

# ECONOMIC AND MATHEMATICAL MODELING AND INFORMATION TECHNOLOGIES IN ECONOMICS

UDC 338.24.009.12

DOI <https://doi.org/10.26661/2414-0287-2023-4-60-04>

## METHODS OF ASSESSING THE LEVEL OF APPLICATION OF INTELLECTUAL TECHNOLOGIES IN THE COUNTRY'S ECONOMY

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**Key words:**economic growth,  
intelligent technologies,  
technological innovations

The article systematizes methods for assessing the level of application of intelligent technologies in the country's economy, which is an important task that allows determining the degree of use of innovative solutions in the business sphere and increasing the country's competitiveness in the global world. The classification of indicators for the assessment of intellectual potential has been carried out. Various evaluation methods are considered, including analysis of economic indicators, surveys of business and population, measurement of the relative importance of markets and the amount of investments in the development of intelligent technologies. International ratings that evaluate human capital have been determined. The basic levels of assessment of intellectual potential are considered. The positive aspects of the application of intelligent technologies in the creation of new markets and business models, which are able to ensure the growth of the economy and the development of society as a whole, have been established. The main purposes and tasks of intelligent technologies are defined, which is characterized by understanding the state of the economy and determining the strategy of its development. Scientific works on the assessment of the level of application of artificial intelligence (AI) and machine learning (ML) in the economy and the use of methods for measuring the impact of AI and ML on productivity, reducing costs and improving the quality of work in business have been studied. It is emphasized that the assessment of the level of application of intelligent technologies in the country's economy is a complex process that requires the involvement of a large amount of various data and its analysis using modern methods of information technology, however, with a thorough assessment, it allows to identify the weak points of the economy and provide recommendations for their improvements, which helps increase the efficiency of the intelligent technologies and ensures the economic growth of the country, reducing costs and improving the quality of business operations.

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## МЕТОДИ ОЦІНКИ РІВНЯ ЗАСТОСУВАННЯ ІНТЕЛЕКТУАЛЬНИХ ТЕХНОЛОГІЙ В ЕКОНОМІЦІ КРАЇНИ

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інтелектуальні технології,  
технологічні інновації

У статті проводиться систематизація методів оцінки рівня застосування інтелектуальних технологій в економіці країни, що є важливою задачею, яка дозволяє визначити ступінь використання інноваційних рішень у сфері бізнесу та підвищення конкурентоспроможності країни в глобальному світі. Проведено класифікацію індикаторів для оцінки інтелектуального потенціалу. Розглянуто різні методи оцінки, зокрема аналіз економічних показників, опитування бізнесу та населення, вимірювання відносної вагомості ринків та кількості інвестицій у розвиток інтелектуальних технологій. Визначено міжнародні рейтинги, які проводять оцінку людського капіталу. Розглянуто

базові рівні оцінки інтелектуального потенціалу. Встановлено позитивні аспекти застосування інтелектуальних технологій у створенні нових ринків та бізнес-моделей, які здатні забезпечувати зростання економіки та розвиток суспільства в цілому. Визначено основні призначення та завдання інтелектуальних технологій, що характеризується розуміння стану економіки та визначення стратегії її розвитку. Досліджено наукові праці з оцінки рівня застосування штучного інтелекту (AI) та машинного навчання (ML) в економіці та використання методів вимірювання впливу AI та ML на продуктивність, зменшення витрат та покращення якості роботи в бізнесі. Наголошено, що оцінка рівня застосування інтелектуальних технологій в економіці країни є складним процесом, який вимагає залучення великої кількості різноманітних даних та їх аналізу з використанням сучасних методів інформаційних технологій, проте, при ретельній оцінці дозволяє визначити слабкі місця економіки та надавати рекомендації щодо їх подолання, що допомагає підвищувати ефективність використання інтелектуальних технологій та забезпечує економічне зростання країни.

### Formulation of the problem

Current events constantly create challenges for the economic stability of the vast majority of countries in the world. The crisis that arose during the COVID-19 pandemic was greatly exacerbated by the full-scale Russian invasion. The result was a reduction in production, a decrease in income, austerity and a slowdown in development. In this state, entire industries become uncompetitive. One of the key solutions, which aims to help quickly adjust and make quality decisions during a rapid change in the market situation, is the introduction and application of intelligent technologies, which determines their special role. Increasing the level of application of intelligent technologies leads to rapid optimization of production processes, improvement of product quality and reduction of production costs.

