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Modeling of economic assessment of intellectual potential at machine-building enterprises of Ukraine

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Abstract— **The article conducts an economic assessment of intellectual potential, which has a significant impact on its development. The main purpose: research of structure of branch of mechanical engineering of Ukraine. The practice of realization of forms, processes and principles of production activity of machine - building branch is studied and presented. The role of labor resources in the intellectual and innovative development of mechanical engineering as a major factor in the effectiveness of intellectual potential and the national economy in general. Particular attention is paid to the state as a decisive factor in the development of mechanical engineering, because there is a need to create decent conditions for the state to successfully master the economic, managerial, technological, production, intellectual and innovative factors of mechanical engineering. Formulation of the problem - the machine-building industry plays a leading role in the industry of Ukraine. The development of machine-building enterprises depends on a number of factors, the formation of which includes elements of production activity, which necessitates an economic assessment of intellectual potential. After all, with the help of economic evaluation is an analysis of the development and effectiveness of the intellectual potential of the industrial enterprise. Such circumstances, in turn, require the creation of sound scientific and methodological approaches to the assessment, formation, use and development of intellectual potential**

Index Terms— three to six pertinent, specific to the paper, keywords added after the abstract, separated by commas.

I. INTRODUCTION

The prospect of Ukraine's accession to the European Union requires the implementation of the experience of developed countries in the world regarding the effective use of intellectual resources in the practice of domestic machine-building enterprises. In order to make more effective use of intellectual potential, there is a need for their own development of practical tools for economic evaluation. Stochasticity is a constant factor in the functioning of Ukraine's economic system, because economic development is carried out through the mechanism of stabilization and crisis, taking into account changes in the external environment and internal potential.

As an object of economic research, stochasticity is the relationship between economic entities in different conditions of economic development with incomplete (unreliable) information regarding the measurement of quantitative parameters.

Values of unreliability (uncertainty) arise due to the functioning of such factors as:

- complexity in the systematic study of economic activity;
- onlinearity of the nature of the creation and development of complex economic systems;
- growth of uncertainty of economic subjects through transformational transformations of the basic economic categories, namely the person, knowledge, abilities, work, the capital, globalization.

According to the research of T.Stiuart and P. Druker (Drucker 2017), the creation of intellectual potential is a derivative and a factor in the formation of stochasticity. Features of functioning of intellectual potential and factor stochastic influence are shown in:

- increasing the dynamics of economic processes for the formation of intellectual potential and its components of a new type;
- increase of information volumes concerning values, ideas, needs, motives of human activity, etc,
- unpredictable consequences of the impact and development of science, advanced technologies on society and the environment as a whole;
- creation of the newest virtual structures of the economy, which were not adequately reflected in science and institutional units due to the secrecy or lack of information about their functioning (Kocziszky 2012).

These factors reveal the need to improve the methodological

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approach to the economic assessment of the intellectual potential of machine-building enterprises. In the previous sections, we discussed in detail the existing methods and approaches to assessing intellectual potential. The choice of a specific approach is directly dependent on the specifics of the enterprise. Thus, in our case, we consider and apply a methodical approach to the economic assessment of the intellectual potential of the machine-building enterprise, in which the phasing of actions will fully reveal the effectiveness and impact of intellectual potential on the effective functioning of the enterprise.

The distribution of machine-building enterprises was carried out depending on the number and income of staff, in small, medium and large. Economic assessment of intellectual potential concerns the following enterprises: «Turboatom»; Zavod «Pivdenkabel»; Zavod «Elektrovazhmash»; «Kharkivskyi pidshypnykovyi zavod»; «Kharkivskyi traktornyi zavod»; «Khartron»; «Elektromashyna»; «Avtramat»; Kharkivskyi mashynobudivnyi zavod «Svitlo shakhtaria»; Tokmak forging and stamping.

