Parametric identification of the organizational maturity management system

Mikhail Dorrer[1,2,3]

[1]Reshetnev Siberian State University of Science and Technology,
Krasnoyarsk, prospect “Krasnoyarsky rabochy“ 31, Russia
[2]Siberian Federal University, 79 Svobodny pr., 660041 Krasnoyarsk, Russia
[3]mdorrer@mail.ru

Abstract. The article describes the solution of the problem of constructing a mathematical model that describes the behavior of indicators of the level of maturity of a company's business processes as a dynamic management system. This work was carried out in the course of solving the problem of developing a system for managing the level of maturity of the enterprise’s business processes. The set of maturity indicators for a company's business processes is described as a dynamic model in discrete time of a control system in a deterministic formulation. The identification of the parameters of the dynamic model is made on the basis of the data on the maturity of the company's business processes collected at the operating machine-building enterprise. It is shown that a dynamic model of a control system in discrete time in a deterministic formulation adequately describes the behavior of a system of indicators of the maturity of a company's business processes. The resulting model reproduces the available experimental data on changes in the levels of organizational maturity in the company. It shows plausible behavior when predicting a process based on various input data in a real-world expected range of input parameters.

1. Introduction. The problem of managing the maturity of business processes

In the modern world, business process management is one of the key management technologies. Thus, any enterprise implementing a quality management system in accordance with the standards of the ISO 9000 family works in accordance with this approach [1]. According to ISO Survey, the number of such enterprises in the world exceeds one million [2]. Therefore, systematic management of the state of business processes is a highly relevant task. A modern understanding of the process management methodology is set forth in the business process management body of knowledge – BPM CBOK [3]. The first models describing the maturity of business processes were described by Philip Crosby [4]. Wats Humphrey in 1986 developed a maturity model for software development processes [5].

Recommendations for managing the maturity of business processes are designed to a number of standards, both industry-specific and commonly used. Among the industry is a series of standards ISO / IEC 15504 [6-9] regulating the level of maturity of business processes in the field of information technology. The maturity of general management processes is governed by the ISO 9004-2018 standard [10], and economic management is governed by the ISO 10014-2006 standard [11].

The weak point of all the standards described above is that they are limited only to the issues of assessing the maturity of business processes. They do not contain such an important component of management as the development of a decision on the application of efforts and the use of resources.

Methods for improving business processes include reengineering [12], continuous improvement of business processes [13], and lean production [14].

To solve this problem, the article describes a set of maturity indicators for the organization's business processes as a dynamic management system. Further, for the obtained dynamic control system, a parametric identification of the system parameters was performed based on the available experimental data of the operating enterprise.

It is shown that the thus obtained model of a linear dynamic system in discrete time accurately describes the dynamics of a system of indicators of the maturity of business processes of an enterprise, including their prediction over time.

2. Formulation 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 components of organizational maturity.

To solve the problem of growth of organizational maturity, a decision-maker in an organization (DM) spends resources - the working time of its own and attracted employees, the working time of equipment, consumables, which can be enlarged to a single indicator - the cost. The responsibility of the decision maker is the efficiency of using these resources to ensure the organization's development goal - achieving its planned level of maturity.

Thus, the task of managing the levels of maturity of an organization's business processes can be formalized as follows:

- Controlled system – the state of maturity of the organization's business processes.
- Control system – a person (or group of persons) who makes decisions on projects for the implementation of management technologies.
- Managed indicators – maturity level values for selected management components.
- Control signal – the amount of resources invested in the improvement of management.

1. Selected standard of organizational maturity

To build a set of indicators of maturity as a managed system, this paper adopts the ISO 9004-2018 standard "Quality management – Quality of an organization – Guidance to achieve sustained success" [10].

This standard is focused on assessing the maturity of the processes of the organization as a whole in terms of achieving sustainable success and contains tools for assessing the maturity of processes.

The standard assumes 6 main (top-level) factors of organizational maturity. Below is a list that lists these factors. Their numbering in the list corresponds to the numbering of sections of the ISO 9004 standard.

6. Identity of an organization
7. Leadership
8. Process management.
9. Resource management
10. Analysis and evaluation of an organization's performance
11. Improvement, learning and innovation

Each of the estimates can take values from 0 to 5. It is these 6 factors that make up the vector of indicators of the controlled system.

3. Accepted hypotheses

- The quality of an organization's business processes is estimated by the level of maturity, which is expressed in a dimensionless quantity, taking values from 0 to 5.
- The initial understanding of the relationship between indicators of organizational maturity can be formed by statistical analysis of indicators for several time periods.

