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ENGINEERING AND TECHNICAL ASSESSMENT OF THE COMPETITIVENESS OF UKRAINIAN MECHANICAL ENGINEERING ENTERPRISES BASED ON THE APPLICATION OF REGRESSION MODELS

Anna Vitiuk[1], Leonid Polishchuk[2], Nataliia B. Savina[3], Oksana O. Adler[1], Gulzhan Kashaganova[4], Saule Kumargazhanova[5]

[1]Vinnytsia National Technical University, Department of Management, Marketing and Economy, Vinnytsia, Ukraine, [2]Vinnytsia National Technical University, Department of Industrial Engineering, Vinnytsia, Ukraine, [3]National University of Water and Environmental Engineering, Rivne, Ukraine, [4]Turan University, Faculty of Digital Technologies and Art, Department of Computer and Software Engineering, Almaty, Kazakhstan, [5]D. Serikbayev East Kazakhstan Technical University, Department of Information Technologies and Intelligent Systems, Ust-Kamenogorsk, Kazakhstan

Abstract. *The characteristic features of engineering products are revealed. Average industry performance indicators of mechanical engineering enterprises in Ukraine were formed. The competitiveness of mechanical engineering enterprises was studied. The integral indicator of the competitiveness of mechanical engineering enterprises in Ukraine was evaluated. It has been established that the competitiveness industry, despite certain profits received by enterprises, is in a systemic, predictable crisis and only individual enterprises that maintain their own line of economic behavior are successful, increase competitiveness and have prospects for further economic growth.*

Keywords: competitiveness, regression, mechanical engineering, dependence

INŻYNIERYJNO-TECHNICZNA OCENA KONKURENCYJNOŚCI UKRAIŃSKICH PRZEDSIĘBIORSTW BUDOWY MASZYN NA PODSTAWIE ZASTOSOWANIA MODELI REGRESJI

Streszczenie. *Ujawniono charakterystyczne cechy produktów inżynieryjnych. Opracowano średnie wskaźniki wydajności przemysłu przedsiębiorstw inżynierii mechanicznej na Ukrainie. Zbadano konkurencyjność przedsiębiorstw przemysłu maszynowego. Oceniono integralny wskaźnik konkurencyjności przedsiębiorstw przemysłu maszynowego na Ukrainie. Ustalono, że branża konkurencyjności, pomimo pewnych zysków uzyskiwanych przez przedsiębiorstwa, znajduje się w systemowym, przewidywalnym kryzysie i tylko pojedyncze przedsiębiorstwa, które utrzymują własną linię zachowań gospodarczych, odnoszą sukcesy, zwiększają konkurencyjność i mają perspektywy dalszego wzrostu gospodarczego.*

Słowa kluczowe: konkurencyjność, regresja, inżynieria mechaniczna, zależność

Introduction

A feature of mechanical engineering enterprises is the provision of fixed assets for other enterprises, the consequence of which is the further development of other branches of the economy. Therefore, ensuring the active development of mechanical engineering enterprises should be based on the maximum possible use of the conditions of spatial potential: chaotic and systemic trends in the development of the economy, the main directions of development of the corresponding enterprises, infrastructure connectivity, economic ties and partnership relations [10]. In such circumstances, the management of the enterprise, which involves the use of optimal resource provision, rational location of production, development of integration processes and ensuring the effective distribution of tasks will ensure the competitiveness of mechanical engineering enterprises [1, 13].

1. Formulation of the problem

Mechanical engineering is a basic branch of economic development in every country, however, each country has its own conditions and prospects for the development of machine-building industries. The fact remains indisputable that, in order to ensure progressive development, product manufacturers are forced to enter into a competitive struggle for better operating conditions. The result of the progressive development of society was the emergence and formation of the phenomenon of competition, which forces product manufacturers to constantly move and improve themselves, not to stop at the achieved results, that is, to increase their competitiveness [2, 4]. Competitiveness is the most important criterion for the expediency of an enterprise's activity, a condition for the efficiency of production activity, the basis for choosing means and methods of management, and a guarantee of success in competition [7, 11].

