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# Analysis of industrial performance in terms of achieving quality goals

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**Abstract.** An approach is developed to analyze the results of the industrial enterprise in terms of achieving quality goals. The results of approbation of the developed approach are presented on the example of ZAO NPP ‘ANA’ (St. Petersburg). Based on the mathematical models created earlier by the authors, stability conditions are obtained depending on the values of the parameters of the enterprise quality management system, which enables to solve the problems of managing the state of this system as a subsystem of general management. For the study, the following were used: apparatus of the automatic control theory, Data Mining methodology, and elements of a Balanced Scorecard.

## 1. Introduction

To determine attainability of goals in the field of quality, the apparatus of automatic control theory (ACT) was used in [1, 2]. In these works, linear and non-linear mathematical models of the enterprise’s quality management system (QMS) in the state space are presented, while the current values of the goals in the field of quality and the rate of change are selected as variable states. In general terms, both of these models [1,2] are a system of differential equations of the 1-st order and have the following form:

$$d\mathbf{X}(t)/dt = \mathbf{H}(\mathbf{X}(t)) + \mathbf{L}(\mathbf{U}(t)), \quad (1)$$

where  $\mathbf{X}(t)$  and  $d\mathbf{X}(t)/dt$  are vectors of current values of goals in the field of quality and rates of change, respectively;  $\mathbf{H}$  is the operator of the system properties of the activity;  $\mathbf{L}$  is a control operator for purposeful changing of the target values state;  $\mathbf{U}(t)$  is the quality management vector of an enterprise  $\mathbf{U}(t) = [\mathbf{X}(t)]$ ,  $[\mathbf{X}(t)]$  are the required target values.

In [1], four options of specific conditions for the functioning of QMS are considered, the most difficult of which is the option where activities to achieve the goals are interconnected, both through partial use of the general potential of the enterprise, and with organizational resistance to the mutual achievement of these goals. As a rule, open bibliographic sources and the Internet, including [3,4], provide data characterizing the economic activities of enterprises, therefore, it is of considerable interest to analyze properties using experimental data characterizing the activities of enterprises. Such data characterize, as a rule, the sustainable development of industrial enterprises with small changes in economic indicators, which allows the use of a linear QMS model.

The objective of this work is to analyze the performance of an industrial enterprise in terms of achieving quality goals.

## 2. Approach to the performance analysis of the industrial enterprise in terms of achieving quality goals

Sustainable development of the enterprise in modern conditions is impossible without the functioning of a stable and managed QMS [5-7].

To achieve the research goal, we consider a situation where quality goals are interconnected with each other, both through partial use of the general potential of the enterprise, and with organizational resistance to the mutual achievement of these goals (option 4 according to [1]), using the one introduced in [1] conceptual apparatus.

Let the company set two goals of operational management in the field of quality: to achieve the required values of goals  $[x_1]$  and  $[x_2]$  with their initial values:  $x_1(0), x_2(0), x_3(0), x_4(0)$ . Management actions:  $u_1=[x_1]$  and  $u_2=[x_2]$  correspond to the values of the goals that must be achieved after a certain period of time and can be expressed in terms of the Heaviside step function. Then, the generalized mathematical model (1) in a linear approximation when managing by goals will correspond to the system of equations:

$$\frac{d\mathbf{X}(t)/dt}{dt} = \mathbf{AX}(t) + \mathbf{LU}, \quad (2)$$

where  $\mathbf{A}$  and  $\mathbf{L}$  are  $4 \times 4$  square matrices, moreover

$$\mathbf{A} = \begin{pmatrix} 0 & 1 & 0 & 0 \\ -a_2 & -a_3 & -V_1 a_6 & -V_2 a_7 \\ 0 & 0 & 0 & 1 \\ -V_3 a_2 & -V_4 a_3 & -a_6 & -a_7 \end{pmatrix}, \quad (3)$$

or

$$\begin{pmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \\ \dot{x}_4 \end{pmatrix} = \begin{pmatrix} 0 & 1 & 0 & 0 \\ h_{21} & h_{22} & h_{23} & h_{24} \\ 0 & 0 & 0 & 1 \\ h_{41} & h_{42} & h_{43} & h_{44} \end{pmatrix} \begin{pmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{pmatrix} + \begin{pmatrix} 0 & 0 & 0 & 0 \\ 0 & l_{22} & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & l_{44} \end{pmatrix} \begin{pmatrix} u_1 \\ u_2 \end{pmatrix}, \quad (4)$$