- In the process of implementing projects to improve the management system, the level of a specific element of organizational maturity increases in proportion to the number of resources invested in the development of this element.
- Mutual influence of elements of organizational maturity on each other, increasing the level of maturity due to the daily activities of the organization, as well as its corporate values.
- The following indicators are taken into account when planning and implementing the organizational maturity management process:
  - Schedule of increasing the level of maturity of the organization by elements over time;
  - Resource costs (in monetary terms) for projects to improve organizational maturity.

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:

$$\dot{x}(t) = Ax(t) + Bu(t) \qquad (1),$$

Where t – organizational maturity projects implementation time $t \in [0, T]$, T – project duration in planned periods (months, quarters);

$x(t) = [x_1(t), ..., x_N(t)]^T$ – N-vector of organization maturity by elements, where $x_i(t)$ – maturity level of i-th element at time t;

$u(t) = [u_1(t), ..., u_M(t)]^T$ – M-vector of control, where $u_j(t)$ – is the controlling influence from the organization in the form of investing resources in projects of increasing organizational maturity at the moment t

$A = [a_{ij}] - N \times N$ – the matrix that determines the rate of maturity increase by elements due to the factors of the internal environment of the organization ("increment matrix"); a_{ij} – the degree of influence of elements of maturity x_i on x_j

$[b_{ij}] - M \times N$ – the matrix that determines the increase in the level of maturity in the process of strategic development of the management system; b_{ij} is the degree of influence of the control signal $u_i(t)$ on the level of maturity in the j-th element $x_j(t)$.

5. Baseline data on the state of maturity of processes

The enterprise Krasnoyarsk Machine-Building Components (KMK LLC [16]) was chosen as the object of research. The company conducted a procedure for self-assessment of organizational maturity according to ISO 9004 standard [10] using the business process management system (BPMS) ELMA [15]. Description of the implementation of the collection of information about the self-assessment of the enterprise is given in Russian in [16].

To build a reliable mathematical model of the dynamics of organizational maturity of an enterprise, it is desirable to have data on the actual level of organizational maturity over a number of years.

However, in our case, information was collected on the organizational maturity of the company based on the results of 2 years of work - as of December 31, 2016 and December 31, 2017. $x_{2016} = [1,25 \quad 1,27 \quad 1,68 \quad 2,00 \quad 1,33 \quad 1,53]$, $x_{2017} = [1,95 \quad 1,60 \quad 2,03 \quad 2,60 \quad 1,47 \quad 1,80]$.

This amount of experimental data is not enough to build a statistically reliable model that describes the growth of maturity in their relationship. The use of linear interpolation of these indicators for shorter periods of time, for example, for months (such an attempt was made), also does not solve the problem, since the data in the resulting arrays are linearly dependent, which does not allow the use of regression analysis methods.

To overcome this problem, we will additionally adopt the following assumptions:

1. We simplify the structure of the matrix A, neglecting the relationship between the various indicators of the level of maturity, assuming that each of the indicators varies independently.
2. Let us evaluate two hypotheses about the maturity level dynamics:
   - a linear increase in maturity level indicators over time;
   - on the accelerated growth of indicators of maturity, which corresponds to the interpolation of indicators by the exponential law.

Building models of the dynamics of growth indicators of enterprise maturity on the basis of accepted hypotheses will also allow for modeling the process of managing this growth.

6. Linear interpolation and prediction of maturity indicators

Initially, the calculation will be carried out with a time step of 2 months, i.e. for the year, 6 values of the vector of indicators of maturity levels linearly distributed between x_{2016} и x_{2017} are calculated.

It should be noted that here and later the formulas are recorded in vector form, since it was in this way that the parameters were calculated in the Matlab system.

Linear step of maturity levels:

$$D = \frac{x_{2017} - x_{2016}}{5} \quad (2)$$

$$x_i = x_{2016} + (i-1) * D \quad (3)$$

The latter value corresponds to the end of the first year.

We extrapolate the dynamics of maturity levels to a 5-year interval:

$$x_k = x_{2016} + (k * 6 - 1) * D \quad (4)$$

Where *k* is the number of the year (2016, 2017, etc.)

7. Exponential interpolation and prediction of maturity indicators

Similar to the previous item, the calculation will first be carried out according to the formula

$$x_i = x_{2016} + e^{\alpha * i * dt} - I \quad (5)$$

(where *I* - unit vector of dimension *N*) with a time step of 2 months, i.e. for the year, 6 values of the maturity levels vector are calculated. Now we assume they are distributed in an exponential curve between x_{2016} and x_{2017}.

Intermediate exponent in terms of:

$$\alpha = \frac{\ln(x_{2017} - x_{2016} + I)}{t} \quad (6),$$

accordingly, when $t = 1$

$$\alpha = \ln(x_{2017} - x_{2016} + I) \quad (7).$$

Further, according to the formula (6), the values of the vector *x* were interpolated during 2016.

Then, based on the exponential dependence, the extrapolation of the value of the vector *x* was carried out at a 5-year interval.

