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FORMATION OF STRATEGIC DIRECTIONS FOR THE USE OF ARTIFICIAL INTELLIGENCE IN THE ENTERPRISE TO ACHIEVE THE GOALS OF SUSTAINABLE DEVELOPMENT

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ABSTRACT

Rapid artificial intelligence (AI) development opens new opportunities for enterprises to achieve sustainable development goals. This article summarizes the research results of applying AI to optimize production processes, reduce environmental impact, increase productivity, and strengthen social responsibility. The article aims to highlight the potential of AI for achieving enterprises' sustainable development goals and identify effective strategies for its application to increase economic efficiency, social responsibility, and environmental sustainability. A qualitative analysis of statistical data, official regulatory documents, books, and articles from accredited journals was used to achieve the goal. The obtained results showed that AI could be used to analyze production processes and forecast the demand for raw materials, optimize supply chains and reduce energy consumption, identify potential sustainability risks and develop strategies to prevent them, identify defects in production and control product quality in real-time, create personalized services and products for customers. The study highlights the importance of AI's ethical and safe use to ensure its positive impact on society and the environment. The practical value of the article lies in the systematic review of studies on the effects of AI on the sustainable development of enterprises. The obtained results can be used to improve production processes, increase enterprises' competitiveness, and promote sustainable development.

Keywords: artificial intelligence, sustainable development, enterprises, efficiency, social responsibility, environmental sustainability

JEL Classification: O32, O33, Q55, M15

INTRODUCTION

The use of artificial intelligence in enterprises to optimize production processes, control quality and achieve sustainable development goals is driven by the growing responsibility of businesses to society and the environment. The rapid growth of this technology's capabilities makes it possible to help professionals in various industries save time, ensure that monotonous, routine operations are performed faithfully and with the least number of errors, optimize production processes, and implement energy-efficient solutions (Bickley, Macintyre, & Torgler, 2024; Kulkov et al., 2023). Researchers believe that this can significantly increase business efficiency, social responsibility, and environmental sustainability (Isensee, Griese, & Teuteberg, 2021; Strilets, Frolov, Datsenko, Tymoshenko, & Yatsko, 2022). Using the example of mechanical engineering, we see that it is a key industry that provides tools (machines, equipment, units, spare parts, assemblies, components, parts, devices, etc.) to various areas of production. The study should determine the impact of the introduction of modern technologies into the production process on increasing the efficiency and sustainability of enterprises of the machine-building complex. The importance of the research is determined by the need to develop a set of measures that will help increase the competitiveness of manufacturing enterprises and analyze the impact of the implementation of new technologies on achieving the goals of sustainable development.

LITERATURE REVIEW

Recent research and publications indicate a wide range of ideas, theories and concepts related to using artificial intelligence to achieve sustainable development goals (Galaz et al., 2021; Kulkov et al., 2023). The scientific literature on this issue is both theoretical and applied. Academic studies examine the potential of artificial intelligence for sustainable development, and applied research evaluates the effectiveness of specific solutions. Researchers such as Androschuk (2021), Costa et al. (2019), Javaid et al. (2022), Esch and Black (2021), Waltersmann et al. (2021), Zaitsev (2022) argue that artificial intelligence can help businesses improve production efficiency, reduce environmental impact, and improve product quality.

A literature review of the use of artificial intelligence to achieve sustainable development goals was conducted by Singh et al. (2023). The authors determined the number of studies, the main types of activities and methods of implementing this technology to achieve goals. The results of the study help to understand the potential of technology that contributes to the achievement of sustainability.

Researchers Chen and Jin (2023) analysed the impact of artificial intelligence on reducing carbon emissions by Chinese manufacturing companies listed on the A-share from 2012 to 2021. According to the data, the average carbon emissions were 11.4, the minimum value was 8.84, and the maximum was 15.18. This indicates a significant difference in emissions between industrial enterprises. The study showed uneven application of artificial intelligence technology by companies: the average value of the level of its use was 0.18, the maximum was 1, and the minimum was 0. The results showed that the regression coefficient of corporate use of artificial intelligence and carbon emissions intensity was -2.13, significantly negatively correlated at the 5% level. This means that companies with higher levels of AI implementation have lower carbon emissions. This indicates that corporations can reduce their carbon footprint with the help of artificial intelligence.

Modern scientific and environmental research confirms the limitation of many natural resources and the risks of depletion and pollution of the environment. A vital business challenge is the transition to a more sustainable and circular way of using resources that considers the limitations of natural resources and minimizes waste and negative impact (Mishenin et al., 2015). Artificial intelligence has a significant potential to achieve sustainable development goals and offers new business opportunities. It will help increase production efficiency and allow companies to become more sustainable and competitive in the market, Fedulova (2020) believes.

According to Fostolovich (2019) and Duginets (2020), AI engineering continuously improves an enterprise's production processes and management system. A modern enterprise focused on innovative development should develop the AI tools that will be most useful in its activities. All enterprise systems must contain elements of artificial intelligence that can be combined into a single process using software products. This approach will help to make the most effective use of artificial intelligence.

New digital technologies are needed to solve most of the socio-economic and environmental problems of the modern world, enabling us to create management models, improve the quality of environmental analysis, reduce waste and emissions, and maximize resource reuse. The development of these technologies has a positive impact on economic recovery, expanding markets, increasing competition, creating new conditions for business, and increasing opportunities to satisfy consumers' interests (Sotnyk, Zavrazhnyi, 2017). A mandatory element of enterprise plans is the inclusion of sustainable development tasks in business processes and the development of relevant, innovative business models based on forming new consumer behaviour patterns (Fedulova, 2020).

