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Methodical Approaches to Measuring Sustainable Development of Industrial Enterprises

Tatiana Alferova[1], Elena Shilova[2], Elena Tretiakova[3]

Abstract:

The article is devoted to the problems of assessment of sustainable development at industrial enterprises with a dynamic scorecard based on growth rates of key performance indicators, arranged in the way allowing the evaluation of the sustainable development process when kept in the long time interval. The relative indicators allow comparing not only the incomparable values but also enterprises of different sizes. In addition the system allows comparing the results of current period to similar data from previous years, as well as to the results of other companies for the same period to determine their rating position or identify balance / imbalance. This system takes into account not only balanced state of environmental, economic and social spheres in particular time but also helps to reflect the positive changes in development process. This method is considered on the example of chemical industry, one of the leading in Russia.

Key Words: *Sustainable Development Assessment, Dynamic System, Pace of Growth, Indicators Adjustment Graph.*

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1 Ph.D. in Economics, Associate Professor, the Head of the Department of Management, Perm Institute of Economics and Finance, Address: 614068, Perm, 141 Ekaterininskaya St., Email: Talferova@pief.ru
2 Ph.D. in Economics, associate professor of the Department of Management, Perm Institute of Economics and Finance, Address: 614068, Perm, 141 Ekaterininskaya St, Email: elena-7700@mail.ru
3 Doctor of Economics, Professor, professor of the Department of Economics and Finance, Perm National Research Polytechnic University, Address: 614990, Perm, 29 Komsomolsky Av., Email: E.A.T.pnrpu@yandex.ru

1. Introduction

The concept of sustainable development is now one of most popular and supported by the world community concepts of interaction between society and nature. In the "Agenda for XXI century" (Agenda for XXI Century, 1992) this concept was defined as a system of harmonious relations in the "man - environment - economy" triad. Based on the general principles of sustainable development, each component at the same time has its own peculiarities of functioning and interaction.

The general form of evolution of the Russian industry sphere could be presented in the following way. At the first stage, there is formation of the Russian industry as such at the beginning of the 20^{th} century – back then, its influence on the economic development of Russia was insignificant. The second stage includes quick development of the Russian industry in the middle of the 20^{th} century and its transformation into a basis of economy and moving force of national economic development. The third stage includes transition of Russia to post-industrial model of economy development at the beginning of the 21^{st} century – industry moves to far plane, but continues influencing the provision of economic growth and development.
2. Model of the growth rate of indicators for sustainable development assessment
Currently, criteria and indicators for sustainable development are in active development. The developers include the leading international organizations: UN, World Bank, European Commission, World Wildlife Fund, and many others (Alferova and Tretyakova, 2013). Furthermore, this issue is being an object of many research works (Zinger, 2010; Karpova, 2010; Kolosov, 2011; Koryakov, 2012; Lyushin, 2006; Melnik, 2009; Mikitas, 2013), although they generally tend to reflect the state of economic, environmental and social spheres of life in a static state. However, sustainable development is essentially a dynamic process (Alferova and Tretyakova, 2013), therefore, we propose a system of dynamic indicators taking into account not only the balanced state of environmental, economic and social spheres, in a particular period of time, but also helping to reflect positive changes through the development process. In addition to abovementioned advantages relative indicators allow us to compare not only the incomparable values but enterprises of different sizes. To this end, we propose to use such indicator of dynamics as a rate of growth (see. Table 1).

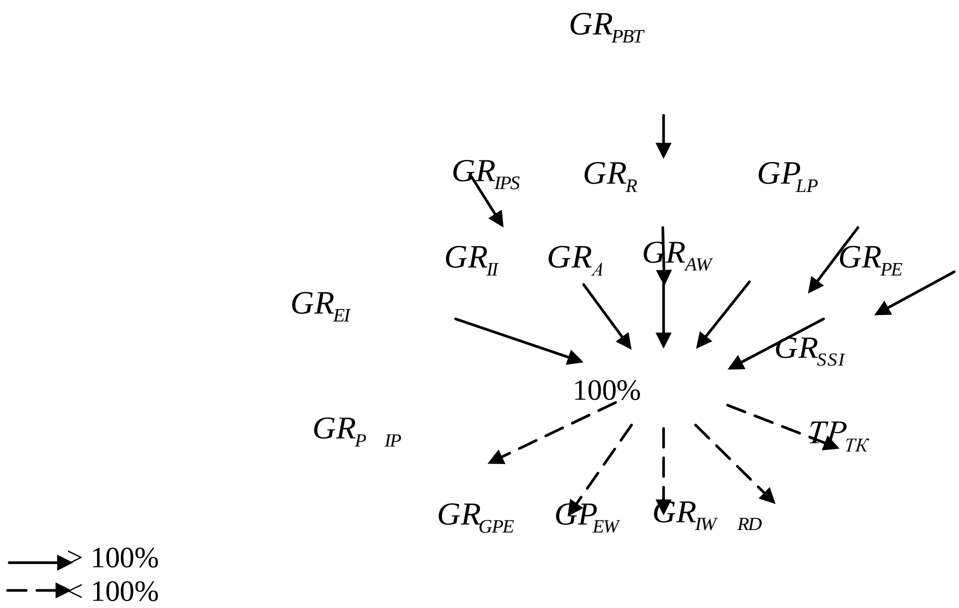
Table 1 - The growth rate of indicators for sustainable development