II. LITERATURE OVERVIEW

Economic indicators that underlie the intellectual potential of the machine-building enterprise have a number of specific qualities. First, there is still no single list for quantifiable parameters, ie an empirical system, and no strict list of operations has been established to assess a specific determinant. Secondly, brief observations and inaccurate experimental data significantly complicate the scientific process, questioning the results and significance of the research. Third, the indicators entered in the tables of databases are mostly presented in a variety of measurement scales: nominal, monetary, metric, ordinal, and so on. Fourth, empirical measurement systems depend on different laws of distribution, which are far from theoretical methods, such as normal or uniform (State Statistics Service of Ukraine).

Problems of development of intellectual potential of machine-building branch are paid enough attention to various kinds of researches, especially, its role and place in the international, economic and scientific and technical cooperation. A large number of monographs, analytical reviews, strategies for the development of the industrial complex of mechanical engineering and its individual industries (automotive, shipbuilding, aircraft, etc.) in the field of intellectual potential (Hrabchenko 1999, pp.45-100).

Examples for this category are the works of such well-known (domestic and foreign) scientists as: P. G. Pererva; T.O. Kobielieva; O. P. Kosenko; R.G. Coyle; P. F. Drucker, who have successfully combined research and practical activities in leading sectors of the national economy. Most researchers of industrial issues take into account only its individual components. The principles of systematicity and consistency among the authors are almost non-existent.

In this regard, the development of a developed system of initial data is a crucial indicator for obtaining reliable results of mathematical modeling of the assessment of intellectual potential in a machine-building enterprise. Earlier we considered qualitative factors of influence on the basis of which there was a finding and quantitative indicators of intellectual potential of the machine-building enterprises.

III. RESEARCH FINDINGS

The next step is the statistical processing of available data. For this purpose rationing is applied - linear transformation of all significant indicators so that values of indicators were looked for in comparison with a big interval. Given the method of rationing, assessments of intellectual potential should be conducted not in nominal terms, but to obtain an integrated assessment. It is necessary to normalize the available data on the enterprise before the integrated review to ensure a generalized integrated assessment of intellectual potential. For the previous method of using the methods of rationing and aggregation, so the need for a classification of basic methods.

1. Ordinal scale (rating rationing method) is the simplest and most commonly used model. In addition to the advantages of this method, there are significant disadvantages that affect the final assessment of intellectual potential: distorted data from private ratings, excessive differentiation of values of the middle group with similar values, underestimation of the polarization of extreme values. Despite the shortcomings, this method contains a substantive problem - the rating does not allow to assess the real change in intellectual potential, because it reflects only the movement of indicators relative to each other.
2. The method of linear scaling - used to calculate the index of intellectual potential of machine-building enterprises. This method is based on determining the maximum and minimum values of indicators (reference points). The result is a reflection of the actual location of quantitative indicators from each specific structural unit of intellectual potential.
3. Method of aggregation - the result of points or indices of all available indicators. The equal priority of quantitative parameters is determined by calculating the arithmetic mean value of all indicators that are equal in weight. Thus, as quantitative parameters are grouped according to the qualitative indicators of the intellectual potential of machine-building enterprises, equal priority and weight for all indices are not inherent.
4. Score method - apply the values of indicators and compare with specific standards. Based on the results obtained, points are accrued for each factor. The disadvantage of scores is the threat of unreliability and formalism both when comparing the scale and when applying it (Pererva 2018, p.689).

The method of linear scaling is used to move to integrated estimation. The necessary calculation of quantitative parameters of intellectual potential at the machine-building enterprise is carried out.

The calculation of quantitative indicators is calculated by the formula:

$$Ikp\,j = \frac{xj - xjmin}{xjmax - xjmi}, \quad (1)$$

where: Ikp j - index of the quantitative parameter of the intellectual potential of the machine-building enterprise; xj is the actual value of the j-th parameter; xjmin - the minimum value of the quantitative parameter for the period under consideration; xjmax - the maximum value of the quantitative parameter for the considered period; j - the number of indicators for the calculation period (Honcharova 1989, pp.150-170).

