Dynamic Normals as an Industrial Enterprise Management Tool in the Digital Economy

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ABSTRACT

Dynamic normals as an industrial enterprise management tool in the digital economy. In the context of the formation of a new technological structure, the digitalization of the economy, digital enterprises formation, characterized by a transition to a qualitatively new level of use of digital technologies in all areas of socio-economic activity, the relevance of researching directions, trends, and the formation of management tools in rapidly changing conditions is growing. One of the promising approaches is the consideration of the enterprise as a self-organizing system. This article is devoted to the formation of methodology for assessing the stage of enterprise development as a self-organizing microeconomic system. The method of dynamic normals has been suggested as a tool for self-organizing systems management. Variants of managerial influence actions depending on the self-organization factor and stages of company development have been proposed.

Keywords: enterprise, management, industrial enterprise, digital economy, correlation analysis, ranking, self-organization, digital enterprise

1. INTRODUCTION

One of the main conditions for the survival and development of modern enterprises in the digital economy is focusing on the implementation of management capabilities and self-organization of social and economic system.

The management of such systems is particularly difficult. This difficulty results in the optimum combination of external managerial influence and internal processes of self-organization. At present, the development of a management mechanism for self-organizing systems at microlevel face a theoretical and practical issue. This mechanism allows combining properties of stability and, at the same time, flexibility and adaptability. The core of the controlling mechanism is the evaluation stage of enterprise development, which in the long run determines the options of managerial influence for social and economic system as it undergoes digital transformation. The developed method of evaluation is intended for:

- monitoring, aimed at rapid identification of critical parameters and determination of the enterprise position (stage) in a self-development cycle;
- analysis, designed to identify benchmarks for self-organizing systems to be adjusted;
- management and development of optimal managerial influence actions according to the stages of development and control parameters of the system identified in the course of monitoring and analysis;
- prediction based on determining the enterprise position in a self-development cycle and its predictable transition to the next stage.

Such foreign scholars as Hermann Haken, Russell L. Ackoff, Norbert Wiener, Paul Krugman, William Ashby, Peter Checkland, Edgar Morin, Humberto Maturana, Stafford Beer, Margaret Mead, Gregory Bateson, and Niklas Luhmann, made great contribution to the theory of self-organisation. Russian scientists S. Kurdyumov, A. Samarsky, B. Kadomtsev, E. Knyazeva, V. Budanov, N. Moiseev, A. Nazaretyan, D. Chernavsky, L. Klimontovich, A. Kolesnikov, G. Ruzavina, A. Ursul, V. Vasylkova, A. Potapov, etc. made valuable contribution to the study of complex self-organizing processes.

The work of such domestic scientists as Delic [1], Hadiguna [2], Macchi [3], Savino [3], Galankashi [4], Helmi [4], Rahim [4], Rane [5], Holbeche [6], Pellizzoni [7], Buganza [7], Annos [8], Thomas [9], Edwards [10].

Application of dynamic normals method while studying the development of socio-economic systems can be found in the works of Syroyezhin [11], Mazhazhikhov [12], Miskhozhev [12], Tonkykh [13], Sizykh [14], Shestakova [15], Prytkov [15], Sitzhanova [15].

Scientific validity is defined by the essence of the author's approach to the problem of enterprise management as a self-organizing socio-economic system. Author's research methodology is based on the method of dynamic normals as a part of the control mechanism for self-organizing systems. This approach creates the basis of forming the mechanism

of enterprise management as a self-organizing system. The choice of management actions is determined by the ratio of self-organization and the stage of enterprise development.

The representation of an enterprise in the concept of self-organization as an open dynamic system causes denial of the static presentation of indicators and its transition to dynamic criteria.

In contrast to the static characteristics, *a dynamic criterion* is more complex in nature. It determines the trend in economic system, showing the state, to which it should aspire at a given period of time.

One of the tools to analyse the set of indicators in dynamics is the method of dynamic norms. The basis for this method was laid by Professor I.M. Syroyezhin [11], who developed the comprehensive indicator for economic performance assessment systems.

