction of the quality level of an educational institution, it is necessary first to identify the most important factors of influence on the first level. These factors will become the initial level (baseline point) for the influence on all the processes in an educational institution. There are many factors that could affect the level of work of educational institution (EI). However, some of them do not exert critical impact while some are very important.

Let us define the most important external factors that will make up the set of initial parameters for a new EI project. We identified three basic initial factors as the initial parameters of the model:

- the initial level of material resources;
- the initial level of human resources (managers, founders);
- availability of necessary documentation for setting up EI;

The initial level of material resources plays one of the most important roles for the possibility to create the most

favorable conditions for the activity of all the staff and conditions for teaching students. This level may vary in the process of EI operation.

The initial level of human resources (managers, founders, lecturers and other employees) defines all issues of the initial management for the proper planning of material and human resources, the documented information and strategy of the whole enterprise and further operations.

Availability of necessary documentation is also an important factor, because without it, it is impossible to create EI at all. Documented information is the basis of all inter-relations of the staff between each other and between the students and their parents, it regulates the rules of these relations and the requirements for each other, determines compensation and punishment, it is the basis for reporting and analysis. This information penetrates all processes in EI from top to bottom. That is, a low level of documented information may lead to a decrease in the level of quality of work of EI.

Initial settings do not only affect all other processes of EI but are constantly changing based on the activity of all processes at the second and other circles of the execution of processes. Therefore, in the structure of the processes they are defined as the processes of the initial level – zero, but, unlike other processes, their initial quality level is not calculated in the first circle but evaluated by the authorities of the institution. In the second and other circles, the quality level of initial parameters is also calculated.

**5. 2. Determining the interaction of processes in the model**

Each process in the structure is exposed to the impact from other processes and it itself influences others. The initial settings are the input parameters for the first level of processes and for others. The calculated quality level of each process becomes an input parameter for other processes that it affects. Thus, the input parameters for the given process are the quality levels of the processes that affect the given process.

All processes affect other processes with the calculated weight. These weights are set with the help of expert evaluation when developing the model. The total of the weights of influence of all processes on a single process is equal to one.

To determine the weights of influence of the processes on each other, the analysis of each process was performed, as defined in Table 1, as well as the structure of its interaction with other processes.

For example, let us analyze the structure of the interaction of the process “External relations” (Fig. 1) with other processes from Table 1.

The process “External relations” establishes relations with different organizations and enterprises, examines their experience in doing business and management of documentation, creates conditions for the expansion of activities in different directions, to increase market of applicants and improve the image of EI. The costs for cooperation and interaction with other businesses are paid for by the creation of new conditions for work and study, new ideas in management and execution of any processes, promotion of its activity, obtaining experience or advice in any field.

This process depends in the beginning of the project mainly on human resources [22]. Human resources of management particularly determine the level of such links in the beginning of the project. In future, its quality level also will

depend on the quality level of the entire EI and on the efficient promotion and public relations, but these are reverse options that begin to act in the 2nd and other circles of calculation of the quality level.

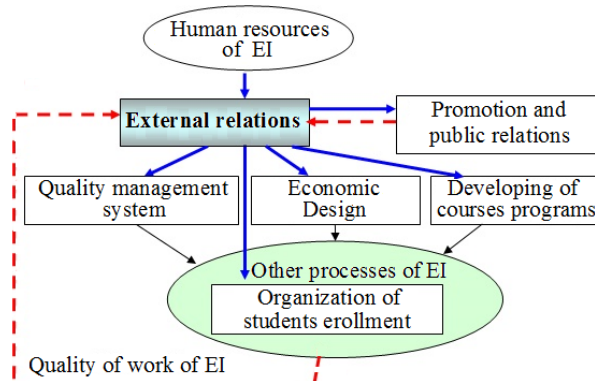


Fig.1. Structure of influences of the process “External relations”

The quality of work affects the image of EI and this influences the desire of authorities of external enterprises and their deputies to communicate and cooperate with an institution. It expands relations and affects their level. Efficient publicity and public relations also spread information about EI and contribute to the expansion of external relations in future [23].

In turn, external relations enhance the management experience of the institution authorities and extend the possibilities of various activities and cooperation. Thus, the process of external relations creates conditions for the development of the documented base of the next level – designing the quality management system (QMS), curriculums and programs, as well as economic projecting.

In the consequent work of EI, external relations also influence directly the process of students enrollment, because these relations expand the market of applicants, as well as increasing publicity process creates new opportunities for publicity and public relations.

