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MODELS OF MANAGING INDUSTRIAL ENTERPRISES UNDER AN UNSTABLE ENVIRONMENT AND TECHNOLOGICAL RE-EQUIPMENT

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Abstract. Under the ongoing process of economic globalization, Russian industrial enterprises are currently facing the need to compete in world markets characterized by an extreme degree of instability due to political, social, economic, and other factors. In such conditions, classical strategic management methods become ineffective, primarily due to no appropriate tools to consider and correct several factors increasingly affecting the performance of enterprises. For example, in view of the deteriorating environmental situation in the world (even interpreted as an environmental disaster), the governments of different countries and various public organizations are putting pressure on industrial enterprises to carry out technological re-equipment. This paper surveys the classical approaches to the strategic management of industrial enterprises and the assessment of their effectiveness using mathematical models. The disadvantages of these approaches are discussed. A strategic management model is proposed that considers a fluctuating demand for the products of industrial enterprises caused by periodic economic crises. In addition, a model is constructed for assessing the effectiveness of enterprises implementing technological transformations to minimize their environmental damage. The models can be used to improve strategic decision mechanisms for managing industrial enterprises.

Keywords: strategy, strategic management, enterprise management, industrial management, global instability, decision-making model, industry, cost management, technological re-equipment.

INTRODUCTION

In the era of globalization and the development of a single world market [1], the performance of industrial enterprises is determined not only by their internal technical and economic potential but also by external conditions (environment) [2]. In recent years, instability has sharply increased in the world due to political, social, and economic factors [3]. In 2020, the COVID-19 pandemic had a shocking effect on the economies of all countries [4, 5].

In such conditions, the complexity of managing various organizational and production structures has grown dramatically [6, 7]. This particularly applies to Russian industrial enterprises: along with global problems, domestic enterprises are experiencing unprecedented political pressure (the sanctions policy) from major world powers and international organizations [8, 9]. Sanctions aim at both Russian enterprises and their owners [10, 11].

In this regard, conducting a competitive struggle in international markets becomes vital for Russian manufacturers [12], which calls for increasing the effectiveness of their activities [13, 14]. At the same time, many Russian enterprises need technological re-equipment [15–17], which is significantly complicated by the current political situation around Russia [18].

It can be stated that under global instability, the quality of management will determine the viability of enterprises and their prospects for further development [19]. Note that in such conditions, the choice of approaches, models, and criteria for assessing the effectiveness of strategic and operational management of industrial enterprises becomes one of the main tasks of good management.

1. ANALYSIS OF APPROACHES TO STRATEGIC MANAGEMENT OF INDUSTRIAL ENTERPRISES AND ASSESSING THEIR EFFECTIVENESS

Nowadays, profit is the most common indicator for assessing the effectiveness of industrial enterprises. Profit is defined as the excess of the company's income over its expenses [20]. The disadvantages of using this indicator include short planning horizons (1–3 years), which creates significant risks for the enterprise. In particular, the time for re-equipping a large industrial enterprise can significantly exceed these periods. With the cyclical dynamics of the world economy [21, 22], this circumstance causes insolvency traps: an enterprise incurring losses during crisis periods cannot complete its technological re-equipment due to insufficient financial resources.

This approach is developed by expanding the number of indicators for assessing the effectiveness of the enterprise and forming a set of financial results to make decisions by the top management [23]. Such a set may include indicators of financial stability, solvency, profitability, resource efficiency, etc.

Management based on a set of financial indicators and short planning horizons leads to the problem of coordinating such indicators for stating the optimal enterprise management problem [24, 25]. Within this approach, the company's results for the current period are often compared with those for previous periods. After comparison, either a general conclusion is made (and a strategy for the company's behavior in the market is developed [26, 27]), or particular conclusions are drawn (and a set of measures for improving the company's performance is formed [28, 29]).