2. MATERIAL AND METHODS

The method of dynamic norms is based on the formation of a fixed set of indicators, arranged on the basis of their movement ranking (generally, index growth rate). The factual and normative (reference) order of parameters is compared using correlation analysis tools.

The selection of relative performance serves as the basis of evaluation due to representation of the transformations from one state to another, so the content of the activity is revealed in the changes being generated. This selection also stipulates the assessment of activity level not at the level of one or another indicator, but by its increment, reflecting the dynamics of the object.

Figure 1 is a flowchart describing the method of dynamic norms for assessing the stage of development for social and economic system self-organization.
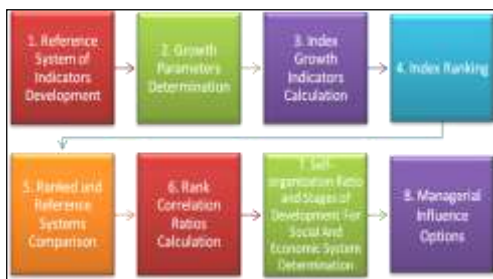

Figure 1 Phases of evaluation for the stage of socio-economic system development by the dynamic norms method

The necessary condition for the method of dynamic norms application is to create a system of economic development indicators that reflect the state to which it should aspire (reference and normative).

The process of developing a reference system of indicators is to solve two problems: first, to construct the system of indicators assessing the best of the company, and, secondly, to establish reference orders for the growth indicators amending.

The following ones are the criteria for inclusion some indices into the system of indicators formed:

1. dynamic performance and relations with the environment, and also the relations between company subdivisions;
2. lack of duplication (excluding indicators calculated as the ratio between or multiplication of each other, since the method developed measures indicators through their relations growth rate);
3. individualization of the profile (expressed in different units of measurement, selection for the calculation base, small changes in names of indicators, depending on the industry specifics and individual peculiarities of a specific entity, with economic essence of the indicators included in the system not being changed);
4. focusing on tactic activities (control of the strategic aspects of management in the developed system of indicators takes place with the help of a set of reference tactical targets relations monitoring).
5. clear formalization and quantification;
6. limitation in the number (optimal set of indicators includes a variety of 6-15 indicators);
7. managerial influence (all indicators included in the system can be adjusted, each indicator could be a control parameter, which would «return» the company into the stage of dynamic equilibrium) ;
8. need to group the indicators on the definite basis (optimal basis for grouping various indicators of activity, in our opinion, is the functional orientation of the enterprise internal subsystems).

3. RESULTS AND DISCUSSION

Research of foreign and domestic valuation methodologies of the enterprise performance, as well as filtering of various indicators according to the criteria mentioned above allowed us to form a system of indicators represented in Table 1. The next step was the construction of the reference system of indicators used while comparing the actual values of indicators for enterprise development with established values. The reference indicator system is the goal, "target", where the system should strive. From the point of view of self-organization theory, it is an attractor.

Formation of the reference system of indicators was carried out with the use of a method based on the classification of the system's functions, "the golden rule of economics", by constructing the reference ranking graph, the matrix of pair wise comparisons, and also expert methods. The result is a ranked order of growth indicators, reflecting the optimal functioning and development of the company (Table 1).

The established relationship has the following logical interpretation. For example, advancing the pace of profit

growth in comparison with the revenue growth means lower costs with an increase in sales volumes; profit growth is greater than the rate of production growth, i.e. the marketing policy of the company is effective and its products are competitive and are demanded by the market.

Table 1 Reference system of performance evaluation stage of enterprise development as a self-organizing social and economic system

Indices	Reference rank of movement
Profit	1
Revenue	2
Production	3
Long term assets	4
Wages fund	5
Average annual headcount of staff	6
Cost value	7
Receivables	8

The effective uses of personnel, as well as earnings growth per employee ratio are expressed in terms of profit growth and a number of employees. The necessary condition for increasing production efficiency, savings of costs and resources is outstripping the pace of earnings growth over the pace of growing costs, payroll, cost of fixed assets, rejects. Similarly, logical relations for all the indicators included in the previously developed system of indicators were established.

The second stage of the enterprise evaluation with the help of dynamic norms method is to determine the actual rate of increase in production and business activities.