**5. 3. Expert evaluation of threshold values and weights of influence of parameters on the processes**

After an analysis of the relations of each process, the table – questionnaire is created to determine the weights of influence on the process from other processes (input parameters).

For example, the form of the questionnaire may be individual for each process (Fig. 2).

Process that affects	% of the influence	Other
material resources		
human resources		
documented information		
external relations		
publicity and public relations		
...		

Fig. 2. Questionnaire of the evaluation of weights of influence on a single process

In this questionnaire, in the column “% of the influence”, the cells without a filler are selected to enter the weights of



influence (coefficients); in the column “Other” there is a possibility for an expert to add the weights for other processes that are not defined by the developer of the model.

This questionnaire is not very convenient because it is needed to print many forms for each process and for each expert. Moreover, the expert should calculate by himself the total of weights so that it is equal to one.

Taking it into consideration, an electronic questionnaire is proposed, which is provided in the form of MS EXCEL table, where all the processes are evaluated at once and the amount of weights and deviation from them are calculated automatically (Table 3). In addition, it is proposed to fill the thresholds for each process in the electronic table simultaneously (the first column in Table 2).

Table 2

Electronic questionnaire for the expert to evaluate the thresholds and weights of all processes

Sign	Processes	Threshold	b1	b2	b3	p1	...
–	Total impact	–	1.00	1.00	1.00	1.00	...
–	Deviation from 1	–	0.00	0.00	0.00	0.00	...
b1	material resources	0.4	0.00	0.00	0.00	0.00	...
b2	human resources	0.6	0.00	0.00	0.00	0.5	...
b3	Documented resources	0.3	0.00	0.00	0.00	0.0	...
p1	external relations	0.3	0.00	0.00	0.00	0.0	...
p2	Publicity and public relations	0.4	0.3	0.2	0.0	0.2	...
...	...	...	...	...	...	...	...

5. 4. Statistical analysis of the expert evaluation

After filling in the questionnaire, the statistical analysis was conducted.

We performed three consistent actions for the statistical analysis:

- defining sufficient number of experts;
- analysis of quality of the experts;
- calculation of the consistency of experts judgments.

Defining sufficient number of experts was conducted taking into account results of the theory of probability under different conditions of generating a random value and the Chebyshev inequality

$$n_{min} \geq \frac{\sigma^2}{(1-p)\epsilon^2}, \tag{1}$$

where  $\sigma^2$  is the testing value of dispersion of experts estimations;  $\epsilon$  is the limit error of estimation, which is set a priori;  $p$  is the probability of coincidence (more precisely not less than) of the true estimation, average by a group.

The limit error of evaluation of each parameter is equal to 0.05, and a probability of matching the true estimation with the average one in the group will equal  $1/20=0.05$ , where 1 is the maximum value of estimation and 20 is the number of estimation options with the error 0.05. The calculation of the minimum number of experts by this method determined that this number for all parameters varies in the range from 2 to 7, that is why 7 experts were selected for the expert assessment.

An analysis of quality of the experts was performed based on the calculation of coefficients of the experts’ competence  $q_i$  by the following calculations:

1) initial values of coefficients of competence of all experts are set the same and equal to  $1/7$  (7 is the number of experts);

2) the averaged vector of group estimation of comparative alternatives is calculated at the t-th iteration of calculations (2).

$$x^t = Xq^{t-1}, \tag{2}$$

where X is the output matrix of estimation of all alternatives of comparison with each expert, where:  $x_{ij}$  is the evaluation of the i-th parameter performed by the j-th expert by interval scale;  $i = 1, m$  is the index of a parameter, m is the number of parameters;  $j = 1, n$  is the index of an expert, n is the number of experts;  $q^t$  is the competence vector of expert at the t-th iteration of calculations.

In turn, the next iteration calculates a new vector of coefficients of experts competence  $q^t$  (3).

$$q^t = X^T x^t. \tag{3}$$

The iterations are calculated until the values  $q^t$  and  $x^t$  are stabilized. The obtained results provide information on the experts competence.

For the model of processes of an educational institution, the results of evaluation of 7 experts were analyzed by 23 indicators and we received rather sufficient coefficients of competence for accepting them in further calculations (Table 3).