where coefficients  $h_{21\dots44} \equiv -a_{2\dots7}$  are determined as follows:  $h_{21} = -c_1 \cdot m_1^{-1}$ ,  $h_{22} = -j_1 \cdot m_1^{-1}$ ,  $h_{43} = -c_2 \cdot m_2^{-1}$ ,  $h_{44} = -j_2 \cdot m_2^{-1}$ ,  $h_{23} = -V_1 h_{43}$ ,  $h_{24} = -V_2 h_{44}$ ,  $h_{41} = -V_3 h_{21}$ ,  $h_{42} = -V_4 h_{22}$ ; and the initial coefficients correspond to  $c_1, c_2$  – the reciprocal of the potential of the enterprise in achieving the 1st and the 2nd quality goals;  $j_1, j_2$  – the resistance arising from the achievement of the 1st and the 2nd goals in the field of quality;  $m_1, m_2$  – levels of complexity of the enterprise's performance in achieving the 1st and the 2nd goals in the field of quality;  $V_{1\dots4}$  – coefficients of interconnectedness of goals,  $V_1$  – the share of specific potential aimed at achieving the second goal, which is used to achieve the first goal,  $V_3$  – the share of specific potential aimed at achieving the first goal, which is used to achieve the second goal,  $V_2$  – the share of resistivity that occurs when the second goal is achieved, which prevents the achievement of the first goal,  $V_4$  – the share of resistivity that occurs when the first goal is achieved, which prevents the second goal from being achieved.

The controllability of QMS described by model (4) will be provided when determining coefficients  $l_{22}$  and  $l_{44}$  from the solution of the system of linear equations [1]:

$$h_{21}x_1 + h_{23}x_3 + l_{22}u_1 = 0, \quad h_{41}x_1 + h_{43}x_3 + l_{44}u_2 = 0. \quad (5)$$

The coefficients  $V_{1\dots4} \in [-1..1]$  characterize the degree and nature of the interconnections arising from the complex interaction of socio-economic, organizational and technical subsystems of enterprises. When  $V_{1\dots4} = 0$ , there is a complete absence of interconnections of subsystems in achieving goals (work is carried out by different units using different resources); with  $V_{1\dots4} = \pm 1$  there is a complete interconnection of subsystems in achieving goals (work is performed by the same units with the involvement of the same resources).

It is advisable to evaluate the ability to achieve the set target values using stability areas. In [8], stability was studied ‘in the small’, based on an analysis of the properties of equation (2), reduced to the following form:

$$\frac{d\mathbf{X}(t)}{dt} = \mathbf{AX}(t) \quad (6)$$

and for the asymptotic stability of system (6) it is necessary and sufficient that all the roots  $\lambda_i$  of the equation

$$\det [\lambda\mathbf{E} - \mathbf{A}] = 0, \quad (7)$$

had negative real parts.

The characteristic equation (7) in the presence of two goals in the field of quality, taking into account the interconnections  $V_{1\dots 4}$  between them, has the following form:

$$\begin{aligned} \lambda^4 + (j_1m_2 + j_2m_1)(m_1m_2)^{-1}\lambda^3 + (1 - V_2V_4)(c_1m_2 + c_2m_1 + j_1j_2)(m_1m_2)^{-1}\lambda^2 + \\ + [(1 - V_1V_4)j_1c_2 + (1 - V_2V_3)j_2c_1](m_1m_2)^{-1}\lambda + c_1c_2(1 - V_1V_3)(m_1m_2)^{-1} = 0. \end{aligned} \quad (8)$$

