Automated procedure for self-assessment and forecast of organizational maturity of university division

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Abstract. The main goal of the article is to support the process of ensuring the effectiveness of organization management. For this, the task of self-assessment according to organizational maturity levels is being solved. The methodological basis of the study is the ISO 9004-2010 standard, the technical implementation of the processes of self-assessment of organizational maturity is performed using the ELMA business process management system. The directorate of the Institute of Informatics and Telecommunications (IITC), Reshetnev Siberian State University of Science and Technology served as an object of study. The process of self-assessment of the organization according to maturity level was implemented. It is shown that the maturity of the organization is on average at level 2 (“Managed”) and is characterized by integrity, without failures for individual components. The developed approach in accordance with the purpose of the standard ISO 9004-2010 can be used both in higher education institutions and for the management of a machine-building enterprise. In addition, the article solves the problem of predicting indicators of organizational maturity of an enterprise as a linear dynamic control system in discrete time. It is shown that such a model adequately reproduces the behavior of the system of an educational institution business processes’ maturity indicators.

1. Introduction
Business processes exist in every organization and determine how the organization performs its work. Business process management is one of the most important management technologies in a highly competitive and constantly changing market environment. The ISO 9000 family of quality management standards is built on the methodological basis of business process management. For this reason, every enterprise developing a quality management system based on these standards must be guided by a process approach [1]. According to the ISO Survey study, the number of such enterprises in the world exceeded one million [2]. Such a massive application of the standards of the process approach confirms the high relevance of the task of managing business processes. A business process is a sequence of related actions or tasks aimed at achieving a valuable, from the point of view of the customer, result [3]. To achieve sustainable success, the organization needs to monitor, improve and eliminate errors of real processes in the enterprise, extracting data from event logs, on the basis of which decisions can be made on making changes to the company’s business processes, and the organization must be able to meet the needs on a long-term basis and the expectations of their customers and other interested parties [4]. The process approach to management was first described in the work of Philip Crosby *Quality is Free* [5]. Further development of the approach is described in the works of Watts Humphrey. The best
practices of business process management are described in the knowledge base on business process management – BPM CBOK [3].

Reshetnev Siberian State University of Science and Technology [7] conducts the training of highly competitive highly qualified engineering personnel, conducts fundamental and applied research in the field of advanced technologies in high technology and high-tech production. Carries out continuous improvement of the quality of all types of activities, considering the requirements and wishes of applicants, students and their parents, graduate students and doctoral students, heads of industrial enterprises, organizations, representatives of state authorities and local governments and the public.

The maturity of the process shows how the activity is defined, manageable, controllable and effective, and the maturity model itself provides the basic principles of management that must be applied to increase maturity [4]. The use of technology for assessing the maturity of a business process implies the formation of potential for growth in the effectiveness of the entire company and reflects both the completeness of the organization's business process and the constancy with which the organization applies this process. In [8], [9] organizational maturity is defined as the degree to which the organization explicitly and sequentially implements practices or processes that are documented, managed, measured, controlled and constantly improved. The maturity of the organizational process can be measured using expert judgment, for example, in the form of assessment by stakeholders [10]. The description of the maturity management framework for business processes is presented in the international standards ISO/IEC 15504 [11], [12], [13], [14], ISO 9004 [4], ISO 10014 [15].

The self-assessment procedure can help identify areas that need improvement and an innovative approach, to establish priorities and develop action plans in order to achieve sustainable success [4]. Diogo Proença in [16] developed an approach to automating the assessment of the maturity of organizations based on its structure. In [17], the application of the Voyager Plant Optimization technique to build a model for managing the improvement of business processes based on assessing the maturity level of an organization is considered.

The question of determining the maturity of an educational organization arises in connection with changes taking place in the vocational education system and primarily related to a change in attitude to education in principle, which in modern conditions is considered a service. In accordance with these ideas, an educational organization can be managed using the same approaches as any other service provider. It was revealed that the Institute of Informatics and Telecommunications (IITC) [18] does not currently use such an assessment, which reduces the opportunities for improving business processes. Thus, the foregoing determines the relevance of solving the problem of effective enterprise management based on an assessment of organizational maturity.