Table 3

Example of evaluation of experts competence

Parameters	expert 1	expert 2	...	expert 7
material resources	0.1448	0.1181	...	0.1554
human resources	0.1409	0.1252	...	0.148
Documented information	0.1402	0.1488	...	0.1406
external relations	0.1417	0.1374	...	0.1478
Promotion and public relations	0.1379	0.1336	...	0.1533
Developing of curriculum	0.1496	0.1399	...	0.1412
...	...	...	...	...

$$W = \frac{S}{\frac{1}{12}m^2(n^3 - n) - m \sum T_i}, \tag{4}$$

where

$$S = \sum d^2; d = \sum x_{ij} - \frac{\sum \sum x_{ij}}{n},$$

where m is the number of experts, n is the number of parameters;  $x_{ij}$  is the evaluation of the i-th parameter by the j-th expert.

As a result of calculation, we obtained predominantly medium results of consistency (Table 4).

Table 4

## Coefficients of experts consistency

Group of indicators	CC	M	H	PC	TV	CV
Material resources	0.69	Mod	H	16.18	9.49	Yes
Human resources	0.63	Mod	Med	17.05	11.07	Yes
Documented resources	0.53	Mod	Med	11.74	9.49	Yes
External relations	0.46	Wk	Med	5.23	5.99	No
Publicity and public relations	0.17	vW	vL	2.00	7.81	No
Development of curriculum	0.57	Mod	Med	12.56	9.49	Yes
Economic projecting	0.76	H	H	17.64	11.07	Yes
Quality management system	0.80	H	vH	23.39	11.07	Yes
Documentation planning	0.06	Abs	vL	0.95	7.81	No
Planning of material procurement	0.38	Wk	Med	8.18	9.49	No
Planning of human resource management	0.73	H	H	11.11	7.81	Yes
Technical support	0.81	H	vH	17.83	9.49	Yes
Maintenance procurement	0.69	Mod	H	15.13	9.49	Yes
Information support	0.72	H	H	15.13	9.49	Yes
Documentation management	0.52	Mod	Med	16.43	12.59	Yes
Organization of students enrollment	0.55	Mod	Med	18.29	14.07	Yes
Study management	0.52	Mod	Med	13.63	11.07	Yes
Staff management	0.48	Wk	Med	12.40	11.07	Yes
Scientific activity	0.54	Mod	Med	15.67	14.07	Yes
Study	0.61	Mod	Med	17.06	14.07	Yes
Educational activity	0.54	Mod	Med	18.30	14.07	Yes
Analysis of indicators. Reporting	0.51	Mod	Med	13.94	14.07	No
Quality level of work of educational institution	0.78	H	H	10.14	5.99	Yes

Notes: *Mod* – moderate; *Wk* – weak; *Abs* – absent; *H* – high; *vW* – very weak; *Med* – medium; *vH* – very high; *vL* – very low; *yes* – important, *no* – unimportant; *CC* – concordance coefficient; *M* – Consistency by the Margolin scale, *X* – Concordance by the Harrington scale; *PC* – the Pearson Criterion; *TV* – Tabular value; *CV* – Coefficient Value

### 5. 5. Evaluation degrees of quality of work of the processes

For the implementation of the developed model, it is necessary to compare the predicted quality level of work of the institution and its processes with the assessment of this quality level for particular educational institutions and to determine an error of prediction for a particular institution. For further application of the developed model, it is also necessary to develop information system to implement this model by educational institution with the possibility of its adjustment taking into account the specific features of the particular educational institution and evaluation of the quality level of basic processes and the work of the educational institution as a whole.

According to the ISO 9004 system, the efficiency of quality management system can be assessed by each section (process) by a 5-point scale, which reflects degrees of efficiency of the system indicators for the self-assessment of quality (Table 5).

Table 5

## Quality Degrees (QD) of indicators of functioning of the processes according to the ISO standards

QD	Indicator degree	Specification
1	No formal approach	No evident formal approach
2	Reaction approach	Systems approach based on the elimination of problem or correction, minimal data on the results concerning improvement are available
3	Stable formal systems approach	Systems approach based on processes; the initial stage of systems improvements; data on compliance with the goals are available, as well as existence of trends towards improvement
4	Concentration on permanent improvement	They use the process of improvement, good results and constant trends for improvement
5	The best indicators	Actively integrated process of improvement; the best results by comparative assessment demonstrated

But this table provides a rather formal approach to the evaluation of processes. That is why for each process it is necessary to develop similar quality assessment taking into account the peculiarities of each process.