The calculation of qualitative indicators of intellectual potential in the machine-building enterprise (Ikq i) is carried out using the method of weighted arithmetic mean of quantitative parameters (Ikp j). The results are shown in table 1. The general assessment of the intellectual potential of the machine-building industry is calculated by the formula:

$$IP = \sum_{i=1}^{m} qi * Ikq\ i\ , \quad (2)$$

where: IP - intellectual potential of the machine-building enterprise; qi - actual quality indicators of the intellectual potential of the machine-building enterprise; Ikq and - integrated quality indicators of the intellectual potential of the machine-building enterprise.

Taking into account the qualitative factors influencing the intellectual potential of the machine-building industry, which were obtained in subsection 2.2, the assessment of intellectual potential will have the following final form (Honcharova 1998, pp.133-160):

$$IP = 0{,}16 * Ikq1 + 0{,}24 * Ikq2 + 0{,}20 * Ikq3 + 0{,}23 * Ikq4 + 0{,}17 * Ikq5\ , \quad (3)$$

where: Ikq1 - staff qualifications; Ikq2 - working conditions; Ikq3 - innovation activity; Ikq4 - information support; Ikq - financial results.

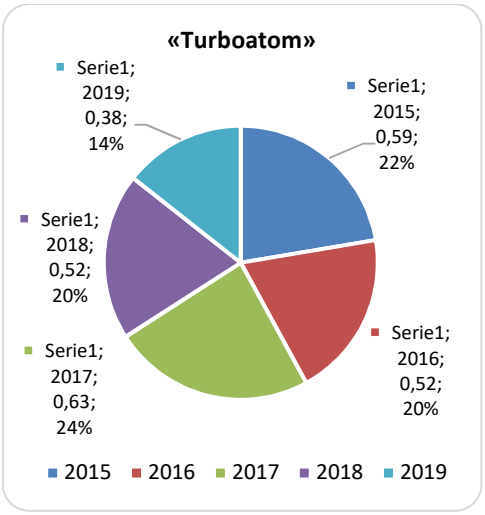
The results of the assessment of intellectual potential at the studied machine-building enterprises are shown in Figures 1 - 3.

TABLE 1 - INTEGRAL VALUES OF QUANTITATIVE PARAMETERS OF THE INTELLECTUAL POTENTIAL OF MACHINE-BUILDING ENTERPRISES AND THEIR LEVERS

Year	Enterprises	Qualitative indicators				
		Staff qualifications	Working conditions	Innovative activity	Information support	Financial results
2015	«Turboatom»	0,41	0,56	1,00	0,59	0,32
2016		0,26	0,71	0,57	0,38	0,59
2017		0,33	1,00	0,44	0,34	1,00
2018		0,21	0,32	0,51	1,00	0,44
2019		0,11	0,15	0,38	0,92	0,18
2015	«Pivdenkabel»	0,95	0,34	0,71	0,24	0,68
2016		0,83	0,18	0,68	0,22	0,81
2017		1,00	0,81	0,57	0,14	0,16
2018		0,65	0,91	0,57	0,16	1,00
2019		1,00	0,62	0,61	1,00	0,12
2015	«Elektrovazhmash»	0,67	0,41	0,89	0,16	0,16
2016		0,51	0,49	0,88	0,27	0,49
2017		0,81	0,81	0,36	0,25	0,26
2018		1,00	1,00	1,00	0,54	1,00
2019		0,12	0,72	0,51	0,16	0,31

Source: the author's own research

FIGURE 1 - DYNAMICS OF INTEGRATED ASSESSMENT OF THE INTELLECTUAL POTENTIAL OF THE MACHINE-BUILDING ENTERPRISE "TURBOATOM" FOR 2015-2019