### Analysis of recent research and publications

Methods of assessing the level of application of intellectual technologies in the country's economy are a topical problem for many scientific studies. For example, economists are investigating the impact of the use of intelligent technologies on increasing labor productivity and increasing economic growth. Computer science and artificial intelligence explore the development of new machine learning algorithms and other methods of applying intelligent technologies. Sociological research studies the attitude of the population to intellectual technologies and their use in the economy.

Methods of assessing the level of application of intellectual technologies in the country's economy are of practical importance for enterprises, state structures and public organizations. The results of the study will allow to determine the most effective methods of using intelligent technologies in various fields.

In recent years, several studies have been conducted on the problem of assessing the level of application of intelligent technologies in the country's economy. For example, Bartos Wachnyk in his article "Analysis of the use of artificial intelligence in the management of Industry 4.0 projects" describes the methodology of analyzing the use of artificial intelligence in the projects of Polish enterprises and determines the factors affecting the level of application of artificial intelligence [1].

In the article by Stefania Albanesi, Antonio Diaz da Silva and others "Artificial Intelligence and Jobs: Evidence from Europe", the authors examine the relationship between AI adoption and employment rates in European Union countries using panel data. The authors concluded that occupations potentially more prone to AI-enabled technologies have increased their share of employment, which undoubtedly has an impact on social and economic development [2].

In the article by Bernd Karsten Stahl, Josephine Antoniou and others "Systematic Review of Assessments of the Impact of Artificial Intelligence", the authors describe the methodology and conduct a review of assessments of the impact of the application of artificial intelligence on the development of society, and also describe the basic process of implementing artificial intelligence technologies, which can be used by regulators and external observers as a critical criterion for evaluating the approaches of the organization of intelligent technologies [3].

So, the latest studies confirm the importance of assessing the level of application of intelligent technologies in the country's economy for the development of business and the economy as a whole. In addition, methods for assessing the level of AI application have been developed, which allow taking into account various aspects of the development of intelligent technologies, such as economic impact, social consequences and impact on business processes. The multi-criteria approach, which allows taking into account various aspects of the development of intelligent technologies, has become very popular in research in recent years.

In general, the assessment of the level of application of intelligent technologies in the country's economy is becoming an increasingly relevant topic in connection with the growing influence of intelligent technologies on business and social development. The development of methods for assessing the level of application of intelligent technologies is an important task for business entities and government bodies to understand how intelligent technologies can help improve business efficiency and contribute to the social development of the country.

### Formulation of the goals of the article

The purpose of this article is to analyze the methods of assessing the level of application of intelligent technologies

in the country's economy and to determine their advantages and disadvantages.

### Presenting main findings

Modern society has entered a new stage of economic development, in which information and knowledge play one of the main roles. Much attention in business is paid to the intellectual component. In Ukraine, one of the priority areas of development is the formation of the innovative character of the national economy. More and more scientists and experts consider the efficiency of using intellectual potential to be the key success factors of this process.

In modern day-to-day life, systems with artificial intelligence have gone far beyond the scope of laboratory use, which has significantly influenced human world perception, creating the latest everyday use of systems with artificial intelligence (or part of it) significantly transforms modern day-to-day life and forms a special type of worldview. Naturally, this led to the development of intelligent information systems (IIS), which is the next stage in the development of such systems.

An intellectual information system (IIS) is an information system that is based on the concept of using a knowledge base to generate algorithms for solving economic problems of various classes, depending on the specific information needs of users. [4]

Every day, the range of application of intelligent technologies is constantly growing due to the increase in the amount of knowledge and the creation of new concepts about artificial intelligence. Based on the understanding of the structure of intellectual potential and the forms of its realization through different types of capital, the following classification of indicators for the assessment of intellectual potential is proposed:

- Human potential (HP). The main parameters for evaluating the indicator: literacy of the adult population; the number of students of educational institutions of higher professional education in a group of 10.000 people; specific weight of students in the total population.

- Creative (innovative) potential (CP). The main parameters for the evaluation of the indicator: number of persons with an academic degree in the number of researchers; internal spending on research and development, as a percentage of the gross regional product (GRP), percentage, value of the indicator for the year; the number of graduate students per 1000 persons of the employed population, people

- Information and communication potential (ICP). The main parameters for evaluating the indicator: specific share of organizations that used the Internet (as a percentage of the total number of surveyed organizations); specific share of organizations that used personal computers (as a percentage of the total number of surveyed organizations); the number of subscriber devices of mobile radiotelephone (cellular) communication (at the end of the year; per 1000 people of the population).

