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SPECIAL FEATURES OF INDUSTRIAL MANAGEMENT IN THE CONTEXT OF APPLYING THE "SMART FACTORY" SYSTEM

ОСОБЛИВОСТІ ПРОМИСЛОВОГО МЕНЕДЖМЕНТУ В УМОВАХ ЗАСТОСУВАННЯ СИСТЕМИ «РОЗУМНА ФАБРИКА»

The relevance of this research is driven by the fact that establishing fundamental principles of industrial management in the context of implementing the "smart factory" system is a highly pertinent task in today's conditions. Therefore, the primary focus of the research lies in exploring the characteristics of industrial management within the framework of utilizing the "smart factory" system. Within the scope of this research, it has been determined that the "smart factory" system represents a significant innovative approach to manufacturing, utilizing cutting-edge technologies to enhance efficiency and quality. However, it has been noted that this approach also gives rise to specific challenges in management. Among the most significant findings of the study, it is worth noting the identification of such characteristics (key aspects) of industrial management in the context of the "smart factory" application, as: specificity of technological integration management, specificity of managing large volumes of data, specificity of cyber security management, specificity of managing corporate culture change, specificity of continuous change management, and a focus on configuring production processes.

Keywords: production, data analysis, technology lifecycle management, Big Data management, production lines.

Актуальність дослідження зумовлена тим, що аналіз базових засад промислового менеджменту в контексті застосування системи «розумна фабрика» є дуже актуальним завданням в сучасних умовах. У межах дослідження звертається увага на той факт, що система «розумна фабрика» є якісно новим підходом до виробництва, який ґрунтується на інтеграції передових технологій, підвищенні ефективності, якості та гнучкості виробництва. Згідно з даними Національного інституту стандартів і технологій США (NIST), основна ідея такої системи полягає в створенні виробничого середовища, де фізичне обладнання, сенсори та програмне забезпечення можуть взаємодіяти в реальному часі, обмінюватися даними та виконувати завдання автоматично або майже автоматично. З такими характеристиками формується не лише підвищена складність, але й специфічність промислового менеджменту, що обумовлена рядом синтезованих системою «розумна фабрика» факторів, включаючи технологічну різноманітність, опрацювання великих обсягів даних, посилення питань кібербезпеки, зміни в організаційній та управлінській культурі, потребу в постійному управлінні змінами та інші. Отже, основна увага у дослідженні спрямована на вивчення особливостей промислового менеджменту в контексті застосування системи «розумна фабрика». У ході цього дослідження було встановлено, що система «розумна фабрика» є важливим і новаторським підходом до виробництва, що використовує передові технології для підвищення ефективності та якості. Серед найбільш значущих висновків дослідження варто відзначити виділення таких особливостей (ключових аспектів) промислового менеджменту в контексті застосування системи «розумна фабрика», як: специфічність управління технологічною інтеграцією, специфічність управління великим обсягом даних, специфічність управління кібербезпекою, специфічність управління зміною корпоративної культури, специфічність постійного управління змінами та орієнтація на налаштування виробничих процесів. З точки зору подальших досліджень можна розглядати такі перспективи: аналіз впливу технологічної інтеграції на різні аспекти виробництва та управління, дослідження методів та підходів до постійного управління змінами у виробництві.

Ключові слова: виробництво, аналіз даних, управління життєвим циклом технології, управління великими даними, виробничі лінії.

Problem statement. The study of the fundamental principles of industrial management in the context of implementing the 'smart factory' system is a highly relevant task in modern conditions. This system was created by a group of businessmen, politicians, and scientists in Germany in 2011. Currently, the 'smart factory' system (known as

'Industry 4.0') is part of the manufacturing concept where many processes and equipment are interconnected through the Internet of Things (IoT), artificial intelligence (AI), data analytics, and automation. Currently, industrial enterprises such as Roshen Corporation, the pharmaceutical company Farmak in Ukraine, and LLC "LASUNKA"

have fully or partially implemented this system. The accumulated experience so far allows us to state that the utilization of 'smart factory' systems is a highly complex task, as they encompass a significant number of technological components, processes, and interactions. Consequently, the specific features of industrial management in the context of applying the 'smart factory' system entail a range of new challenges and management opportunities.

Analysis of recent research and publications. Various issues of industrial management are being investigated by numerous domestic and international scholars (including Zakharov V.A., Neurov I.V., Voronkova V.G., Metelenko N.G.). Typically, these authors explore classical industrial management systems without considering contemporary changes, which also include the implementation of technologies and 'smart factory' systems. In fact, there is currently a lack of publications that analyze industrial management in the context of applying the 'smart factory' system.

