Відомі методи формування узагальнених показників якості діяльності освітніх закладів, як правило, передбачають усереднення багатьох параметрів. Такі технології не враховують різнорідність показників, які неможливо узагальнити єдиним показником. Параметрична формалізація освітньої системи на основі моделювання дозволяє перейти до багатофакторної оцінки якості, що створює умови для проактивного удосконалення та поліпшення діяльності освітніх закладів

Ключові слова: освітні заклади, оцінка якості, проактивне управління, декомпозиція, моделювання, узагальнені показники

Известные методы формирования обобщенных показателей качества деятельности образовательных учреждений, как правило, предусматривают усреднение многих параметров. Такие технологии не учитывают разнородность показателей, которые невозможно представить единственным показателем. Параметрическая формализация образовательной системы на основе моделирования позволяет перейти к многофакторной оценке качества, что создает условия для проактивного совершенствования и улучшения деятельности образовательных учреждений

Ключевые слова: образовательные заведения, оценка качества, проактивное управление, декомпозиция, моделирование, обобщенные показатели

UDC 005.8
DOI: 10.15587/1729-4061.2016.66562

DEVELOPMENT PROCESS MODELS FOR EVALUATION OF PERFORMANCE OF THE EDUCATIONAL ESTABLISHMENTS

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1. Introduction

Today, much research is conducted in the field of project management and quality analysis of the already operating companies.

The elaboration of the general concept of forecasting the future quality of work is important for Ukraine, where many organizations are created and constantly change in the course of development. The managers of those organizations have no tools to predict the future development and act at their own discretion. The development of a specific model based on the general concept will help managers to develop a correct process structure, allocate initial resources (initial parameters) and analyze the future quality of the organization.

The general concept is based on international quality management standards using a process approach when the organization project is divided into individual interrelated processes. Processes and relationships between them create a special structure of each company. This structure is an important part of the model of specific organization and evaluation of the projected quality of its work.

However, the projected quality depends not only on the structure of processes, but also on various parameters that affect them. An educational institution may have its own vector of these parameters with various impacts on each process. The general concept offers the means to normalize these parameters and the general function which uses them to evaluate the quality of each process.

The general concept describes the basic construction principles of the process structure, the system of normalized parameters and the process quality evaluation function based on relationships between processes and the impact of various parameters.

2. Literature review and problem statement

The process approach to the management system when the entire organization system is divided into individual processes, interconnected by the document information transmission system has become widespread. The process structure can be based on various management schemes. The general management scheme should be based on the key quality control standards and apply the scheme: Plan → → Do → Check → Action [1].

Specific recommendations on the use of general quality standards are developed for different types of companies. So, when developing a management system for educational institutions, one should consider recommendations on the use of the ISO 9001 standard in the field of education [2], which focus on the document management, managers' responsibilities, resource management, as well as performance measurement, analysis and continuous improvement of management and educational systems.

The ISO 9001 principles in the field of education are consistent with the recommendations of the European Group for quality assurance in higher education [3], which have summarized the experience and issued the recommendations for both internal and external quality assurance and highlighted the recommendations for quality assurance agencies. These same principles in different aspects are considered in [4, 5] and others.

However, these principles do not cover the managers' problems – whether they developed a correct structure of the educational institution according to these requirements and how to test the future quality of the organization in view of the developed process structure? Other systems should assist in verifying the allocation correctness of these processes and their relationships.

Furthermore, it should be noted that many studies consider the relations between processes only as document information flows [5], and recurrence of these flows is observed. Based on these studies, the conclusion about the effectiveness of the entire system is drawn. However, the process structure effectiveness should be analyzed not only in terms of document information flows between the organization processes, but also other parameters that affect the quality of each process and the entire company.

The parameters that affect the process quality depend on various aspects of quality, which are examined in different works. For example, for machine-building companies [6], the following were considered:

– consumer quality, determined by market research and consumers;

– quality, determined by the design, depends on the company designers;

– quality as the product compliance, provided by the product control;

– quality, determined by maintenance.

However, there are many organizations, such as educational institutions, for which quality is determined not only by material and intellectual values, maintenance and control, but, for example, psycho-emotional aspects, social position and motivation of students, team management [7], etc.

Therefore, the general concept considers the vector of parameters in the overall normalized form, not associated with a particular company. This vector is specified when developing the educational institution model for based on quality aspects of educational institutions.

Selection of parameters that affect the process quality is also a difficult task. Only by experts in their field can do it. The work [8] considers the methods for estimating the factors of influence on the company quality and the implementation of the quality management system in terms of priority of these factors. But the selection of factor in terms of priority is not enough for a comprehensive quality assessment, because not only priority, but also the value is important.

Also, the quality of management and the entire company can be affected by various types of organizational culture [9], process intermediaries (SPC), lean production (LP) [10], and other factors. But are these factors principal or optional to affect the organization quality? The studies do not give any answers. The general concept does not specify what parameters should be considered in the evaluation of the predicted quality of the organization. Therefore, two evaluations can be done for the educational institution model, rejecting or involving these parameters. The difference of the estimated quality, which points to the importance of this parameter for evaluation will be obtained after comparing the evaluations.

3. Research goal and objectives

The goal of the research is to develop the general concept for developing various quality forecasting models of organizations based on their process structure and normalized system of parameters that affect their quality, including educational institutions.

To achieve this goal, the following tasks were set:

– to analyze existing methods and tools for creating process structures, describe the structure development strategy and selection rules of processes;

– to identify the main types, selection and normalization rules of parameters and their influence on processes;

– to develop the function for the quality evaluation of each process and the entire company depending on the parameters and their influence on processes;

– to determine the requirements for the information system of the quality forecasting of the educational institution and information collection about the actual performance.

4. Research methods for constructing the general concept

The concept of the process approach, defined in the international quality standards is the basis of the research to create the general concept of quality forecasting of the educational institution [1]. The proposed model is also based on the structure of processes, selection of which is performed according to the recommendations of the Project Management Institute [11].