It should also be noted that existing methods for improving business processes have a significant drawback. It consists in the fact that decision-making on the investment of resources in certain activities in them is carried out only on the basis of the financial result indicator. To eliminate this problem, the authors proposed to create an enterprise management system according to a single target indicator - the level of organizational maturity. To solve this problem, the article describes a set of business processes maturity indicators of an organization as a dynamic management system. Further, for the obtained dynamic control system, parametric identification was performed on the basis of the available experimental data collected as a result of the maturity assessment of the IITC Directorate of Reshetnev Siberian State University of Science and Technology.

2. Methods

2.1 Methodological background
The research method is based on a survey among employees of the IITC Directorate and an analysis of self-assessment of their organizational maturity according to the ISO 9004 standard “Management for achieving sustainable success of an organization. The approach based on quality management” [10], which describes the use of self-esteem as an important tool for analyzing the level of organizational
maturity, covering its management system, ongoing processes, used resources, in order to identify strengths and weaknesses and opportunities for improvement.

The organization may be characterized by different levels of maturity for each of the elements. A discrepancy analysis can help the manager in planning and identifying priority improvement measures needed to move individual elements to a higher level [4]. The basis for employee self-assessment was the list of elements described in the ISO 9004 standard [4], [16].

2.2 Organizational Maturity Standard Used
To build a set of maturity indicators as a managed system, in this paper we adopted the ISO 9004-2008 standard “Achieving sustainable success through the use of an approach based on quality management” [12]. The standard assumes 7 main (top-level) factors of organizational maturity, for which sections are highlighted in it:

- Key elements.
- Process management.
- Resource management.
- Monitoring, measurement, analysis and evaluation.
- Strategy and policy.
- Improvements, innovations and training.
- Sustainable success.

Each of the maturity estimates can take values from 0 to 5. The data of 7 assessments of the maturity levels (ML) of the organization’s business processes in accordance with sections of the ISO 9004-2008 standard comprise a vector of indicators of the managed system.

2.3 Statement of the problem of describing the level of maturity of business processes as an object of management
As controlled parameters of the organizational system, we will consider a set of maturity levels of the organization. To solve the problem of growing organizational maturity, the decision-maker in the organization (DM) spends resources — working hours of their own and attracted employees, working hours of equipment, consumables, which can be integrated into a single indicator — cost. The responsibility of the decision maker is the efficient use of these resources to ensure the organization’s development goal - to achieve its planned maturity level. Thus, the task of managing the maturity levels of an organization’s business processes can be formalized as follows:

- **Managed system** - a set of indicators of the organization maturity levels.
- **Management system** - a person who makes decisions on projects for the implementation of management technologies.
- **Managed indicators** – ML values for selected management components.
- **The control signal** is the amount of resources invested in improving management technologies.

Accepted hypotheses:
- The quality of the organization's business processes is assessed by the level of maturity, which is expressed by a dimensionless value in the range from 0 to 5.
- In the process of implementing projects to improve the management system, ML for each element increases in proportion to the number of resources invested in the development of this element.
- Perhaps the mutual influence of ML on each other, an increase in the level of maturity due to the daily activities of the organization, as well as its corporate values.
- The initial idea of the relationship between ML can be formed by a statistical analysis of indicators over several time periods.
- When planning and implementing the organizational maturity management process, the following indicators are taken into account:
  - a graph of the growth of the organization maturity levels by elements over time;
  - resource costs (in monetary terms) for projects to increase organizational maturity.
2.4 Organizational Maturity Process Management Model

We describe the process of increasing organizational maturity in the form of a linear dynamic system in a deterministic formulation, excluding the effect of interference:

\[ x(t) = Ax(t) + Bu(t) \]

where \( t \) - organizational maturity projects implementation time \( t \in [0, T] \), \( T \) - project duration in planned periods (months, quarters); \( x(t) = [x_1(t), \ldots, x_N(t)]^T \) - vector of organizational maturity by elements, \( x_i(t) \) - maturity level of \( i \)-th element at time \( t \); \( u(t) = [u_1(t), \ldots, u_M(t)]^T \) - vector of control, \( u_i(t) \) is the controlling influence of the organization in the form of investing resources in projects of increasing organizational maturity at the moment \( t \); \( A = [a_{ij}] \) - control matrix; \( a_{ij} \) - degree of influence of elements of maturity \( x_i \) on \( x_j \); \( b_{ij} \) - control vector; \( b_{ij} \) is the degree of influence of the control signal \( u_i(t) \) on the level of maturity in the \( j \)-th element \( x_j(t) \).