The purpose of the article is to study the peculiarities of industrial management in the context of implementing the "smart factory" system.

Presentation of the main material. Within the scope of the research, we emphasize that the "smart factory" system represents a qualitatively new approach to manufacturing, founded on the integration of advanced technologies to enhance efficiency, quality, and production flexibility. According to the National Institute of Standards

and Technology (NIST) in the USA, the core idea of such a system is to create a manufacturing environment where physical equipment, sensors, and software can interact, exchange data, and perform tasks automatically or semi-automatically in real-time [2]. The key characteristics of the "smart factory" system are illustrated in Figure 1.

These characteristics not only contribute to increased complexity but also create a distinctive nature of industrial management, driven by a range of factors synthesized by the "smart factory" system. Among these factors are technological diversity, handling large volumes of data, heightened cybersecurity concerns, organizational and managerial culture variability within the enterprise, and the need for ongoing change management, among others. Considering the above, let's examine the characteristics of industrial management in the context of implementing the "smart factory" system through the lens of their inherent key aspects, which, due to their systemic combination, essentially constitute the fundamental reasons for the complexity of industrial management.

A key aspect refers to a fundamental part or feature that holds significant value or influence over a particular situation, issue, process, or domain. In the context of our discussion, key aspects point to the primary, most essential, and sometimes integral features that define or impact a specific topic or situation. In the context of implementing the "smart factory" system, it is distinguished

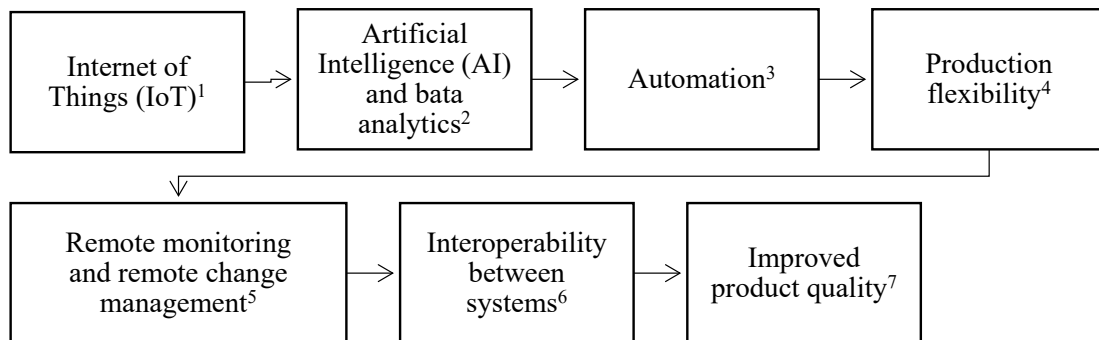


Figure 1. Key characteristics of the "smart factory" system

Note:

1. Industrial devices and equipment are connected to the Internet, enabling data collection and exchange for monitoring and control purposes.
2. Utilization of artificial intelligence algorithms and data analysis to forecast equipment performance and create process optimization models.
3. Implementation of process automation tools to carry out tasks with minimal human intervention.
4. Adoption of flexible manufacturing tools, allowing rapid shifts to new products or variations and adjustments of production parameters according to changing market demands.
5. Employing remote monitoring and control tools for real-time management of production processes, enabling swift communication of directives to remote operators.
6. Utilization of a virtual environment where various systems and components can interact, facilitating information exchange and coordinated actions.
7. Utilizing a virtual environment that allows real-time quality tracking, aiding in early detection and correction of defects during production stages.

Source: formed based on [1; 2; 4]