Implementing digital technologies and artificial intelligence into production will optimize processes, increase productivity, and reduce costs (Sotnyk et al., 2020). The global interest in promoting sustainable development (Tu et al., 2023) will force companies to focus on environmental responsibility, emissions reduction, and energy efficiency, using green technologies, renewable energy sources and environmentally friendly products (Skibina et al., 2021). Artificial intelligence can significantly contribute to achieving sustainable development goals by increasing efficiency, developing new products and services, and improving customer and employee experience (Kramarenko, 2023; Artantas, Gursoy, 2024). Moreover, using AI technology by startups can stimulate their growth, promote innovation, create new jobs, and contribute to sustainable development (Zhou et al., 2023).

Tomakh et al. (2023) note that implementing the transformation of the national economy to achieve sustainable development goals requires compliance with the principles and sustainable development goals in managing enterprises. Information technologies and innovative solutions can accelerate transition processes and ensure economic activity optimization and enterprise development management (Koblianska et al., 2023). Thamik and Wu (2022) identified the positive and

negative impacts of artificial intelligence systems on the sustainable development of electronic markets, explored both sides of artificial intelligence, including behavioural, psychological, ethical, social, and cultural issues and proposed solutions to improve the situation. The researchers identified social and ethical considerations as the most essential component of using artificial intelligence technology.

In the study of the experience of applying artificial intelligence for the sustainable development of the enterprise, the scientometric database Scopus was used, in which scientific publications were filtered by the keywords "artificial intelligence, sustainable development, enterprise". Accordingly, 328 articles from 2003 to 2024 were selected for further analysis. As a result of the bibliometric study, it was found that the number of publications on the specified topic has increased significantly over the past 3 years, which indicates the relevance of the problem for the scientific community. To identify research trends, publications indexed by the Scopus scientometric database were analysed using the VOSviewer analytical platform. This powerful tool allows the creation of various types of visualisations that show the relationships between keywords, citations, authors, countries, and other bibliometric data.

Using the capabilities of the VOSviewer software made it possible to divide 115 keywords into 7 main clusters by the method of relationship density. The results of the bibliometric analysis are presented in Figure 1; the selected clusters are marked with red, green, blue, yellow, purple, blue, and orange colours. The circles represent the keyword; the larger circle's diameter means the higher frequency of the corresponding concept. Based on the content and contextual analysis results, the main directions of researching the role of artificial intelligence in achieving an enterprise's sustainable development goals were revealed.

