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METHODOLOGICAL APPROACH TO DEVELOPING THE MECHANICAL ENGINEERING INDUSTRY THROUGH GREEN INVESTMENTS

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A B S T R A C T

This article analyzes methodological approaches to developing the industrial machinery sector through green investments. It explores systemic, functional, sustainable development, and innovative approaches to enhance the environmental efficiency of industrial enterprises. Modern tools such as Life Cycle Assessment (LCA), Sustainable Return on Investment (S-ROI), and Multi-Criteria Decision Analysis (MCDA) are applied in a combined framework. The article also highlights digital transformation processes supported by IoT and Big Data technologies. Empirical and theoretical analysis methods are integrated to develop strategies based on real-world data. An interdisciplinary approach ensures the integration of economic, environmental, and social criteria. Emphasis is placed on forming a competitive and sustainable industrial machinery model through green investment. The proposed methodological model can serve as a practical basis for policy-making and investment projects.

K E Y W O R D S

Green investments, industrial machinery, methodological approach, LCA, S-ROI, MCDA, digital transformation, sustainable development

Introduction

In the world practice of developing the mechanical engineering industry, new innovative opportunities, green investments and advanced methodological approaches are developing from year to year. The development of these areas is taking the mechanical engineering industry to a new stage of development. Currently, the practice of abandoning old systems, technologies and programs in the development of the mechanical engineering industry and using new scientifically based methodological approaches instead is developing at a global pace. Because it is clearly demonstrated in practice that old systems and technologies have high costs and do not produce high results in terms of efficiency. Therefore, in order to reduce costs and achieve high efficiency, the opportunities for introducing new methodological approaches, scientifically substantiating them and widely applying them in practice are increasing. In order to achieve high efficiency in the implementation of

methodological approaches in practice, it is precisely through green technologies that high results are achieved. Because financing green technologies through green investments serves to protect the environment, organize waste-free production, ensure resource efficiency, and increase economic efficiency. Therefore, when implementing methodological approaches, their implementation is taken into account in a closely linked manner with green technologies. Green technologies are safe technologies for the development of the industry and also serve to ensure environmental sustainability in countries.

The development of methodological approaches mainly requires scientific justification. Because if they are scientifically based, their effectiveness is clear and records high results. It is precisely the introduction of scientifically based methodological approaches in the development of the mechanical engineering industry that ensures new opportunities in the industry and the growth of efficiency indicators from year to year.

Literature review on the topic

Omar Farooq and Md. Ataur Rahman Chowdhury have conducted a study that examines the role of Big Data in the development of green investments. They found that digital data and advanced analytics have a significant impact on investment decisions. The study also found that macroeconomic factors such as inflation negatively affect investment flows; however, countries' GDP and foreign direct investment are relatively minor factors in this process. This study provides fundamental knowledge for more effective management of green investments and strengthening the financial decision-making process with technological approaches [1]. According to economists Bernardo Caldarola and Dario Mazzilli, there is a correlation between economic complexity and the ability to produce green technologies. The researchers argue that complex economic systems have a high potential to adopt green investments and develop competitive technologies during the transition to sustainability. Their analysis considers economic indicators, innovative potential and technological development as a single unit, and this model helps to determine the future directions of green investment strategies. This study shows that as the level of economic complexity of countries increases, the demand for green technologies and the amount of investment can also increase significantly [2].

According to the views of well-known scientists F. Knobloch and J.-F. Mercure, they focused on the psychological and behavioral factors of the subjects participating in the investment process. According to their model, if under ideal conditions it is possible to increase investments up to 81%, in real conditions this indicator drops significantly and remains only around 20% due to restrictions on the individual behavior of decision-makers. This model shows that not only economic factors, but also human psychology and social relations play an important role in stimulating green investments. The results of the study prove that it is necessary to take into account not only financial indicators, but also human factors when developing investment strategies [3].