Indicator	Sustainable development sphere	Symbol
Social indicators (I)		
The growth rate of professional education level	I-III	GR_{PE}
The growth rate of investment into the social sphere	I-II	GR_{SSI}
The growth rate of the personnel turnover	I	GR_{PT}
The growth rate of injury and work-related diseases	I	$GR_{JW\ RD}$
Economic indicators (II)		
The growth rate of the average wage	I-II	GR_{AW}
The growth rate of labor productivity	I-II	GR_{LP}
The growth rate of profit before tax	II	GR_{PBT}
Revenue growth	II	GR_{R}
Asset growth	II	GR_{A}
The growth rate of equipment wear	II-III	GR_{EW}
The growth rate in the share of innovative products	II	GR_{IPS}
The growth rate of investment in innovation	II	GR_{II}
Ecological indicators (III)		
The growth rate of investment into environment	II-III	GR_{EI}
The growth rate of penalties for environmental pollution	I-II-III	$GR_{P\ \ IP}$
The growth rate of gross pollutant emissions	I-III	GP_{GPE}

In our model, economic sustainable development is represented by six parameters including the rate of growth in profit before tax, revenue growth, asset growth, the pace of growth in the share of innovative products, the growth rate of investment into innovation and the growth rate of equipment wear. There are two indicators: the growth rate of average wages and productivity growth have been attributed to our socio-economic sphere, as being a purely economic indicators they can indirectly characterize this social aspect of human activity and the tension to facilitate the implementation of the principle of social justice when paid(Ferrero and Hisgen, 2014). We relate the growth rate of penalties for environmental pollution to economic and environmental field, since the use of economic measures is aimed at reducing the harmful effects of enterprises on the environment. This rate can be partly attributed to the social sphere, given that law compliance is an essential feature of the social responsibility of enterprises (Platania, 2014). Except that the environmental field is presented by growth rate of emissions and growth rate of investment in the environment. Despite the fact that investing into environment is an economic indicator, in our model they are included into the unit characterizing the economic and environmental spheres, since they also characterize environmental cost effectiveness on environmental protection measures (Ozkan and Ozkan, 2012).

Social sphere is represented by the growth rate of training costs, the growth rate of investment into social sector, the growth rate of personnel turnover and the growth rate of injury and work-related diseases (Chen, 2013). As a distinctive feature of proposed system of measure instruments is a possibility to reflect changes in each area of sustainable development, as well as their interaction, the principle of ordering and mutual correlation of these dynamic parameters should be analyzed more detailed (see Figure 1).

Figure 1. Dynamic model of sustainable development measurement



Thus, the ordering of economic indicators in the model is implemented in accordance with the golden economic rule: the growth rate of assets should be higher than 100% and indicate the property capacity building of enterprise, while the growth rate of sales revenue should exceed the growth rate of assets showing the effective use of capital and providing accelerated capital turnover, and profit growth should exceed the revenue growth showing a consequence of unit costs reduce (Popkova et al., 2013).

Within this model we suggest to use the indicator of profit before tax, as the net profit only belongs to the owner, and, therefore, cannot take into account the interests of social and ecological spheres of business. Assessment of the dynamics of the main indicators of economic sphere can be performed on the basis of the system of inequalities:

$$GR_{PBT} > GR_R > GR_A > 100\% \quad (1)$$

The following dynamic guidelines reflect the attitude of the most important economic indicator - labor productivity - towards interdependent parameters. If we consider productivity as revenue attributable to one employee, then in dynamic it needs to grow faster than assets as a factor of production increase, production costs decrease and profit increase. Alongside this, productivity growth must be higher than growth rate of wages, and those, in turn, should exceed 100% being one of the most important factors in reducing staff turnover. The above systems of standards can be represented as inequalities:

$$\begin{cases} GR_{PBT} > GR_{LP} > GR_A > 100\% \\ GR_{LP} > GR_{AW} > 100\% > GR_{PT} \end{cases} \quad (2)$$