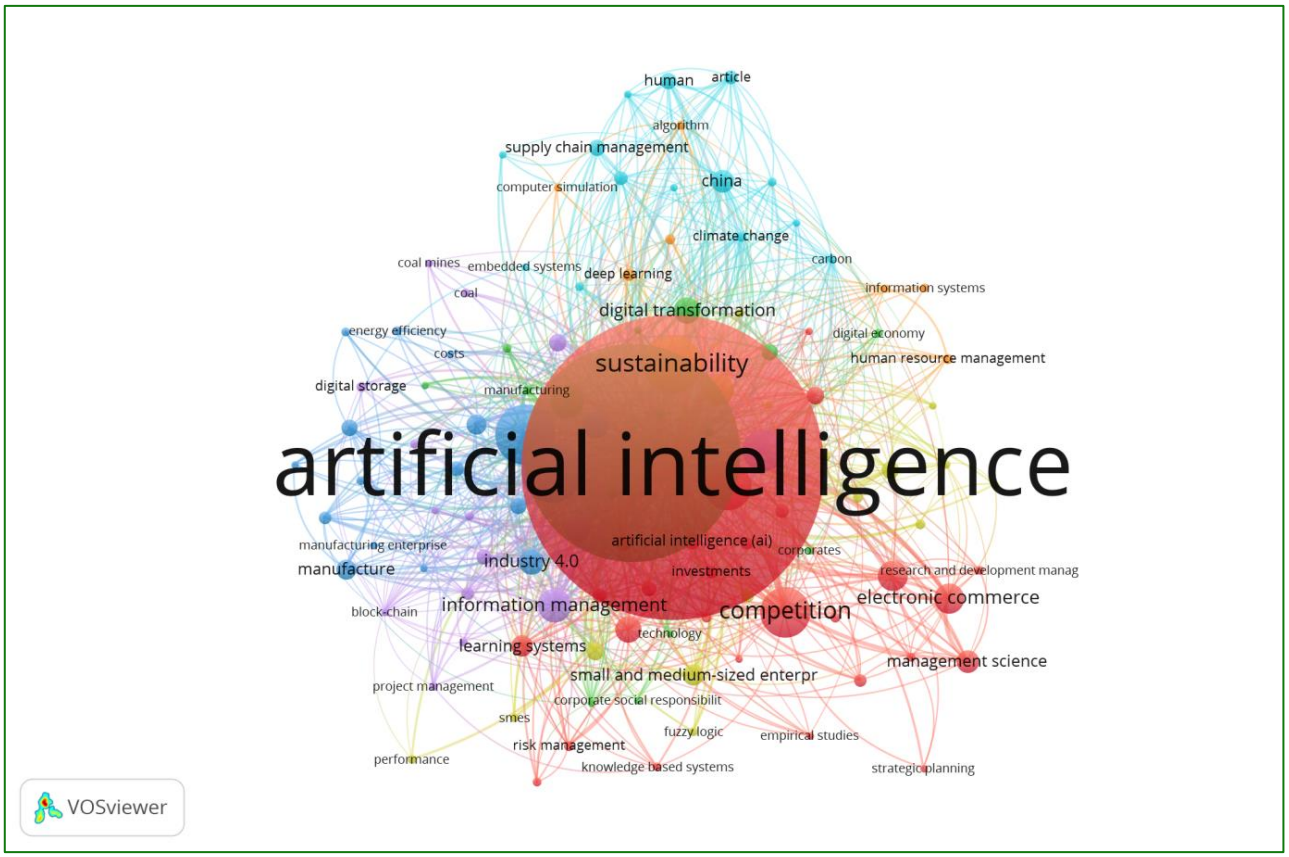

Figure 1. Graphical visualisation of the interrelationships of scientific research to the application of artificial intelligence for sustainable development of the enterprise. *(Source: compiled by the authors using VOSviewer via Scopus, WoS, and Google Scholar databases)*

The first and largest cluster (red) contains 28 categories and unites an array of scientific research focused on studying the impact of artificial intelligence on various aspects of business. This cluster covers the following keywords: artificial intelligence, data mining, economics, electronic commerce, empirical studies, finance, forecasting, knowledge management, recourse planning, learning systems, competition, core competitiveness, industry, enterprise management, algorithms, technologies, based systems, science, research and development management, risk management.

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The second cluster (green) covers 17 categories and is related to the study of the role of artificial intelligence in achieving enterprises' sustainable development goals. This cluster is based on keywords: sustainable development, digital economy, technology, transformation, automation, business, commerce, corporates, digital transformation, economic and social effects, and metadata.

The leading scientific publications, part of the third (blue) cluster, focus on understanding how artificial intelligence can improve management and sustainable production processes. In this cluster, 17 concepts are often used: decision-making, support systems, energy efficiency, industrial economics, industrial production, Industry 4.0, life cycle, manufacturing enterprise, and sustainable manufacturing.

The fourth (yellow) cluster is built based on 17 categories and artificial intelligence's impact on increasing enterprises' efficiency. This cluster covers the following keywords: business development, decision support system, digitization, fuzzy logic, innovation, small and medium enterprises, and efficiency.

The fifth (purple) cluster covers 15 terms and contains studies devoted to using big data to improve the effectiveness of the application of artificial intelligence in enterprises.

The sixth (blue) cluster contains 14 categories and focuses on the impact of artificial intelligence on climate change and environmental sustainability. This cluster's most frequently used concepts are article, carbon, climate change, embedded systems, emission control, energy utilization, environmental protection, human, information technology, productivity, recycling, and supply chain management.

The seventh (orange) cluster explores the application of deep learning and algorithms in various resource management and optimization aspects. This cluster is based on 7 keywords: deep learning, algorithm, computer simulation, human resource management, information systems, optimization, and resource allocation.

A recent study on the application of artificial intelligence to achieve sustainable development goals shows that scientists consider artificial intelligence a powerful tool that can be used to solve a wide range of sustainable development challenges. Still, they often focus on specific aspects of artificial intelligence without considering them in a complex. The complex and interdisciplinary disposition of the problem of applying artificial intelligence to achieve the goals of sustainable development of the enterprise, the dynamics of changes in digital technologies, and the variability of the business environment require further research.

AIMS AND OBJECTIVES

The purpose of the article is to study the potential of artificial intelligence as a tool for achieving the goals of sustainable development of enterprises and to prove the effectiveness of implementing AI to improve economic efficiency, social responsibility and environmental sustainability of enterprises.

The article defines the main objectives:

- to analyze the capabilities of artificial intelligence for optimizing production processes;
- to study its potential for automating tasks and improving decision-making;
- to identify options for using AI to monitor and minimize the impact of enterprises on the environment.

METHODS

The article uses various scientific methods to analyze the possibilities of using artificial intelligence to achieve the goals of sustainable development of enterprises. The authors apply both qualitative and quantitative methods to ensure a comprehensive approach to the study of the issue. The main method for analyzing existing research and scientific works on the concepts of sustainable development of enterprises and the implementation of artificial intelligence is a literature review. Scientific databases Scopus, Web of Science, and Google Scholar were used to search for relevant articles. VOSviewer was chosen for bibliometric analysis due to its ability to visualize scientific data and identify key trends and influential authors in the researched area. Bibliometric analysis made it possible to build a theoretical base and identify the key elements of the study. A retrospective and comparative analysis was conducted to identify trends, gaps, and future research directions. The application of the analytical-synthetic method made it possible to determine the effectiveness of the introduction of artificial intelligence in enterprises and its impact on achieving the goals of sustainable development. Conclusions, recommendations and proposals are formulated using the method of generalization.

RESULTS

The traditional model of economic development, known as the linear economy, based on the hypothesis of infinite natural resources, does not consider the actual limits of sustainable resource use. Modern scientific and environmental research confirms that many natural resources are limited, and their extraction can lead to depletion and environmental pollution. For example, oil and gas reserves, the primary energy sources, are limited and may be exhausted over the next few centuries. The extraction of such resources also leads to air, water, and soil pollution. A significant challenge is to move towards a more sustainable and circular way of using resources. The circular economy involves reducing waste, reusing materials, and reducing environmental impact (Melnyk et al., 2019).

The overall goal of sustainable development is to meet the needs of today's society without compromising the ability of future generations to meet their own needs. This concept considers economic, social, and environmental factors to achieve harmony between the needs of people and the planet's limited resources. Sustainable development is often described using the metaphor of a triangle. The three sides of the triangle symbolise the three pillars of sustainable development: economic efficiency means that economic development should be equitable and promote the well-being of all people. Social justice means that economic development should provide equal opportunities for all people and protect human rights. Environmental sustainability means that economic development should be ecologically safe and contribute to preserving natural resources for future generations. The interaction of these three pillars should ensure long-term sustainability and well-being for society.