- Vital potential (VP). The main parameters for evaluating the indicator: the number of doctors per 10.000 people; the number of people engaged in physical culture and health clubs, sections and groups per 1000 people.

- Cultural potential (CP). The main parameters for evaluating the indicator: the number of spectators of professional theaters on average per 1000 people of the population; the number of visits to museums on average per 1,000 people, units; library stock on average per 1,000 people, copies.

It is proposed to combine the described indicators into an integral indicator – the index of intellectual development (IID).

IID will be calculated as the arithmetic average of five sub-indices characterizing the level of development of education, science, innovation, informatization of society, health care, and cultural component. The calculation of private indices is carried out in the same way as when calculating the index of human development and is highlighted in the formula [5]:

$$IID = \sum_{j=1}^{aj} \frac{X_i - m_i}{M_i - m_i}, \quad (1)$$

where:  $X_i$  is the actual value of the indicator describing the  $j$ -th element of the development of human potential;  $m_i$  and  $M_i$  are the minimum and maximum value of the indicator describing the  $j$ -th element of the development of human potential;  $aj$  is the weight of the corresponding IID element index

According to the scale of the assessed object, approaches to assessment are divided into three levels: micro-level (assessment at the level of an individual and organization), meso-level (at the level of large corporations and regions), macro-level (at the level of the country's economy) [6].

At the micro level, human capital valuation more or less focuses on estimating the value of an organization's human capital and/or evaluating the return on investment (including training costs) in an organization's human capital, which in turn can play a significant role in determining the value of a company after a sale. Studying the impact of employees on the company's financial activities is a key element of career opportunity analysis, professional development, and successful personnel management. The assessment of human capital is used in the assessment of development prospects, development of innovative policy. The methodology for evaluating the human capital of an enterprise is presented below [7]:

- Assessment of structural elements. Scientists distinguish two components of human capital – advanced and developed. In order to estimate the value of advanced human capital, investments in education (preschool, special, general) are brought to a single dimension and summed up.

- Depreciation assessment. It is characterized by the equation, which is illustrated by the following formula:

$$HCP = \sum_{k=1}^k A_i * T_i * K_i, \quad (2)$$

where:  $A_i$  is the annual amount of depreciation investments in human capital;  $T_i$  is the depreciation term of this type of investment;  $K_i$  is the number of depreciable objects

- Estimation of costs incurred. It is characterized by an indirect method (Tobin coefficient) and a direct method (estimation of all costs of the enterprise for the creation and development of human capital)

• Evaluation of the effects of elements. It is characterized by the equation, which is illustrated by the following formula:

$$HCP = \frac{\sum(E_{ch} + E_{wc} + E_{ic} + E_{oec} + E_{cmc})}{N_{Einv}}, \quad (3)$$

where:  $E$  – annual effects of labor, intellectual, organizational-entrepreneurial, cultural-moral capital and health capital;  $N_{Einv}$  is the required efficiency of investments, the coefficient is from 0.15 to 0.25.

• Assessment of managerial added value. It is characterized by the equation, which is illustrated by the following formula:

$$AM = BAV - AIC - MC, \quad (4)$$

where:  $BAV$  – business added value;  $AIC$  – alternative income on capital;  $MC$  – management costs.

• Cost estimate. It is characterized by a cost factor (expenditure on human capital), added value (adjusted rate of return), profit (ROI of the organization’s employees), profit factor (assessment of the effectiveness of the use of human capital)

• Integral evaluation. Integral assessment of human capital based on qualitative and quantitative indicators characterizing the elements of human capital. In its simplest form, it is a combination of indicators with corresponding weighting factors.

At the level of countries and regions, human capital is used in rankings to compare countries’ level of development, scientific potential and technological progress. The main international ratings are presented in Table 1:

Table 1

We will provide several examples of calculations related to methods of assessing the level of application of intelligent technologies in the country’s economy:

1. Calculation of the cost of developing an intelligent system to support decision-making in business. It may include the costs of software development, the purchase of necessary equipment and other technical solutions, the salary of programmers, analysts and other employees who will be engaged in the development and maintenance of the system.

2. Calculation of the effectiveness of the implementation of an intelligent production system. Such a calculation can be made on the basis of data on increased labor productivity, reduced production time, reduced waste, and other indicators that reflect the impact of intelligent technologies on production.

