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MODERN PRACTICES FOR IMPROVING THE EFFICIENCY AND FLEXIBILITY OF BUSINESS PROCESSES IN MANUFACTURING ENTERPRISES

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СУЧАСНІ ПРАКТИКИ ПОКРАЩЕННЯ ЕФЕКТИВНОСТІ ТА ГНУЧКОСТІ БІЗНЕС-ПРОЦЕСІВ ВИРОБНИЧИХ ПІДПРИЄМСТВ

Сучасні виробничі підприємства повинні бути максимально ефективними та гнучкими. Це забезпечує можливості для їх життєздатності, адаптації до постійно змінюваного зовнішнього середовища, а також для подолання численних загроз (таких як коливання ринку, технологічні збої, зміни в законодавстві чи економічні кризи). Враховуючи ці потреби, необхідність у впровадженні новітніх практик покращення ефективності та гнучкості бізнес-процесів на виробничих підприємствах є безсумнівною. Метою цієї статті є аналіз сучасних практик покращення ефективності та гнучкості бізнес-процесів виробничих підприємств з урахуванням особливостей їх розвитку в умовах цифрової трансформації. У контексті активної цифрової трансформації виробничих підприємств виокремлено кілька ключових практик, які сприяють підвищенню ефективності та гнучкості бізнес-процесів. Зокрема, практика впровадження технологій Індустрії 4.0 є комплексною трансформацією, що охоплює інтеграцію IoT, AI, великих даних і автоматизації для зміни всього виробничого процесу, що підвищує його гнучкість та адаптивність. Практика впровадження гнучких методологій управління вимагає специфічних органі-

заційних змін і не обмежується лише інструментами чи методами. Практика впровадження ERP— та MES-систем спрямована на інтеграцію різних аспектів управління підприємством — від фінансів до виробничих процесів, що дозволяє забезпечити цілісне управління на всіх рівнях організації. Практика активної автоматизації та роботизації виробничих процесів є сукупністю технологічних і організаційних змін, які покращують продуктивність і точність виконання операцій. Практика переходу на інтелектуальне управління ланцюгами постачання забезпечує інтеграцію всіх елементів ланцюга, що дозволяє знижувати витрати, зменшувати ризики та покращувати прозорість процесів управління ресурсами. Практика розумного технічного обслуговування орієнтована на оптимальне управління життєвим циклом обладнання та використання передових технологій для прогнозування поломок і забезпечення ефективного обслуговування.

Modern manufacturing enterprises must be as efficient and flexible as possible, as this ensures the ability to survive and adapt to the constantly changing external environment and overcome numerous threats, such as market fluctuations, technological disruptions, changes in legislation, or economic crises. Given these needs, the necessity of implementing the latest practices to improve the efficiency and flexibility of business processes in manufacturing enterprises is indisputable. Therefore, the outlined article aims to analyze modern practices for improving the efficiency and flexibility of business processes in manufacturing enterprises, taking into account the peculiarities of their development in the context of the digital transformation of manufacturing enterprises. In the context of the active digital transformation of manufacturing enterprises, several key practices have been outlined that contribute to improving the efficiency and flexibility of business processes. One such practice is the implementation of Industry 4.0 technologies, which is a comprehensive transformation involving the integration of IoT, AI, big data, and automation technologies to change the entire manufacturing process, enhancing its flexibility and adaptability. The practice of implementing agile management methodologies requires specific organizational changes and is not limited to just tools or methods. The practice of implementing ERP and MES systems aims to integrate various aspects of enterprise management, from finance to manufacturing processes, enabling comprehensive management at all levels of the organization. The practice of active automation and robotics in manufacturing processes represents a combination of technological and organizational changes that allow for cost reduction, improved product quality, and minimized human intervention, enhancing productivity and operational accuracy. Transitioning to intelligent supply chain management ensures the integration of all supply chain elements, allowing for cost reduction, risk mitigation, and improved transparency in resource management processes. The practice of smart maintenance is focused on the optimal management of equipment life cycles and the use of advanced technologies to predict failures and ensure efficient servicing.

Key words: resource management; ensuring effective service; smart maintenance; development; costs; lifecycle management.

Ключові слова: управління ресурсами; забезпечення ефективного обслуговування; розумне технічне обслуговування; розвиток; витрати; управління життєвим циклом.