Rising productivity allows providing employees with additional social benefits and payments from the profit. Investments into social services (recreation, insurance, preferential payments and one-time premium, targeted compensation, etc.) define reduction of personnel turnover and the number of occupational diseases at the same time motivating increase in labor productivity:

$$\begin{cases} GR_{SSI} > 100\% > GR_{IWRD} \\ GR_{LP} > GR_{SSI} > 100\% > GR_{PT} \end{cases} \quad (3)$$

Vocational training improvement can also serve as a reserve of labor productivity increase which also leads to higher wages and thus decrease in personnel turnover. The increase in level of vocational education will generally improve the share of innovative products. Also, the growth of educational, cultural and technical levels of employees will reduce occupational diseases, injuries and accidents:

$$\begin{cases} GR_{LP} > GR_{AW} > GR_{PE} > 100\% > GR_{PT} \\ GR_{IPS} > GR_{PE} > 100\% \\ GR_{PE} > 100\% > GR_{JW\ RD} \\ GR_{PE} > 100\% > GR_{GPE} \\ GR_{PE} > 100\% > GR_{P\ IP} \end{cases} \quad (4)$$

Along with the socio-economic factors of company performance increase, a huge role is allocated to logistical factors: use of new materials, energy sources, technical and technological improvement and others.

Since the volume of production is constrained with techniques and technologies applied, to change them to more progressive by investing into innovation means to create conditions for increasing productivity by improving productivity and reducing costs through resource conservation, and increasing competitiveness through increasing the share of innovative products.

$$\begin{cases} GR_{PBT} > GR_{R} > GR_{II} > 100\% > GR_{EW} \\ GR_{PBT} > GR_{LP} > GR_{II} > 100\% > GR_{EW} \\ GR_{IPS} > GR_{II} > 100\% > GR_{EW} \end{cases} \quad (5)$$

That is investment in innovation which will allow the company to restructure and modernize production, which should ensure in dynamics a reduction of the volume of emissions (below 100%), indirectly affecting the dynamics of occupational diseases, reducing harmful effects of production factors on organisms of employees. Decrease in the number and scale of accidents is logically related to the dynamics of the number of penalties for environmental pollution (below 100%).

$$\begin{cases} GR_{II} > 100\% > GR_{EW} > GR_{GPI} \\ GR_{II} > 100\% > GR_{EW} > GR_{P\ IP} \\ GR_{II} > 100\% > GR_{EW} > GR_{IW\ RD} \end{cases} \quad (6)$$

Along with investments in innovations aimed at equipment modernization in order to reduce negative impact on the environment, and introduction of resource-saving technologies, with the same purpose it is advisable to consider environmental investments aimed at eliminating negative impact on the environment (measures for environmental monitoring, programs of rehabilitation of disturbed and contaminated land, recycling and other environmental programs). The above measures, in addition to the favorable impact on the environment will contribute to improvement of environmental quality of the labor process (microecology of jobs) reducing occupational diseases and the potential personnel turnover.

$$\begin{cases} GR_{EI} > 100\% > GR_{PT} \\ GR_{EI} > 100\% > GR_{GPE} \\ GR_{EI} > 100\% > GR_{P\,IP} \\ GR_{EI} > 100\% > GR_{JWRD} \end{cases} \quad (7)$$

Thus, the system of dynamic standards – shown as a graph in Figure 1 and presented in the form of inequalities 1-7 – is the reference model of the ratio of the dynamics of economic, environmental and social spheres of sustainable development. Since the model used applies nonlinear orders of growth of sustainable development indicators, the degree of actual dynamics tend to the reference one is appropriate to be measured using the mathematical apparatus of matrix theory [13].