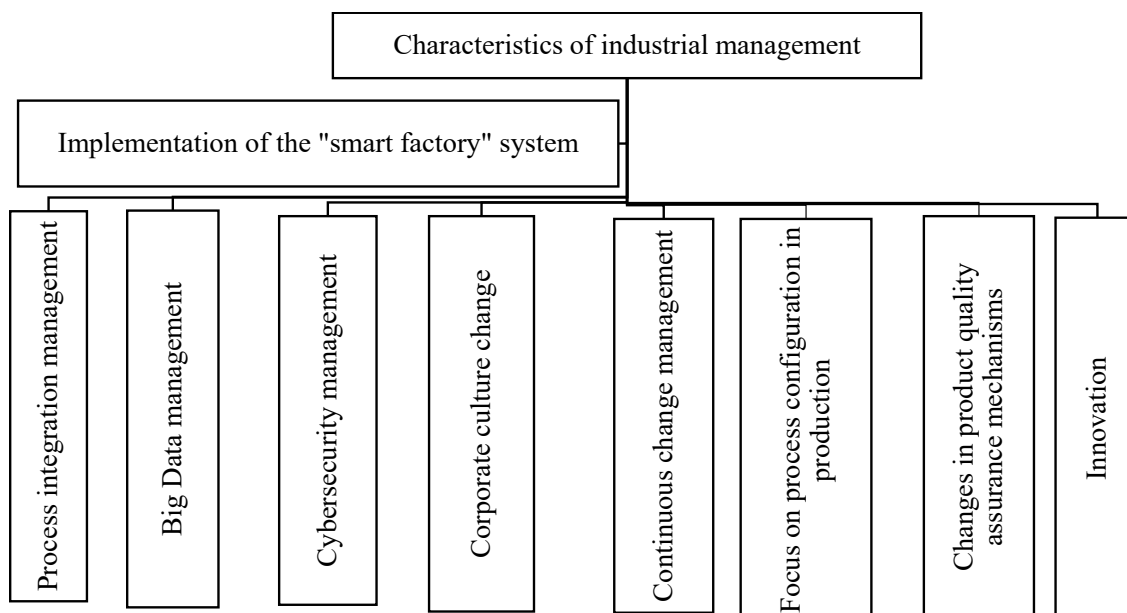


Figure 2. Characteristics of Industrial Management in the Context of Implementing the "Smart Factory" System

Source: formed based on [2; 6]

by aspects such as: process integration management (with regard to the process of combining various technologies, systems, or components into a single shared infrastructure or ecosystem), Big Data management (with regard to the process of combining various technologies, systems, or components into a single shared infrastructure or ecosystem), cybersecurity management (with regard to the set of actions and strategies aimed at safeguarding information systems, computer networks, data, and other digital resources from the risks of cyberattacks, unauthorized access, data breaches, and other threats), corporate culture change (with regard to the implementation of changes in values, norms, practices, and behavior within the internal sociocultural system of an organization), continuous change management (with regard to the implementation of a systematic and continuous process of change aimed at adapting to new conditions, fostering development, and sustaining competitiveness), focus on process configuration in production, orientation towards configuring production processes, focus on changing product quality assurance mechanisms, innovation.

Therefore, it should be noted that the situation of implementing a smart factory requires industrial management to incorporate into its management system the integration of diverse technologies. It presents a challenge in the form of the need to develop specialized solutions for the interaction of these technologies and their optimal utilization. In this regard, the key aspects

of technological integration management are as follows (Table 1):

- Defining standards and protocols for interaction among various technologies.
- Developing systems for data collection.
- Processing, and exchange among different components,
- Ensuring cross-functionality.
- Technology lifecycle management.
- Risk management.
- Reviewing and rethinking production processes.
- Technological support management.
- Personnel training management.

Managing technological integration requires achieving a balance between technical aspects and organizational aspects.

The implementation of the "smart factory" system requires managing volumes of big data. This is because as the volume of data collected from connected devices and sensors increases, management necessitates the development of strategies for data storage, processing, and analysis to make informed decisions.

In this regard, the key aspects of data management are as follows (Table 2):

- Data collection and storage.
- Data processing.
- Data analysis.
- Data quality assurance.
- Data security.
- Orientation towards analytics and visualization platforms.
- Generating reports and queries.

Table 1

Characteristics of basic aspects of technological integration management within the "smart factory" system

Direction of industrial management	Features of industrial management	Signs of industrial management effectiveness
Definition of standards and protocols for interaction between different technologies	Before implementing the "smart factory" system, it is essential to establish standards and protocols for interaction between different technologies.	It will help ensure compatibility between different components and facilitate their effective interaction.
Development of a system for data collection, processing, and exchange among different components	When using the "smart factory" system, technologies are employed that generate a large amount of data. It's crucial to develop a system for data collection, processing, and exchange among different components.	It will assist in data analysis and making decisions based on these data.
Cross-functionality	When using the "smart factory" system, a condition is established where technological components need to be capable of interacting with various functions of the production process.	It helps utilize data collected from sensors, which can be used for automatic equipment tuning or predicting maintenance needs.
Technology lifecycle management	When using the "smart factory" system, the employed technologies have different lifecycles, including introduction, development, and decommissioning.	Development of strategies for the effective implementation of new technologies, as well as for the support and modernization of existing ones.
Risk management	The integration of different technologies into the "smart factory" system can lead to risks such as interaction complexities, system vulnerabilities, and non-compliance with standards.	It helps identify potential risks and develop plans for their management.
Reviewing and rethinking production processes	The implementation of a smart factory may necessitate the review and rethinking of production processes.	It assists in analyzing and implementing changes to achieve greater efficiency and optimal technology utilization.
Technological support management	The implementation of the "smart factory" system may require a support and technical assistance system.	It helps ensure the proper functioning of technologies and the resolution of potential issues.
Personnel training management	The launch of the "smart factory" system is carried out in conjunction with the implementation of new technologies.	It aids in developing training programs for staff to effectively use new tools and technologies.