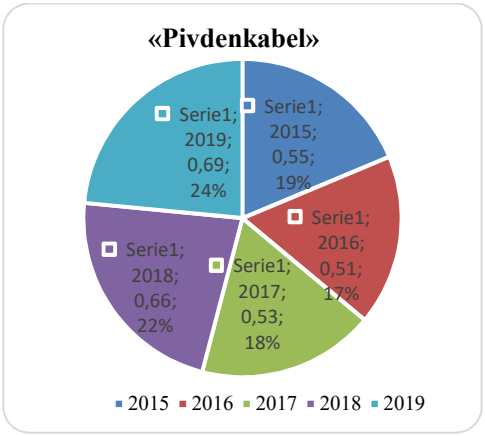


*Source:*author's own research

The analysis of the study of the integrated assessment of the development of intellectual potential at "Turboatom" for the last five years revealed a sharp decline in 2019. This phenomenon is due to a decrease in the number of orders and foreign investment in the enterprise. Comparing the value of intellectual potential for other years, we can conclude that there is a significant increase in 2017 (by 0.12% since 2016), stable development of intellectual potential occurred in 2015, with a slight deviation in 2016 and 2018. The decline in 2019 was negatively affected by as much as 0.14% less than in 2018.

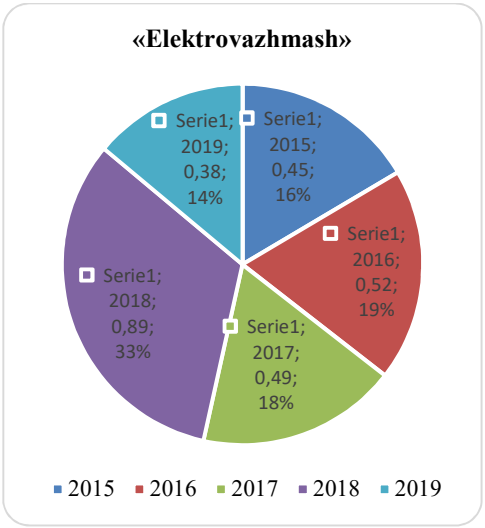
Regarding the values of intellectual potential at "Pivdenkabel", the analysis of the dynamics shows a stable development during 2015-2017 with a slight deviation, and from 2018 on the growth of the indicator first by 0.13% compared to 2017, then another 0 , 3% compared to 2019. When comparing the values of intellectual potential of "Electrovazhmash" we see a rapid increase during 2015-2018, especially high growth intellectual potential in 2018 gained 0.9% higher by 0.41% compared to 2017 and above other surveyed enterprises. The indicator fell in 2019 - a decrease of 0.52% compared to 2018 (Marchuk 2018, pp.95-102).

FIGURE 2 - DYNAMICS OF INTEGRATED ASSESSMENT OF THE INTELLECTUAL POTENTIAL OF THE MACHINE-BUILDING ENTERPRISE PIVDENKABEL FOR 2015-2019



Source: author's own research

FIGURE 3 - DYNAMICS OF INTEGRATED ASSESSMENT OF THE INTELLECTUAL POTENTIAL OF THE MACHINE-BUILDING ENTERPRISE OF "ELECTROVAZHMASH" FOR 2015-2019



Source: author's own research

Let me remind that the companies I selected were taken from each block, ie distributed by size: large, medium and small. Therefore, it is necessary to understand that the intellectual potential of the studied enterprises cannot be objectively compared, because we have completely different levels of indicators, especially profit, number of staff, innovation, etc. Therefore, to assess the level of intellectual potential of competing machine-building enterprises, I proposed the use of decomposition-aggregate method. This method provides systematic management of the level of intellectual potential and reveals the weaknesses of production in the machine-building enterprise. This method is also used in enterprises that belong to different groups: large, medium and small. In order to compare the level of intellectual potential, a formula is used taking into account the added value of each machine-building enterprise, which is obtained as a result of deduction from the net income of the organization (Starostina 2009).

TABLE 2 - CALCULATION OF THE LEVEL OF INTELLECTUAL POTENTIAL IN MACHINE-BUILDING ENTERPRISES

Enterprises	Indicator	2015	2016	2017	2018	2019
«Turboatom»	Intellectual potential	0,59	0,52	0,63	0,52	0,38
	Net profit	2541571	2195412	2377535	2615422	5000000
	Material costs	1239874	1123659	1131320	1503066	3210370
	Added value	1301697	1071753	1246215	1112356	1789630
«Pivdenkabel»	Intellectual potential	0,55	0,51	0,53	0,66	0,69
	Net profit	371542	354631	369416	329829	354698
	Material costs	234751	187452	214301	160729	210367
	Added value	136791	167179	155115	169100	144331
«Elektrovazhmash»	Intellectual potential	0,45	0,52	0,49	0,89	0,38
	Net profit	1750777	1185087	1437322	2341854	1642675
	Material costs	281547	102136	123954	118173	129836
	Added value	1469230	1082948	1313368	1160101	1512839