The general condition of the system stability, in which goals in the field of quality are achievable, corresponds to the system of inequalities obtained by the Hurwitz criterion [9]:

$$\left\{ \begin{array}{l} a_3 + a_7 > 0; \\ -a_3a_6(1 - V_1V_4) - a_2a_7(1 - V_2V_3) + (a_3 + a_7)(a_2 + a_6 + a_3a_7(1 - V_2V_4)) > 0; \\ -(a_3a_6(1 - V_1V_4) + a_2a_7(1 - V_2V_3))^2 - a_2a_6(a_3 + a_7)^2(1 - V_1V_3) + \\ +(a_3 + a_7)(a_2 + a_6 + a_3a_7(1 - V_2V_4))(a_3a_6(1 - V_1V_4) + a_2a_7(1 - V_2V_3)) > 0; \\ -a_2a_6(a_3a_6(1 - V_1V_4) + a_2a_7(1 - V_2V_3))^2(1 - V_1V_3) - a_2^2a_6^2(a_3 + a_7)^2 \times \\ \times (1 - V_1V_3)^2 + a_2a_6(a_3 + a_7)(a_2 + a_6 + a_3a_7(1 - V_2V_4))(a_3a_6(1 - V_1V_4) + \\ + a_2a_7(1 - V_2V_3))(1 - V_1V_3) > 0, \end{array} \right. \quad (9)$$

where  $a_2 = c_1 \cdot m_1^{-1}$ ;  $a_3 = j_1 \cdot m_1^{-1}$ ;  $a_6 = c_2 \cdot m_2^{-1}$ ;  $a_7 = j_2 \cdot m_2^{-1}$ .

The following section presents the results of testing the developed approach to the analysis of the performance of the industrial enterprise in terms of achieving quality goals.

### 3. Results of testing the developed approach to the analysis of the industrial enterprise performance in terms of achieving quality goals

In [3], a list of indicators characterizing organizational sustainability and used to assess the performance of textile and light industry enterprises from 2013 to 2018 is presented. The given indicators are characterized by the coefficients:  $X_1$  – renewal of fixed assets;  $X_2$  – absolute cash liquidity;  $X_3$  – autonomy of capital;  $X_4$  – debt to equity ratio;  $X_5$  – staff turnover;  $X_6$  – information armament;  $X_7$  – proportion of social benefits in the net profit amount;  $X_8$  – proportion of social benefits in the payroll;  $X_9$  – environmental friendly products;  $X_{10}$  – current activities of the enterprise;  $X_{11}$  – innovative potential of the enterprise;  $X_{12}$  – mechanization (automation) of labor;  $X_{13}$  – rhythm. Based on an expert assessment, it was found that the key indicators characterizing the organizational sustainability of enterprises, which can also be considered as goals in the field of quality, are environmental friendliness coefficient ( $X_9$ ) and rhythm coefficient ( $X_{13}$ ).

To build a mathematical model for the formation of product quality (4), it is necessary to determine the coefficients of matrix  $A$ .

Product certification is one of the activities of an organization. Since the ecological coefficient  $X_9$  is determined by the volume of certified products, and when determining the rhythm coefficient  $X_{13}$ , the scope of certification is also taken into account, the achievement of the required target values ( $X_9$ ,  $X_{13}$ ) does not contradict each other. At the same time, regardless of whether the product passed certification or not, the work was carried out according to the plan and the general potential was used.

By experts, the authors found to which component of the dynamics equation the indicators  $X_1-X_8$ ,  $X_{10}-X_{12}$  belong: to the complexity of the process, to the organizational resistance coefficient, or to

the organization's potential. Also, depending on the goal, weights of each indicator are determined. Results of the expert assessment are presented in Table 1.

**Table 1.** Results of expert assessment for identifying indicators.

Weight coefficient for goal $i$	Process complexity, $m_{ij}$			Given potential of the organization, $c_{ij}$							
	$X1$	$X6$	$X12$	$X2$	$X3$	$X4$	$X5$	$X7$	$X8$	$X10$	$X11$
$X9$	0.35	0.30	0.35	0.13	0.12	0.08	0.15	0.08	0.13	0.15	0.15
$X13$	0.35	0.20	0.45	0.12	0.14	0.07	0.15	0.07	0.12	0.17	0.17

To determine the coefficients of system (4), the values of all indicators must satisfy the conditions:  $m \in [0..1]$ ;  $j \in [-1..1]$ ;  $c \in [0..1]$ .