Artificial intelligence in modern business has significant potential to achieve sustainability goals and make businesses more resilient and competitive. Artificial intelligence is used to analyse production processes, forecast demand for raw materials and supplies, optimize the supply chain, and reduce energy and water consumption, helping to achieve sustainability goals and reduce negative environmental impact. Data analysis with the help of artificial intelligence can identify potential sustainability risks and develop strategies to avoid them, making businesses more resilient to external influences. AI also helps to detect defects in production and monitor product quality in real-time, reducing waste and improving product properties. The application of AI facilitates the development of personalised services and products, increasing customer satisfaction (Zavrazhnyi & Kulyk, 2023). It also allows businesses to use resources more efficiently and reduce waste and negative environmental impact, aligning with sustainable development goals. Market analysis and identification of innovation opportunities is another advantage of artificial intelligence. Automating routine tasks frees human resources for more critical tasks and helps reduce costs. Creating environmentally sustainable products, optimizing production and improving forecasting using this technology is an important step towards creating a circular economy.

Analysis of the data obtained on the practical application of artificial intelligence in business processes provides an opportunity to assess its impact on specific aspects of sustainable development, such as resource optimization, emissions reduction, productivity improvement, and social responsibility (Sotnyk et al., 2020).

Using anomaly detection systems based on artificial intelligence and the Internet of Things (IoT) in the oil and gas industry can reduce well and equipment downtime, contributing to increased efficiency and environmental sustainability. When predicting technical failures, AI can analyse large amounts of data from sensors and equipment in oil and gas wells. It helps identify equipment performance anomalies, which may indicate possible technical problems or failures. This predictive analysis allows maintenance decisions before serious problems occur and reduces downtime. With the help of IoT systems, it is possible to install sensors to measure various environmental parameters, such as air or water pollution levels, thus monitoring emissions and achieving environmental sustainability. Artificial intelligence can analyse this data and make predictions about the impact of oil and gas production on the environment, helping to reduce the environmental impact. Data analysis from sensors and anomaly detection systems allows for maintenance and repair planning. Businesses will be able to use resources efficiently and reduce downtime by automating equipment maintenance and repair schedules.

In a circular economy, artificial intelligence can be used in product design to create environmentally sustainable products. The technology's ability to analyze different materials and their interactions in product design will help reduce waste and promote a closed cycle. The creation of a sequence of manufacturing parts based on a product design model will help reduce costs and increase resource efficiency. An important factor in ensuring the safety of the user is the analysis of the chemicals and materials used in the product. AI technology can predict the toxicity and compliance with environmental safety standards of products.

The circular economy involves the rational use of resources, taking into account environmental factors. Automation of product monitoring and identification systems at the end of their life cycle will help to separate materials for reuse and

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recycling, analyzing which valuable resources should not be wasted and pollute the environment. Optimization of transport logistics through intelligent dispatching will help to develop optimal routes for transport, which will reduce fuel consumption, shorten delivery times and reduce CO2 emissions. Automating waste sorting will allow the recognition and separation of different types of materials and waste, which will simplify the recycling and reuse process. The use of robots and machine learning systems will help improve sorting efficiency and reduce errors (Melnyk et al., 2023).

Based on the analysis of the collected data, a proposal for implementing deep learning and computer vision to achieve the goals of sustainable development of machine-building enterprises and create a model for automated defect detection in production lines was developed (Table 1). The plan consists of 9 stages, divided into two main parts: preparation for the implementation of the model, including the definition of the business task, technology analysis, development of the model description and justification of the decision; direct implementation of the model, including the definition of accuracy, creation of the Convolutional Neural Network (CNN) architecture, development of the model and analysis of the received results. Detection of defects at the early stages of production and identification of potential hazards will help reduce the amount of waste and emissions, contributing to the optimization of production processes, increasing labour safety and improving the environmental performance of the production enterprise.

Table 1. A proposal for a deep learning and computer vision implementation plan.

Stage	Description
Formation of a business task	Development of a business task based on the existing problems: the manufacturer wants to improve the production line through automated defect inspection and proactive monitoring.
Technology analysis	Analysis and introduction to computer vision and image segmentation.
Model description	Formation of a description of the construction of an image segmentation model for defect detection.
Justification of the decision	Justification of the benefits of the solution in terms of reducing waste, lowering prices, and creating a safe working environment.
Definition of accuracy	Rationale for the use of deep learning and convolutional neural networks for the accuracy of the result.
Developing the CNN architecture	Developing the CNN architecture and applying for implementation of proactive maintenance.
Development	Creation of computer vision elements and their variants to improve image segmentation for defect detection.
Control and correction	Monitoring the compliance of the obtained results with the goals set. Adjusting the model if necessary.
Analysis of the obtained results	Analysis of the obtained results. Conclusions the possibility of practical implementation of the developed model.

For this study, we take a group of machine-building enterprises, i.e., companies that manufacture machinery and equipment. We will define the components of machine-building enterprises: what areas of production can be present in this industry; what equipment is usually used. In general, this research aims to study the impact of artificial intelligence technologies on increasing the efficiency of production processes in the machine-building industry.