An important method of research is the determination of the parameters of influence on processes. The studies in [12], which identified three types of parameters were used to develop the model of parameters.

Creating tables of weight values of parameters influence and threshold values of quality is an important part of research. The parametric model is developed using the method for determining the weight values of parameters influence on processes based on experimental survey data, which is described in [13].

The proposed general model can be used in various activities of companies, but the model of the educational institution should consider the main development stages of company management projects [14]:

– determining the type of the organization and the way its structure can affect the project management;

– coordinating business goals with project goals;

– determining the difference between the product (service) lifecycle and the project lifecycle;

– determining the project initiation and why it is important;

– determining roles in the project initiation;

– understanding of how the project is created;

– understanding what is a key role of project planning for its success and what tools to use and others.

To develop the educational institution management model, it is necessary to form basic strategic objectives first and create the structure of management, processes and parameters according to them.

Particular attention should be paid to the quality indicators and performance of the educational institution, the structure and evaluation of them have a crucial role in the whole management process.

The quality management system, which is responsible for the company quality and involves a parametric model for the company quality forecasting should be developed in the model for the quality forecasting and analysis of the educational institution to analyze the quality of its actual activity and adjust the management structure.

5. Description of the structure and properties of the parametric model for the company quality forecasting

The quality of each company is determined by its strategic goals. Typically, the main strategic goals of each company are:

– maximum quality of services or products (quality of work);

– maximum profit at minimum cost (efficiency of work).

Those opposed, but united and strategic goals should be a guideline in determining the process lists and the parameters of the company.

The general concept of the parametric model development for the company quality evaluation and forecasting, its structure and properties are described below.

5. 1. The strategy of creating the list of processes and the structure of their influence on each other

The high-quality structure of processes is very important for the allocation of responsibilities, creation of instructional and reference information, operational management of all the structure links and achieving a high quality of the company.

The entire structure of the company, as the management structure should consist of a few links – processes. The project management standard identifies the following groups of processes [11]:

– project management;
– initiation;
– planning;
– implementation;
– monitoring and management;
– completion.

It is desirable to follow these recommendations when determining the process list. However, each company depending on its scale and activity can combine some groups of processes in a single process, and some groups may have several processes.

The process list can be determined by one of the primary company processes – Quality Management System (QMS). If the company is just created and its structure is determined, the function of QMS can be performed by the founders meeting and the head. This process may involve experienced experts in the relevant field. For example, the principles of quality management system for the educational process are determined and the process map of higher education institutions in terms of quality management processes is proposed in [6]. This research can be used to create the process structure for higher education institutions.

It is important to rely on the international experience in project management and modern information technologies. The creation of the process list and its structure is guided by the international standards ISO 9001 [1].

The process list can be initially created by managers, and then adjusted by specialists. The general factors that influence the company quality and performance can be analyzed first to create the process list. These factors are reference points in the process list creation.

For example, the list of factors for the educational institution (EI) can be as follows:

– EI management structure;
– document management;
– economic planning;
– accounting;
– advertising;
– reception;
– personnel management;
– work with documents and storage (efficiency, convenience, ...);
– educational process organization;
– educational, scientific and creative work;
– office management (quality of premises and materials);
– technical support;
– information support;
– cooperation with other companies;
– educational market requirements;
– legal and MES requirements;
– convenient location of EI and others.

In analyzing these factors, those can be identified that depend on the EI management (managed) and those that do not (not managed). Only managed factors will be used to improve the EI management. For example, "Educational market requirements", "Legal and MES requirements", "Convenient location of EI" are not managed, and others are managed. All parameters are used to create the process model for the quality forecasting, and only managed parameters – for the efficiency analysis.

The projected quality of the company will be evaluated based on the management structure of processes and all major parameters of influence.

Some factors can be combined in a single process if they depend on the same parameters, and as a result get the same quality parameters.

5. 2. Parameters of influence on processes

Each process has a set of input parameters (call them A_1, $A_2 \ldots A_K$), which are transmitted to it from other processes or are initial. These parameters affect the process quality. Each parameter has a factor of influence on the process quality – the parameter weight. The weight of each parameter on the process is determined by the value from 0 to 1. Let's denote the weight of each parameter P_{ji} ($i=1\div k$) for the process PS_j ($J=1\div m$). For normalization we assume that the sum of the weights of all input parameters on a process PS_j will be equal to unity:

$$\sum_{i=1}^{\kappa} Pji = 1. \qquad (1)$$

The weight of parameters can be estimated by various methods. One of them is presented in [13], which uses the method based on experimental survey data and estimates the evaluation error. The normal law of distribution of random variables and the maximum allowable standard error of evaluation with the known expressions of mathematical statistics are used for the error evaluation. Calculation of transition probabilities was performed according to the survey results during promotions.

The parameters, in turn, also have specific values (parameter quality) at the process input. Various parameters may have different values and different units of measurement of these values. But for the analysis of the entire company management structure, it is important to summarize these values in a single system – to normalize. For normalization, the value of each parameter should be brought into record with the values from 0 to 1. In this case, 0 means no value, and 1 means maximum parameter quality, required for maximum process development, affected by this parameter.

What parameter value has a positive impact (process quality growth), negative (process quality reduction) or stable (process quality does not change) can be determined using the threshold parameter value. If the parameter value is over the threshold, its impact on the process is positive, if lower – negative, and if equal – stable. Threshold parameter values are estimated by experts in the field of the company, for which the parametric management model is developed. Means and methods of evaluation can be varied. Threshold parameter values also range from 0 to 1.

Thus, each parameter has three properties:

– real quality value;
– threshold quality value;
– weigh value of influence on the process (weight).

As a result of the process, the quality of it – the initial parameter, which also has the threshold and estimated quality value is obtained.

