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УДК: 338.242.2
DOI: 10.36919/2312-7812.1.2023.13

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DIGITAL TRANSFORMATION IN AUTOMOBILE MANUFACTURING: IMPACT ON BUSINESS DEVELOPMENT STRATEGY, CHALLENGES AND PROSPECTS

В останні роки цифрова трансформація стала ключовим рушієм змін та інновацій у багатьох галузях промисловості, включно з автомобілебудуванням. Цифрові технології трансформують кожен аспект конкурентоспроможності та автомобільного ланцюжка створення вартості: від розробки електричних і автономних транспортних засобів до впровадження передової аналітики та робототехніки. Ця трансформація не тільки впливає на те, як розробляються, виготовляються та продаються автомобілі, але також змінює підхід компаній до розвитку бізнесу та формування стратегії.

Цифрова трансформація автомобільної промисловості призвела до значних змін у способах ведення бізнесу, що призвело до підвищення ефективності, продуктивності та прибутку. Однак, є також виклики, які виникають у результаті цієї трансформації, такі, як загрози у сфері кібербезпеки та потреба в опануванні нових навичок. У сучасному світі, де автомобільна промисловість продовжує активно розвиватися, важливо зрозуміти вплив цифрової трансформації та Інтернету речей (IoT) на стратегії розвитку бізнесу та економіку. Ці питання розглядаються в даній статті. Авторами проаналізовано вплив цифрової трансформації та Інтернету речей на

автомобільну промисловість, а також досліджено потенційні шляхи вирішення проблем, які виникають у зв'язку з цією трансформацією.

In recent years, digital transformation has become a key driver of change and innovation in many industries, including automobile manufacturing. Digital technologies are transforming every aspect of competitiveness and the automotive value chain, from the development of electric and autonomous vehicles to the implementation of advanced analytics and robotics. This transformation is not just affecting the way cars are designed, built, and sold, but it is also changing the way companies approach business development and strategy formation.

The digital transformation of the automotive industry has brought about significant changes in the way business is conducted, leading to increased efficiency, productivity, and revenue. However, there are also challenges that arise from this transformation, such as cybersecurity risks and the need for new skill sets. In today's world, where the automotive industry continues to grow rapidly, it is important to understand the impact of digital transformation and the Internet of Things (IoT) on business development strategies and the economy. These issues are considered in this article. The authors analyzed the impact of digital transformation and the Internet of Things on the automotive industry, as well as explored potential solutions to the problems that arise in connection with this transformation.

Ключові слова: автомобільне виробництво, Індустрія 4.0, Інтернет речей (IoT), цифрова трансформація, планування виробництва, економічна стратегія.

Keywords: automotive production, Industry 4.0, Internet of Things (IoT), digital transformation, production planning, economic strategy.

Formulation of the problem: The automobile manufacturing industry is facing a range of challenges and opportunities as it undergoes a digital transformation. On the one hand, digital technologies offer a range of benefits such as increased efficiency, cost savings, and improved customer experiences. On the other hand, the implementation of digital technologies also presents significant challenges such as the need for new skills and capabilities, cybersecurity risks, and potential disruption to existing business models.

One of the key problems facing the automobile manufacturing industry is how to effectively manage the digital transformation process. This requires a holistic approach that considers the entire value chain, from design and engineering to manufacturing, sales, and service. Companies must also consider the impact of digital transformation on their organizational structures and cultures, and how they can effectively leverage digital technologies to remain competitive in a rapidly changing industry.

Another key problem facing the industry is how to effectively balance the benefits of digital technologies with the risks and challenges associated with their implementation. For example, while advanced analytics and AI can help companies optimize their supply chains and improve product quality, they also raise concerns about data privacy and security. Similarly, while electric and autonomous vehicles offer new business opportunities, they also require significant investments in new technologies and infrastructure.

In this article, we will explore these and other problems facing the automobile manufacturing industry as it undergoes a digital transformation. We will examine how companies are approaching these challenges, and the strategies and solutions that are emerging to help them effectively navigate the digital transformation process.