The study covers three main issues:

1. Repair costs. Thanks to artificial intelligence, emergency repairs can be avoided in advance and planned repairs can be carried out, saving labour costs.
2. Visual control of products. The camera photographs the product from different sides, artificial intelligence analyzes the image for defects. This saves a lot of time on quality control.
3. Control of the execution of the sequence of operations by the worker. Tracking violations and improving processes with the help of artificial intelligence.

Machine-building enterprises require periodic scheduled repairs and/or overhauls of equipment in workshops that use robotic systems that do not generate significant noise during operation. AI-based solutions help in this process. The equipment is equipped with microphones that constantly analyze the noise coming from robotic systems. Artificial intelligence determines whether emergency repairs are needed, or if a malfunction can be detected before the robot stops or other problems occur that could lead to product shortages. This avoids emergency costs and enables preventive maintenance to be carried out in advance.

Analyzing the processes of repair production within the framework of general processes of engineering production management, it is possible to determine key features such as the variability and uncertainty of processes, the dependence of the course of the process on the results of defects, and inventory planning taking into account probabilities. Table 2

provides information on the type of technical service that uses artificial intelligence for predictive maintenance and audio anomaly detection on equipment. These approaches to maintenance using artificial intelligence help enterprises provide more efficient and predictable equipment maintenance and reduce costs.

Table 2. Aspects of maintenance using artificial intelligence.

Aspects	Description
Predictive maintenance	This type of maintenance is based on the use of data and analytics to predict technical failures and equipment repair or maintenance needs before they occur. Artificial intelligence can be used to analyze large amounts of data collected from sensors and create models that predict future breakdowns. This allows businesses to plan repairs and maintenance more efficiently, reducing downtime and service delivery costs.
Detection of sound anomalies on equipment for predictive maintenance	This aspect includes the use of acoustic sensors and microphones to monitor the operation of the equipment and detect anomalies in the sound that may indicate possible problems. Artificial intelligence processes sound data, analyses it and provides warnings about possible problems or breakdowns, which allows us to take preventive maintenance measures.
Image segmentation on product images for automatic defect detection	This type of maintenance uses artificial intelligence to analyze product images and detect possible defects or breakdowns. Artificial intelligence can automatically highlight areas in images where there are potential problems and provide information for further use.

One of the elements of quality control of products on the conveyor of machine-building production is visual control. For this, we suggest using cameras that are installed in such a way as to have a complete overview of the working area. They must continuously record videos or take pictures in real-time. A Convolutional Neural Network (CNN) trained on a large number of examples can be used to analyze these images or videos for possible defects. This network has the ability to automatically detect important features in images and the main field of application is computer vision recognition.

In order to implement CNN technology on a production line, it is necessary to collect data first. A specialist collects a dataset of images of parts that have defects and those that are normal, without defects. Each image must be accompanied by segmentation masks that indicate where the defects are located on the image. The prepared data will be used for training the model. During training, the model will learn to identify which pixels in the image correspond to defects. In order to improve the segmentation accuracy, the responsible person at the machine-building enterprise must evaluate the model results and adjust the training parameters and architecture. The implementation of CNN will allow to detect problems much faster since the quality of parts on the conveyor will be analyzed without human intervention. Thanks to technological advances, these systems are affordable and can be implemented without much cost.

Applying the loss (or cost) function, a critical element of machine learning makes it possible to measure the difference between the model's predicted values and the actual (known) values in the training data set. The task is to determine how accurately the model represents the input data. The loss function can look different depending on the type of task (regression, classification, segmentation, etc.) and the algorithm used. Its goal is to minimize losses and thus make model forecasts as close as possible to actual data. For example, a pixel distribution comparison function can be used for an image segmentation task. The loss function helps the learning algorithm adjust the model weights to achieve the best trade-off between prediction accuracy and computational efficiency. After training, the model can be used to segment new product images. It will automatically highlight areas where defects are located. The next step is to analyse the segmentation results to identify defects and estimate their sizes and other characteristics.

Convolutional neural networks have a great potential for accurate image segmentation and automatic product defect detection. They can help businesses improve product quality control efficiency and save time and effort previously spent on visual inspection.

Automating product inspections with advanced computer vision will allow faster detection of defects and deficiencies, improving product quality and increasing overall production efficiency. Timely detection of defects in the early stages of production will avoid the manufacture of defective products, which will reduce the amount of waste and costs for processing and disposal, as well as reduce the number of emissions into the environment. In addition, computer vision can optimize the use of energy, water, and other resources needed to inspect products through data analysis and parameter adaptation.

The system of visual control using cameras and artificial intelligence for the execution of a sequence of operations by a conveyor worker of a machine-building enterprise makes it possible to monitor violations and improve processes. We propose to place video cameras at workplaces where important production operations are performed, the video will be analyzed by an artificial intelligence system that can recognize the sequence of actions performed by employees. AI is able to detect irregularities, such as incorrect operations, skipping certain steps, or execution operations in the wrong order. It

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can detect violations in real-time or based on the analysis of records, and this allows timely detection and correction of errors, preventing the release of low-quality products. Based on the analysis of the execution of operations, it is possible to identify weak points in the processes and make changes to improve them. For example, it is possible to optimize the sequence of operations, reduce the time required to perform certain tasks or improve the training of workers.

To create a model of economic calculations for the implementation of a system of visual control over the sequence of operations by workers using cameras and artificial intelligence at a machine-building enterprise, we propose to use the following main stages: determination of initial data, calculation of initial costs, calculation of operating costs, assessment of economic benefits, and analysis of return on investment (ROI). Table 3 shows summary calculations of economic indicators that demonstrate the expected effectiveness of the implementation of the visual control system.