If we denote the value of the i-th input parameter of the process PS_j ($j=1\div m$) as L_{ji}, and the threshold value – N_{ji}, where $i=1\div k$, $j=1\div m$, the threshold value of the output parameter – VN_j, the evaluation function of the value of the output parameter V_j of the process PS_j in the first round (the first sequence of actions) can be described by the following rules:

$$V_j = VNj + \begin{cases} L_{ji} \geq N_{ji}; (1-VN_j)\cdot\sum\limits_{i=1}^{k}\dfrac{L_{ji}-N_{ji}}{1-Nji}\cdot P_{ji}, \\ L_{ji} < N_{ji}; VN_j\cdot\sum\limits_{i=1}^{k}\dfrac{L_{ji}-N_{ji}}{N_{ji}}P_{ji}, \end{cases} \quad (2)$$

where P_{ji} is the weight of the input parameter A_i on the process PS_j; V_j is calculated based on the weight values of the input parameters influence because it is the projected quality of the process PS_j.

Here are some explanations for this calculation. Assume that the process PS_j affects three parameters pr_1, pr_2, pr_3, which have the real values $N_{j1}=0.4$, $N_{j2}=0.6$, $N_{j3}=0.5$, threshold values $N_{j1}=0.4$, $N_{j2}=0.6$, $N_{j3}=0.5$ and weights of influence on the process $P_{j1}=0.3$, $P_{j2}=0.2$, $P_{j3}=0.5$ respectively. Note that necessarily $P_{j1}+P_{j2}+P_{j3}=0.3+0.2+0.5=1$. The threshold value of the process is PS_j is $VN_j=0.7$ (Fig. 1).

For the quality level evaluation of the process PS_j we make it a rule that this level is proportionally influenced by the growth (or reduction) factors of each parameter and their weights. The value of the parameter will be at the level of growth or reduction, determined by the threshold value of the parameter N_{ji}. Based on this rule, we determine the growth and reduction factors for one parameter.

The growth factor ($KUji$) of the parameter pr_i equals to the relation of real to maximum growth level. Similarly, the reduction factor (KD_{ji}) of the parameter pr_i equals to the relation of real to maximum reduction level. Let us calculate the factors for the given parameters. The factors of reduction KD_{ji} or growth KU_{ji} for the parameters pr_i will be equal to:

$$L_{j1}<N_{j1},\ \text{so}\ KD_{j1}=\frac{Lj1-Nj1}{Nj1}=\frac{0.3-0.4}{0.4}=-0.25, \quad (3)$$

$$Lj_2>Nj_2,\ \text{so}\ KU_{j2}=\frac{L_{j2}-N_{j2}}{1-N_{j2}}=\frac{0.8-0.6}{1-0.6}=0.5, \quad (4)$$

$$Lj_3>Nj_3,\ \text{so}\ KU_{j3}=\frac{L_{j3}-N_{j3}}{1-N_{j3}}=\frac{0.6-0.5}{1-0.5}=0.2. \quad (5)$$

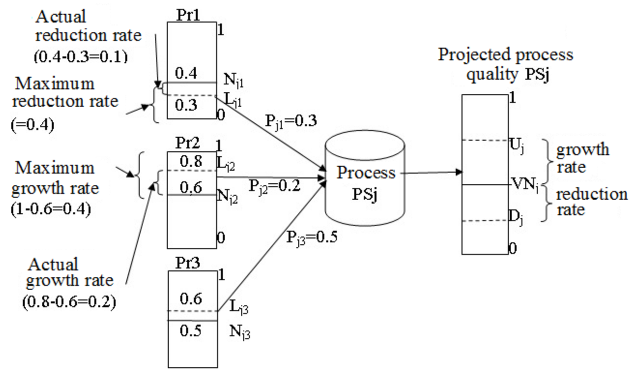

Fig. 1. Example of parameters influence on the process quality

The parameter pr_1 in the example influences the quality reduction of the process PS_j with a factor of −0.25, but its weight of influence on the process P_{j1} is 0.3. Therefore, the final quality reduction factor KDe_{j1} of the parameter pr_1 for the process PS_j is equal to the total reduction factor KD_j:

$$KD_j=\sum_i KDe_{ji}\cdot P_{ji}=-0.25\cdot 0.3=0.075. \quad (6)$$

Also for this process, taking into account the reduction factor KD_j, the reduction level:

$$D_j=VN_j\cdot KD_j=0.7\cdot(-0.075)=-0.0525. \quad (7)$$

The parameters pr_2 and pr_3 influence the quality growth of the process PS_j with the weights of influence $P_{j2}=0,2$ and $P_{j3}=0,5$.With these weights for the process PSj, the final quality growth factors KUe_{ji} will be equal to:

for pr_2: $KUe_{j2}=KU_{j2}\cdot P_{j2}=0.5\cdot 0.2=0.1,$

for pr_3: $KUe_{j3}=KU_{j3}\cdot P_{j3}=0.5\cdot 0.2=0.1.$

And for the process PSj, the total growth factor:

$$KU_j=\sum_i KU_{ji}\cdot P_{ji}=0.1+0.1=0.2. \quad (8)$$

Given the total growth factor of the parameters KU_j, the growth rate of this process:

$$U_j=(1-VN_j)\cdot KU_j=(1-0.7)\cdot 0.2=0.06. \quad (9)$$

Finally, the quality V_j of the process PSj will be the sum of the threshold value of the quality of the process VN_j and growth and reduction rates:

$$V_j=VN_j+U_j+D_j=0.7+0.06-0.0525=0.7075. \quad (10)$$

Compared with the threshold value, that will mean a slight growth in quality by 0.0075 or as a percentage of the maximum process quality growth: 0.0075/0.3×100 %=2.5 %.