The purpose of this paper is to explore the impact of digital transformation and the Internet of Things (IoT) on the development strategies of the automotive industry.

This includes an analysis of the advantages and prospects of Industry 4.0, as well as the potential challenges and solutions that may arise during its implementation. The paper aims to provide a comprehensive understanding of how digital technologies can improve production efficiency, reduce costs, and enhance customer satisfaction in the automotive sector, and to offer insights for industry practitioners and policymakers.

Analysis of recent research and publications. Digital transformation and the implementation of IoT in the automotive industry is a widely discussed topic in both academia and industry. Among Ukrainian scientists, research in this area was carried out by B. Rezanov, V. Aulin, A. Hrynkiv and A. Holovatyi.

On the international field Stephan Weyer, Mathias Schmitt, Moritz Ohmer, Dominic Gorecky identified the key components of Industry 4.0 and outlined the benefits of digitization for the manufacturing process. Another study by Ransbotham et al. (2015) highlighted the importance of data analytics and the potential for IoT to enable predictive maintenance in the automotive industry. There are numerous case studies of IoT implementation in the automotive industry, such as the BMW Group's use of IoT to optimize their logistics processes (Fasano and Prasad, 2017) and Daimler AG's use of IoT to improve their after-sales service (Kagermann and Wahlster, 2019). Overall, researchers suggest that digital transformation and IoT have the potential to improve production efficiency, reduce costs, and enable new business models in the automotive industry. However, there are also challenges such as cybersecurity risks and the need for workforce upskilling that must be addressed to fully realize the benefits of these technologies.

Presentation of the main material. Digital transformation refers to the integration of digital technologies into various aspects of a business or industry to fundamentally change how it operates and delivers value to its customers. This involves the adoption of new technologies such as artificial intelligence, the Internet of Things (IoT), big data analytics, and cloud computing to streamline operations, enhance productivity, and improve customer experience.

Industry 3.0, also known as the Third Industrial Revolution, is characterized by the widespread adoption of automation and computerization in manufacturing and production processes. This era began in the late 20th century and continued until the early 21st century. Industry 3.0 saw the rise of industrial robots, programmable logic controllers, and computer-aided design and manufacturing systems.

Industry 4.0, also known as the Fourth Industrial Revolution, is the current era of technological advancement in industry and manufacturing. Industry 4.0 builds on the automation and computerization of Industry 3.0 by incorporating the Internet of Things (IoT), artificial intelligence (AI), and other advanced technologies. Industry 4.0 aims to create smart factories that are more flexible, efficient, and responsive to changing customer demands. The difference between Industry 3.0 and Industry 4.0 is the incorporation of digital technologies into every aspect of the business or industry, creating a more interconnected and intelligent system.

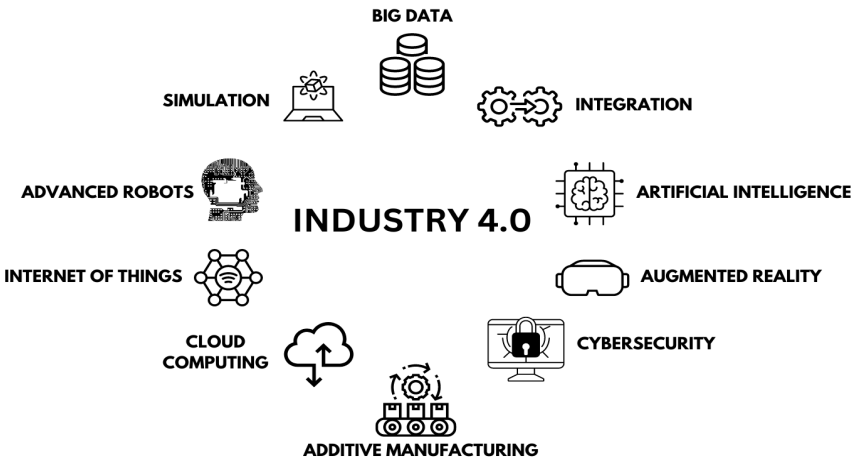

Figure 1. General concept of Industry 4.0 technologies

While the concept of Industry 5.0 is still in its infancy and has yet to be fully defined, some experts believe that it may emerge as the next stage of industrial development in the future. Industry 5.0 would build on the principles of Industry 4.0, but with a greater focus on the human element of manufacturing and production. One possible vision of Industry 5.0 is the integration of collaborative robots, or "cobots," which work alongside human workers to enhance productivity and efficiency while maintaining a safe and flexible work environment. Another possible aspect of Industry 5.0 is the use of virtual and augmented reality technologies to enable remote collaboration and enhance the training and skills development of workers.