We are going to illustrate the implementation of the method of dynamic norms by the example of «Plant A», specializing in the production of sunflower oil. Annual reports, financial statements, explanatory notes of «Plant A» for the years 2012-2019 served as the information basis for this research. Table 2 shows the indicators for the development of «Plant A» in 2012-2019. The indicators of businesses have different names, units of measurement, different coverage of bonds.

In order to analyse all the parameters further we are going to define the continued growth indicators of the enterprise in question (Table 3).

Here we can observe the uneven change of indicators; some indicators of social and economic development have a tendency to fall from year to year, while others remain the same or grow in a certain time interval. The determination of the growth rate does not provide a "cumulative assessment of the final performance, and evaluates the likely change in the conditions in which it takes place" [11, p. 59].

The integral characteristic of the enterprise development can be obtained by identifying the index of movement indicators, defined as continued relations of their growth indicators (Table 4).

The results represented in Table 4 clearly illustrate the change in the numerical structure of values in comparison with Table 3.

The table of correlations for growth performance reflects the development of assessment for individual subsystems of enterprise through selected indicators. In order to obtain a complete picture of enterprise development through the individual motion of separate indicators one should use methods of rank statistics.

Table 2 Key indicators of «Plant A» economic activity for 2012-2019

Indices	2012	2013	2014	2015	2016	2017	2018	2019
Net income, thousand rubles	31261	26041	30637	22074	31237	28388	34842	85204
Revenue, thousand rubles	1122477	945488	1267528	1580166	560879	1238265	1104484	1406935
Volume of output, tones	108616	111650	107132	99960	106750	115831	102650	114103
Average annual cost of long term assets, thousand rubles	49853	52933	52519	51769	58435	58211	59451	59084
Wages fund, thousand rubles	31468,3	34774	48869,7	39076,8	49241,5	54922,4	54168,9	68256
Headcount of staff	365	356	332	320	318	307	294	309
Cost value, thousand rubles	1047194	883205	1179073	1492114	489824	1148643	1006131	1208400
Receivables, thousand rubles	39915	37531	114973	121874	198411	124585	729116	503746
Turnover of staff, %	10,88	16,44	20,18	23,04	14,54	13,84	14,15	15,68
Net loss of oil, %	0,68	0,67	0,73	0,77	1	0,85	0,82	0,87

Table 3 Continued growth indicators of economic activity of «Plant A» for 2013-2019

Indices	2013	2014	2015	2016	2017	2018	2019
Net income, thousand rubles	0,833	1,176	0,721	1,415	0,909	1,227	2,445
Revenue, thousand rubles	0,842	1,341	1,247	0,355	2,208	0,892	1,274
Volume of output, tones	1,028	0,960	0,933	1,068	1,085	0,886	1,112
Average annual cost of long term assets, thousand rubles	1,062	0,992	0,986	1,129	0,996	1,021	0,994
Wages fund, thousand rubles	1,105	1,405	0,800	1,260	1,115	0,986	1,260
Headcount of staff	0,975	0,933	0,964	0,994	0,965	0,958	1,051
Cost value, thousand rubles	0,843	1,335	1,265	0,328	2,345	0,876	1,201
Receivables, thousand rubles	0,940	3,063	1,060	1,628	0,628	5,852	0,691
Turnover of staff, %	1,511	1,227	1,142	0,631	0,952	1,022	1,108
Net loss of oil, %	0,985	1,090	1,055	1,299	0,850	0,965	1,061

Table 4 Indices of growth indicators of economic activity of «Plant A» for 2013-2019

Indices	2013	2014	2015	2016	2017	2018	2019
Net income, thousand rubles	0,833	1,412	0,612	1,964	0,642	1,351	1,992
Revenue, thousand rubles	0,842	1,592	0,930	0,285	6,220	0,404	1,428
Volume of output, tones	1,028	0,933	0,972	1,145	1,016	0,817	1,254
Average annual cost of long term assets, thousand rubles	1,062	0,934	0,993	1,145	0,883	1,025	0,973
Wages fund, thousand rubles	1,105	1,272	0,569	1,576	0,885	0,884	1,278
Headcount of staff	0,975	0,956	1,034	1,031	0,971	0,992	1,097
Cost value, thousand rubles	0,843	1,583	0,948	0,259	7,143	0,374	1,371
Receivables, thousand rubles	0,940	3,258	0,346	1,536	0,386	9,320	0,118
Turnover of staff, %	1,511	0,812	0,930	0,553	1,508	1,074	1,084
Net loss of oil, %	0,985	1,106	0,968	1,231	0,655	1,135	1,100