This calculation changes in the second and subsequent rounds, as the process quality growth or reduction is measured not by the threshold value but the calculated one in the previous round. Thus, the calculation function in other rounds (except the first) will be as follows:

$$V_{jk+1}=V_{jk}+\begin{cases} L_{ji}\geq N_{ji};(1-VN_j)\cdot\sum\limits_{i=1}^{k}\dfrac{L_{ji}-N_{ji}}{1-Nji}\cdot P_{ji}, \\ L_{ji}<N_{ji};VN_j\cdot\sum\limits_{i=1}^{k}\dfrac{L_{ji}-N_{ji}}{N_{ji}}P_{ji}, \end{cases} \quad (11)$$

where V_{jk+1} is the estimated quality in the round with the number k+1, V_{jk} is the estimated quality in the round with the number k.

5. 3. Selection principles of process parameters and properties

In [12], three types of indicators are identified:

– Key Result Indicators (KRI);

– Production Indicators (PI);

– Key Performance Indicators (KPI).

Key result indicators are identified as the outer shell of the company. It usually determines the monetary valuations of the company: profit, staff satisfaction, meeting market requirements, etc.

Similar parameters correspond to the indicators for the parametric model defined in [12]. So, the reporting result parameters, which are not essential but supplementary for the reports of the founders, but not to analyze the performance of the company to improve its operation correspond to the result indicators.

KPI – key performance indicators (key result parameters) are basic indicators to analyze the performance of the company enterprise to improve its operation. In the parametric model they should be indicators of quality and efficiency of the entire company for further analysis in the QMS. In [12], seven features of these parameters are identified:

– non-financial nature (the value is not determined in dollars, euros, yens, pounds, etc.);

– frequently monitored (e. g., daily or even hourly);

– require the intervention of the CEO and top managers;

– require understanding and appropriate corrective actions of all personnel;

– assume the responsibility of the person or a team;

– have a significant influence – for example, affect the most critical success factors and more than one component of the balanced scorecard;

– have a positive influence (e. g., positive impact on all other indicators of the organization).

These indicators point to what should be done to increase the company performance. They also require daily reporting of the staff to the management and close supervision by senior management staff.

In [15], the approach to ranking (ordering) of indicators into the result as the extent of implementation of goals and performance, which realize the connection between the results achieved and resources used is defined. The author examines the types of indicators measurement and the influence of the process results on the results of the entire company. These studies relate only real measurement of the vector of indicators and do not relate to the predicted quality measurement.

It is important to single out PI – production indicators (process parameters) for each process. This is a basic set of parameters used in the parametric model. The chart of the types and flows of parameters is shown in Fig. 2.

The process parameters are created of all links of the process structure and transmitted from one process to another. Some process parameters create a set of result parameters, which are divided into key and reporting.

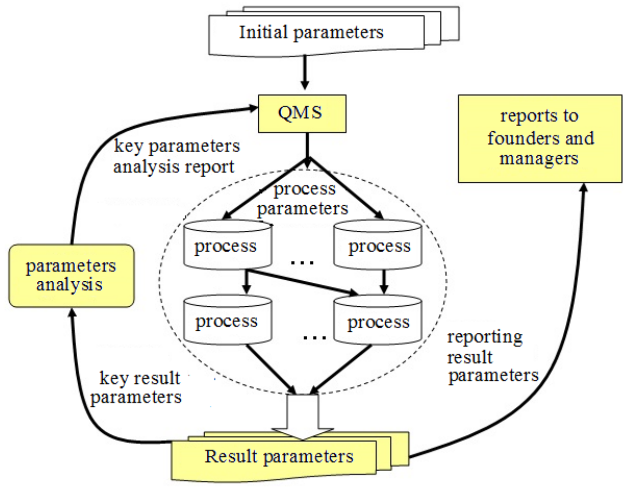

Fig. 2.The chart of flows of parameters according to the purpose

Key parameters play a major role in analyzing the quality and performance of the company. They are engines of development.

Reporting parameters provide convenient and easy to understand information on the company performance.

It is advisable to be guided by the following parameter selection rules to determine the effect of various parameters on the quality of any process or the entire company.

The number of parameters should not be too large because the system of creation and analysis will then be too cumbersome and therefore ineffective.

The first selection of parameters, weights of influence and quality thresholds is conducted by the heads of departments, performing certain processes. This can be done by means of a survey. The number of heads of identical departments participating in the survey is determined in the survey by calculating the error probability of the survey results similar to the determination of the weights of influence of parameters and their threshold quality. If the error is satisfactory, the survey is finished and the first selection of parameters is considered complete. The primary list also can be created by the management or QMS, and further adjusted according to a survey of experts.

In the second stage, the parameters need to be filtered by the weight of influence on the process, which has been estimated by experts. What weight is important for the parameter selection can be estimated in comparison with the calculation of the error of assessment results: if the weight of the parameter is "close" to the error, such parameter can not be taken into account.

Also, the selection of parameters can be guided by the Pareto principle 80/20 [15], in which 20 % of the indicators are responsible for the bulk of results.

The authors of the work on the company performance analysis [16] recommended using the "10/80/10" rule (Table 1), in which the organization should have 10 key result indicators, 20 production indicators and 10 key performance indicators.

Table 1

The "10/80/10" rule

Indicator	Amount	Content
key result indicators	10	The company condition as a whole
production indicators	80	Indicates what to do
key performance indicators	10	Indicates the ways of radical changes to improve quality and performance

A new expert evaluation of the remaining, new error calculation and new filtering of parameters are performed parameters after rejecting minor parameters. This process continues until there are no minor parameters after expert evaluation.

The weights of influence and quality thresholds of "significant" parameters according to the latest survey are averaged and their final values are obtained.

5. 4. Influence of the process structure on the organization quality

The final quality of the organization depends not only on the correct scorecard, but the structure of processes (management). The change in the management structure affects relationships between processes and hence the entire scorecard.

Shortcomings grow with the long management chain, i.e. input parameters for the following processes are increasingly reduced. Therefore, the management structure should be optimized so that the final quality is not lower than acceptable.