Source: formed based on [1–2; 6]

Table 2

Description of fundamental approaches to managing large volumes of big data within the "smart factory" system

Direction of industrial management	Features of industrial management	Signs of industrial management effectiveness
Data collection and storage	The implementation of the "smart factory" system requires determining what data needs to be collected and how to store it.	It assists in selecting the infrastructure for storage (such as cloud solutions or local servers) which should correspond to the volume and type of data.
Data processing	The implementation of the "smart factory" system leads to the accumulation of large volumes of data, thus necessitating effective data processing methods.	It helps choose technologies for utilizing Big Data, aggregating, filtering, and analyzing data to build a digital twin of the enterprise.
Data analysis	The implementation of the "smart factory" system involves the adoption of tools for data analysis and extracting valuable information.	It creates the potential to identify new opportunities for process optimization, synchronize data between the automated planning system and equipment-derived data, and enable real-time adjustments to plans.

(End of Table 2)

Direction of industrial management	Features of industrial management	Signs of industrial management effectiveness
Data quality assurance	The implementation of the "smart factory" system leading to the accumulation of a large volume of data can result in errors and shortcomings.	It assists in developing strategies for data quality checking and cleansing.
Data security	The implementation of the "smart factory" system, leading to the generation of a substantial amount of data, requires ensuring their confidentiality and security.	It helps in devising cybersecurity measures to prevent unauthorized access to data.
Orientation towards analytics and visualization platforms	The implementation of the "smart factory" system involves the utilization of tools to create convenient platforms for data analysis and visualization.	It aids in understanding patterns and trends more swiftly and efficiently.
Generating reports and queries	The implementation of the "smart factory" system results in generating queries and reports for conducting data analysis based on specific parameters and indicators.	It enables staff to select and analyze data that are most critical for addressing specific tasks and making decisions.

Source: formed based on [2; 4–5]

The implementation of a "smart factory" system requires cybersecurity management. This is because as connectivity to networks increases, the risk of cyberattacks and unauthorized access also grows. For instance, at the enterprise LLC "LASUNKA," a "smart factory" has been implemented. In this context, the industrial equipment at the enterprise is connected to the Internet of Things (IoT) network to enable real-time monitoring and control of production. The equipment gathers a large amount of data about the production processes and their status, which is transmitted to the central control system. In fact, there are always specific risks for the enterprise among them (Figure 3) are production process interruptions and equipment parameter change due to a cyberattack, data theft, and the creation of hazardous conditions for workers.

This example illustrates how unauthorized access to the production equipment control system can have significant consequences for safety, product quality, and production process efficiency.

Understanding such risks leads production management to enhance cybersecurity systems and develop action plans in case of cyber incidents.

The implementation of a "smart factory" system requires managing changes in corporate culture. This is driven by the need to adopt innovative technologies, which in turn requires a shift in the organization's mindset and work processes. It's crucial to establish a conducive atmosphere for embracing change and fostering initiative. In this context, the key aspects of managing changes in corporate culture are as follows (Table 3):

- Leadership and support.
- Promoting openness.
- Involving the workforce.
- Continuous communication with employees.
- Training and development.
- Supporting initiatives.