Since the large values of indicators  $X1$ ,  $X6$ ,  $X12$  ensure the achievement of goals, and reduce complexity, the following expressions were used to normalize them:  $(1 - X1)$ ;  $(1 - 0.28X6)$ ;  $(1 - X12)$  [10]. Thus, the difficulty score for goal  $X9$  will be determined by the formula

$$m_1 = m_{91}(1 - X1) + m_{96}(1 - 0.28X6) + m_{912}(1 - X12). \quad (10)$$

For goal  $X13$ , such an indicator will be determined by the formula

$$m_2 = m_{131}(1 - X1) + m_{136}(1 - 0.28X6) + m_{1312}(1 - X12). \quad (11)$$

The reciprocal of the potential (reduced potential) for goal  $X9$  is determined by the formula

$$c_1 = c_{92}X2 + c_{93}X3 + c_{94}X4 + c_{95}X5 + c_{97}X7 + c_{98}X8 + 0.8c_{910}X10 + c_{911}X11. \quad (12)$$

The reduced potential  $c_2$  for goal  $X13$  is determined similarly.

The organizational resistance coefficient depends on the complexity ( $k_1$ ) and the reduced potential ( $k_2$ ) of the process, and its calculation is performed as follows:

$$j = k_1 \cdot m + k_2 \cdot c, \quad (13)$$

where  $k_1$ ,  $k_2$  – the coefficients determined by expert assessment methods, here they were taken equal: for goal  $X9$ :  $k_1 = 0.4$ ;  $k_2 = 0.6$ ; for goal  $X13$ :  $k_1 = 0.3$ ;  $k_2 = 0.7$ .

Table 2 presents the initial data of indicators  $X1 - X13$  ZAO NPP ‘ANA’, St. Petersburg according to [3] from 2013 to 2018, the values of indicators themselves are given without taking into account standardization, and the columns of target values are highlighted. Using expressions (10) - (13), the values of the parameters of system (2) were obtained: indicators of complexity, reduced potential and organizational resistance for the enterprise in question (Table 3).

**Table 2.** Baseline data of factors and goals according to years of ZAO NPP ‘ANA’ [3].

Year	$X1$	$X2$	$X3$	$X4$	$X5$	$X6$	$X7$	$X8$	<b><math>X9</math></b>	$X10$	$X11$	$X12$	<b><math>X13</math></b>
2013	0.094	0.652	0.775	0.291	0.125	1.875	0.020	0.200	<b>0.129</b>	1.061	0.740	0.625	<b>0.850</b>
2014	0.105	0.680	0.799	0.252	0.118	2.941	0.022	0.220	<b>0.141</b>	1.09	0.850	0.647	<b>0.870</b>
2015	0.119	0.682	0.825	0.213	0.105	3.158	0.024	0.240	<b>0.154</b>	1.119	0.870	0.737	<b>0.900</b>
2016	0.121	0.673	0.836	0.196	0.095	3.571	0.025	0.250	<b>0.159</b>	1.127	0.900	0.714	<b>0.930</b>
2017	0.148	0.687	0.857	0.167	0.083	3.417	0.027	0.270	<b>0.161</b>	1.148	0.940	0.667	<b>0.960</b>
2018	0.159	0.721	0.875	0.142	0.074	3.111	0.028	0.280	<b>0.177</b>	1.200	0.980	0.630	<b>0.980</b>

**Table 3.** The obtained values of indicators of complexity, reduced potential and organizational resistance for ZAO NPP ‘ANA’.

Year	Goal X9			Goal X13		
	$m_1$	$c_1$	$j_1$	$m_2$	$c_2$	$j_2$
2013	0.592	0.492	0.532	0.582	0.516	0.542
2014	0.492	0.518	0.507	0.509	0.544	0.530
2015	0.437	0.525	0.490	0.451	0.553	0.512
2016	0.410	0.529	0.482	0.438	0.558	0.510
2017	0.430	0.541	0.497	0.458	0.571	0.526
2018	0.465	0.559	0.521	0.488	0.589	0.549