5. 5. Result parameters of the organization

A set of result parameters that are selected from the initial process parameters can also be determined for the entire project of the company. These parameters are selected for the final quality evaluation of the entire company, creation of various reports and analysis of the organization performance.

Special attention should be paid to the determination of these parameters because they influence the decision-making to change the work of the entire organization, including the process structure, redistribution of the initial managed parameters.

The overall quality of the company can be evaluated from the result parameters by the function:

$$f(L_i)=\frac{\sum_{i=1}^{k} L_i \cdot P_i}{k}, \tag{12}$$

where L_i is the value of the quality of the i-th result parameter; P_i is the weight of influence of the i-th parameter on the overall evaluation; k is the number of the result parameters.

The weights of influence of the result parameters on the performance of the entire company are evaluated by experts similarly to the weights of the input parameters for individual processes, but the evaluation is done not for the result of a particular process, but for the entire organization.

5. 6. The multilevel process structure

The influence of the results of some process on the other is determined by the order of their execution in the first stage (round) of all the processes. The execution order of processes in the first round (at the beginning of the institution) can be represented as the multilevel process structure.

All processes are divided into levels. The same level of processes means their simultaneous execution in the first round. Higher levels (with a lower number) are executed prior to the lower levels, and are the basis for the execution of processes of all lower levels. The process levels can be identified if the whole educational project is analyzed starting from its foundation.

For example, only one process – "Quality Management System" is executed on the first level of the foundation stage of the educational institution, on which the strategic objectives, the management system and primary documents of the institution are created, and the material and human resources are identified. The institution management is established in the second stage (second level), which creates document management departments, the economic planning department and the accounting department. At the same time, the study of the experience of other similar institutions is carried out, and relationships with other organizations are developed to ensure all future processes. This will be the 3rd level and so on.

5. 7. Restrictions and types of input parameters

Input parameters can be of 3 types (Fig. 3):
– initial;
– direct;
– reverse.

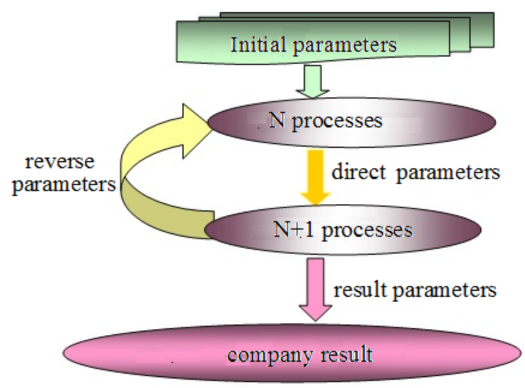

Fig. 3. Types of input parameters

Initial parameters can be managed or independent.

Basic initial managed parameters for all processes are material support and staffing of the process. Unmanaged parameters include, for example, the location of the educational institution (proximity to resources and users), risk level, etc.

Evaluation of initial parameters can be quite complicated, especially if parameters have no material essence. But its own evaluation algorithm can be defined for each parameter. The material parameters can be determined by their monetary value – actual and most essential for the quality growth of the process, affected by the parameter. The material support of the process is estimated as a percentage of the whole. The whole (unit) is the most necessary material resources for the maximum process development. For example, the cost of the process for its maximum performance is 1000 USD, and only 650 USD are allocated after redistribution of all resources, the initial index of material resources will be 650/1000=0.65.

Non-material parameters can be evaluated by the company management, founders or industry experts according to two estimates: actual and maximum. For example, the method of testing the existing personnel capacity (actual value of the parameter) and the best personnel selection criterion (maximum value) can be used to determine the value of the personnel quality parameter. The indicator of personnel resources of the process can be estimated by different methods described, for example, in [17, 18], (experience, knowledge, communication skills...) and is similar to the material indicator as a percentage of the maximum possible (1 is the maximum required staff).

Direct parameters are transmitted from the higher-level processes (with a smaller number) as the results of evaluation of their quality (values of output parameters) to lower-level processes (with a larger number). The values of the parameters are used for calculation in all rounds. Only these parameters are used in the first round of the process quality evaluation.

Reverse parameters are transmitted from the lower-level processes or the same-level processes and are the results of evaluation of their quality (output parameters). They begin to influence the process only after the execution of other processes,the output parameters of which they are.

5. 8. Adjustment of the parametric model

As a result of the real operation of the organization, the actual results of each process can be determined and compared with estimated for the existing model. In [19], the creation of the strategic model of the quality management system (QMS) and the use of practices for investigating the QMS potential are analyzed. These studies can be used to analyze the existing model in terms of additional opportunities for the QMS.

In [6], the factors that influence the quality of products are investigated and various types of product quality indicators: weighted average, defining and integrated are identified. These means to identify indicators can be used for the real quality evaluation of each process.

It is necessary to analyze how the influence of input parameters distributed on the result, what new parameters appeared and how they relate to other processes.

A new analysis determined:

– new values of the probability of parameters influence on processes;

– new parameters of influence;

– parameters that are rejected;

– new threshold values of parameters;

– change of the process structure and influence.

New values and thresholds of parameters are also inaccurate, so it is necessary to average new and previous values to adjust them. Thus, the sum of all new probabilities of influence of input parameters on a single process also equals to 1.

The process of adjustment will continue until the value of adjustment does not exceed the allowable probability error of influence.

If the analysis added new parameters, the probability of their influence in the previous cycle can be taken as 0 and then calculate the adjustments of this parameter according to the above algorithm.

If any parameter is rejected, the probabilities of influence are redistributed and a new cycle is considered primary for further adjustments.

The most complicated case is a requirement to change the structure and composition of processes. Process restructuring needs a recomposition of the entire model and completely new definitions of all parameters. It is therefore important to approach carefully the model base – structure and parameters of processes from the beginning.