2.5 The technology of self-assessment of the maturity level of the studied object

This process was implemented in the ELMA BPM business process management system, which allows you to switch from instructions to automatic execution and business process management [19]. This platform contains a set of basic functions for modeling business processes.

To implement the business process, it is necessary to create an organizational structure that includes those employees among whom the survey was conducted. For each interviewed employee to be able to independently launch the testing process, it was decided to build a business process within the framework of a dynamic area of responsibility (selection from the list). To do this, users were created in the settings of the zone of responsibility - the Initiator and the Respondent. After setting up the area of responsibility, a business process was built, the scheme of which is presented in Figure 1. The business process includes one start, intermediate and final event, as well as seven blocks of the "user task" type:

1) launch of a survey for employees of the IITC Directorate;
2) selection of a list of questions on the topic "Key element";
3) selection of a list of questions on the topic "Sustainable success";
4) selection of a list of questions on the topic "Policy and strategy";
5) selection of a list of questions on the topic "Resource Management";
6) selection of a list of questions on the topic "Process Management";
7) selection of a list of questions on the topic "Monitoring";
8) selection of a list of questions on the topic "Improvements";
9) familiarity with the results of the survey for employees of the IITK Directorate.

Also, a script has been added to the graphic model that saves the results of the survey to an Excel file.

The next step is to create context variables in which each question from the test is one variable. The variable is displayed on the form as a drop-down list that contains values from 1 to 5, which are maturity levels and describe them in accordance with the provisions of ISO 9004 standard. Next, you need to transfer all the context variables to the form and configure the transitions between them. Before starting the process in a web application, you need to create a script that will process the values entered by the user and write the data to the Excel file.

The process is launched by the Initiator by clicking on the appropriate button “Run the process”. Further, Respondents defined in the Organizational structure can start testing, and select one answer for each context variable. All fields are required, the user also has the opportunity to return to the previous form and change the selected values. After answering all the questions, the Initiator completes the process. Figure 2 shows the “Strategy and Policy” form, on which context variables are located -
questions, with answer options in the form of a drop-down list. The remaining forms have a similar appearance.

Figure 1. A graphical model of the business process “Interview with employees of the IITC Directorate”

Figure 2. Form “Strategy and Policy”

3. Results

3.1 Results of the collection of data on the state of maturity of the processes of IITC

Analysis of the collected data was carried out on the main elements of the group: key elements, managing the organization to achieve sustainable success, strategy and policy, resource management, process management, monitoring, measurement, analysis and evaluation, improvement, innovation and training. At the moment, there are results of a survey of employees of the IITC Directorate for three years of operation, from 2017 to 2019. A fragment of the results of employee testing is presented in Figure 3.

Figure 3. A fragment of the table of test results for 2019

Based on the test results, a pivot table was constructed, which is shown in Figure 4.
Figure 4. Summary table of the main elements of the group

| Key element                                      | 05.04.2017 | 05.04.2018 | 31.05.2019 |
|-------------------------------------------------|------------|------------|------------|
| Process Management                              | 2.72       | 2.81       | 2.58       |
| Resource Management                             | 2.00       | 2.17       | 2.70       |
| Monitoring, measurement, analysis and evaluation| 2.50       | 2.58       | 2.60       |
| Policy and strategy                             | 2.00       | 2.33       | 2.80       |
| Improvements, Innovations and learning          | 2.17       | 2.00       | 2.13       |
| Sustainable success                             | 1.88       | 2.00       | 2.55       |
| **Grand total**                                 | **2.30**   | **2.47**   | **2.58**   |

Figure 5. Summary diagram of the main elements of the group

Figure 5 shows the Maturity Profile of the IITC Directorate built in accordance with the recommendations contained in the ISO 9004 standard, based on the data obtained as a result of self-assessment conducted among employees of the IITC Directorate. Each of the axes of the diagram reflects the organization's compliance with certain recommendations of the standard in areas of activity. A scale from 0 to 5 reflects maturity levels in accordance with the recommendations of ISO 9004, where 1 - reflects the least mature state of the organization, 5 - compliance with the maximum (reference) level of maturity, 0 - complete absence of activity in this area.