In the fourth step, the ranking of growth rates of indicators, i.e. the process of making room in the ordering of selected indicators takes place. Such kind of rank scoring (Table 5) provides a whole comparable picture of changes, and represents itself as a numeric mapping of structural dynamics characterizing the development of economic system within a given time interval.

The larger value of index corresponds to the highest rank. The smallest value is ranked according to the number of benefiting values.

If some multiple values are equal, the problem of corresponding index movement indicators can be solved by logical differentiation of ranks or by weighing the values obtained under the conditions where the dynamics of activities is implemented.

Thus, in the method of dynamic norms it is proposed to think that " ....the ranked number of evaluations measuring a specific set of motion parameters, the whole order of changes, considered as human activities is the measuring economic system efficiency in this time interval in whole" [11 , p. 70].

Having constructed the actual number of indicators ranging activities of businesses one can start comparing it with the reference rank, presented in Table 1.

There are two possible comparisons of rank orderings, showing properties and different forms of communication subsystems of the enterprise: the one according to deviations and the one according to inversions.

In the first case the deviation is determined, distinguishing rank of an element in the analyzed period of this same rank in the series, taken as a reference. Comparisons of series according to deviations are presented in Table 6.

Table 5 Rank evaluation of development indicators of «Plant A» for 2013-2019

Indices	2013	2014	2015	2016	2017	2018	2019
Net income, thousand rubles	10	4	8	1	9	2	1
Revenue, thousand rubles	9	2	7	9	2	9	2
Volume of output, tones	4	9	3	6	4	8	5
Average annual cost of long term assets, thousand rubles	3	8	2	5	7	5	9
Wages fund, thousand rubles	2	5	9	2	6	7	4
Headcount of staff	6	7	1	7	5	6	7
Cost value, thousand rubles	8	3	5	10	1	10	3
Receivables, thousand rubles	7	1	10	3	10	1	10
Turnover of staff, %	1	10	6	8	3	4	8
Net loss of oil, %	5	6	4	4	8	3	6

Table 6 Rank evaluation Comparison of actual performance ranks of «Plant A» for 2013-2019 with standard deviations of the reference rank

Indices	Reference rank	Deviations for the compared (Table 5) and reference ranks (Table 1)						
		2013	2014	2015	2016	2017	2018	2019
Net income, thousand rubles	1	9	3	7	0	8	1	0
Revenue, thousand rubles	2	7	0	5	7	0	7	0
Volume of output, tones	3	1	6	0	3	1	5	2
Average annual cost of long term assets, thousand rubles	4	-1	4	-2	1	3	1	5
Wages fund, thousand rubles	5	-3	0	4	-3	1	2	-1
Headcount of staff	6	0	1	-5	1	-1	0	1
Cost value, thousand rubles	7	1	-4	-2	3	-6	3	-4
Receivables, thousand rubles	8	-1	-7	2	-5	2	-7	2
Turnover of staff, %	9	-8	1	-3	-1	-6	-5	-1
Net loss of oil, %	10	-5	-4	-6	-6	-2	-7	-4

The disadvantage of comparing the deviations is the assessment of each element of the system in isolation, without considering the relations between elements.

In order to build a complete picture of the object the method of comparison by inversions is used. This method takes into account all the permutations of the elements while ranking. The order of ranks under analysis, as a rule, is "confused", modified, "repositioned" relative to a given reference arrangement of the indicators. This change of a normal, fixed order in the reference number is called inversion.

The easiest way to determine the inversion lies in the following: one counts the amount of numbers with a lower rank and also numbers of the considered rank located below. The result is the inversion.

Table 7 shows the comparison of the actual and reference series by method of inversions.