5. 9. Recommendations for developing the information management system of quality parameters and process structure

For effective management of the process of creation and change of the management structure, based on the quality parameters, it is necessary to develop an information system that in an accessible and convenient form will allow:

– to create the process management structure;

– to set the values of the initial parameters of influence on processes;

– to set threshold values of all parameters;

– to introduce the results of each process;

– to analyze “bottlenecks” of the quality of the entire organization or individual processes;

– to generate various reports;

– to adjust the system of parameters and management structure of processes;

– to estimate the quality level for each process and for the entire company.

The information system should allow building the structure of parameters for each process in a graphic form.

The quality levels of the results of processes should be also highlighted both in graphic, and tabular form.

It is also important to track the “chain” of processes throughout the operation cycle of the organization and see them in a convenient graphic and tabular form. It is possible to track the influence of each parameter on the quality of each process and the entire organization. This will help the manager to distribute the company’s resources properly, focus on the most important components and parameters of the entire system to achieve the best result.

Without the information system, it will be difficult for the management to track the influence of indicators on the efficiency of the work.

6. An example of the structure of processes, parameters and quality evaluation of the organization

Let us analyze the parametric model on the example of a small random process structure, shown in Fig. 4.

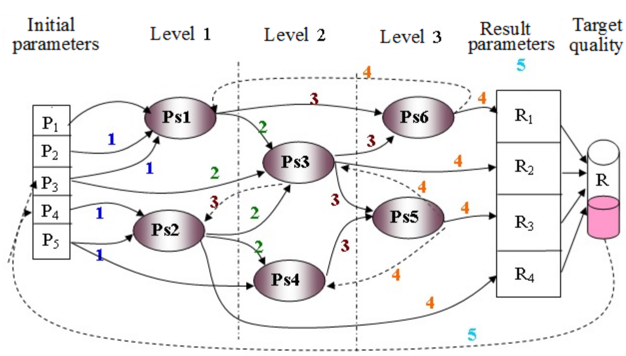

Fig. 4. An example of the process structure and parameter flows at different levels

The above structure denotes the process as PsN, where N is the process number, the set of the initial parameters as Pi, and the result parameters as Ri.

The structure identifies three levels of processes. The transmission of parameters is performed step by step from the initial parameters to the result parameters. Each step is numerated in the diagram. In total, 4 steps are performed from the initial parameters to the end result parameters. The transmission of initial and direct parameters is marked by solid lines, and reverse – dash-dotted.

The first step transmits the initial parameters to the first-level processes. The initial parameters and result parameters of the first-level processes are transmitted to the second-level processes in the second step. In the third – initial parameters and result parameters of processes of the first and second levels.

Note that the reverse parameter appears in the third step, marked by the dash-dotted line from the process Ps3 to the process Ps2. This parameter takes effect on the result of the process Ps2 in the second pass of processes (round). Thus, the results of processes in the first pass of all processes (round) are affected only by direct and initial parameters, and in the second and subsequent rounds – all parameters, including reverse.

The fourth step is final for the processes. It forms the vector of the result parameters, which estimates the quality of the entire organization in the first round. Also, there are three reverse parameters transmitted in the second round to the processes Ps1, Ps3 and Ps4.

The fifth step is special. It transmits the reverse parameter – the quality of the enterprise that affects the change in the initial parameters P1, P3 and P4. It also has the weights of influence on these parameters.

For the quality evaluation of the organization for the given example it is first necessary to generate the vector of parameters. This vector will contain the initial parameters (P1–P5), the results of processes (Ps1–Ps6, they are the input parameters for other processes, or the result of the entire organization) and the result of the entire organization (R, it is the input parameter to change the initial parameters). All parameters have to be ordered by the levels of parameters according to the rule:

– initial parameters correspond to a zero level;

– results of processes correspond to the levels of these processes;

– result of the organization – to the level a unit above the last level of processes.

In the above example, the initial parameters (P1–P5) are at the level 0, the results of processes (Ps1–Ps6) have appropriate levels from 1 to 3, and the result of the organization (R) – level 4. For each parameter it is necessary to specify its threshold and actual value (for initial parameters). So, the generated vector of parameters is, for example, such as shown in Table 2.

Table 2

The vector of parameters and their values

level	0	0	0	0	0	1	1	2	2	3	3	4
parameter	P1	P2	P3	P4	P5	Ps1	Ps2	Ps3	Ps4	Ps5	Ps6	R
threshold values N_{ji}	0.2	0.4	0.3	0.5	0.5	0.3	0.5	0.4	0.2	0.6	0.2	0.5
actual values L_{ji}	0.5	0.8	0.2	0.7	0.3	–	–	–	–	–	–	–

The developed vector of parameters is the basis for creating a relational matrix (L) indicating the levels of relations according to Table 3.

Table 3

Relational matrix L according to the levels

le-vels	para-meters	0	0	0	0	0	1	1	2	2	3	3	4
		P1	P2	P3	P4	P5	Ps1	Ps2	Ps3	Ps4	Ps5	Ps6	R
0	P1	–	–	–	–	–	1	–	–	–	–	–	–
0	P2	–	–	–	–	–	1	–	–	–	–	–	–
0	P3	–	–	–	–	–	1	–	2	–	–	–	–
0	P4	–	–	–	–	–	–	1	–	–	–	–	–
0	P5	–	–	–	–	–	–	1	–	2	–	–	–
1	Ps1	–	–	–	–	–	–	–	2		–	3	–
1	Ps2	–	–	–	–	–	–	–	2	2	–	–	4
2	Ps3	–	–	–	–	–	–	3	–	–	3	3	4
2	Ps4	–	–	–	–	–	–	–	–	–	3	–	–
3	Ps5	–	–	–	–	–	–	–	4	4	–	–	4
3	Ps6	–	–	–	–	–	4	–	–	–	–	–	4
4	R	5	–	5	5	–	–	–	–	–	–	–	–

The element of the relational matrix L(i, j) contains the number of the level at which the initial parameter (rows 1–5, P1–P5), or the result of the process (rows 6-6–11, Ps1–Ps6), which correspond to the row "i" are transmitted to the input of the initial parameter (columns 1–5, P1–P5), another process (columns 6 –11, Ps1–Ps6) or the result of the entire company (column 12, R). Rows and columns in the matrix correspond to the developed vector of parameters.