Table 3. Summary calculations of the economic efficiency of the implementation of the visual control system.

Indicator	Value
Number of workplaces (N)	10
The number of cameras per workplace (K)	2
The cost of one camera (UAH) (Ck)	18325
The cost of AI software (UAH) (Cp)	733000
The cost of system implementation (UAH) (Cs)	183250
Annual maintenance costs (UAH) (Co)	109950
The number of shifts per day (S)	2
Average employee salary per hour (UAH) (W)	733
Shift duration (hours) (H)	8
Average percentage of defects before implementation (Pb)	5
Average reject rate after implementation (Pp)	1
Average cost of defective products per year (UAH) (Cb)	1832500
Average time to identify a defect before implementation (minutes) (Tb)	30
Average time to detect a defect after implementation (minutes) (Tp)	5
Number of production cycles per year (Nc)	10000
Initial costs (UAH)= (N * K * Ck) + Cp + Cs	1282750
Annual operating expenses (UAH)= Co	109950
Savings on shortage (UAH)= Cb * (Pp - Pb)	73300
Salary savings (UAH) = Time savings * W= Nc * (Tb - Tp)/60* W	3054167
Total annual savings (UAH) = Savings on unemployment + Savings on wages	3127467
ROI (%) = ((Total Annual Savings − Annual Operating Costs) / Initial Costs) × 100%	235.24

Based on the calculations, it can be concluded that the implementation of a visual control system using cameras and artificial intelligence is an economically beneficial solution for a machine-building enterprise. This innovation will help reduce production costs and improve product quality, develop a high-quality and reliable infrastructure based on the use of innovative technologies. The total annual savings exceed the initial costs by more than 2.3 times, which indicates the feasibility of such an implementation.

Table 4 shows the main goals and conclusions regarding the impact of the automation of product inspection with the help of advanced computer vision on the sustainable development of the machine-building enterprise.

Table 4. The economic and environmental effects of implementing visual control with the help of cameras and artificial intelligence at machine-building enterprises.

Goal	Conclusion
Increasing production efficiency	Automation of product inspection allows faster detection of defects and deficiencies, which contributes to the improvement of product quality. Reducing the time required to detect and correct defects leads to an increase in overall production efficiency.
Waste minimization	Timely detection of defects allows to avoid the production of defective products, reducing the amount of waste and processing costs.
Saving resources	Reducing the number of deviations and defective products allows to save raw materials and other production resources.
Promotion of sustainable development	Reducing the environmental impact through reducing the amount of waste and optimizing production processes contributes to sustainable development.
Ensuring product quality	The use of advanced computer vision makes it possible to detect even the smallest defects, which improves the overall quality of products.
Cost optimization	Automating the inspection process can help reduce manual labour costs and increase the speed of production processes.
Increasing competitiveness	The use of advanced technologies, such as advanced computer vision, can make a business more competitive in the market.
Innovation and development	The implementation of the latest technologies into production processes can become the basis for innovation and business development as a whole.
Supporting digital transformation	The use of smart technologies, such as computer vision, is an important component of the digital transformation of an enterprise.
Attracting investments	The implementation of advanced technologies can make business investment more attractive to investors who value innovation and sustainability.

Computer vision and machine learning systems, combined with AI, can be used to automatically recognize materials and objects in images from cameras or other video data sources. Thanks to deep learning algorithms, they will be able to recognize specific types of waste and sort them efficiently. The implementation of such systems at machine-building enterprises is an important step on the way to sustainable development, which will increase the efficiency of processing, reduce the amount of waste that ends up in landfills, and reduce the ecological footprint. Table 4 shows examples of using artificial intelligence to improve waste sorting.

Table 5. The use of artificial intelligence to improve waste sorting at machine-building enterprise

Concept	Example
The system can be trained to recognize different materials such as metal scraps, shavings, electroplating slags, burnt moulding earth, slags, plastics, etc.	The camera registers an image of the waste and the AI determines its material, helping to automatically sort the waste into categories. This will increase the accuracy of sorting and reduce the amount of materials that need to be reprocessed or disposed of.
AI can be used to recognize hazardous waste and separate it for special treatment	Machine manufacturing generates waste that contains heavy metals and other hazardous substances, such as galvanic sludge. AI can effectively recognize and separate these wastes for safe recycling, reducing environmental pollution and improving workplace conditions.
The system can automatically learn new waste types using examples	As new materials or products emerge, the AI can quickly adapt by adding them to the database and learning to recognize them.
AI can keep statistics and analyze the efficiency of the sorting system in real-time	The system can send reports on the amount and types of waste sorted, allowing for improvements in sorting processes and problem-solving.

AI systems will allow companies to reduce the cost of manual waste sorting, reduce raw material losses and increase productivity. Moreover, automation of processes will facilitate more efficient processing of slag, abrasives, wood and other waste, which will significantly reduce the amount of disposal and increase the economic profitability of recycling.

The importance of AI-enabled maintenance is growing as companies look for efficient and innovative ways to support operational equipment. The use of sound data for forecasting the state of technology is a promising area of research. Sound, as a parameter, can carry important information about the operation of machines, detect anomalies and predict possible breakdowns. Consider a plan for predictive maintenance based on sound, which is aimed at creating an intelligent system that uses acoustic data analysis to predict the state of equipment at a machine-building enterprise. The application of this approach has the potential not only to improve maintenance efficiency but also to contribute to the overall context

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of sustainable development. Reducing the number of failures and early detection of problems will lead to reduced waste, energy consumption and improved overall operational safety. The sound-based approach to predictive maintenance is presented in Table 6.