3. Calculation of indicators of the economic efficiency of the use of intelligent technologies relative to alternative methods of solving tasks. This may include comparing the cost of production using intelligent technologies with the cost of production that would be achieved using traditional methods, as well as comparing performance and product quality indicators.

4. Calculation of the level of application of intelligent technologies in the country’s economy based on data analysis of relevant statistics and reporting. This may include identifying the number of companies using smart technologies.

Calculation of the cost of developing an intelligent system to support decision-making in business. Let the software development costs amount to UAH 500.000, the equipment purchase costs to UAH 100.000, and the salaries of programmers and analysts to UAH 300.000 per year. Then:

$$\begin{aligned} \text{Total expenses} &= 500.000 + \\ &+ 100.000 + 300.000 = 900.000 \text{ UAH.} \end{aligned} \quad (5)$$

Thus, the total costs are equal to the costs of software development, to which are added the costs of equipment and the salaries of programmers and analysts.

Calculation of the effectiveness of the implementation of an intelligent production system. Suppose that thanks to the implementation of the system, it was possible to reduce production time by 10%, increase labor productivity by 15% and reduce waste by 5%. Then you can calculate the efficiency of system implementation as follows: Efficiency is equal to the sum of increased productivity, reduced production time, and reduced waste divided by 3. That is:

$$\text{Efficiency} = (15\% + 10\% + 5\%) / 3 = 10\% \quad (6)$$

Calculation of indicators of the economic efficiency of the use of intelligent technologies relative to alternative methods of solving tasks. Let the cost of production using intelligent technologies be UAH 2,000 per unit of production, and the cost of production using traditional methods be UAH 2,500. Then you can calculate the economic efficiency of using intelligent technologies according to the following equation: economic efficiency is equal to the difference between the cost of production by traditional methods and the cost of production using intelligent technologies, divided by the cost of production by traditional methods. That is:

Table 1 – Evaluation of human capital in international ratings

Rating	Compiler	Comment
Knowledge Economy Index	The World Bank	Evaluates conditions for effective use of knowledge in economic development [8].
Global Knowledge Index	UN	Assesses the country's ability to generate and disseminate knowledge [9].
Human Development Index	UN	Measurement of standard of living, literacy, life expectancy [10].
Global Competitiveness index	It is preparing for the World Economic Forum	Included in the sub-indices: health and primary education, higher education and professional development, availability of technologies [11].
The Global Innovation Index	INSEAD	The sub-indices include an assessment of education, qualifications, results and effectiveness of their use [12].

$$\begin{aligned} \text{Economic efficiency} &= (2500 - 2000) / 2500 = \\ &= 0.2 = 20\%. \end{aligned} \quad (7)$$

The obtained result means that the use of intelligent technologies allows to reduce the production costs by 20%, which can have a significant positive effect on the company's profit.

Calculation of ROI (return on investment) in intelligent technologies. Let the cost of investments in intellectual technologies be UAH 1 million, and the expected profitability from their use is UAH 2 million per year. Then you can calculate the ROI, which is the difference between the expected return and the cost of the investment, divided by the cost of the investment. That is:

$$\text{ROI} = (2 \text{ million} - 1 \text{ million}) / 1 \text{ million} = 1. \quad (8)$$

The obtained result means that the ROI is equal to 100%. In turn, this shows that the expected profitability of intelligent technologies exceeds the cost of investment by 100%, which is very beneficial for the enterprise.

### Conclusions

Determining the optimal method of evaluating intellectual resources remains a problem area. The

complexity of choosing methods for evaluating an intellectual resource is due to a number of factors, among which one can highlight the variety of definitions of an intellectual resource, its elusiveness and intangible essence, and the uniqueness of its individual elements.

There are three approaches to the assessment of intellectual resources: the first approach is based on the theory of human capital; focuses attention on a person, his basic qualities, abilities. The second approach is based on the theory of intellectual capital; the assessment of the company's financial indicators, related to the use of intangible assets and features of the company's organizational structure, prevails. The third approach considers the system of relations for the production of new knowledge and intellectual abilities of individuals.

Most methods of human capital assessment can be conditionally divided into two groups of models. Asset models use the similarities between human and fixed capital and estimate the cost of capital creation and its depreciation. Utility models evaluate the effectiveness of investments in human capital or its structural elements. Such models contain an economic assessment of changes in employee motivation, to estimate the additional profit of the enterprise from hiring or retaining an employee.

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