2. Results of the research and discussion

Having established the competitiveness of the enterprise as the most general characteristic of the development of the enterprise, we will evaluate the indicator according to the methodology presented by O. Kuzmin, O. Melnyk and O. Romanko [4] where the main emphasis is placed on highlighting competitiveness through indicators of financial and economic efficiency, indicators of production efficiency and indicators of commercial efficiency. The peculiarity of the method is taking into account the share of defective products that are manufactured and the presence of which can distort the further production process. In order to identify the share of defects in the manufacture of mechanical engineering products, it is important to take into account the complexity of the manufactured products.

The work of O. Danchenko, O. Zanora, V. Borkun [3] presents results where the share of defects in the manufacture of mechanical engineering products of various precision was clearly established. It has been proven that in the process of precise processing there is a defect, the costs of which are 2% of the total cost of processing blanks in the case of processing according to the 8th quality and 17% of the cost – according to the 7th quality. With a further increase in the accuracy of processing to the 6th quality, the cost of defects reaches 32% of the cost of processing blanks. Therefore, let's assume the following levels of shortage for the industries: agricultural, nuclear, electrical engineering, heavy and transport, construction, road and utility engineering, engineering for light and food industry, animal husbandry and fodder production – 2%; machine-tool, tool, chemical, petroleum and power engineering – 17%; instrumentation, production of automation and control equipment (32%). We will use 17% of defects of the total cost of processing blanks for researched enterprises [2, 14].

The effective tool for modeling the development of an enterprise and its activities is the formation of an integral indicator of the enterprise's competitiveness. To form the integral level of the enterprise's competitiveness, there is a need to translate indicators into relative values according to the developed scale presented in the work [5]:

$$X_1 = \begin{cases} \text{from 0 to 0.5 – if the indicator is worse than the baseline;} \\ \text{0.5 – if the indicator is completely identical to the base one;} \\ \text{from 0.5 to 1.0 – if the indicator exceeds the baseline.} \end{cases}$$

It is worth noting that the average industry or market indicators should be taken as the base. According to the noted expert scale, the above mentioned indicators are converted into point estimates, and weighted values are also assigned to them, which makes it possible to obtain integral levels of various components of the efficiency of the enterprise's functioning. Based on the generalization of the values of these levels using the geometric mean, the integral level of the enterprise's competitivness is determined (E_p):

$$E_c = \sqrt[3]{E_f \cdot E_p \cdot E_{com}} \quad (1)$$

The interpretation of the obtained results is carried out similarly: if E_p exceeds the value of 0.5 and approaches to 1, then we can talk about a high level of competitivness of the enterprise's functioning and exceeding the average industry or market average level according to this parameter, if $E_p = 0.5$, then this indicates a complete compliance with competitiveness standards formed in the industry, if E_p is less than the limit of 0.5, then this demonstrates significantly worse parameters of the enterprise's competitiveness compared to competitors.

Based on the specified parameters, we consider it expedient to assign $X_i = 0.2$, if the investigated indicator is lower than the industry average, and $X_i = 0.7$, if the investigated indicator exceeds the industry average, and $X_i = 0.5$ if the indicator is completely identical to the base one. Therefore, based on the analysis of the theoretical requirements for the financial indicators of the company's activity and statistical indicators, a system of average industry indicators was formed (table 1).

Table 1. Average industry performance indicators of mechanical engineering enterprises in Ukraine in 2020

A group of indicators	Partial indicators	Value
Indicators of financial and economic efficiency (E_f)	Coefficient of profitability of capital in mechanical engineering	-8..% [8]
	Total liquidity ratio	1.5…2.5, but not less than 1
	Autonomy ratio	more than 0.5
	Financial leverage ratio	1
	Asset turnover rati	>=1.0
Indicators of production efficiency (E_p)	Fund return (F)	0.65
	Material return (Mv)	2.73*
	Productivity (Pr)	823.24*
	Profitability of production (Rv)	-5.15
	The share of defects in commodity products	0.17
Indicators of commercial efficiency (E_{com})	Operating activities profit/Net sales revenue	-0.00005
	The number of orders completed on time/Total number of orders	≈1
	Warehouse occupancy level	≈1
	The term of repayment of payables	Reduction
	Repayment period of receivables	Reduction

3. Mathematical model of of the competitiveness of Ukrainian mechanical engineering enterprises

Using a methodical approach, a number of performance indicators of well-known mechanical engineering enterprises in Ukraine in 2017–2020 was formed (Tab. 2 i 3, Fig. 1).