An attempt to solve the problems associated with using the enterprise profit as a target is an approach to increase the company's value. In 1938, J. B. Williams [30] proposed using the "internal" value of an investment asset (an enterprise) as such a measure, calculated by discounting future dividends (the total amount of funds received by enterprise stockholders). Later on, B. Graham [31] discriminated between the internal (fundamental) value and the external (asset price) one, which should converge to each other under market mechanisms. Thus, the company's management should strive to increase the fundamental value of the enterprise. As shown by W. Buffett, the internal value can be calculated as the discounted value of funds withdrawn from the business [32, 33].

Currently, the direction focused on the growth of the company's value is called Value-Based Management (VBM), and its main goal is to maximize the value of companies [34, 35]. The main disadvantage of this direction is no clear understanding of how to calculate the value of a company: different approaches involve particular methods and calculation formulas.

When assessing and analyzing the effectiveness of investment projects, the *discounted cash flow* (DCF) method is often used. Here, the objective function (target indicator) is the *net present value* (NPV) calculated by the formula

$$NPV=\sum_{t=1}^{n}\frac{CF_t}{(1+r)^t}-I_0,$$

where CF_t denotes the cash flow in period $t = 1,\ldots, n$; I_0 is the initial investment; r specifies the discount rate.

If $NPV>0$, then the project's yield is higher than the invested capital. In other words, this project will increase the company's value by NPV. If $NPV<0$, the project will reduce the company's value.

According to this approach, the growth of the company's value can be achieved either by increasing the cash flows received as a result of the project (CF_i), or by reducing the initial investment (I_0), or by decreasing the discount rate (e.g., by reducing risks).

There exist other methods for calculating the company's value, particularly the total yield of stockholders, the cash flow yield per unit investment, etc. [36, 37].

The methods mentioned above are based on calculating the company's future discounted cash flows and the weighted average capital value [38, 39].

A significant benefit of the approach aimed at increasing the company's value is a longer-term forecast [40] compared to the approach based on several financial indicators of the enterprise.

Note that despite its advantage, the former approach actually models the company's activities and is intended to identify the parameters with a favorable effect on the target level of the company's value. After forming and analyzing the company's value model, top managers focus on improving some parameters of the organization's performance: reducing costs, optimizing inventories, reducing the time of asset turnover, etc. [41].

Another direction of assessing the effectiveness of an enterprise is an approach focused on meeting the needs of stakeholders (Stakeholder Value, STV) [42, 43]. This concept considers the interests of the owners and many other subjects engaged, in one way or another, in projects implemented by the enterprise (managers, creditors, employees, trade unions, etc.). The problems of this approach lie in the choice of an appropriate criterion for assessing the degree of satisfaction of particular stakeholders (see the corresponding indicators in the table below), and the need to coordinate (through appropriate mechanisms) the interests of different stakeholders for elaborating an enterprise management: in most cases, the interests of stakeholders can be multidirectional.

Parameters for assessing enterprise's effectiveness by different groups of stakeholders

Stakeholders	Parameters for assessing enterprise's effectiveness
Owners (stockholders, investors)	Yield per stock, stock price gains, total dividends
Managers	Enterprise's financial indicators determining the profit of managers: sales revenue, financial result, profitability level, asset turnover, market share, etc.
Creditors	Guaranteed repayment of loan obligations, the level of security of borrowed funds with assets
Staff	Remuneration, career growth
State authorities	Taxes and fees paid to the budget and extra-budgetary funds, employment of the population
Public organizations and unions (trade unions, mass media, political parties, etc.)	Compliance with environmental safety requirements, maintaining political stability and loyalty, etc.

As an enterprise's effectiveness criterion, such approaches adopt either an integral (aggregated) indicator for the disparate interests of different stakeholders [44] or an indicator reflecting an agreed assessment of their interests [20]. For example, the stakeholders are ranked based on the importance of satisfying their interests.

In addition, there are mixed approaches to assessing the effectiveness of manufacturing companies. For example, M. Jensen [45] suggested a hybrid model considering the interests of different stakeholders: the idea is to maximize the company's value taking into account the interests of other stakeholders.

This approach suffers from the multicriteria objective function, which is difficult or even impossible to quantify. In the paper [46], the interests of different stakeholders were considered through the iterative coordination of their opinions.