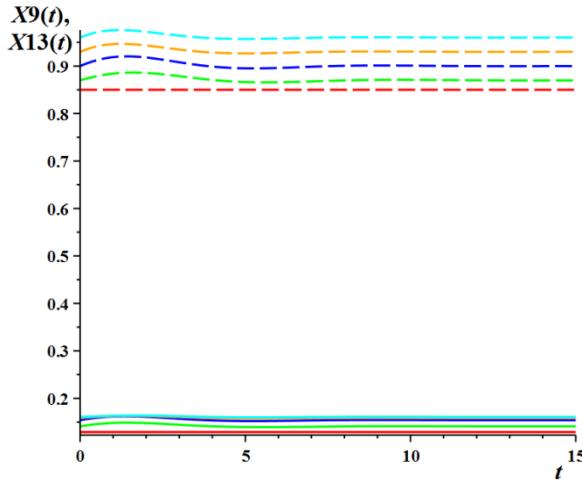
The values of coefficients  $V_{1\dots 4}$ , characterizing the mutual influence of potential and organizational resistance, should be determined on the basis that these values should take into account the magnitude and nature of the influence. Thus, for certification, the resources of a limited number of units are used, while their activities ensure, inter alia, the achievement of a rhythm index. In other words, almost all potential aimed at achieving goal  $X9$  will affect the achievement of goal  $X13$ . However, only a small part of the potential aimed at achieving goal  $X13$  will affect the achievement of goal  $X9$ . The complexity indicators are not changed. In this example, the magnitude of the impact on the achievement of goal  $X13$  was 0.9. For goals  $X9$  and  $X13$ , interconnection through organizational resistance contributes to their mutual achievement, the goals do not contradict each other, therefore the parameters have negative signs:  $h_{41} = -1 \cdot 0.9 \cdot h_{21}$ ,  $h_{42} = -1 \cdot 0.9 \cdot h_{22}$ , t.e.  $V_3 = V_4 = -0.9$ . Here the factor ‘-1’ reflects the direction of influence.

At the same time, 0.12 of the potential aimed at achieving goal  $X13$  will be aimed at achieving goal  $X9$ :  $h_{23} = -1 \cdot 0.12 \cdot h_{43}$ ,  $h_{24} = -1 \cdot 0.12 \cdot h_{44}$ , t.e.  $V_1 = V_2 = -0.12$ .

Determination of all specific conditions for the operation of the enterprise from 2013 to 2017 inclusive (system parameters (4) are presented in Table 4) enabled to simulate goals in the field of quality and the speed of their achievement, the results of which are shown in Figures 1 and 2 (the solid line indicates goal  $X9$  and the speed of its achievement, the dotted line shows goal  $X13$ , red - goals and speed of their achievement in 2013, green - in 2014, blue - in 2015, orange - in 2016, blue - in 2017).

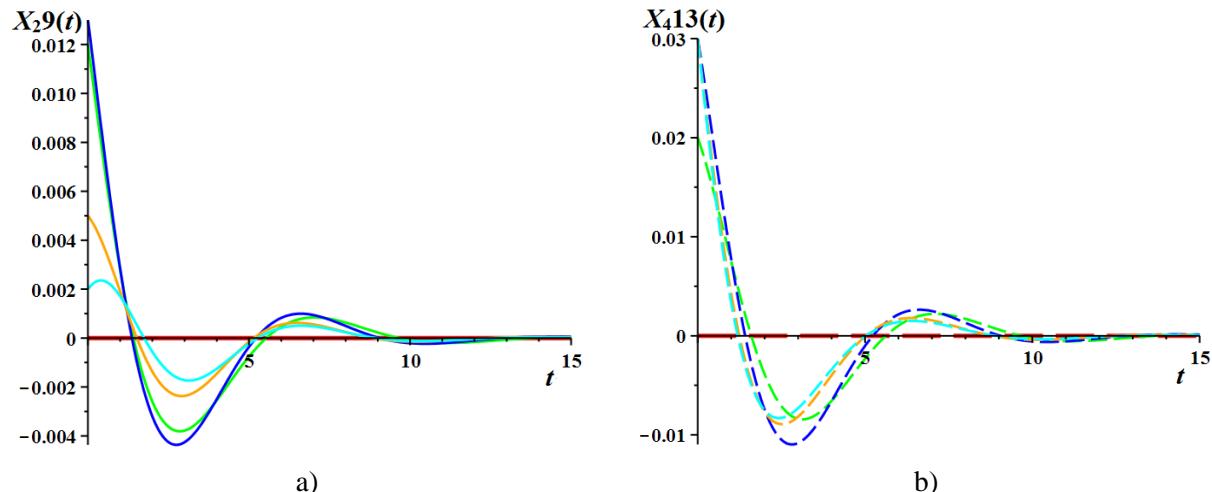
**Table 4.** Model parameters.