Local scientist Madina Raimzhanova's research emphasizes the important role of investments in the development of a green economy. According to the scientist, although green financing instruments (green loans, subsidies, state guarantees) are not yet fully formed in Uzbekistan, there is a legal, institutional and economic basis for their introduction.

She emphasizes the need to define clear roles and responsibilities between the state and private sectors, as well as create a stable investment environment. Raimzhanova suggests referring to international experience in this process, especially the experience of the European Union and South Korea [4].

Another economist, R. Shodmonov and Sh. Mustafakulov, have thoroughly substantiated the possibility of supporting a green economy through the digitalization of industry. They argue that in Uzbekistan, there is a need for the expanded implementation of Industry 4.0 technologies to introduce green indicators (energy efficiency, waste reduction, CO2 emissions) in industrial enterprises [5].

Sukhrob Allayarov's research focuses on financing mechanisms, in particular green banks, green bonds, and credit lines from international financial institutions. He argues that by introducing these instruments in Uzbekistan, capital flows can be attracted to sectors such as solar and wind energy, waste recycling, and environmental infrastructure.

Allayarov also argues that private investors can be attracted to environmental projects through the development of special financing channels, tax incentives, and loan guarantees [6].

The research conducted by the above economists shows that green investments are not only necessary for the country's economy, but also relevant for the investment process around the world.

Research Methodology

To study the problem in the article, methods such as systematic analysis, scientific observation, analysis and synthesis, induction and deduction were widely used.

Analysis and Discussion of Results

We will consider an analysis of methodological approaches that are widely used in world experience in the development of the mechanical engineering industry. First of all, we will analyze the definition of a methodological approach.

A methodological approach is a set of scientifically based theories, principles, methods and methodological steps used to study, analyze and solve a specific problem. In other words, a methodological approach is a method of answering a number of questions with a scientific basis: "what is done?", "how is it done?" and "why is it done this way?". There are a number of types of methodological approaches used in world experience, the names of which are given in Table 1 below.

Table 1 Types of methodological approaches used in world experience [7]

No.	Type of Methodological Approach	Implementation Process
1	**Systematic Approach**	Objects are considered in interrelation, as a single integrated system.
2	**Functional Approach**	The role and function of each component are clearly identified.
3	**Complex Approach**	Various sciences, methods, and approaches are integrated.
4	**Innovative Approach**	New technologies and ideas form the basis of the approach.
5	**Sustainable Development Approach**	Economic, environmental, and social criteria are harmonized.
6	**Empirical Approach**	Based on real-world data such as energy consumption, emissions, and waste.
7	**Theoretical Approach**	Models like LCA and S-ROI are mathematically represented and analyzed.
8	**Combined Approach**	Integrates empirical and theoretical methods, using sensor data within LCA (Life Cycle Assessment).
9	**Interdisciplinary Approach**	Integrates economics, ecology, technology, and social factors.
10	**Advanced Integrated Methodology**	Combines LCA (Life Cycle Assessment), MCDA (Multi-Criteria Decision Analysis), S-ROI, and IoT/Big Data.

Table 1 shows the types of methodological approaches that are widely used in world practice in the development of the mechanical engineering industry, and also describes the processes by which they are implemented in the development of the mechanical engineering industry.

We will consider the following methodological types of analysis, as shown in Table 1 above. Here:

- One of the developed methodological integrated approaches is the LCA (Life Cycle Assessment) approach, which is mainly used to analyze the emissions and energy requirements of a product or process at the raw material, production, use and disposal stages.

Therefore, this type of methodological approach is widely used in the mechanical engineering industry. The goal is to improve production processes in mechanical engineering enterprises.

- The MCDA (Multidimensional Analysis) approach evaluates options based on several criteria, such as (economic, environmental, technical, risk and social). The effectiveness of this approach in the development of the mechanical engineering industry is very high, and multidimensional analysis is used to determine in advance which criteria will increase profit indicators and which criteria will decrease their growth. This approach will enable us to identify problems in the mechanical engineering industry and find effective solutions to them.