Another drawback of this concept is the need to consider the interests of participants not investing in the company's development: the rights of investors and owners are discriminated against, which may reduce investment.

Thus, effective management of industrial enterprises should be based on the models of future cash flows generated by the management of these enterprises. Moreover, the mathematical models of industrial enterprise management should include various factors with the greatest effect on the enterprise's activities in the corresponding periods.

2. A MODEL OF MANAGING INDUSTRIAL ENTERPRISES IN A STABLE ENVIRONMENT

Under small fluctuations of demand and supply in world markets, the objective function (Φ_1) describing the efficiency of an industrial enterprise [20] can be the profit on sales (Π^T) in period T:

$$\Phi_1 = \Pi^T \to \max .$$

The profit on sales in period T is calculated as

$$\Pi^T = \sum_f I_f^T C_f^T - \sum_f \Bigg(I_f^T \Bigg(\sum_n S_{fn}^{ET} + \sum_n \sum_m S_{fnm}^{MT} + \sum_k \sum_n Z_{fkn}^T \Bigg) \Bigg) - S^{OT}, \qquad (1)$$

where C_f^T denotes the unit price of product f manufactured in period T; I_f^T is the total output of product f in period T; S_{fn}^{ET} specifies the electrical energy costs per unit of product f manufactured on machine n in period T; S_{fnm}^{MT} indicates the costs of material m per unit of product f manufactured on machine n in period T; Z_{fkn}^T is the total wages of production workers in gang k per unit of product f manufactured on machine n in period T; finally, S^{OT} gives the total fixed costs of the industrial enterprise in period T.

Thus, in a stable environment, an enterprise should maximize profit primarily by increasing output and, in addition, reducing variable and fixed production costs (management costs, security costs, payments for environmental damage, etc.).

3. A MODEL OF MANAGING INDUSTRIAL ENTERPRISES UNDER FLUCTUATING DEMAND FOR PRODUCTS

We emphasize that the modern capitalist system is characterized by a cyclical demand for industrial products due to various imbalances and contradictions. They are determined by the characteristic features of capitalist production [21].

Under an increased demand for its products, the company seeks to raise outputs, adapting to market demands. The enterprise's management makes this operational decision based on the current assessment of the market conditions and production capabilities. Hence, the expression for calculating the enterprise's profit can be written as

$$\Pi^T = \sum_f \left(\left(I^T_{f\text{cont}} + I^T_{f\text{add}} \right) C^T_f \right) - \sum_f \left(I^T_{f\text{cont}} + I^T_{f\text{add}} \right) \times$$
$$\times \left(\sum_n S^{ET}_{fn} + \sum_n \sum_m S^{MT}_{fnm} + \sum_k \sum_n Z^T_{fkn} \right) \Bigg) - S^{OT},$$

where $I^T_{f\text{cont}}$ denotes the total output of product f manufactured by the enterprise according to the contractual obligations in period T; $I^T_{f\text{add}}$ is the additional output of product f in period T.

Since the fixed costs S^{OT} remain unchanged in favorable periods, an increase in production will lead to profit growth if the profitability of product f is positive.

Profit should be maximized subject to several constraints, in particular: the output of product f must be not smaller than the volumes stipulated by the contracts; the outputs cannot exceed the technological capabilities of the enterprise. There may exist other constraints for a specific industrial enterprise.

Under a dropped demand for its products due to the world economic crisis, the enterprise seeks to minimize production costs instead of maximizing profits [47, 48]. In this case, the objective function can be written as

$$\Phi_2 = \min F\left(S^{ET}, S^{MT}, Z^T, P^T_d\right),$$

where S^{ET} denotes the electrical energy costs in period T; S^{MT} is the material costs in period T; Z^T specifies the remuneration costs in period T; P^T_d indicates the unexpected losses in period T due to the economic crisis effect.