In the course of development of the assessment, it is necessary to take into account the requirements of the ISO 9001:2015 standard for the analysis and evaluation of quality of the organization, which defined that an educational institution (EI, in the standard of the organization) must conduct monitoring of how customers perceive the degree of fulfillment of their requirements, must receive information about attitude of the users to the educational institution and the quality of education, their thoughts about EI.

The means of obtaining and using this information must be put in place (defined) by the educational institution taking into account its peculiarities.

It is also necessary to consider using these assessments and analysis for:

- compliance of education quality with the requirements;
- evaluation and increase in satisfaction of the users of educational services;
- ensuring the results and conformity with the quality management system;
- demonstrating that the plans are successfully implemented;
- evaluation of the indicators of functioning of the processes;
- evaluation of the indicators of functioning of the processes of external suppliers;
- detection of necessity and possibilities for improving the processes.

These requirements should be reflected in the explanations to the verbal scale of evaluation. For most employees of the institution, verbal evaluation is preferable among the evaluation tools than the digital [20].

Using 5 steps of the evaluation simplifies the questioning process but reduces the accuracy of evaluation to 20 %. In order to compare with the results of parametric model, it is necessary to increase the degree of accuracy to 10 %. It is

predetermined by expert assessment of the threshold values that are evaluated by the experts in values from 0 to 1 with accuracy, mostly, to 0.1 and only some – to 0.05. That is why the accuracy of the scale is mainly 10 %. Quality level in the lowest accuracy is also evaluated to 0.1, which is 10 % of the total scale for assessing the quality level of work of the processes (from 0 to 1).

That is why for evaluation it is advisable to apply the scale of 10 degrees of quality (Table 6).

Table 6

Degrees of evaluation of the level of work of the processes according to parametric model

QD	Indicator degree	Specification
1	No formal approach	There is no formal systems approach to requirements and quality management process. Influences on the quality of the process are random
2	Formal approach is random and partial	There is no obvious formal approach, and there are only a few individual cases of systematization of the quality management
3	Partially reacting approach	Systems approach, which is based only on the elimination of problems. No data on improvement
4	Reacting approach	Systems approach to the elimination of problems and correction of the most important actions; minimal data on the results concerning the improvement are available
5	Stable partial formal systems approach	Systems approach, which is based on processes; the initial stage of systematic improvements, but there are deviations from systematization, there are no existing data on compliance with the goals and existence of trends towards improvement
6	Stable formal systems approach	The initial stage of systematic improvements is implemented; data are available on compliance with the goals and existence of trends towards improvement
7	Planning of constant improvement	They planning the process of improvement but the fulfillment is not always good. There is a process of improving the implementation
8	Concentration on constant improvement	They apply the process of improving, good results and stable trends to improvement
9	Very good indicators	Integrated process of improvement but not always actively; demonstrated very good results by the comparative assessment
10	The best indicators	Actively integrated process of improvement; demonstrated the best results by the comparative assessment

This scale of evaluation was integrated for each process taking into account its features. Some processes are grouped according to their levels.

For example, for the processes of the level “Procurement”, the questionnaire of the same type was designed because the processes of economic, technical and informational support have similar quality assessment. For the processes of procurement, the quality requirements were designed, which are defined by the following parameters:

– fulfillment of all requirements to the quantitative provision of all parts of EI;

- fulfillment of all requirements to the qualitative provision of all parts of EI;
- efficiency of spending of planned funds;
- existence of strategy for efficient purchasing;
- existence of documented substantiation of a chosen provision;
- planning of means of searching for the efficient suppliers;
- systems approach to improving the allocation and servicing of available resources;
- monitoring and analysis of indicators of provision.

Based on these indicators, the questionnaires for the evaluation of quality of the provision processes were developed (Table 7).