Managing changes in corporate culture plays a crucial role in creating a conducive environment for the implementation of innovative technologies in the "smart factory" system. Especially in

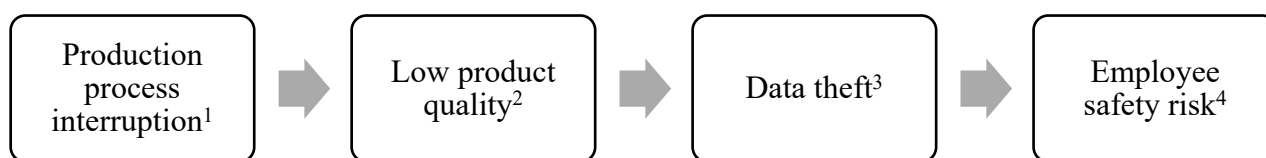


Figure 3. Possible consequences of unauthorized access to the production equipment control system

Note:

1. A hacker can modify equipment parameters, leading to its shutdown or faulty operation. This can result in production stoppage and financial losses.
2. A hacker can alter equipment settings, causing the production of low-quality goods. This may impact the company's reputation and client relationships.
3. A hacker can gain access to critical data about the production process, technical solutions, patents, etc. This can lead to the theft of confidential information.
4. By modifying equipment operation parameters, a hacker can create hazardous conditions for workers, potentially causing accidents or injuries.

Source: formed based on [1–2]

Table 3

Characteristics of basic directions in managing corporate culture changes within the "smart factory" system

Direction of industrial management	Features of industrial management	Signs of industrial management effectiveness
Leadership and support	The implementation of the "smart factory" system requires a high level of leadership. This is a crucial aspect for creating a culture that fosters change.	Helps actively support initiatives for the implementation of new technologies.
Promoting openness	The implementation of the "smart factory" system requires an atmosphere where employees could express their ideas, discuss issues, and put forward suggestions.	Helps consider the opinions of all stakeholders.
Involving the workforce	The implementation of the "smart factory" system requires involving the staff in the process of change implementation.	Helps the staff understand how their work is connected to the goals of implementing the "smart factory."
Continuous communication with employees	The implementation of the "smart factory" system requires clear and open communication with employees.	Helps convey to the staff the changes, their importance, and the positive impact of these changes on the production process.
Training and development	The implementation of the "smart factory" system requires providing opportunities for training and development of the staff.	Helps the staff acquire the necessary skills for working with new technologies.
Supporting initiatives	The implementation of the "smart factory" system requires encouraging employees to contribute internal initiatives.	Helps in the implementation of new technologies and the optimization of staff work.

Source: formed based on [2; 3; 6]

this context, it is important to maintain a positive attitude of the staff towards changes and stimulate their initiative.

The implementation of the "smart factory" system requires continuous change management. This is driven by the need to adopt new technologies and involves changing roles and responsibilities of employees. Therefore, management must develop training and support plans for the staff during this process. Key aspects of change management include (Table 4):

- Technical training.
- Hands-on application training.
- Learning new skills.
- Guidance and support.
- Defining new roles.
- Tracking progress.
- Feedback.

Therefore, successful change management arising from the implementation of the "smart factory" system includes the development of an appropriate plan, active support, and training of personnel to ensure a smooth and successful transformation of the enterprise's manufacturing system.

The implementation of the "smart factory" system requires a focus on configuring manufacturing processes through production lines or CNC machines, 3D printers, and other additive technologies. This enables real-time monitoring and control of processes, facilitating networked

interactions, timely responses to changes, and continuous improvement of production efficiency. The aspects that managers should consider when configuring manufacturing processes within the context of a smart factory are as follows (Table 5):

- Configuring the operation of sensors in production lines and CNC machines and IoT devices.
- Configuring real-time monitoring processes.
- Ensuring flexibility and adaptability of production processes.

Note that the management of configuring production processes within the "smart factory" system enables detailed and real-time visualization, tracking, and adjustment of the operational status of the production system and its individual components (such as individual production lines or CNC machines).

During the implementation of the "smart factory" system, changes occur in the mechanisms of ensuring product quality. Specifically, this system enables the early detection of defects and shortcomings in the production process, leading to the improvement of product quality.

The implementation of the "smart factory" system requires a focus on creating opportunities for innovation and the development of new technologies, which helps businesses remain competitive. In this context, key aspects of creating opportunities for innovation include the following (Table 6):

Table 4

Characteristics of the basic directions of change management within the "smart factory" system