We see that exponential extrapolation provides a more optimistic forecast than linear extrapolation.

8. Prognosis of the maturity level indicators

We calculate the increase in the level of maturity on the basis of model (1) with the expert task of control signals $u(t)$.

Based on the calculations, we will identify the parameters of the control model.

Create a matrix A (matrix of increments of controlled indicators in the control model in the formula (1)), based on the average values of the ultrasonic increase factors in one step x_{i+1}/x_i for all components of the vector x.

Let us make a simulation of the functioning of the management system of the company's maturity levels by deviation from the target value. To do this, set the target value of the vector of maturity levels $X_{targ} = [5 \quad 5 \quad 5 \quad 5 \quad 5 \quad 5]$ corresponding to a fully mature company.

The relative magnitude of the control action is determined by the matrix $U = V^{-1}$, where V is the diagonal matrix based on the vector D. Thus, each diagonal element of the matrix U is inversely proportional to the increment of maturity levels for the corresponding component of the vector x.

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

Calculate the increase in ultrasound over 5 years, varying k in the range from 0.00 to 0.03.

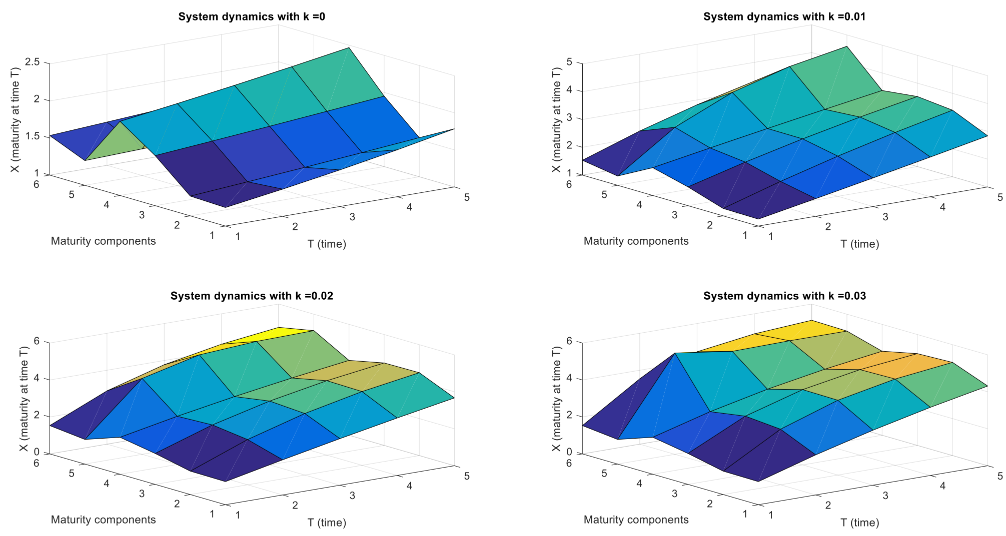

Figure 1. The evolution of the maturity levels of the system with different indicators of the efficiency of using funds for the development of management technologies.

In Figure 1, it can be seen that when $k = 0$ (low efficiency of investment in development projects), the system shows extremely slow growth in terms of indicators, and even a decline in indicators.

As the efficiency of investments increases, the growth rate of maturity increases with time, and the higher the efficiency, the faster the reduction of the gap between the current state of the indicators and the target one.

Efficiency equal to 0.3 and 0.4 ensures the achievement of the target level of maturity during the 5-year forecast interval.

Conclusion

Thus, the proposed method of planning and evaluating the process of managing the maturity of business processes allows you to create a mathematical model of organizational development in terms of the theory of dynamic systems management. The classical dynamic model of the control system allows us to describe the nature of the behavior of such an indicator of an organization as the level of maturity. In this case, the actual data on the dynamics of the level of maturity of the organization allow for the identification of control system parameters.

The deterministic model of the control system in discrete time reproduces such effects as:

- stagnation of the level of maturity of the organization with low efficiency of investment;
- increase of maturity when applying a control signal;
- efficient operation of the regulator with deviation feedback, ensuring that the maturity level of the system is brought to the target indicator.

The advantage of the proposed methodology is that it is possible to vary the degree of detail of taking into account the components of organizational maturity - a single total indicator of organizational maturity of the entire company, self-assessment only on key elements or detailed self-assessment. Since the technique is based on matrix mathematics, an increase in the dimension of the problem will not cause a fundamental change in the computational algorithms.

Further work may be as follows.

- development of methods for optimizing the allocation of resources for projects to improve maturity by the criterion of maximum efficiency of their spending;
- development of methods and algorithms for assessing the impact of organizational maturity indicators on the parameters of business processes - execution time, cost of implementation, including an assessment of statistical parameters - mathematical expectations that characterize the parameter itself and their variances that characterize the predictability of their management process.

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