Table 6. Approaches to predictive maintenance of a machine-building enterprise based on sound.

Stage	Result
Formation of understanding of sound data	Overview of the basics of sound processing and acoustic features. Study of sound representation in the form of spectrograms and the Mel frequency cepstral coefficients (MFCC).
Collection and analysis of sound data	Definition of the field of application: machines, equipment, systems. Collection of sound samples from objects for further analysis.
Data preprocessing and transformation	Using libraries to obtain spectrograms and the MFCC. Normalization and standardization of audio data for data fusion.
Separation of the main acoustic features	Determination of key acoustic features for a specific type of equipment. Selection of functions that indicate the state of the object.
Creating a model for forecasting	Choice of prediction model: CNN, the long short-term memory, or a combination of both. Development of training and test datasets.
Model training and testing	Using the training set to train the model. Testing the model on a test set to evaluate performance.
Classification and definition of anomalies	Definition of categories of sound samples: normal state, low-level anomalies, high-level anomalies. Detection of anomalies and determination of their potential impact.
Integration with the maintenance system	Development of an interface for integration with sound monitoring models. Checking the system in real operating conditions.
Optimization and support	Analysis of results and optimization of model parameters. Continuous improvement of the system based on new sound data and feedback.
Documentation and reporting	Creating documentation for a sound-based prediction system. Ensuring reporting of results and conclusions.
Staff training and education	Training of technical staff to use and understand the system. Definition of commissioning and support procedures.
Monitoring and continuous improvement	Implementation of a monitoring system to detect possible deviations in system performance. Continuous improvement of the model and algorithms based on new requirements and data.
Data protection and privacy	Ensuring the confidentiality of sound data and prediction results. Using the latest security standards to prevent unauthorized access.
Final evaluation and report	Conducting a final assessment of the system's effectiveness. Preparation of a final report with results and recommendations for future improvement.
Scaling and expansion	Consideration of the possibilities of scaling the system to process more data. Expanding the functionality of the system to consider new requirements and tasks.

We propose to use convolutional neural networks (CNN) to monitor the condition of machine-building enterprise equipment. The process of developing and applying such a model has several stages: collecting and uploading a data set with audio recordings of equipment operation in normal mode and with various types of malfunctions; creation of CNN architecture; model training and evaluation. To analyze the effectiveness of the implementation of the equipment condition monitoring system at machine-building enterprises, we suggest using a separate test data set that the model did not see during training. Metrics such as classification accuracy, confusion matrix, or others can be used to measure the model performance. The confusion matrix provides detailed information about the performance of the classification model. Accuracy is the ratio of the number of correctly classified samples to the total number of samples in the formula dataset:

Accuracy = The number of correctly classified samples (True Positives and True Negatives) / Total number of samples

Matrix elements consist of:

1. True Positives (TP): The number of positive examples that are correctly classified.
2. False Negatives (FN): The number of examples that are true positives but were falsely classified as negatives.
3. False Positives (FP): The number of examples that are true negatives but were falsely classified as positives.
4. True Negatives (TN): The number of correctly classified examples as unfavourable.

This information allows us to evaluate the model's effectiveness and determine how well it recognizes certain classes and what errors it makes.

The implementation of a predictive maintenance system based on sound data has the potential to significantly impact sustainability the sustainable development of machine-building enterprises. First, it will help to increase the efficiency of the resource used, as it will allow to plan maintenance and repair work as needed, preventing unexpected costs and minimizing equipment downtime. Faulty equipment can lead to the release of harmful substances into the environment. Sound-based technical forecasting detects equipment problems at an early stage, reducing emissions. In addition, the prevention of technical issues through sound monitoring contributes to the safety of industrial processes. It can prevent emergencies, which is essential for ensuring the safety and health of workers. In this way, sound monitoring systems not only help to improve maintenance but also contribute to the sustainable development of the enterprise through efficient use of resources, preservation of equipment and improvement of working conditions.

Optimization and automation of work processes at a machine-building enterprise increase production efficiency and reduce costs. An important component of the implementation of innovations is the monitoring of key performance indicators (KPIs). We suggest using an AI system to track sustainability KPIs such as energy efficiency, amount of waste and CO2 emissions. The KPI analysis of the sustainable development of the machine-building enterprise is given in Table 7.

Table 7. Analysis of the KPI.

KPI	Description	Analysis
CO2 emissions	Measuring the amount of CO2 emissions to determine the ecological footprint of a machine-building enterprise. This allows to track the sources of emissions and work on their reduction.	Study of the impact of technological changes (optimization of production processes, introduction of energy-efficient systems) on the reduction of CO2 emissions. For example, using technologies to reduce the amount of fuel consumed.
Energy and its spending	Tracking of total energy consumption by the enterprise and distribution by processes. This allows to use energy efficiently and reduce its consumption.	Analysis of energy costs by separate stages of production. The introduction of energy-saving technologies, and the transition to energy-efficient engines will reduce the total cost of electricity.
The rate of energy consumption	Determination of fluctuations in the rate of energy consumption in various production processes for optimal use of resources.	Study of the correlation between fluctuations in energy consumption and the intensity of production operations. This helps implement strategies that reduce energy consumption during equipment downtime or reduced production loads. For example, optimizing the operation of furnaces during casting or machining.
Production levels	Monitoring of production volumes and production stages allows better management of material flows, resources and process optimization.	Study of the impact of quality and volume of production on the overall sustainability and consumption of resources. The implementation of efficient production strategies contributes to the sustainable development of the enterprise.