In other words, the objective function Φ_2 takes the form

$$\Phi_2 = \sum_f \left(I^T_f \sum_n \left(S^{ET}_{fn} + S^{MT}_{fnm} + Z^T_{fkn} \right) \right) + P^T_d \to \min \cdot$$

The enterprise's activities in period T are assessed by analyzing the total costs in this period:

$$\Phi^{\circ}_2 = \sum_T \left(S^{ET} + S^{MT} + Z^T + P^T_d \right) \cdot$$

During this period, a possible management decision is decreasing the output to reduce the total costs. Note that, first of all, the outputs of products with a negative marginal profit should be decreased. At the same time, in some industries (e.g., metallurgy), it is impossible to lower the output below a certain threshold due to technological restrictions: the production process cannot be resumed after stop. All these features should be considered when constructing mathematical models of particular industrial enterprises.

Thus, under a significantly fluctuating demand for products during economic crises, the objective function of an industrial enterprise is to reduce the total production and non-production costs while fulfilling all contractual obligations.

In this case, the company's stockholders need timely forecasts of possible crisis phenomena to make economically sound managerial decisions, allowing the company to adapt to abrupt exogenous changes.

4. A MODEL OF MANAGING INDUSTRIAL ENTERPRISES WITH TECHNOLOGICAL RE-EQUIPMENT AND EMISSION REDUCTION

Note that the environmental damage caused by production is an important factor affecting the demand for industrial products. If an enterprise uses technologies with a significant impact on the environment, the society responds by mechanisms forming negative public opinion about the consumption of its products manufactured using "dirty" technologies.

As an illustrative example, consider the concept of carbon footprint. Carbon footprint refers to the greenhouse gas emissions from production associated with fuel combustion, separate industrial processes, agriculture, etc. For example, the manufacture of stamped metal parts for cars emits a small volume of carbon dioxide, in contrast to metal production for such parts. Also, an industrial enterprise consumes a large amount of electricity, which can be generated at various types of power plants (CHP, NPP, HPP, etc.), leaving behind a greater or lesser carbon footprint.

The ISO 14061-14064 standard is the most commonly used method for determining the carbon footprint in the world. In Russia, separate guidelines exist for quantifying the volume of greenhouse gas emissions; see orders no. 300 of June 30, 2015, and no. 330 of June 29, 2017, of the Ministry of Natural Resources and Environment of the Russian Federation.

As a result, the carbon footprint of products includes the total volume of emissions of the enterprise and its main suppliers. An enterprise consuming electricity from fuel power plants to manufacture its products will generate a larger carbon footprint than the one consuming electricity from cleaner power plants with comparable technologies.

When choosing suppliers, many large enterprises are guided by the volume of their carbon footprint. For example, Volkswagen has introduced an environmental rating for suppliers; Hewlett Packard Enterprise sets requirements for suppliers to reduce greenhouse gas emissions; Walmart is decreasing the number of suppliers with a large carbon footprint [49].

Thus, industrial enterprises will face an acute need to carry out technological re-equipment in the near future due to the transition to environmentally friendly technologies. (Otherwise, they will suffer from reduced demand for their products.)

The models considered above, particularly formula (1), overestimate the forecasted profit by neglecting the drop in demand due to the enterprise's technological lagging. To compensate for this overestimation, we introduce a correction coefficient into formula (1):

$$\Pi_g^T = \sum_f I_f^T C_f^T g_f^T \sum_f \left(I_f^T g_f^T \left(\sum_n S_{fn}^{ET} + \right.\right.$$
$$\left.\left. + \sum_n \sum_m S_{fnm}^{MT} + \sum_k \sum_n Z_{fkn}^T \right)\right) - S^{OT}, \tag{2}$$

where Π_g^T is the enterprise's profit on sales in period T considering the drop in demand due to using "dirty" technologies; g_f^T is a coefficient showing how many times the demand for product f will drop in period T due to using "dirty" technologies by the enterprise.

It should be understood that $\Pi_g^T < \Pi^T$. With the constant total costs S^{OT}, a decrease in demand can make the enterprise unprofitable in period T, whereas the classical model will predict profit.

Next, we study decision-making on the enterprise's technological re-equipment, transforming the expression (1) under several assumptions:

– Re-equipment will require additional investment, which reduces free retained profits.