A graph of reference ordering was converted to matrix form by the following rules: M[RD] = $\{\mu_{ij}\}$,

$$\mu_{ij} = \begin{cases} 1, \ if \ \ t^H(i) > t^H(j) \ \ and \ \ for \ \ i = j \\ -1, \ if \ \ t^H(i) < t^H(j) \ \ and \ \ for \ \ i = j \\ 0, \ if \ \ ordering \ between \ \ t^H(i) \ \ and \ \ t^H(j) \ \ not \ set \end{cases} \quad (8)$$

where μ_{ij} – the element of the reference ordering matrix,
i, j – indicator numbers,
$t^H(i)$, $t^H(j)$ – normative rate of i, j indicators change.
For the actual order a similar matrix with the same principle is constructed: M[AD] = $\{\eta_{ij}\}$,

$$\eta_{ij} = \begin{cases} 1, \ if \ \ t^{\Phi}(i) > t^{\Phi}(j) \ \ and \ \ for \ \ i = j \\ -1, \ if \ \ t^{\Phi}(i) < t^{\Phi}(j) \ \ and \ \ for \ \ i = j \\ 0, \ if \ \ ordering \ between \ \ t^H(i) \ \ and \ \ t^H(j) \ \ not \ set \end{cases} \quad (9)$$

where η_{ij} – the element of the actual ordering matrix,
i, j – indicator numbers,

$t^{ф}(i)$, $t^{ф}(j)$ – the actual growth rate of indicators *i, j*,
$t^{н}(i)$, $t^{н}(j)$ – normative growth rate of indicators *i, j*.
The assessment of the level of deviation of sustainable development indicators actual dynamics from the reference dynamics is organized by measuring the distance between M[RD] and M[AD]:

$$d = \sum_{i=1}^{n} \sum_{j=1}^{n} \left| \mu_{ij} - \eta_{ij} \right| , \qquad (10)$$

where d – the distance between M[RD] and M[AD],
μ_{ij} – the matrix element at the intersection of the *i*-th row and *j*-th column of M[RD],
η_{ij} – the matrix element at the intersection of the *i*-th row and *j*-th column of M[AD].
Then relative magnitude of the distance is defined with a specific formula:

$$R = \frac{d}{2 \cdot K} , \qquad (11)$$

where R – regulation value: $0 \leq R \leq 1$.
K –the number of non-zero cells in M[RD] not considering the cells in the main diagonal.

In conclusion, the index of similarity measure of the reference and actual models of sustainable development is defined as follows:

$$S = (1 - R) \cdot 100\%, \qquad (12)$$

where S – similarity measure.
The degree of the actual dynamics tending to the reference dynamics will define the level of sustainable development.

We propose to consider this method in the context of chemical industry which is the one of the most important components of the Russian Federation economy. The chemical complex may include the production of mineral fertilizers, plastics, rubber, chemical fibers, paints and varnishes, medicines, etc. Consuming industries of the chemical complex are practically all industrial areas of the economy: agricultural sector, pharmaceutical industry, automotive industry and others.

Furthermore, the chemical industry has always been considered as the industry defining scientific and technical progress. Its significance for the national economy is determined by the following factors:
1. Chemical industry is expanding the raw material base of production and construction, as its branches are able to create new effective materials with predetermined properties.

2. Chemical industry contributes to the intensification of agriculture as a source of production of mineral fertilizers and bio-stimulants.

3. The branches of chemical industry are socially oriented since products they manufacture meet the needs of the population.

4. The modern technology of the chemical industry has an unlimited advantage over mechanical methods of processing materials and enables:

- to engage almost unlimited range of raw materials into production process and to turn it into industrial products: chemical minerals (apatite, phosphates, potash, salt, sulfur, bauxites); minerals used in other sectors of the economy (oil, gas, coking coal, limestone, gypsum, etc.); plant raw materials (wood); waste of various sectors of the economy (e.g. waste of lead-zinc and copper industry are used in production of sulfuric acid);
- to use raw materials comprehensively producing various products from one kind of raw materials (e.g., more than 70 kinds of products can be received from oil, due to organic synthesis chemistry), and also to resolve the same product from various types of raw materials (for example, synthetic rubber might be received on the basis of oil, coal, forest resources, food waste, etc.);
- to dispose the waste of other sectors of economy.

5. The chemical industry is capable of performing a district-forming role, i.e. it is able to attract other industries in the territory which is substantial in terms of formation of economy (Russian Chemical Industry, 2015).

3. Application of the Method to the Sustainable Development of Russian Industrial Enterprises

According to a research by "ID Marketing" the chemical production index in 2013 compared with 2012 amounted to 104.9%, and in January - September 2014 it came out at 100.5%. (Gurieva, 2014).

The most significant representatives of the chemical industry are (Leading Russian companies, 2015):
- OJSC "Acron" (The official website of "Akron" JSC, 2015). The company is among the world's largest producers of mineral fertilizers. Main production enterprises are the "Acron" and "Dorogobuzh". The range of products includes both compound fertilizer and nitrogen fertilizer.