Table 7 Comparison of actual performance ranking of «Plant A» with the reference rank in inversions

Indices	Reference rank	The number of items in inversion for the compared rank with respect to each element of the reference rank						
		2013	2014	2015	2016	2017	2018	2019
Net income, thousand rubles	1	9	3	7	0	8	1	0
Revenue, thousand rubles	2	8	1	6	7	1	7	0
Volume of output, tones	3	3	6	2	4	1	6	2
Average annual cost of long term assets, thousand rubles	4	2	4	1	3	4	3	5
Wages fund, thousand rubles	5	1	2	4	0	3	4	1
Headcount of staff	6	2	3	0	2	2	3	2
Cost value, thousand rubles	7	3	1	1	3	0	3	0
Receivables, thousand rubles	8	2	0	2	0	2	0	2
Turnover of staff, %	9	0	1	1	1	0	1	1
Net loss of oil, %	10	0	0	0	0	0	0	0

The advantage of the inversion procedure is not assessing each element separately, and comparing the observed deviations, but analyzing all the permutations of the elements ranked.

In order to interpret the evaluations presented in Tables 6 and 7, the correlation analysis tools are used. Score deviations make it possible to determine the Spearman's coefficient of rank correlation; the inversion evaluation is used in the determination of the Kendall's coefficient of correlation.

Spearman's rank correlation coefficient in our sample (in the absence of the same ranks) is defined by the formula (1):

$$r_s = 1 - 6\frac{\Sigma d^2}{N(N^2-1)}, \text{ where} \qquad (1)$$

$\Sigma d2$ − the sum of the squares for the differences between the ranks;

Ta and Tb − amendments to the same ranks;

N – the number of attributes involved in the ranking.

The following one is an example of calculating the Spearman coefficient based on the development of indicators of «Plant A» in 2013. Similarly, the coefficients are determined for the remaining period of the enterprise development (Table 8).

$$r_{s2006} = 1 - 6\frac{(81 + 49 + 1 + 1 + 1 + 0 + 1 + 1 + 64 + 25)}{10(10^2 - 1)}$$
$$= -0,406$$

Having regulated the Spearman coefficients one should determine the critical value r_s for a given number of elements (using a table of critical values of the Spearman rank correlation coefficient). In our example, for N = 10 the critical value is 0.64. If the calculated value r_s exceeds a critical one or at least is equal, then a real number is close to the reference one.

$$r_k = 1 - \frac{4\sum_{i=1}^{N} m_s}{N(N-1)}, \text{where} \qquad (2)$$

rk – Kendall's coefficient of rank correlation;

N – the number of indicators included in the assessment system;

ms– sum of inversions.

Thus, based on the data presented in Table 6, Kendall tau rank correlation coefficient in 2013 is determined as follows:

$$r_{k2006} = 1 - \frac{4 \times 24}{10(10 - 1)} = -0,067$$

Similarly, Kendall's tau (τ) coefficients, characterizing the development of enterprises in 2014-2019, are determined (Table 8).

Kendall's and Spearman's coefficients give the estimate of the proximity of one rank to another one (reference rank) over the interval from +1 to -1. The result equal to (+1) is obtained, if the ranks of both pairs for orders are arranged in the same sequence (i.e., the coincidence of the order being compared to the reference one). A negative value is evidence of the full differently directed motions of indicators for the actual performance rank and the reference rank.

Negative values of Kendall's and Spearman's coefficients obtained in 2013, 2015 and 2018, show the development of the enterprise, which differs significantly from the desired (planned) operation modes.

The calculation of rank correlation coefficients allows to determine the index integrating three-dimensional (evaluation by deviations) and structural (estimated by inversions) side of the enterprise into a single assessment.

This ratio is a tool for determining the stage of self-organization of social and economic system, thus appearing as an integral factor of self-organizing social and economic system (Kso). The degree of relationship between the values of the actual parameters and the reference series indicates the absolute value of the correlation coefficient.