– The demand for products will not change since the company eliminates environmentally "dirty" technologies ($g_f^T = 1$).

– If the adoption of new technologies changes power consumption, material consumption, and the number of required personnel, this should be considered by introducing appropriate correction coefficients.

Then the mathematical model of the company's profit with technological re-equipment can be written as

$$\Pi_{tech}^T = \sum_f I_f^T C_f^T - \sum_f \left(I_f^T \left(\sum_n S_{fn}^{ET} e_n^{ET} + \right.\right.$$
$$\left.\left. + \sum_n \sum_m S_{fnm}^{MT} r_{nm}^{MT} + \sum_k \sum_n Z_{fkn}^T p_{kn}^T \right)\right) - S^{OT} - \sum_f F_f^T, \tag{3}$$

where F_f^T is the re-equipment investment for product f in period T; e_n^{ET} denotes the coefficient of electrical energy consumption variation per unit of product f manufactured on machine n in period T; r_{nm}^{MT} denotes the coefficient of consumption variation for material m per unit of product f manufactured on machine n in period T; p_{kn}^T denotes the coefficient of variation of the total wages of production workers in gang k per unit of product f manufactured on machine n in period T.

The correction coefficients g_f^T, e_n^{ET}, r_{nm}^{MT}, and p_{kn}^T are determined using expertise depending on the macroeconomic forecast.

Recall that formulas (1)–(3) represent the profit evaluated for period T, often one year. However, technological re-equipment and its economic effect should be assessed over a longer period. Therefore, when making decisions, it is necessary to consider the total amount of profit (cash flows) for the compared period, i.e.,

$$\sum_T \Pi_g^T = \sum_T \left[\sum_f I_f^T C_f^T g_f^T - \sum_f \left(I_f^T g_f^T \times \right.\right.$$
$$\left.\left. \times \left(\sum_n S_{fn}^{ET} + \sum_n \sum_m S_{fnm}^{MT} + \sum_k \sum_n Z_{fkn}^T \right)\right) - S^{OT} \right],$$
$$\sum_T \Pi_{tech}^T = \sum_T \left[\sum_f I_f^T C_f^T - \sum_f \left(I_f^T \left(\sum_n S_{fn}^{ET} e_n^{ET} + \right.\right.\right.$$
$$\left.\left.\left. + \sum_n \sum_m S_{fnm}^{MT} r_{nm}^{MT} + \sum_k \sum_n Z_{fkn}^T p_{kn}^T \right)\right) - S^{OT} - \sum_f F_f^T \right].$$

Thus, we write two problem statements of the maximization problem:

- without technological re-equipment (the enterprise's cash flow in period T is estimated without technological re-equipment and under a dropped demand due to using "dirty" technologies):

$$\Phi_3 = \sum_T \Pi_g^T \to \max;$$

- with technological re-equipment (the enterprise's cash flow in period T is estimated after elimination of "dirty" technologies and under the same demand for products ($g_f^T = 1$, and the current cost coefficients (e_n^{ET}, r_{nm}^{MT}, and p_{kn}^T) may even decrease):

$$\Phi_4 = \sum_T \Pi_{tech}^T \to \max.$$

The decision about technological re-equipment should be made if $\Phi_4 > \Phi_5$:

$$\Phi_5 = \max\{\Phi_3; \Phi_4\} = \max\left\{ \sum_T \Pi_g^T; \sum_T \Pi_{tech}^T \right\}.$$

In other words, for the period under consideration, the total forecasted cash flow with technological re-equipment should exceed the one in the case of preserving the existing production technologies.

CONCLUSIONS

When implementing strategic management, the enterprise's owners and managers must first choose an appropriate effectiveness criterion for assessing managerial decisions. This paper has presented ways and methods for constructing mathematical models of assessing the effectiveness of industrial enterprises in an unstable environment. In particular, models of assessing the effectiveness of activities with fluctuating demand for products and the need for technological re-equipment have been constructed. These factors have the greatest effect on the performance of modern enterprises. The general logic of modeling proposed above can be used to consider other significant factors that may affect industrial enterprises in future.

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