- S-ROI (Sustainable Return on Investment) is the name of this approach. The main goal is to convert the economic, environmental and social results of investments into monetary units. The application of this approach in the machine-building industry shows high results. Because the effective use of this approach ensures the development of green investments in the machine-building industry and the improvement of the state's machine-building industry indicators.

- IoT + Big Data monitoring approach is a modern approach that provides real-time collection of indicators in enterprises, namely gas emissions, electricity consumption and other types of indicators, through sensors. It serves to automatically combine data from enterprises with LCA, MCDA and S-ROI approaches. The importance of this approach in the development of the machine-building industry is very important, it facilitates the processing of all data. It ensures the storage of a very large database. Therefore, it has been serving the development of the industry due to its fast and high-quality monitoring of data in mechanical engineering enterprises.

- If we analyze the systematic approach, since the mechanical engineering industry is a complex system, it is an approach that ensures that all components, namely raw materials, production, logistics, processing and other processes, work in an interconnected state to redirect activities in the industry. Therefore, the effective use of a systematic approach in the development of the mechanical engineering industry ensures the effective functioning of all components in the industry, and as a result, the production process in the industry develops. It serves to create new opportunities in the industry.

- An integrated approach means the joint operation of several types of approaches in the mechanical engineering industry. An approach that combines several scientific methods is considered to assess the effectiveness of green investments in the mechanical engineering industry. This includes LCA (Life Cycle Analysis) – which measures the environmental impact of a product or service over its entire life cycle, MCDA (Multi-Criteria Decision Analysis) – which compares investment options from an economic, environmental, and social perspective, and S-ROI (Sustainability-Based Return on Investment) – which evaluates the benefits and socio-environmental impacts of investments. An integrated approach is achieved by analyzing several approaches.

- innovative and digital approach is understood as an approach that includes new ideas aimed at developing the mechanical engineering industry. The main emphasis is on the development of new technologies and ideas in the industry.
- sustainable development approach combines the following approaches in the mechanical engineering industry. In particular, it is an approach that arises from the combination of a number of approaches, such as economic efficiency (cost optimization, competitiveness), environmental safety (reduction of emissions) and social stability (job creation, health care).

Currently, in world practice, many methodological approaches are developing year by year in the development of the mechanical engineering industry. One of these is the following methodology.

- hybrid methods, the reason why this methodology is called hybrid is that it is a method that combines 3 methods at once. That is, the hybrid method - MCDA + LCA + IoT, is a combination of 3 methods, which is a modern methodology with very high efficiency.

According to recent studies, methodological approaches combined with multi-criteria decision analysis (MCDA) and life cycle assessment (LCA) methods, as well as Big Data and IoT integration, take into account sensor-based monitoring and real-time environmental indicators in the development of the machinery industry. As a result, it allows machinery enterprises to more reasonably assess the effectiveness of investments.

In the world experience, the widespread implementation of many of the above modern methodologies aimed at developing the machinery industry has led to the achievement of a number of high-level performance indicators. In particular, global machinery production is expected to grow in 2025 The global machinery sector is expected to recover in 2025 after a 2.1% decline in 2024. According to the international Interact Analysis, machinery production is expected to end the year with a 3% growth rate by mid-2025.

Despite uncertainties such as trade tariffs, industry slowdown and AI arms race, the industry outlook remains positive and stable growth is expected until 2029 [8].

In China, despite a global decline in the machinery industry in 2024, China's manufacturing industry recorded a growth of 1.2%. China’s manufacturing economy has seen its growth forecast for 2025 revised upwards, with strong growth expected in 2026 and beyond.

In Europe, regions such as Germany and the UK are seeing minimal growth in the machinery industry and are struggling to compete globally. Deindustrialization is a major concern for Germany, as German automakers have significantly impacted European manufacturing with plant closures and mass layoffs.

In the US, the machinery industry is expected to show stability with growth of 2.7 percent in 2024. However, there are still some obstacles that could hinder future economic growth, and despite these, there is optimism for increased production in the US machinery industry [9]. As we can see, the development of the machinery industry is largely driven by China, Europe, and the US, which are major players in the global market.