Table 2. Integral indicator of competitiveness of mechanical engineering enterprises in Ukraine

Enterprise	Period			
	2017	2018	2019	2020
PJSC "Kharkiv Tractor Plant"	2.38	2.19	2.35	2.35
PJSC "Zaporizhzhia Automobile Plant"	2.06	1.86	2.03	2.33
PJSC "Kryukov Railway Car Building Works"	2.87	3.19	3.01	2.64
State Enterprise "Production Association Yuzhny Machine-Building plant named after A.M. Makarov"	1.71	1.69	2.69	1.69
PrJSC "Barskii Machine-Building Plant"	2.87	2.84	2.64	2.64
PrJSC "Kalynivsky Machine Building Plant"	2.31	2.13	2.43	2.13
PJSC "Nasosenergomash Sumy"	2.65	2.18	2.56	1.96

Table 3. Mathematical models of dependence of competitiveness of machine-building enterprises on profit mechanical engineering

Enterprises	Mathematical models	R^2
PJSC "Kharkiv Tractor Plant"	$y = 8E\text{-}17x^3 - 2E\text{-}11x^2 + + 4E\text{-}07x + 2.3926$	1
PJSC "Zaporizhzhia Automobile Plant"	$y = 3E\text{-}19x^3 - 1E\text{-}12x^2 + + 5E\text{-}07x + 2.2924$	1
PJSC "Kryukov Railway Car Building Works"	$y = -1E\text{-}17x^3 + 1E\text{-}11x^2 + - 2E\text{-}06x + 2.7512$	1
State Enterprise "Production Association Yuzhny Machine-Building plant named after A.M. Makarov"	$y = 3E\text{-}18x^3 + 5E\text{-}12x^2 + + 3E\text{-}06x + 2.247$	1
PrJSC "Barskii Machine-Building Plant"	$y = 4E\text{-}05x + 2.6016$	0.9959
PrJSC "Kalynivsky Machine Building Plant"	$y = 0.0612\ln(x) + 1.7247$	0.3001
PJSC "Nasosenergomash Sumy"	$y = 8E\text{-}12x^2 + 3E\text{-}06x + 2.1715$	0.998

The modeling of the competitiveness of the studied enterprises proved the existence of polynomial ($y = b_0 + b_1x + b_2x^2$), linear ($y = b_0 + b_1x$) and logarithmic relationships (y = aln(x) + b), between the competitiveness of mechanical engineering enterprises and their profit. All researched enterprises, with the exception of PrJSC "Kalynivsky Machine Building Plant" and PrJSC "Barskii Machine-Building Plant" were characterized by polynomial regression – that is, the relationship between the independent variable x (profit) and the dependent variable (competitiveness) y, which is modeled as a polynomial of the n^{th} degree from x. That is, the detected polynomial regression corresponds to a non-linear relationship between the value of x and the corresponding conditional mean value of y. At the same time, we note that the polynomial regression models were selected using the least squares method, which minimizes the variance of the unbiased estimates of the indicators [3].

Therefore, the competitiveness of the Ukrainian mechanical engineering enterprises is described by 3 three types of dependencies:

1. Polynomial – the vast majority of enterprises;
2. Logarithmic – PrJSC "Kalynivsky Machine Building Plant";
3. PrJSC "Barskii Machine-Building Plant".