Direction of industrial management	Features of industrial management	Signs of industrial management effectiveness
Technical training	The implementation of the "smart factory" system requires providing training to the staff on the use of new technologies, systems, and software tools.	Helps create trainings, workshops, webinars, or educational courses.
Hands-on application training	The implementation of the "smart factory" system requires educating the personnel about the specifics of applying new technologies in their day-to-day work.	Enables the creation of simulations, role-playing games, and practical tasks.
Learning new skills	The implementation of the "smart factory" system necessitates the adoption of new technologies and, consequently, acquiring new skills that were not relevant before.	Helps train employees in skills related to data analytics, programming, or robotics.
Guidance and support	The implementation of the "smart factory" system requires the organization of mentoring or support.	Facilitates the creation of an environment where more experienced employees can assist those with less experience in working with new technologies.
Defining new roles	The implementation of the "smart factory" system requires a change in roles and responsibilities.	Assists in providing clear information about roles and responsibilities in ensuring the functionality of the "smart factory" system.
Tracking progress	The implementation of the "smart factory" system requires establishing mechanisms to track the progress of training and the adaptation of the personnel to changes.	Aids in identifying potential issues and shortcomings in ensuring the functionality of the "smart factory" system.
Feedback	The implementation of the "smart factory" system requires support for open feedback loops.	It helps create an environment where employees can share their thoughts, questions, and suggestions regarding the implementation of new technologies.

Source: formed based on [1–2; 4]

Table 5

Characteristics of the basic directions of management of configuring manufacturing processes within the "smart factory" system

Direction of industrial management	Features of industrial management	Signs of industrial management effectiveness
Configuring the operation of sensors in production lines and CNC machines and IoT devices	The implementation of the "smart factory" system ensures synchronization of the operation of manufacturing lines, machine tools, and IoT through mobile platforms.	Assists in creating a digital twin of the enterprise's manufacturing system and provides opportunities for visualizing the real-time situation within the company.
Configuring real-time monitoring processes.	The implementation of the "smart factory" system ensures the acquisition of reliable information about the progress of manufacturing processes.	Facilitates the transition to real-time execution of planning tasks.
Ensuring flexibility and adaptability of production processes	The implementation of the "smart factory" system enables the formation of an automatic response of the manufacturing system to production situations.	Each change in production processes is the result of a decision made individually for specific equipment, which is individually configured. The system will be able to trigger automatic reactions to production events.

Source: formed based on [2; 3; 6]

Table 6

Characteristics of the basic directions of creating opportunities for innovation within the "smart factory" system

Direction of industrial management	Features of industrial management	Signs of industrial management effectiveness
Innovative solutions	The implementation of the "smart factory" system requires the application of new technologies, such as artificial intelligence, data analytics, blockchain, and others, which can lead to the development of new methods of production, management, and collaboration.	Helps implement automated processes that enhance production efficiency and quality.
New business models	The implementation of the "smart factory" opens opportunities for creating or reorganizing business models.	Assists in implementing the realization of platform solutions, allowing for additional revenue generation, and expanding the customer base.
Establishment of an innovative ecosystem	The implementation of the "smart factory" system enables the creation of a platform for building an ecosystem where various departments of the enterprise and its partners collaborate, exchanging data and resources.	Facilitates the testing and implementation of innovations and collaborative development of new technologies into production.

Note: The main platform solutions can be as follows: order management and capacity planning for innovation implementation in production, operational planning to produce new types of products (APS – Advanced Planning and Scheduling), production logistics management.

Source: formed based on [1–2; 6]

- Innovative solutions.
- New business models.
- Establishment of an innovative ecosystem.

Overall, focusing on innovation and the development of new technologies is a crucial step for enterprises in implementing the "smart factory" system [5]. This enables them to maintain high competitiveness and ensures long-term success in the market.

Conclusions. Within this study, it was determined that the "smart factory" system represents a significant innovative approach to manufacturing, leveraging advanced technologies to enhance efficiency and quality. However, it was noted that this approach also presents specific management challenges.

Among the most significant conclusions of the research, it is worth noting:

1. Specificity of Technological Integration Management. Implementing "smart factories" involves integrating various technologies and systems, necessitating specific approaches to managing technological integration.

2. Specificity of Big Data Management. The "smart factory" generates a substantial volume

of data that requires effective management and analysis.

3. Specificity of Cybersecurity Management. Incorporating advanced technologies requires heightened attention to cybersecurity, as new attack vectors can emerge.

4. Specificity of Corporate Culture Change Management. Transitioning to the "smart factory" may require changes in corporate culture, necessitating change management efforts.

5. Specificity of Continuous Change Management. "Smart factories" entail ongoing development and adaptation, making continuous change management a necessity.

6. Orientation towards Production Process Configuration. "Smart factories" aim for production flexibility, which demands the configuration and individualization of production processes.

From the perspective of further research, potential avenues could include examining the impact of technological integration on various aspects of production and management, as well as investigating methods and approaches for continuous change management in manufacturing.

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