PROBLEM STATEMENT

Modern manufacturing enterprises operate in a dynamic and highly competitive environment, requiring continuous improvement of business processes. It is worth noting that triggers such as globalization, digitalization, and rising consumer expectations are driving manufacturers to seek and implement new approaches to enhance the efficiency of production processes, reduce production costs, and increase productivity. In this context, modern methods of business process management use of Industry 4.0 technologies, the implementation of flexible methodologies (Agile, Lean, Six Sigma), process automation, and the integration of intelligent data analysis systems are becoming increasingly relevant. Regarding the overall relevance of the research, the authors emphasize that it is important not only to evaluate production operations but also to optimize them and ensure their quick adaptability in response to changes in the external environment.

ANALYSIS OF RESEARCH AND PUBLICATIONS

Modern manufacturing enterprises must be as efficient and flexible as possible as this ensures the ability to survive and adapt to the constantly changing external environment and overcome numerous threats, such as market fluctuations, technological failures, changes in legislation, or economic crises.

In this context, significant scientific interest is generated by the works of domestic scholars such as Demkiv I.O. [4], Bondarenko S. [1], Staninov S.B. [5], and Gavrylchenko O.V. [2]. They focus on studying general approaches to identifying the efficiency and flexibility of business processes in enterprises, particularly in the light industry, where special attention is given to aspects such as improving production quality, cost management, and innovative technologies. At the same time, most of these studies primarily focus on the general identification and assessment of the efficiency and flexibility of processes without delving deeply into the issues of their optimization. The lack of attention to practices that can contribute to the optimization of these processes leaves significant gaps in the scientific literature.

FORMULATION OF THE ARTICLE'S OBJECTIVES

Thus, the outlined article aims to analyze modern practices for improving the efficiency and flexibility of business processes in manufacturing enterprises, taking into account the specifics of their development in the context of the digital transformation of manufacturing companies.

<table>
<tr><td colspan="2">Practice 1: Implementation of Industry 4.0 technologies
(involves the integration of advanced digital technologies to enhance efficiency, automation, and flexibility in production) [1]</td><td>Practice 2: Implementation of flexible management methodologies
(involves the integration of flexible approaches to business process management, enabling quick adaptation to changes in conditions of uncertainty and high competition)[2]</td></tr>
<tr><td>Practice 3: Implementation of ERP and MES systems
(involves the integration of software for enterprise management and production process management) [3]</td><td>Practices for implementing cutting-edge technologies and methodologies to optimize operations, quickly adapt to changing market conditions, reduce costs, and improve product quality.</td><td>Practice 4: Transition to intelligent supply chain management
(involves the use of advanced technologies to optimize, monitor, and automate all stages of the supply chain) [4]</td></tr>
<tr><td>Practice 5: Active automation and robotics of production processes
(involves the implementation of technologies and systems that replace or support human labor, ensuring increased efficiency, accuracy, and safety in production processes) [5]</td><td colspan="2">Practice 6: Transition to smart maintenance
(involves integration of innovative technologies to improve the servicing and repair process of equipment)[6]</td></tr>
</table>

Figure 1. Modern practices for improving the efficiency and flexibility of business processes in manufacturing enterprises

Note:

1. Involves the implementation of the Internet of Things, digital twins, and automated cyber-physical systems.
2. Involves the implementation of Agile, Lean, and Six Sigma methodologies.
3. Involves the implementation of ERP systems (SAP, Oracle, Microsoft Dynamics) to integrate production, financial, and management processes, MES systems (manufacturing execution systems) for real-time production management, and RPA (Robotic Process Automation) use for automating routine administrative tasks.
4. Involves Blockchain use for supply chain transparency and eliminating the risk of product counterfeiting, AI optimization for procurement and supply to form predictive analytics and accurate material demand forecasting.
5. Involves the use of robotics and automated lines to reduce costs and improve quality, as well as intelligent systems for order processing and inventory management.
6. Involves the use of real-time monitoring systems, big data analytics, the Internet of Things, and Artificial Intelligence to predict failures and optimize resources, reducing maintenance costs and extending equipment lifespan.

Source: compiled based on [1—2; 5—6].

THE PAPER MAIN BODY

In the context of active digital transformation, manufacturing enterprises have developed the following practices to enhance the efficiency and flexibility of business processes [1—2; 6]:

1. Implementation of Industry 4.0 technologies. It is a standalone tool or method, but a comprehensive transformation strategy that integrates various technologies (IoT, AI, big data, automation) used to entire production process change.

2. Implementation of flexible management methodologies. It's a set of specific methods or tools and approaches to management that require organizational changes.

3. Implementation of ERP and MES systems. These standalone tools and multi functional solutions integrate various aspects of enterprise management, from finance to production processes.

4. Active automation and robotics of production processes. These are a combination of technological solutions and organizational changes that transform production processes.