Source: the author's own research

The level of intellectual potential in competing companies is calculated using the following formula:

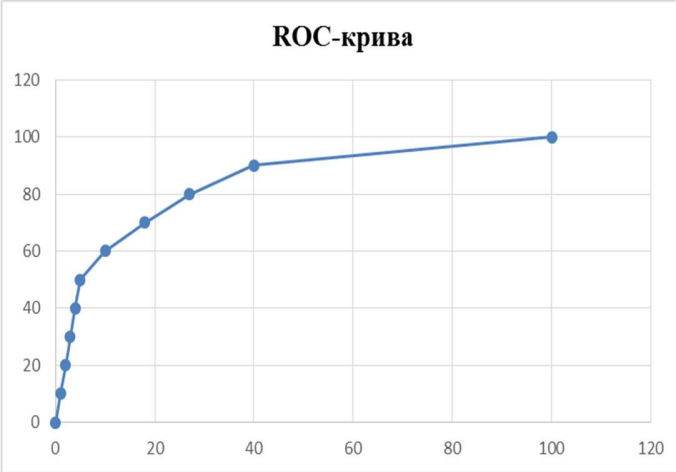
$$RIP = \rho * IP + (1 - \rho) * DC/DCmax \ , \quad (4)$$

where RIP - the level of intellectual potential in the machine-building enterprise; - the importance of the intellectual potential of the machine-building enterprise (0 ≤ ≤ 1); - intellectual potential at the machine-building enterprise; - added value of the researched enterprise; - the maximum value added value among competing companies.

Thus, there is a scientific task to create a model to determine the adequacy of the intellectual potential of machine-building enterprises. In order to build such a model it is necessary to use a binary selection system. The logistic function and the standard distribution function are used as a special function of the binary choice model. Binary choice models based on a logistic function are called logistic regression or logistic model. Logistic model is a statistical model used to predict the probability of a specific phenomenon or event using a logistic function. To model such a probability, a special monotonically

increasing function is usually selected, which has values ranging from 0 to 1. Due to logistic regression, the response probability is predicted for the dependent variable from (included in the model) independent variables. Based on the prediction of the obtained probability values, the classification of observations is divided into two groups. Also, when building a logistics model, a separate analysis is performed, namely: Receiver Operator Characteristic (analysis of ROC-curves). This analysis allows you to choose the most optimal value of the probability threshold for classification. The ROC curve is a curve that reflects the results of binary classification and its efficiency (Pepe 2003).

This curve solves two problems: 1) models the relationship; 2) creates an effective classification of observations.Based on the data obtained as a result of our study on the intellectual potential of machine-building enterprises of Ukraine, we construct an error curve (ROC-curve), shown in Figure 4.



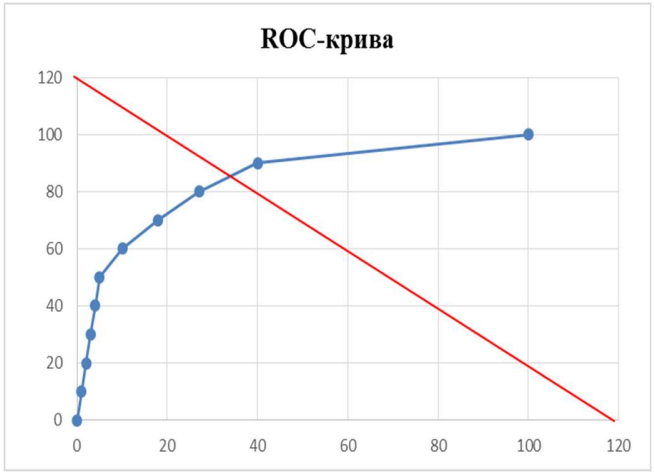
Source: author's own elaboration

The next point of our study is to determine the area under the curve, more precisely its numerical indicator AUC (Area Under Curve): in our case, the area under the error curve is 0.6, which indicates a qualitative model. Next, we determine the threshold value of the value of intellectual potential, for this it is necessary to decide which companies are classified as class №1, and which to class №0. This process is based on choice, because we choose a certain threshold and determine the class (companies with estimates above the threshold are considered to belong to class №1, below the threshold - 0.