3.2 Formation of a mathematical model for forecasting maturity levels
To build a reliable mathematical model of the dynamics of the ML of the enterprise, it is desirable to have data on the actual level of organizational maturity over a number of years.

In our case, information was collected on the organizational maturity of the company according to the results of 3 years of work - on 04/05/2017, 04/05/2018 and 05/31/2019. The maturity levels on these dates are:
The data \( x_{2017} = [2.72, 2.00, 2.50, 2.00, 2.17, 2.00, 1.87] \),
\( x_{2018} = [2.82, 2.17, 2.58, 2.33, 2.00, 2.67, 2.00] \) and
\( x_{2019} = [2.58, 2.70, 2.60, 2.80, 2.13, 2.53, 2.55] \)

It should be noted that such a volume of experimental data is not enough to build a statistically
reliable model that describes the growth of maturity indices in their relationship, the volume of
identifiable indices in this case is at least \( N^2 \), that is 49. To overcome this problem, the following
assumptions were additionally made.

- Model (1) is simplified by reducing the increment matrix \( A \) to a diagonal form. This means that we
  neglect the relationship between different indicators of the maturity level, believing that each of the
  indicators changes independently.
- The data \( x_{2017}, x_{2018} \) and \( x_{2019} \) were interpolated at intermediate time points with an interval of two
  months based on the hypothesis of the exponential dynamics of the company maturity levels.
- The construction of models of growth dynamics of indicators of the organization maturity levels
  based on the accepted hypotheses made it possible to obtain an approximate model for controlling
  this process.

3.3 Exponential Interpolation of Maturity Indicators
The dynamics of maturity indicators were interpolated, which were assumed to be distributed
exponentially between \( x_{2017} \) and \( x_{2019} \). The calculation was carried out in the MatLab system using the
fit function with the interpolation setting 'exp1' on a grid of 24 steps with a step of 1 month. The last
value corresponds to the end of the third year (May 2019). The results are shown in Table 1.

| t  | 1    | 2    | 3    | 4    | 5    | 6    | 7    |
|----|------|------|------|------|------|------|------|
| 1  | 2.770| 1.965| 2.516| 2.015| 2.116| 2.172| 1.828|
| 2  | 2.764| 1.991| 2.520| 2.044| 2.114| 2.191| 1.853|
| 3  | 2.758| 2.017| 2.524| 2.073| 2.113| 2.210| 1.878|
| 4  | 2.752| 2.044| 2.528| 2.103| 2.111| 2.230| 1.904|
| 5  | 2.746| 2.071| 2.532| 2.133| 2.110| 2.249| 1.930|
| 6  | 2.740| 2.100| 2.536| 2.163| 2.109| 2.269| 1.956|
| 7  | 2.734| 2.126| 2.540| 2.194| 2.107| 2.289| 1.983|
| 8  | 2.728| 2.154| 2.544| 2.225| 2.106| 2.309| 2.010|
| 9  | 2.722| 2.182| 2.548| 2.257| 2.104| 2.330| 2.038|
| 10 | 2.716| 2.211| 2.553| 2.289| 2.103| 2.350| 2.065|
| 11 | 2.710| 2.240| 2.557| 2.322| 2.101| 2.371| 2.094|
| 12 | 2.704| 2.270| 2.561| 2.355| 2.100| 2.392| 2.122|
| 13 | 2.698| 2.300| 2.565| 2.389| 2.099| 2.413| 2.151|
| 14 | 2.693| 2.330| 2.570| 2.423| 2.097| 2.434| 2.181|
| 15 | 2.687| 2.361| 2.573| 2.457| 2.096| 2.455| 2.211|
| 16 | 2.681| 2.392| 2.577| 2.492| 2.094| 2.477| 2.241|
| 17 | 2.675| 2.423| 2.582| 2.528| 2.093| 2.499| 2.271|
| 18 | 2.669| 2.455| 2.586| 2.564| 2.091| 2.521| 2.303|
| 19 | 2.663| 2.488| 2.590| 2.600| 2.090| 2.543| 2.334|
| 20 | 2.658| 2.520| 2.594| 2.637| 2.089| 2.566| 2.366|
| 21 | 2.652| 2.554| 2.598| 2.675| 2.087| 2.588| 2.398|
| 22 | 2.646| 2.587| 2.603| 2.713| 2.086| 2.611| 2.431|
| 23 | 2.640| 2.621| 2.607| 2.752| 2.084| 2.634| 2.464|
| 24 | 2.634| 2.656| 2.611| 2.791| 2.083| 2.657| 2.498|
3.4 Prediction of maturity level dynamics based on a deterministic model