The elements above the main diagonal correspond to transmission of direct parameters, and below – reverse. Indeed, direct parameters are transmitted from the higher-level processes (with a smaller number of the level) to lower, and reverse – from processes of lower levels or the same level. Therefore, only matrix elements above the main diagonal are used in the first round of calculations, and in other rounds – all.

Similarly, the matrix of weight influences of parameters (P) is generated according to Table 4, where the matrix rows and columns are also organized by levels. This matrix indicates the weights of influence of parameters instead of numbers of levels.

Table 4

The matrix P of weight influences of parameters

le-vels	param-eters	0	0	0	0	0	1	1	2	2	3	3	4
		P1	P2	P3	P4	P5	Ps1	Ps2	Ps3	Ps4	Ps5	Ps6	R
0	P1	0.7	–	–	–	–	0.27	–	–	–	–	–	–
0	P2	–	1	–	–	–	0.54	–	–	–	–	–	–
0	P3	–	–	0.8	–	–	0.09	–	0.18	–	–	–	–
0	P4	–	–	–	1	–	–	0.34	–	–	–	–	–
0	P5	–	–	–	–	1	–	0.51	–	0.32	–	–	–
1	Ps1	–	–	–	–	–	–	–	0.18	–	–	0.9	–
1	Ps2	–	–	–	–	–	–	–	0.53	0.48	–	–	0.1
2	Ps3	–	–	–	–	–	–	0.15	–	–	0.7	0.1	0.3
2	Ps4	–	–	–	–	–	–	–	–	–	0.3	–	–
3	Ps5	–	–	–	–	–	–	–	0.12	0.2	–	–	0.5
3	Ps6	–	–	–	–	–	0.1	–	–	–	–	–	0.1
4	R	0.3	–	0.2	0.1	–	–	–	–	–	–	–	–

Each element of the matrix P (i, j) contains the value of the weight of influence of the parameter "i" on "j". The elements above the diagonal are used in the round 1 because they meet the weights of influence for direct and initial parameters.

The quality evaluation is performed in steps that correspond to the levels of parameters. The first step calculates the values of parameters of the level 1 (results of the first-level processes). Only initial parameters P1–P5 are influential in this step. For the given example, in the step 1 the results will be obtained shown in Table 5.

The quality growth U_j of processes Ps_j is calculated by the above formula (9) and shows the growth in comparison with the threshold for these processes. Similarly, the quality reduction of processes is calculated by the formula (7). The result of quality for the first-level processes is calculated by the formula (10).

The input data for the calculation are the threshold values of input parameters and processes of the level 1, the actual values of the input parameters (Table 2) and the weights of influence of input parameters (Table 4). The process Ps1 is influenced by three initial parameters P1–P3. So, the data for the calculation are: N_{11}=0.2, N_{12}=0.4, N_{13}=0.3; L_{11}=0.5, L_{12}=0.8, L_{13}=0.2; P_{11}=0.27, P_{12}= 0.54, P_{13}=0.09. Similarly, two initial parameters P4–P5 for the process Ps2: N_{21}=0.5, N_{22}=0.5; L_{21}=0.7, L_{22}=0.3; P_{21}=0.34, $P2_{22}$=0.51.

As a result of these calculations (Table 5), for the first-level processes Ps_j (j=1÷2) we get the following (with rounding to 2 digits): for the process Ps1 the quality growth U_1 will be given by the parameters P1, P2 ($L_{1i}>N_{1i}$, i=1÷2), and reduction D_1 by the parameter P3 ($L_{13}<N_{13}$), so using the formulas 6–10 we get:

$$KU_1=\frac{0.5-0.2}{0.8}\cdot 0.27+\frac{0.8-0.4}{0.6}0.54=0.46,$$

$$U_1=(1-0.3)\cdot 0.46=0.32,$$

$$KD_1=\frac{0.2-0.3}{0.3}\cdot 0.09=-0.03,$$

$$D_1=0.3\cdot(-0.03)=-0.01,$$

$$V_1=0.3+0.32-0.01=0.61.$$

The values for the process Ps2 are calculated similarly.

Table 5

Results of the 1 step of calculation

Level	0	0	0	0	0	1	1	2	2	3	3	4
parameter j	**P1**	**P3**	**P3**	**P4**	**P5**	**Ps1**	**Ps2**	**Ps3**	**Ps4**	**Ps5**	**Ps6**	**R**
threshold value Nji	0.2	0.4	0.3	0.5	0.5	0.3	0.5	0.4	0.2	0.6	0.2	0.5
actual value Lji	0.5	0.8	0.2	0.7	0.3	–	–	–	–	–	–	–
growth Uj	–	–	–	–	–	0.32	0.14	–	–	–	–	–
reduction Dj	–	–	–	–	–	–0.03	–0.2	–	–	–	–	–
estimated level Vj	–	–	–	–	–	0.61	0.47	–	–	–	–	–

Analyzing the first step, we can conclude that the process Ps1 provides the quality growth (red) compared with the threshold value, and Ps2 – reduction (blue).

The quality of the level 2 processes is calculated in the second step (Table 6).

Table 6

The results of the 2 step of calculation

level	0	0	0	0	0	1	1	2	2	3	3	4
parameter j	**P1**	**P3**	**P3**	**P4**	**P5**	**Ps1**	**Ps2**	**Ps3**	**Ps4**	**Ps5**	**Ps6**	**R**
threshold value N_{ji}	0.2	0.4	0.3	0.5	0.5	0.3	0.5	0.4	0.2	0.6	0.2	0.5
actual value L_{ji}	0.5	0.8	0.2	0.7	0.3	0.61	0.47	–	–	–	–	–
growth U_j	–	–	–	–	–	–	–	0.08	0	–	–	–
reduction D_j	–	–	–	–	–	–	–	–0.09	–0.16	–	–	–
estimated level V_j	–	–	–	–	–	–	–	**0.41**	**0.17**	–	–	–

The results of the first step for the processes Ps1 and Ps2 are used in this step. For the process Ps3, the quality growth, and for the process Ps4 – reduction are observed.