The global industrial machinery market is growing year by year. According to statistics, the industrial machinery market is estimated to be worth $714.5 billion in 2024. The market is expected to grow to $743.1 billion in 2025. It is expected to grow to $1.61 trillion by 2034.

In terms of operation, the global industrial machinery market is segmented into automated machinery, semi-automated machinery, manual machinery, and robotic machinery. According to global statistics, the automated machinery segment is expected to generate revenue of $311.6 billion in 2024 and is expected to grow at a CAGR of 9.3% during the forecast period. As of 2024, North America dominated

the global industrial machinery market, accounting for about 45.2% of the global market share and generating revenue of about $322.7 billion in 2024. Therefore, many large manufacturers and innovators in the industrial machinery industry are currently established in this country, which is the most important factor contributing to continuous growth and competitive advantage.
Among the companies in the industrial machinery market, the companies listed in Table 2 below are the main companies operating in the industrial machinery industry.

Table 2 The main participants of the industrial machinery market companies [10]

№	Company	Headquarters Location	Market Capitalization (July 2025)
1	**Caterpillar Inc.**	Deerfield, Illinois, USA	$194.6 billion
2	**Deere & Company**	Moline, Illinois, USA	$135.4 billion
3	**Honeywell International**	Charlotte, North Carolina, USA	$152 billion
4	**ASML Holding**	Veldhoven, Netherlands	$288.8 billion
5	**Illinois Tool Works (ITW)**	Glenview, Illinois, USA	$75 billion
6	**Ingersoll Rand**	Davidson, North Carolina, USA	$34.5 billion
7	**Atlas Copco**	Nacka (Stockholm), Sweden	$70.1 billion
8	**AGCO Corporation**	Duluth, Georgia, USA	$7.98 billion
9	**Alfa Laval**	Lund, Sweden	$18.1 billion
10	**CNH Industrial**	Basildon, United Kingdom	$16.2 billion

This table 2 mainly lists the names of the main companies in the global machinery industry. These companies supply industrial machinery for sectors such as agriculture, construction, manufacturing, mining and automation. In particular, AGCO is a manufacturer of agricultural machinery. Its brands such as Fendt, Massey Ferguson and Valtra produce modern equipment.
Similar companies include CNH Industrial and Deere & Company (or John Deere), which manufacture construction and road equipment, including tractors and excavators. In the fluid handling and processing sector, Alfa Laval offers pumps, valves, and tank cleaning equipment, and offers automation systems, brewing equipment, centrifuges, and bioreactors.
In semiconductors, ASML is a leader in lithography and metrology, and has chip manufacturing capabilities. Atlas Copco provides assembly tools, fastening solutions, and material removal equipment for industrial needs.
Illinois Tool Works (ITW) serves a range of industries with welding, food processing equipment, and specialty products. Caterpillar, Hitachi Construction Machinery, and ESCO manufacture heavy construction and mining equipment, such as dozers, loaders, hydraulic excavators, and rugged mining components. Steelmaker Gerdau makes parts for agricultural and construction equipment.
Honeywell International is a company that specializes in sensors and automation systems, and Protection Equipment Brandt Industries offers professional industrial equipment. These companies produce products for all aspects of industrial operations, from construction and agriculture to manufacturing and technology.

Conclusion and Suggestions

In conclusion, it is worth noting that the widespread implementation of modern methodological approaches in the development of the machine-building industry through green investments will serve to create new opportunities.

There are many modern methodological approaches in world experience, and countries that effectively use them have recorded high performance indicators in the machine-building industry. Therefore, the effective use of LCA (Life Cycle Assessment), MCDA (Multidimensional Analysis), S-ROI (Sustainable Return on Investment), IoT + Big Data monitoring, integrated, innovative and digital, and sustainable development approaches, which are widely used in world practice, to develop the machine-building industry in our country through green investments and methodological approaches, will ensure the emergence of new innovative results in the machine-building industry.

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