Table 7

Significance of evaluation of quality of work of the provision processes

Grade	Specification
0.1	Provision does not meet the requirements. There is no any strategy for efficient provision. There is no description of purchasing and its justification. Analysis of provision indicators is missing
0.2	Provision hardly meets the requirements. Random means of searching for efficient suppliers are present. There is no evident systems approach to procurement planning and means of provision as well and there are only some separate actions to improve its quality
0.3	Provision partially meets the requirements. There is a partially systems approach to planning purchases and means of procurement. Means of search for efficient suppliers are partial
0.4	Provision meets only the main requirements. There is a partial strategy and efficient systems approach to provision. There is a low level of substantiation of purchasing and means of procurement
0.5	Provision meets basic requirements but there are some drawbacks. There is strategy and stable systems approach to provision, based on planning its quality and its systematic improvement but there are certain deviations from the systematization
0.6	Provision meets basic requirements at a good level. There is a reasonable strategy and stable systems approach to the organization of provision. Monitoring of the majority results of provision is implemented
0.7	Provision meets basic requirements at a very good level. There is a process of improving and expansion of actions to increase the quality of provision. There is a sufficient quality level of substantiation of purchases and means of provision
0.8	Provision absolutely meets basic requirements. There are a large number of diverse, long-term means of improving the quality of provision and obtaining permanent good results from them. There is a quality level of substantiation of purchases and means of provision
0.9	Provision absolutely meets basic requirements and there are certain additional proposals. The process of improving the system of provision is integrated. New and efficient means of improving the quality are constantly introduced
1.0	Provision absolutely meets basic requirements and there are constant additional proposals. The process of improving the system of provision is actively integrated. Active process of constant search for new and efficient means of improving the quality of provision is implemented. There is a high level of substantiation of procurement and means of supplying

Similar questionnaires were developed for each process and resource.

### 6. Discussion of results of research into developed model

The research into the structure of processes was carried out based on the process approach and international quality standards. The designed structure is not final. It identified the most common processes, but it can vary for different types of educational institutions.

As a result of the studies we created the structure of the processes (Fig. 3), which has 7 levels of processes according to the sequence of their execution. The structure of the processes also includes relations between the processes that determine the impact of some processes on others (the impact parameters). If the structure of the processes changes, then the system of the impact parameters should also change.

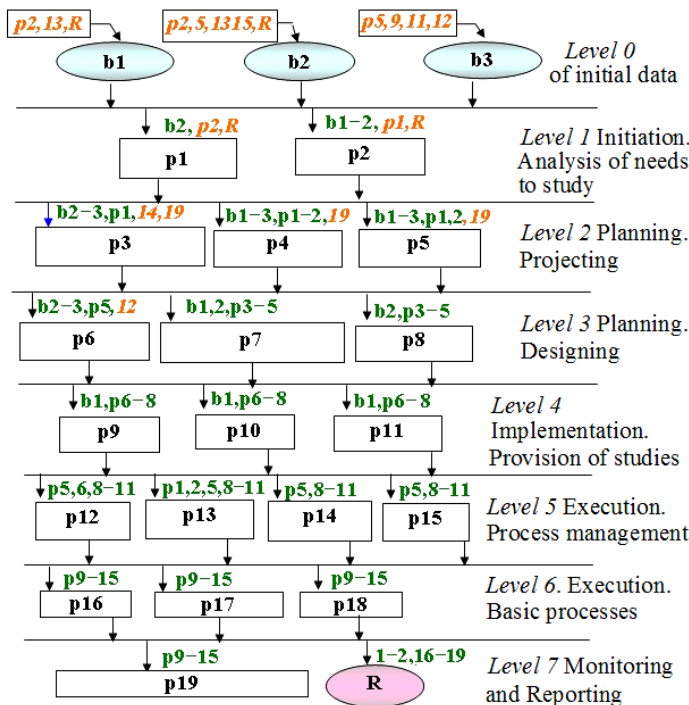


Fig. 3. Structure of processes, their levels and flows of parameters

Fig. 3 demonstrates: b1 – material resources, b2 – Personnel resources, b3 – Documented information, p1 – external relations, p2 – Advertising and public relations, p3 – Development of study plans and programs, p4 – Economic Projecting, p5 – Quality management system, p6 – Planning of documentation, p7 – Planning of material provision, p8 – Planning personnel provision, p9 – Technical support, p10 – Maintenance provision, p11 – Information support, p12 – Documentation management, p13 – Organization of students enrollment, p14 – Study management, p15 – Personnel management, p16 – Scientific activity, p17 – Teaching, p18 – Educational work, p19 – Analysis of indicators. Reporting, R – the level of quality of work of educational institution.