The final evaluation Kso obtained on the basis of two correlation coefficients rs and rk is determined as follows:

$$K_{so} = \frac{(1+r_s)(1+r_k)}{4} \qquad (3)$$

Table 8 shows the values of coefficients obtained earlier than those of Spearman (rs) and Kendall (rk) and are calculated on the basis of their self-organization coefficients (Kso) in 2013-2019.

Table 8 Coefficients of self-organization of «Plant A» for 2013-2019

Coefficients	2013	2014	2015	2016	2017	2018	2019
Spearman's (r_s)	-0,406	0,127	-0,042	0,152	0,055	-0,285	0,588
Kendall's (r_k)	-0,333	0,067	-0,067	0,111	0,067	-0,244	0,422
Self-organization(K_{so})	0,099	0,301	0,223	0,320	0,281	0,135	0,565

Kso value changes over the range from 0 to 1. The coefficient of 1 indicates the coincidence of the actual and the reference system performance set in the order when all relations established for growth indicators take place. This ratio is typical for the most effective level of implementation for financial, personnel, marketing, and investment policy of the company. The closer the value of Kso to 1 is, the greater is the standard rate of growth observed. The value of 0 indicates the inefficiency of business, when the actual index ratio is inconsistent with the motion parameters.

Based on statistics taken in numerical interpretation of the correlation coefficients the proximity of two operation modes can be estimated: actual and reference ones. Table 9 shows the degree of closeness between the actual and the reference value for the indicators and the relevant options of managerial influence depending on the value of self-organization coefficient.

The ratio of self-organization and managerial influence processes depends on the Kso value in the following way: the level of self- enterprise subsystems also increases with the increase of the correlation coefficient.

Each stage of self-organization process corresponds to the definite value of the self-organization coefficient. Thus, the enterprise in a cycle of self-development can be found in the following areas, i.e.: bifurcation area, critical area, normative and reference areas.

The trajectory of "Plant A" development for 2013-2019, built on the basis of self-organization calculated coefficients is shown in Figure 2.

Table 9 Control actions options for the system of self-organization coefficient different values

Integral Coefficient of Self-Organization Value	0-0,2	0,2-0,4	0,4-0,7	0,7-1
Degree of Closeness between Reference Value and Actual Performance	Absent	Weak	Moderate	Strong
Self-organi-sation Stage	Development of a new self-organi-sation model for subsystems	Stage of transition	Dynamic equilibrium	Dynamic equilibrium
Area Name	Bifurcation	Critical	Normative	Reference
Managerial Influence Options	Targeted self-organization, development of a new self-organizing structure	Targeted self-organization, development of a new self-organizing structure	Self-organization and intended effect correspond to the same degree	Prevalence of self-organization, if necessary − regulation aimed at a return to the equilibrium state

Figure 2 Correlation of self-organization coefficients with the stages of «Plant A» development in 2013-2019

4. CONCLUSION

In general, the presented graph indicates that the enterprise is located in the critical area, where purposeful managerial impact (influence) dominates, and self-organizing internal subsystems are minimized. In 2018 the company got into the bifurcation area which is characterized by the revision of the strategy, setting new goals, and also creates a qualitatively new self-organizing structure. At present, the enterprise is entering the stage of dynamic equilibrium. In the future, optimal managerial influence will contribute to the realization of the enterprise potential of self-organization and the achievement of the development trajectory, as close as possible to the standard.

To sum up, we should note that the considered method of dynamic norms has a number of advantages:

- it is based on the assessment of the system effectiveness in the form of growth indicators (i.e., the dynamic property as the main parameter of the self-organization of social and economic system is taken into account, as well as the irregular movement of various indicators in the course of time) ;
- it allows you to bring indicators of various dimensions to the *comparable* numerical characteristic;
- a small number of indicators can reflect the range of "real dynamical states" [11 , p. 90] in the appraiser;
- it allows one to analyse the internal structure of an object and the ratio of the individual parts;
- it reflects a diverse set of properties of all interdependent elements, emphasizing the uniqueness of the participation of each element in the formation of a common result;
- it is suitable for the evaluation of development of social and economic systems at macro-, meso- and microlevels .

The method of dynamic norms is the tool of choice for managerial influence on the economic system, acting as the element of a holistic mechanism of management of the social and economic system.

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