5. Transition to intelligent supply chain management. This is a strategic approach to integrating all elements of the supply chain, enabling effective management of resources and risks, reducing costs, and improving transparency.

6. Transition to smart maintenance. This is a strategy focused on managing the equipment life cycle and ensuring its optimal maintenance.

We emphasize that we have outlined practices, not processes, tools, or methods, as they encompass a combination of strategies, actions, approaches, and technologies aimed at achieving results.

We emphasize that we have outlined practices, not processes, tools, or methods, as they encompass a combination of strategies, actions, approaches, and technologies aimed at achieving results.

It should be noted that processes are often regular, repetitive actions performed to achieve specific results (e.g., maintenance or procurement [6]), tools are individual means or programs used within a particular strategy or practice (therefore, they are part of a process, not the entire approach

Table 1. Practices of implementing flexible management methodologies in manufacturing enterprises

Modern practices	Direction of implementation	Key principles	Results of application
Lean Production	Elimination of all types of waste in production processes, such as excessive inventory, waiting time, product defects, unnecessary movements, and other forms of inefficiency.	Continuous improvement, standardization of work, process rationalization, and optimization of resource usage.	Reduction in costs, shorter production times, and improved quality by eliminating inefficient stages.
Six Sigma	Ensuring high product quality by reducing variations in processes and minimizing defects.	Process improvement and quality standards through the DMAIC structure (Define, Measure, Analyze, Improve, Control).	Improved product quality, reduced defects, increased customer satisfaction, and lower costs for rework or product returns.
Agile Manufacturing	The ability to quickly adapt production processes to market changes, shifting consumer demands, and new technologies.	Enhancing flexibility and rapid response to changes. Manufacturing systems should be flexible, scalable, and adaptable to rapid changes in demand or market conditions.	The ability to quickly adjust production capacity, adapt to new market trends, and reduce time to launch new products or models.

Source: compiled based on [1—2; 6].

[5—6]), and methods are specific ways to achieve a particular goal. At the same time, each of the listed practices involves implementing changes at the level of the manufacturing enterprise through the use of several processes and different sets of tools and methods (open to change formats [2]). We emphasize that the term "practice" in research refers to a combination of approaches, strategies, and technologies that help businesses adapt to changing conditions and achieve better results in management and production.

These practices require integration to achieve synergy and significant changes in business processes. It should be emphasized that the essence of the synergy from integrating the outlined practices lies in increasing the rational use of resources and maximizing productivity, with the ability of a specific production system to quickly adapt to changes in both the external and internal environments while maintaining efficiency and product quality (as evident from the data in Figure 1).

Let's take a closer look at the outlined practices for improving the efficiency and flexibility of business processes in manufacturing enterprises (as shown in Figure 1).

The practices of implementing Industry 4.0 technologies include the adoption of the Internet of Things, digital twins, and automated cyber-physical systems.

The practice of implementing IoT involves setting up effective real-time equipment monitoring through various sensors and connected devices, as well as real-time analytics. This allows for improved maintenance planning, reduced production downtime, and increased efficiency of production equipment.

The practice of using digital twins involves comprehensive modeling of production processes through the application of virtual replicas of the production system, production lines, and even environmental conditions. For example, a digital twin of a production line can include a model of all its components, from equipment to robotic systems, by gathering information about each stage of the production process. This practice helps reduce costs and increase flexibility in managing individual production processes, as well as simulating different production conditions without the need for physical intervention by personnel.

The practice of automating data collection and analysis for timely decision-making involves the creation of automated systems for continuous monitoring of all stages of the production process. For example, at a manufacturing plant, such as an automobile production facility, sensors are installed at all key stages of the production process-from assembling components to testing the final product. As a result, data on each production process is collected in real time, processed using analytical tools, and transmitted to a central system for decision-making.

By implementing the practices outlined above, manufacturing enterprises are able to increase productivity, reduce costs, adapt more quickly to market changes, and improve product quality. An additional benefit is a reduction in the risks of unauthorized stoppages or breakdowns, as every aspect of production is monitored and optimized in real-time.

The practices of implementing flexible management methodologies in manufacturing enterprises involve the adoption of Agile, Lean, or Six Sigma. Lean Production is effective in eliminating waste in production processes, as is evident from the data in Table 1.

Examples of such practices include systems like 5S (Sorting, Systematizing, Standardizing, Sustaining Order) and Kanban for inventory management. These systems help

reduce setup time, improve material flow efficiency, and minimize waste in processes. Six Sigma is effective in establishing quality control and minimizing production defects. Examples of such practices include forecasting and analyzing the root causes of defects, applying statistical methods to measure and control quality. Agile Manufacturing is effective in adapting production to rapid market changes [1—2]. Examples of such practices include the creation of flexible production lines that can quickly reconfigure to meet new requirements without significant costs. All of these practices can be used together or separately, depending on the specifics of the enterprise and the demands of the production process [6].