Analysis of sustainability KPI is an essential tool for monitoring sustainability goals, which allows the assessment of the impact of operational aspects on the overall sustainability and efficiency of the enterprise. Reducing CO2 emissions corresponds to the company's strategic objectives, as it affects not only its ecological footprint but also its compliance with modern standards of sustainable development. Optimizing the use of energy and implementing energy-saving technologies can significantly reduce costs and contribute to the creation of an energy-efficient production environment. Adapting to energy rate fluctuations allows the enterprise to efficiently use resources in changing conditions, contributing to production stability, and ensuring efficient operation. Managing the quality and volume of production is critical to sustainable development; therefore, balanced production levels contribute to the optimal use of resources and support sustainable functioning. The general trend is the understanding that effective implementation of sustainable development strategies requires comprehensive monitoring and analysis of various aspects of business activity. The use of KPIs indicates that production can be not only profitable but also environmentally responsible. Therefore, it opens opportunities for successful development in the growing demand for sustainability and environmental responsibility.

DISCUSSION

The study's main results indicate the potential benefits of the implementation of artificial intelligence in promoting the sustainable development of enterprises by improving the processes of forecasting and optimizing resources, increasing the efficiency of production, and reducing the negative impact on the environment. This is consistent with the work of Melnyk, Matsenko et al. (2022), who also noted the significant impact of artificial intelligence on optimizing production processes, accelerating economic growth, and reducing environmental burdens and social risks. The capability of technical systems for self-organization and self-improvement plays an essential role in ensuring their stability and constantly increasing the efficiency of functioning, particularly the rational use of resources. In addition, two studies by Melnyk et al. (2019) confirm

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that artificial intelligence improves the customer and employee experience, highlighting this aspect's importance in sustainable development.

The conducted analysis indicates the growing interest of the scientific community in the topic of the implementation of the latest technologies at enterprises and their impact on sustainability. The attention of scientists is focused on solving issues of increasing the efficiency of activities, developing new products and services, and improving interaction with customers and employees. Along with the benefits, there are threats of job losses, ethical and societal issues, and data security issues (Yarovoy, 2023). These issues require analysis and development of strategies to minimize the risks of introducing artificial intelligence.

CONCLUSIONS

The article analyzes the possibilities of using artificial intelligence in enterprises to achieve the goals of sustainable development. The results of the study show that the integration of technology into key business functions significantly increases the efficiency of production processes, optimizes the use of resources, and contributes to reducing the impact on the environment. This enables enterprises to increase their competitiveness, reduce costs and improve product quality.

In addition, the ability of AI to predict energy consumption and identify opportunities for energy savings helps to reduce the carbon footprint of enterprises, implementation in waste sorting and recycling processes also supports the principles of the circular economy, increasing the recovery rate of materials and reducing the amount of waste that ends up in landfills. This is closely related to the global goals of sustainable development, which determine the priorities of resource efficiency and environmental protection.

The findings indicate the need for further study of the interaction between technological and social issues of AI use. Issues of data privacy, workforce mobility, and ethical use of technology must be addressed. The recommendations are limited to expanding the scope of AI applications to achieve economic efficiency, social responsibility and environmental sustainability. The successful implementation of artificial intelligence in management and production processes will allow not only to increase the productivity of enterprises but also contribute to the achievement of the goals of sustainable development, which, in turn, will strengthen the domestic market and the global competitiveness of the economy.

ADDITIONAL INFORMATION

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CONFLICT OF INTEREST

The Authors declares that there is no conflict of interest.

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ФОРМУВАННЯ СТРАТЕГІЧНИХ НАПРЯМІВ ВИКОРИСТАННЯ ШТУЧНОГО ІНТЕЛЕКТУ НА ПІДПРИЄМСТВІ ДЛЯ ДОСЯГНЕННЯ ЦІЛЕЙ СТАЛОГО РОЗВИТКУ

Стрімкий розвиток штучного інтелекту (ШІ) відкриває перед підприємствами нові можливості для досягнення цілей сталого розвитку. У цій статті узагальнено результати досліджень застосування ШІ для оптимізації виробничих процесів, зменшення впливу на довкілля, підвищення продуктивності та посилення соціальної відповідальності. Метою дослідження є висвітлення потенціалу штучного інтелекту для досягнення цілей сталого розвитку підприємств і визначення ефективних стратегій його застосування для підвищення економічної ефективності, соціальної відповідальності та екологічної стійкості. Для досягнення мети використано якісний аналіз статистичних даних, офіційних нормативних документів, книг і статей з акредитованих журналів. Отримані результати показали, що ШІ можна використовувати для аналізу виробничих процесів і прогнозування попиту на сировину, оптимізації ланцюгів поставок і зниження енергоспоживання, виявлення потенційних ризиків сталого розвитку та розробки стратегій запобігання їм, виявлення дефектів у виробництві та контролю якості продукції в режимі реального часу, створення персоналізованих сервісів і продуктів для клієнтів. Дослідження підкреслює важливість етичного та безпечного використання ШІ для забезпечення його позитивного впливу на суспільство й навколишнє середовище. Практична цінність статті полягає в систематизованому огляді досліджень впливу ШІ на сталий розвиток підприємств. Отримані результати можуть бути використані для вдосконалення виробничих процесів, підвищення конкурентоспроможності підприємств і сприяння сталому розвиткові.

Ключові слова: штучний інтелект, сталий розвиток, підприємства, ефективність, соціальна відповідальність, екологічна стійкість

JEL Класифікація: O32, O33, Q55, M15