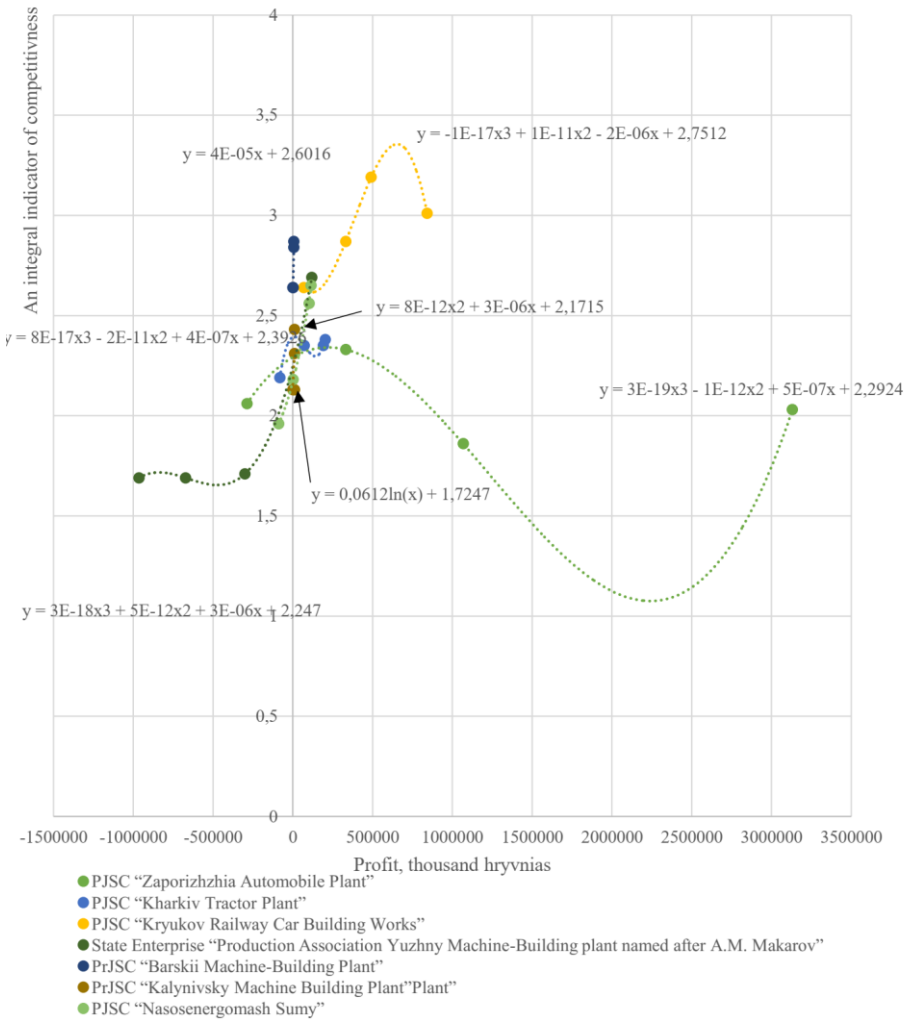

Fig. 1. Modeling the competitiveness of mechanical engineering enterprises in Ukraine

The degrees of the polynomial determine the number of extremes (determining factors of influence). Therefore, the polynomial of the third degree, which was recorded in the regression dependence of most enterprises, indicates the presence of two extremums, the use of which can allow a qualitative description of the development process of such mechanical engineering enterprises. The enterprises PJSC "Kharkiv Tractor Plant", PJSC "Zaporizhsky Automobile Plant", PJSC "Kryukov Railway Car Building Works", State Enterprise "Production Association Yuzhny Machine-Building plant named after A.M. Makarov" are characterized by two defining extremes, that is, the influence of two separate influencing factors. It is quite an interesting fact that the presence of the two most important factors of influence is characteristic of both large enterprises engaged in the production of a large number of heterogeneous products, and small enterprises operating in a narrow niche. The closeness of extremums on the graph indicates an increase in the influence of the time factor on the enterprise's activity, that is, an increase in its competitiveness, and, accordingly, the technical condition of these enterprises.

The logarithmic function revealed at the PrJSC "Kalynivsky Machine Building Plant" indicates that there is a large set of factors influencing competitiveness, the values of which change rapidly at first, and gradually stabilize over time, which indicates a significant adaptability of the enterprise to external conditions. Therefore, the company has the ability to control the main influencing factors and quickly react to the emergence of new circumstances.

The linear function in the development of PrJSC "Barskii Machine-Building Plant" reflects a direct relationship between the competitiveness of the enterprise and the level of its profit, which indicates the constancy of other factors influencing competitiveness, which can be ensured on the basis of high performance indicators of the enterprise in the previous period, which has already been proven in other studies [9].