The practices of implementing ERP and MES systems in manufacturing enterprises involve the deployment of comprehensive software solutions that integrate all key business processes of the enterprise (including production, financial, and management processes [3]), real-time production management systems, and automation of routine administrative tasks, according to the specifications outlined in Table 2. For example, an MES system can integrate with an ERP system to receive data on material inventories, production plans, and resources, and automatically update production status in real time. For instance, when a certain production line reaches a set level of product readiness, the MES can pass data to the ERP system to update inventory and supply status [3-4]. The implementation of RPA can automate processes such as generating invoices or confirming orders within the ERP system. For example, when an order is received, the system automatically generates an invoice and sends it to the accounting department, reducing manual work and errors.

Table 2. Practices for implementing ERP and MES systems in manufacturing enterprises

Modern practices	Direction of implementation	Key principles	Results of application
ERP systems (SAP, Oracle, Microsoft Dynamics, and others)	Comprehensive software solutions that integrate all key business processes of an enterprise, including production, finance, logistics, procurement, human resources, and accounting.	Reduction of costs, improvement of management reporting, and ensuring access to critical data in real-time.	Integration of data from different departments into a single platform. Improved order processing, inventory management, and financial control. Enhanced decision-making through access to up-to-date real-time data. Reduction of operational costs through process automation.
MES systems	Provide management and control of production processes in real-time and serve as a link between ERP systems and the monitoring of actual production processes on production lines.	Effective resource utilization, minimizing downtime, and ensuring product quality.	Improved production efficiency and reduced downtime. Enhanced product quality through monitoring at all stages. Streamlined information exchange between production departments and other parts of the business.
RPA (Robotic process automation)	A business process automation technology that uses software robots.	Execution of routine, repetitive tasks.*	Helps by freeing up employees for more creative and analytical work. Aids in automating processes between different software systems that lack standard interaction mechanisms.

Note:
*This refers to tasks such as document processing, data entry, information verification, record keeping, etc.
Source: compiled based on [1; 3—4].

Table 3. Practices of active automation and robotics in manufacturing processes

Modern practices	Direction of implementation	Key principles	Results of application
Robotics and automated lines	Help automate physical tasks and reduce equipment setup time.	Reduces employee workload and ensures high precision and speed in task execution.	Reduces labor costs and risks associated with the human factor. Improves production productivity and speed. Enhances quality through the precision of robotic operations.
Intelligent order processing and snventory management systems	Assist in order processing.	Predicts demand, automatically generates orders based on real-time data, and quickly responds to changes in market conditions or customer requests.	Reduces storage and transportation costs. Increases order accuracy and processing speed. Optimizes procurement and inventory management processes, helping to avoid shortages or excess goods.
Integration of robotics and intelligent systems	Adjust the operation of robotic lines.	Enhances the adaptability and efficiency of the manufacturing enterprise.	Ensures integration with robotic lines for automatic adjustment of production capacities or modification of production plans based on real-time data.

Source: compiled based on [2; 5—6].

Table 4. Practices for manufacturing enterprises transitioning to smart maintenance

Modern practices	Direction of implementation	Key principles	Results of application
Real-time monitoring systems	They allow for collecting data on the equipment's condition, operational parameters, wear, temperature, vibrations, pressure, fluid levels, and other critical indicators.	These systems can be integrated with IoT (Internet of Things), allowing for continuous monitoring of equipment status at any time.	Rapid response to changes in equipment condition. Early diagnosis of potential issues, allowing for the prevention of major breakdowns and costly repairs.
Big Data analytics for failure prediction	It allows processing and analyzing vast amounts of information coming from sensors and monitoring systems to identify patterns and trends that may indicate the likelihood of breakdowns or failures.	These systems help predict when and which equipment may fail, enabling the planning of preventive maintenance.	Timely forecasting of potential issues before they occur, reducing downtime risks and minimizing the need for emergency repairs. Optimization of maintenance through intelligent algorithms.
Internet of Things for collecting equipment condition data	It allows equipping equipment with sensors that collect various data, which is transmitted in real time to central management systems.	These systems provide the ability to monitor remote equipment, reducing inspection costs and allowing real-time analysis.	Timely access to real-time data on the condition of all equipment within the enterprise. The ability to set up remote monitoring, which is particularly useful for complex or hazardous systems that are difficult to inspect physically.
Artificial Intelligence for optimizing maintenance operations	It meets the need for processing data coming from monitoring systems and sensors.	These systems are ideal for creating algorithms that improve over time, enabling the prediction of failures with high accuracy.	Quick and accurate fault diagnosis, allowing for the planning of maintenance and repairs before a breakdown occurs. Optimizing the work of maintenance personnel, reducing unnecessary time spent on scheduled maintenance without issues.