In order to calculate the deterministic model of the control system based on formula (1), based on the performed calculations, we will identify the parameters of the control model.

We compose matrix A (the increment matrix of the control model in formula (1)), based on the average values of the ML indicators increase coefficients in one step \( x_{i+1} \) for all components of the vector X calculated in Section 3.3 by the method of exponential interpolation. In accordance with the assumptions adopted in Section 2.4, matrix A has a diagonal form with the following vector on the main diagonal: [0.956 0.971 0.960 0.972 0.958 0.967 0.971].

3.5 A control model for the deviation of the vector X from the target value of ML

We set the target value of the ultrasound vector \( X_{tar} = [5 \ 5 \ 5 \ 5 \ 5 \ 5] \), which corresponds to a fully mature company (all components of maturity have reached the maximum, fifth level).

We introduce the coefficient \( k \), which determines the amount of financing for the process. The dimension of this indicator is the number of units of the maturity level received by the system for 1 thousand rubles (ML units / 1 thousand rubles). The economic interpretation of this indicator is the efficiency of investing in management technologies.

Based on the formula (1), we calculate the increment of ML in discrete time:

\[
X(t + 1) = A \cdot X(t) + k \cdot (X_{tar} - X(t))
\]  

(2)

We calculate the growth of ultrasound over 5 years, varying \( k \) in the range from 0.00 to 0.03. The calculation results are shown in Figure 6.

![System dynamics with different k values](image)

Figure 6. Dynamics of maturity levels of the system with values of \( k \) from 0.00 to 0.03

4. Discussion

As a result of the study, elements of the system that require improvement were identified. From the data of the summary tables and diagrams, it can be concluded that insufficient attention is paid to the organization’s strategy and policy (they do not contribute to the achievement of sustainable development), the goals and objectives of the organization are also not aimed at achieving sustainability, and the improvements are not permanent.
In the period from 2017 to 2018, the IITC Directorate was at the 2nd level of organizational maturity. The level of work is 25%. In some areas, practical activities are ongoing. Some goals are set, some positive results are achieved. Random analyzes or evaluations are conducted that may lead to some improvements. For 2019, the level of organizational maturity increased only in some components, the results for 2019 compared with 2017-2018 show the alignment of the overall structure, but it is still far from reaching the target value and sustainable success of the organization.

The calculation of the maturity level forecast shows that the deterministic model of the control system in discrete time reproduces such effects as:

• stagnation of the ultrasound organization with low efficiency of resource investment (can be seen in Figure 6);
• an increase in maturity when a control signal is applied (we can see by the difference between the dynamics of the system in Figure 6 with varying coefficient $k$);
• effective operation of the regulator with feedback on the deviation, ensuring bringing the ML system to the target indicator, 5 maturity levels (the best result is in Figure 6).

5. Conclusion
The performed analysis shows that the maturity of the SibSU processes is balanced, there are no components that are clearly “sagging”. Further work on its development should have the same systemic nature, to ensure uniform efforts to grow all components of maturity.

Thus, the obtained result creates a reserve for solving the scientific problem of measuring the influence of the level of maturity on the physical and process efficiency.

The proposed methodology for planning and evaluating the process of managing the organizational maturity of an educational institution allows us to formalize the mathematical model of organizational development in terms of the theory of control of dynamic systems. The classical dynamic model of the control system allows us to describe the behavior of such an organization indicator as the level of maturity. At the same time, actual data on the dynamics of the level of maturity of the organization, collected using the business process management system, allow for identification of the parameters of the management system.

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