In this and other rounds, the quality evaluation of the processes varies according to the formula (11). In the evaluation function, previous quality evaluations of the corresponding process instead of the threshold values become the starting values. Comparison of the results of different rounds allows tracking the dynamics of changes in the organization quality in the long term.

To perform the quality evaluation of the entire company on the basis of the developed process structure in steps, it is necessary to create:

– the vector of parameters and their initial values, ordered by levels;

– the matrix of relations between the parameters and processes according to their levels;

– the matrix of weight influences of parameters.

The quality evaluation of the processes and the entire organization is desirable to do using the information system, which performs not only the calculation, but the analysis of the results.

7. Conclusions

As a result of the research, the general concept of the parametric model development for the quality evaluation and forecasting of the organization was proposed:

1. The basis of the concept was the multilevel process structure of the company, which is based on the transmission of parameters from one process to another. The levels of processes are determined by the order of their execution at the initial stage. Definition of processes and structures is based on the concept of ISO 9001.

2. The parameters are divided into input and output for the process. Input parameters are divided into initial, direct and reverse. Initial parameters are determined prior to the start of the company and can influence directly on any process. Direct and reverse are the output parameters

of other processes. Direct parameters are transmitted from the processes performed earlier, and reverse – from processes executed later. Some output parameters are defined as result parameters of the company and are used in the function of the quality evaluation of the entire enterprise. Some result parameters are also used to analyze the efficiency of all activities, and some – to create economic reports in an accessible form. All parameters are normalized to values from 0 to 1 Expert estimates are used for weights of influence of parameters and threshold values. For the values of initial parameters, their calculation relative to the maximum value is used.

3. To calculate the projected quality of the company, the following are used:

– relative values of quality of initial (<=1) parameters, calculated by the proposed evaluation method relative to the maximum required quality;

– relative values of quality of direct and reverse parameters, transmitted from other processes;

– threshold values of quality of all parameters;

– weights of influence of parameters on the process.

Calculation of the quality level is performed using certain functions (2) or (11) consistently by the levels of processes: for the first level, then for the second, etc.

At the last level, the final result parameters, used to calculate the projected quality of the entire company are developed. This completes the first step (round) of calculation. If the projected quality is above the threshold, this means the growth of the company, and if lower – reduction, and if equal – stability.

In the first round, the process of forecasting, which will determine the projected quality of one full cycle of the process can be completed. But it is possible to calculate the quality in the new round – the second, then the third, etc. In these rounds, reverse parameters, calculated on previous rounds begin to affect.

In calculating the quality of processes and the entire company, the trends in the quality of processes depending on the long-term operation of the company and its rate of approaching the maximum or minimum can be observed in many rounds.

Based on the projected quality of the company and analysis of key result parameters, quality “bottlenecks” in the process structure, the quality management system (QMS) can change the initial parameters (redistribute the values) or the process structure and a list of parameters and their properties, then the quality calculation is performed again. If the calculation is positive in general and meets the QMS requirements, the company management is based on the developed structure and quality indicators, which correspond to the result parameters.

4. Information system plays a dual role. First, it calculates the projected quality of the company based on the data on the process structure and properties of all parameters. Second, it collects and analyzes actual performance indicators, creating reports for each process and for the entire company. These reports are compared with the projected and become the basis for further improvement of the structure and indicators of processes.

The downside of all this work is too much generalization of the structure and parameters of processes. The development of a specific model requires a special study of the chosen industry of the company, structure of processes and key parameters.

The present paper is not the end result of the research, only the first complete step to determine the general concept and its properties. The next step is to create a specific model implementation on the example of the educational institution and analyze the forecasting results compared with the actual quality.

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Розглянуто вплив основних чинників на параметри пожежі. Отримано залежності, що дають змогу визначити значення тривалості слідування пожежного автомобіля до місця виклику та площі пожежі. Обґрунтовано необхідність та розроблено алгоритм ефективного управління діями пожежно-рятувальних підрозділів. Наведено приклад та описано роботу програмного забезпечення для вибору оптимальної технології пожежогасіння

Ключові слова: пожежно-рятувальний підрозділ, маршрутизація спецтранспорту, оцінка тривалості слідування, параметри пожежі, технологія пожежогасіння, протипожежна техніка

Рассмотрено влияние основных факторов на параметры пожара. Получены зависимости, позволяющие определить значение продолжительности следования пожарного автомобиля к месту вызова и площади пожара. Обоснована необходимость и разработан алгоритм эффективного управления действиями пожарно-спасательных подразделений. Приведен пример и описана работа программного обеспечения для выбора оптимальной технологии пожаротушения

Ключевые слова: пожарно-спасательное подразделение, маршрутизация спецтранспорта, оценка продолжительности следования, параметры пожара, технология пожаротушения, противопожарная техника

UDC 656.13 : 614.843(075.32)
DOI: 10.15587/1729-4061.2016.71604

DEVELOPMENT OF ALGORITHMS FOR EFFICIENT MANAGEMENT OF FIRE RESCUE UNITS

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1. Introduction

The activity of operational rescue service of civil protection, in particular fire rescue units, is associated with the rapid response to fires and all sorts of emergencies. Efficiency of fire and rescue service depends on competent and rapid execution of actions aimed at minimizing the damage that may be caused by environment, such as a fire. The development of fire is associated with an increase in the area of burning and the possibilities of the impact of its dangerous factors.

There are three periods in the development of fire: free development $\tau_{f.d.}$, localization τ_{loc} and the liquidation of fire τ_{liqv}. From the view of reduction of losses, caused by the fire,