The choice of the point on the error curve corresponds to the choice of the threshold. In economics, there are several options for such a choice, the main ones are: Neumann-Pearson test; zero value of x logistic regression; the criterion of the ideal observer; Kotelnikov's criterion and others. For economic problems, the most accurate and simple to calculate is the criterion of the ideal observer, so we decided to use this criterion in further research. In determining the threshold value of economic value by the criterion of the ideal observer, there is no reason to distinguish the significance of errors of the first and second kind - this criterion of the ideal observer differs from other economic criteria (Zweig 1993, pp.561-577).

The geometric understanding of this criterion is that to determine the threshold value for which decisions will be made - on the error curve (by the criterion of an ideal observer) it is necessary to draw a diagonal from the upper left corner to the lower right corner of the diagram, the intersection of the constructed diagonal and error curve - will threshold of intellectual potential. Using the criterion of the ideal observer, we determine the threshold value of the intellectual potential of machine-building enterprises, which reaches 0.87 (Figure 5).

FIGURE 5 - CRITERION OF AN IDEAL OBSERVER ON THE ERROR CURVE



Source: author's own elaboration

Thus, it can be argued that our proposed methodological approach to assessing the level of intellectual potential of machine-building enterprises allows to identify the level of intellectual potential of machine-building enterprises of Ukraine not only in general but also to assess intellectual potential at different stages of calculation. management decisions, which in turn help to improve the intellectual level and performance of the enterprise as a whole (Coyle 1996)

IV. CONCLUSIONS AND RECOMMENDATIONS

Analysis of the state and place of mechanical engineering in the structure of industry in our country indicates a significant decline in recent years (difficult conditions in eastern Ukraine also have a negative impact on the mechanical engineering industry). Today in Ukraine there are about 20 specialized engineering industries and 58 subsectors. In order for machine-building enterprises to be competitive on the market, a modern breakthrough is needed, because sustainable development (sustainability) and efficiency of not only the machine-building industry, but also other sectors of industry, as well as the state and level of development of the national economy as a whole depend on stable activity. During our study, a significant role of innovation was identified, because the overall effectiveness of innovation in machine-building enterprises is noticeable.

Analysis of the industry showed that without the introduction of innovations, modern industrial enterprises will be difficult to compete with similar enterprises in world markets, it is the development of innovation allows to ensure flexibility, efficiency, reliability and efficiency of production processes at the enterprise. For the development of the machine-building complex of Ukraine the direction of creation of a network of

machines and corresponding control systems at all stages of activity of the enterprise is rather actual. This approach will help reduce errors and ensure the most efficient interaction of all systems of the machine-building enterprise, while there is an opportunity to autonomously change production processes (as needed) and remain a highly efficient industrial enterprise. An important role is given to the process of managing the intellectual potential of an industrial enterprise.

Based on the above facts of the use of economic systems and methodological approaches indicate that the process of intellectual potential management should be carried out in real time, using modern information technology, because it is SMART-technology allows you to immediately obtain the necessary calculations and make management decisions to improve the effectiveness of the process of managing the intellectual potential of the industrial enterprise.

The system of qualitative and quantitative indicators of intellectual potential obtained as a result of our research has a logical and clear structure, which allows a comprehensive assessment of both individual components of intellectual potential and to determine the intellectual level of the enterprise as a whole. But the assessment of the intellectual potential of one machine-building enterprise has no significance for the management decision-making process, so we compared the obtained parameters with the company's competitors.

Based on the decomposition-aggregate method, we determined the assessment of the level of intellectual potential of competing machine-building enterprises of Ukraine

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