Source: compiled based on [4; 6].

These practices enable manufacturing enterprises to enhance efficiency, provide greater flexibility in production processes, and optimize internal operations to achieve better results.

The practices of active automation and robotics in production processes involve the use of robotics and automated lines to reduce costs and improve quality, as well as intelligent order processing and inventory management systems, according to the specifics outlined in Table 3.

For example, at most modern automotive factories such as Volkswagen, Toyota, and BMW, robotic manipulators are used for assembling car components, such as installing doors or assembling engines. These robots reduce time costs, increase accuracy, and minimize human intervention, which helps reduce the level of errors and defects in products. At most food industry companies (including Nestl?, PepsiCo, Mondelez, etc. [6]), robotic packaging lines automatically package finished products into boxes or other containers, ensuring consistent quality and significantly increasing packaging speed. At the same time, order management systems can be linked to robotic lines for automatic adjustment of production capacities or modification of production plans based on real-time data. This integration ensures more efficient resource allocation, better alignment with actual demand, and a higher level of flexibility in adapting to changes in production needs.

So, the practices of active automation and robotics in manufacturing processes significantly enhance the efficiency of enterprises by reducing labor costs, minimizing the risk of production errors, increasing production speed, and ensuring consistent product quality.

The practices of transitioning to intelligent supply chain management include the use of Blockchain for supply transparency and eliminating the risks of product counterfeiting, AI optimization of procurement and supply to generate predictive analytics, and accurate forecasting of material needs. In particular, Blockchain provides a decentralized and transparent platform for tracking every stage of the supply chain, from the supplier to the end consumer. For example, blockchain can guarantee the authenticity and quality of food products. If a manufacturer processes organic vegetables, every stage-from sourcing organic raw materials, transportation, and storage to sale in a supermarket-can be recorded on the blockchain. It creates a secure and immutable chain of records for each step of the supply process. The use of AI ensures high-quality demand forecasting, procurement optimization,

and inventory management. For example, a manufacturing company can use AI to analyze historical sales data, seasonal demand fluctuations, and external factors (such as market changes or weather conditions [6]). Thus, by transitioning to intelligent supply chain management, manufacturing enterprises can significantly improve their ability to adapt to market changes, reduce costs, enhance security and transparency, and improve forecasting and inventory management.

The practices of transitioning to smart maintenance involve the use of real-time monitoring systems, big data analytics, the Internet of Things (IoT), and artificial intelligence (AI) to predict failures and optimize resources. This approach helps reduce maintenance costs and extend equipment lifespan, as outlined in Table 4. In fact, all these outlined actions aim to leverage combined data from IoT, AI, and big data analytics to predict when and which equipment will require maintenance. It significantly reduces costs associated with emergency repairs [6].

These practices allow manufacturing enterprises not only to significantly reduce maintenance costs but also to substantially enhance the efficiency and safety of production processes.

CONCLUSIONS

In the context of active digital transformation of manufacturing enterprises, several key practices have been outlined that contribute to improving the efficiency and flexibility of business processes:

1. The implementation of Industry 4.0 technologies is a comprehensive transformation strategy that involves the integration of IoT, AI, big data, and automation technologies to revolutionize the entire manufacturing process, enhancing its flexibility and adaptability.

2. The implementation of flexible management methodologies is an approach that requires organizational changes and is not limited to just tools or methods. This approach helps enterprises quickly adapt to changes in the external environment and improves management efficiency.

3. The implementation of ERP and MES systems aims to integrate various aspects of enterprise management, from finance to production processes, ensuring comprehensive management at all levels of the organization.

4. Active automation and robotics in production processes represent a combination of technological and organizational changes that reduce costs, improve product quality, and minimize human intervention, which in turn enhances productivity and operational accuracy.

5. The transition to intelligent supply chain management ensures the integration of all elements of the supply chain, enabling cost reduction, risk minimization, and improved transparency in resource management processes.

6. The transition to smart maintenance is focused on optimal equipment lifecycle management and the use of advanced technologies to predict failures and ensure efficient servicing.

The prospects for further research lie in exploring the most effective ways to integrate practices for improving the efficiency and flexibility of business processes in manufacturing enterprises, taking into account the potential for synergy and the requirements for changes in business processes.

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