Year	$h_{21}$	$h_{22}$	$h_{23}$	$h_{24}$	$h_{41}$	$h_{42}$	$h_{43}$	$h_{44}$	Goal speeds		$l_{22}$	$l_{44}$
									$X2_9$	$X4_{13}$		
2013	-0.830	-0.898	0.106	0.112	0.747	0.808	-0.886	-0.932	0	0	0.119	0.755
2014	-1.052	-1.031	0.128	0.125	0.947	0.928	-1.069	-1.041	0.012	0.020	0.239	0.884
2015	-1.201	-1.121	0.147	0.136	1.081	1.009	-1.224	-1.135	0.013	0.030	0.332	1.006
2016	-1.291	-1.175	0.153	0.140	1.162	1.057	-1.273	-1.164	0.005	0.030	0.392	1.041
2017	-1.259	-1.155	0.149	0.138	1.133	1.040	-1.245	-1.147	0.002	0.030	0.335	1.034



**Figure 1.** Results of modeling goals  $X_9$  and  $X_{13}$  in the field of quality of ZAO NPP ‘ANA’.

According to the results presented in Figures 1 and 2, it can be seen that from 2013 to 2017 both quality goals were achievable, while the system was in a stable state, which is confirmed by the data provided by the enterprise, as well as the fact that the ZAO NPP ‘ANA’ continues to operate successfully. A change in the value of goal  $X_9$  upon its achievement was accompanied by smaller deviations than upon achievement of goal  $X_{13}$ . This is due to the fact that large resources were involved to achieve goal  $X_9$ , including units unrelated to goal  $X_{13}$ . Such conclusions confirm the found values of the eigenvalues of matrix  $A$  (Table 5).



**Figure 2.** The results of modeling the rates of achievement of goals  $X_9$  and  $X_{13}$  in the field of quality of ZAO NPP ‘ANA’: a) for goal  $X_9$ ; b) for goal  $X_{13}$ .

**Table 5.** The eigenvalues of matrix  $A$ .

Year	Eigenvalues of matrix $A$	Year	Eigenvalues of matrix $A$
2013	$-0.307 \pm 0.693i; -0.608 \pm 0.879i$	2016	$-0.393 \pm 0.841i; -0.777 \pm 1.049i$
2014	$-0.348 \pm 0.769i; -0.688 \pm 0.967i$	2017	$-0.386 \pm 0.831i; -0.765 \pm 1.039i$
2015	$-0.379 \pm 0.819i; -0.749 \pm 1.025i$	2018	$-0.377 \pm 0.817i; -0.746 \pm 1.022i$

The properties of the enterprise system, as well as the possibilities of achieving the set goals, can be judged on basis of identified relationships between the coefficients  $V_{1..4}$ . Thus, knowing the type of interconnection of goals for the enterprise in question:  $V_1 = V_2$ ,  $V_3 = V_4$ , the condition for system stability (9) for ZAO NPP ‘ANA’ looks like that:

$$\begin{cases} a_3 + a_7 > 0; \\ -a_3 a_6 V - a_2 a_7 V + (a_3 + a_7)(a_2 + a_6 + a_3 a_7 V) > 0; \\ -V^2(a_3 a_6 + a_2 a_7)^2 - V(a_3 + a_7)(a_2 a_6(a_3 + a_7) - \\ -(a_2 + a_6 + a_3 a_7 V)(a_3 a_6 + a_2 a_7) > 0; \\ -V^3 a_2 a_6(a_3 a_6 + a_2 a_7)^2 - V^2 a_2 a_6(a_3 + a_7)(a_2 a_6(a_3 + a_7) + \\ +(a_2 + a_6 + a_3 a_7 V)(a_3 a_6 + a_2 a_7) > 0, \end{cases} \quad (14)$$

where  $V = 1 - V_1 V_3$ .

When substituting numerical values in system (14) for the considered example, using the data from 2013, the system is stable under the following conditions:  $V_1 = V_2 \in [-1..1]$ ;  $V_3 = V_4 \in [-1..1]$ ;  $\{V_1 = V_2\} \neq \{V_3 = V_4\} \neq \pm 1$ .