- PJSC "Uralkali" (The official website of "Uralkali" PJSC, 2015). The leading vertically integrated global manufacturer of potassium which is one of the most important elements necessary for the evolution of all living organisms. The company accounts for about 20% of world production of potash. The company controls the entire production chain - from the extraction of potash ore to the delivery to its customers.

- OJSC UCC "Uralchem" (The official website of the "URALCHIM" JSC UCC, 2015). One of the largest producers of mineral fertilizers in Russia, CIS and Eastern Europe.

- OJSC "FosAgro" (The official website of "FosAgro" JSC, 2015). One of the world's leading producers of phosphate fertilizers. The main activity is the production of phosphate fertilizers, high-grade phosphate raw material - phosphate rock, as well as feed phosphates and nitrogen fertilizers and ammonia.

Non-financial reports of the above companies have been used to assess the sustainable development of the chemical industry, on which basis an average annual growth of key indicators for sustainable development of enterprises and the industry as a whole were calculated (see Table 2).

Table 2 –The average annual growth rate of sustainable development indicators of the chemical industry in the Russian Federation for 2011-2014.

Indicator	Indicator value				
	OJSC UCC "Uralchem"	PJSC "Uralkali"	OJSC "FosAgro"	OJSC "Acron"	Chemical industry
Social indicators (I)					
The growth rate of professional education level	117,8	117,8	122,8	115	118,4
The growth rate of investment into social sphere	190	140,3	108	121	139,8
The growth rate of the personnel turnover	0	97,9	82	79,7	64,9

Indicator	Indicator value				
	OJSC UCC "Uralchem"	PJSC "Uralkali"	OJSC "FosAgro"	OJSC "Acron"	Chemical industry
The growth rate of injury and work-related diseases	93,5	82,7	99,9	98	93,5
Economic indicators (II)					
The growth rate of the average wage	109,2	105	112	111,5	109,4
The growth rate of labor productivity	116	117	113,8	97	111,0
The growth rate of profit before tax	-374,8	61,6	3,8	70	-59,9
Revenue growth rate	102	92,6	107,3	104,6	101,6
Asset growth	201	122	119	120	140,5
The growth rate of equipment wear	65	100,9	0	64,5	57,6
The growth rate in the share of innovative products	121	121	121	121	121,0
The growth rate of investment in innovation	143,7	128	128	165,2	121,1
Ecological indicators (III)					
The growth rate of investment into environment	126	88,7	80	84,6	94,8
The growth rate of penalties for environmental pollution	67,7	340	215	238	215,2
The growth rate of gross pollutant emissions	107,5	113,3	98,4	106,6	106,5

Variables in Table 2 are determined as the rate of growth of indicators, i.e., ratio of value of economic development at given time to its initial value, which is a basis for calculation measured in per cent.

As the table shows, the average annual growth rate of sustainable development indicators significantly vary. For example, the growth rate of social investment reaches 190% in OJSC "Uralchem", while OJSC "FosAgro" has 108%. The growth rate of personnel turnover remains unchanged for "Uralchem", while other enterprises index tends to decrease. All enterprises demonstrate a decrease in profit before tax, etc.

Then, following the method, the growth rates obtained were applied to the inequality to determine deviations from the reference values and construct the actual indicators ordering matrices for companies and for the industry as a whole. According to the results the distance (d) between M[ЭП] и M[ФП], the relative magnitude of the distance (R) and the similarity measure index of actual and reference models of sustainable development (S) were calculated (see Table 3)

Table 3 –The results of evaluation of sustainable development of chemical industrial enterprises in the Russian Federation

Industrial enterprise	Distance between M[ЭП] and M[ФП], *d*	Relative magnitude of the distance, *R*	Similarity measure index of actual and reference models of sustainable development, *S, %*
OJSC UCC «Uralchem»	38	0,183	81,7
PJSC «Uralkali»	54	0,5	50
OJSC «FosAgro»	48	0,231	76,9
OJSC «Akron»	52	0,481	51,9
Chemical inducstry	36	0,173	82,7

4. Conclusion

The calculations showed that the values of S both in enterprises and in the industry indicate the average balance of the average annual growth rate of basic indicators of sustainable development and enterprise, and the chemical industry as a whole. The most balanced performance belongs to UCC "Uralchem" (81.7%), followed by JSC "FosAgro" (76.9%), the next position has JSC "Acron" (51.9%), the lowest balance is for PJSC " Uralkali" with the index of 50%. In general, the chemical industry sustainable development indicators are fairly balanced (82.7%), indicating its sustainable development.

Thus, the dynamic model allowed to comprehensively assess the sustainable development of the chemical industry and identify the deviation of actual mode of operation from the reference one.

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