As a result of all of the above performed actions, we developed a parametrical model of the processes of educational institution, based on which it is possible to predict the quality

of work of the processes by the function of calculation [1]. This function (5) was modified:

$$V_{jk+1} = V_{jk} + \begin{cases} L_{ji} \geq N_{ji}; (1 - V_{jk}) \cdot \sum_{i=1}^k \frac{L_{ji} - N_{ji}}{1 - N_{ji}} \cdot P_{ji}, \\ L_{ji} < N_{ji}; V_{jk} \cdot \sum_{i=1}^k \frac{L_{ji} - N_{ji}}{N_{ji}} \cdot P_{ji}, \end{cases} \quad (5)$$

where k is the number of iteration;  $L_{ji}$  is the value of quality level of the i-th input parameter of the process  $PS_j$  ( $i=1 \div k$ ,  $j=1 \div m$ );  $N_{ji}$  is the threshold value of quality level of input parameter;  $V_{jk}$  is the quality level of the process  $PS_j$  on the k-th iteration;  $P_{ji}$  is the weight of the i-th input parameter on the process  $PS_j$ ;  $V_{jk}$  on the first iteration equals the threshold value of the process  $PS_j$ .

In addition to forecasting the quality, it is possible by using the developed questionnaires to carry out assessment of quality by the real results of activities of an educational institution at the end of any teaching period (semester, academic year, etc.).

The compiled assessment can be compared with the results of previous forecasting (at the beginning of the period). This comparison will provide new facts for improving the parametric model of prediction of the level of quality of educational organization. The quality assessment can also be used not only for the comparison with prediction, but separately to determine the bottlenecks in the work quality of processes.

### 6. Conclusions

Thus, to enhance the efficiency of implementation of quality standards in EI, we proposed a parametrical model of estimation and prediction of quality level taking into account international standards of quality management and process-oriented approach to the activities of EI.

1. To create the model, the appropriate levels of processes of parametric model were compared to the level of processes according to recommendations of the project management and instruction of DSTU for educational institutions.

2. We examined relations of each process with other processes (Fig. 2), defined direct and reverse links between processes, which mean transfer of parameters between them.

3. To determine the weights of influence of each parameter on specific process and threshold values of processes, we conducted an expert survey. For this purpose we developed electronic questionnaire (Table 2) that automates the process of calculating the sum of the weights per one process and deviation from it. The performed analysis of a sufficient number of experts, which was performed using the Chebyshev inequality, revealed a sufficient number of experts for the evaluation with limiting error of 0.05. The analysis of sufficient quality of experts employed iterative calculation of coefficients of competence, which shows the deviation from the averaged vector of group estimation of each expert.

4. We proposed 10 stages of real assessment of quality level of the processes, which made it possible to carry out a



comparison of the actual indicators of quality of EI with the forecasted ones and to identify problematic processes based on questionnaires of quality evaluation of each process of educational institution by the end of the stages of studying: semester or academic year.

Thus, a developed parametrical model for forecasting and assessing the quality level of the processes of educational institution and its work as a whole based on the multilevel and

multifactorial structure of processes enables us to conduct proactive management of resources allocation at EI and ensure the quality of educational services at EI. For realization of the parametric model, Authors can create information system containing 3 blocks: creating and adjusting the parametric model, forecasting quality level of the model's processes and actual assessment of the level of quality of work of educational institution.

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*Визначені основні різновиди вибірок для елементів залягання тріщин покладів лабрадोरиту та обґрунтовані оптимальні методики кластерного аналізу. Досліджено взаємозв'язок між кількістю тріщин в системі та їх просторовою орієнтацією для оптимізації вибору напрямку розвитку гірничих робіт. Для оцінки перспективності розробки родовищ або окремих ділянок запропоновано нову кластерно-геометричну методику визначення блочності*

*Ключові слова: кластерний аналіз, декоративний камінь, тріщинуватість, блочність, орієнтування фронту видобувних робіт*

*Определены основные разновидности выборки для элементов залегания трещин месторождений лабрадорита и обоснованы оптимальные методики кластерного анализа. Исследована взаимосвязь между количеством трещин в системе и их пространственной ориентацией для оптимизации выбора направления развития горных работ. Для оценки перспективности разработки месторождений или отдельных участков предложена новая кластерно-геометрическая методика определения блочности*

*Ключевые слова: кластерный анализ, декоративный камень, трещиноватость, блочность, ориентирование фронта добычных работ*

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# CLUSTER ANALYSIS OF FRACTURING IN THE DEPOSITS OF DECORATIVE STONE FOR THE OPTIMIZATION OF THE PROCESS OF QUALITY CONTROL OF BLOCK RAW MATERIAL

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## 1. Introduction

When developing the deposits of decorative facing stone, the economic efficiency of mining to a large extent will

depend on the effectiveness of management of technological processes. According to the results of research into approaches to the process of extraction of blocks of decorative stone [1–8], the efficiency of application of separate