Developing the prospects of the established enterprises, it is worth emphasizing that in 2021–2022 PJSC "Kryukov Railway Car Building Works", PJSC "Zaporizhzhia Automobile Plant", State Enterprise "Production Association Yuzhny Machine-Building plant named after A.M. Makarov" and PJSC "Kharkiv Tractor Plant" are located in regions where hostilities are ongoing. Therefore, as of the beginning of 2023, only 2 enterprises among researched have prospects for increasing competitiveness - PrJSC "Kalynivsky Machine Building Plant" and PrJSC "Barskii Machine-Building Plant". According to previous studies [8], the last two enterprises ensure the growth of competitiveness due to active foreign economic and research activities.

The totality of the identified trends in the development of mechanical engineering enterprises was evidenced on the basis of modeling the dependences between the absolute values of the company's profit and the relative values of the integral indicator of the competitivness. The extremely negative trends regarding the systemic impairment of the competitiveness of mechanical engineering enterprises in the past, which were additionally worsened with the beginning of the war, were evidenced. Therefore, the mechanical engineering industry, despite certain profits received by enterprises, is in a systemic, predictable crisis, and only individual enterprises that maintain their own line of economic behavior are successful, they increase competitiveness and have prospects for further economic growth.

4. Conclusions

The study of competitiveness was made based on the analysis of seven mechanical engineering enterprises wich engaged in different directions of production. As a result of the analysis, an integral indicator of competitivness of mechanical engineering enterprises in Ukraine was formed for each studied enterprise with dynamics over four years. The use of an integral indicator made it possible to simulate the value of the competitiveness of enterprises depending on the change in their profitability. The simulation results showed extremely negative trends regarding the systemic deterioration of the competitiveness of mechanical engineering enterprises.

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Ph.D. Anna Vitiuk
e-mail: anna_vitiuk@ukr.net

Ph.D., associate professor, Vinnytsia National Technical University, Vinnytsia.
Scientific direction: spatial development problems of engineering enterprises, investment activity, investment management of engineering entities.

http://orcid.org/0000-0001-5211-4948

D.Sc. Leonid Polishchuk
e-mail: leo.polishchuk@vntu.edu.ua

D.Sc., professor, Vinnytsia National Technical University, Vinnytsia.
Scientific direction: dynamics of drive systems with devices and control systems with variable operating modes and diagnostics of metal structures of hoisting-and-transport and technological machines

http://orcid.org/0000-0002-5916-2413

D.Sc. Nataliia B. Savina
e-mail: n.b.savina@nuwm.edu.ua

D.Sc. in Economics, professor, Vice-Rector for Research and International Relations in National University of Water and Environmental Engineering. Scientific directions are evaluation and forecasting of the efficiency of investments in entrepreneurial projects, in logistics and economic systems of various levels, in human capital. Deals with Financial instruments of international scientific and technical cooperation, modeling of the marketing business-processes under the industrial enterprise's competitiveness reflexive control, and modeling of the dialogue "human-computer" for ergonomic support of e-learning.

http://orcid.org/0000-0001-8339-1219

Ph.D. Oksana O. Adler
e-mail: oksana_adler1983@ukr.net

Associate Professor of department of Enterprise Economics and Production Management, Vinnytsia National Technical University.
Research interests: advanced methods of diagnosis and increasing the competitiveness of modern enterprises in a market economy.

http://orcid.org/0000-0002-4673-366X

Ph.D. Gulzhan Kashaganova
e-mail: guljan_k70@mail.ru

Associate professor of the Department of Computer and Software Engineering, Faculty of Digital Technologies and Art, Turan University, Almaty, Kazakhstan.
Scientific interests: fiber-optic technologies, information systems, information protection.

http://orcid.org/0000-0001-8150-1621

Ph.D. Saule Kumargazhanova
e-mail: SKumargazhanova@gmail.com

She is currently the dean of the Department of Information Technologies and Intelligent Systems of D. Serikbayev East Kazakhstan Technical University. She is a co-author over 50 papers in journals and conference proceedings.
Her professional interests are software engineering, data processing and analysis.

http://orcid.org/0000-0002-6744-4023