If the values of the parameters  $m, j$  and  $c$  are unchanged, the enterprise would be able to achieve its goals in the field of product quality by considering such a formulation of the control problem, and its QMS is stable for any admissible numerical values of the relationship of goals, with the exception of  $V_1 = V_3 = \pm 1$ .

The analysis of the interaction of  $V_{1..4}$  coefficients, together with the simulation results, allowed us to draw the following conclusions:

- the most favorable and effective for the enterprise in question was 2016, because it is for this year that the largest permissible values for the coefficients  $V_{1..4}$  are characteristic; in addition, it was in 2016 that the most stable QMS of the enterprise was observed, as evidenced by the maximum real parts of the eigenvalues of matrix  $A$  (Table 5);

- with known values  $c_1 \cdot m_1^{-1}, j_1 \cdot m_1^{-1}, c_2 \cdot m_2^{-1}, j_2 \cdot m_2^{-1}$  in order to achieve the goals of the enterprise, coefficients  $V_3$  and  $V_4$  in 2016 could take any values from the interval  $[-1..1]$  under the following conditions:  $V_1 = -0.6 \cup V_2 \in [-0.33..0.22]$ ;  $V_1 = -0.5 \cup V_2 \in [-0.54..0.52]$ ;  $V_1 = -0.4 \cup V_2 \in [-0.65..0.57]$ ;  $V_1 = -0.3 \cup V_2 \in [-0.73..0.63]$ ;  $V_1 = -0.2 \cup V_2 \in [-0.79..0.68]$ ;  $V_1 = -0.1 \cup V_2 \in [-0.81..0.72]$ ;  $V_1 = 0 \cup V_2 \in [-0.77..0.77]$ ;  $V_1 = 0.1 \cup V_2 \in [-0.72..0.81]$ ;  $V_1 = 0.2 \cup V_2 \in [-0.68..0.79]$ ;  $V_1 = 0.3 \cup V_2 \in [-0.63..0.73]$ ;  $V_1 = 0.4 \cup V_2 \in [-0.57..0.65]$ ;  $V_1 = 0.5 \cup V_2 \in [-0.52..0.54]$ ;  $V_1 = 0.6 \cup V_2 \in [-0.22..0.33]$ ;

- the possibility of entering into the interval  $[-1..1]$  the values of coefficients  $V_3$  and  $V_4$  with  $V_1 = -0.6$  and the permissible values of coefficient  $V_2$  appears only in 2014, i.e. in 2013, at  $V_1 = -0.6$ , the quality system of the enterprise in question could be stable only at specific points in the values of the considered coefficients;

- for the remaining  $V_1$  and  $V_2$  in 2016 there are no areas in which  $V_3$  and  $V_4$  can take any value from the interval  $[-1..1]$ .

#### 4. Results and discussions

Before directly summarizing the results of the studies, we note the methods of working with data implicitly used by the authors. The assumption that if certain goals were set is due to the fact that in [3, 4] the considered indicators were not management objectives at the enterprise level, which is typical when using a balanced scorecard (BS) [11, 12]. The use of this system is characterized by a limited set of indicators that reflect all areas of the enterprise, therefore, goals X9 and X13 basically could not be considered as goals at the level of the entire enterprise. However, we note that such a consideration is possible when deploying / decomposing BS to the lower level of processes. The use of such data itself was performed in accordance with the Data Mining methodology [13, 14].

Thus, the paper proposes an approach to the analysis of the results of an industrial enterprise in terms of achieving quality goals, based on mathematical models of product quality dynamics obtained by the authors earlier. The developed approach to the analysis of the industrial enterprise activity results was tested on the example of ZAO NPP ‘ANA’, the main result of which is substantiation of the applicability of the developed approach. The results of the analysis showed the possibility of determining the degree and nature of the relationships arising from the interaction of enterprise subsystems, as well as the possibility of regulating and managing QMS in achieving quality goals.

The directions of further research are related to the continuation of the analysis of complex interaction of socio-economic, organizational and technical subsystems of specific industrial enterprises and their parameters on the values of product quality indicators and the nature of their changes over time based on open data on the activities of other industrial enterprises. In particular, it is of considerable interest to choose the laws of change in control actions based on continuous functions that depend on time, for which the initial and required values of goals in the field of quality will be boundary conditions.

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