However, it is important to note that the emergence of Industry 5.0 is still highly speculative, and it remains to be seen whether this concept will gain traction in the coming years.

The rise of Industry 4.0 technologies, such as the Internet of Things (IoT), artificial intelligence (AI), and advanced robotics, has had a significant impact on the automotive industry. Manufacturers have increasingly turned to these technologies to enhance their production processes, improve efficiency, and reduce costs.

One notable example of a car manufacturer that has embraced Industry 4.0 technologies is Audi [1]. In 2016, Audi opened its "Smart Factory" in Ingolstadt, Germany, which features a range of advanced automation and IoT technologies. These include collaborative robots, smart logistics systems, and real-time data analytics tools. The Smart Factory is designed to be flexible and agile, allowing Audi to quickly adapt to changing market demands and production needs. Another example of Industry 4.0 adoption in the automotive industry is BMW's "Industry 4.0 production line" at its Dingolfing plant in Germany [2]. This production line features more than 4,000 networked machines and robots, as well as advanced data analytics and visualization tools. The system is designed to optimize production and reduce waste, while also improving the quality and reliability of BMW's vehicles. Porsche is another car manufacturer that has embraced Industry 4.0 technologies [3]. In 2018, the company opened its "Factory 4.0" in Stuttgart, Germany, which features

a range of advanced automation and IoT technologies. These include automated guided vehicles, collaborative robots, and smart logistics systems. The Factory 4.0 is designed to be highly flexible, allowing Porsche to quickly adjust its production processes to meet changing market demands. Volkswagen's "Transparent Factory" in Dresden, Germany, is another notable example of Industry 4.0 adoption in the automotive industry [4]. The Transparent Factory features advanced automation technologies such as autonomous transport systems and virtual reality training tools. The factory is designed to be highly efficient and flexible, allowing Volkswagen to quickly adapt to changing market demands and production needs.

Overall, these examples demonstrate the growing importance of Industry 4.0 technologies in the automotive industry. By embracing these technologies, car manufacturers can improve efficiency, reduce costs, and enhance the quality and reliability of their vehicles. As these technologies continue to evolve, it is likely that we will see even greater adoption of Industry 4.0 in the automotive industry in the years ahead.

Digital transformation and IoT have had a significant impact on various processes within the automotive industry [16]. One of the main areas of focus has been on production and supply chain management. By implementing IoT-enabled devices and sensors, car manufacturers are able to collect real-time data on production processes and supply chain activities. This data can then be used to optimize production and improve efficiency.

For example, IoT-enabled sensors can be used to monitor equipment performance and detect potential issues before they result in downtime or other production delays. Real-time data analytics can also help manufacturers identify opportunities for process improvement and make adjustments to production processes in real-time.

Another area where digital transformation and IoT have had an impact is in vehicle connectivity and automation. With the rise of connected cars, car manufacturers are able to collect data on vehicle performance and usage in real-time. This data can then be used to develop more advanced and personalized services for drivers, such as remote vehicle monitoring and maintenance. IoT-enabled devices and sensors can also be used to enable greater automation in the production process. For example, autonomous robots can be used for tasks such as welding and painting, reducing the need for manual labor and improving production efficiency. In addition to production and vehicle connectivity, digital transformation and IoT are also being used to improve customer experiences. For example, car manufacturers are increasingly using digital channels to interact with customers and provide personalized services, such as online vehicle configuration and ordering. As these technologies continue to evolve, it is likely that we will see even greater adoption of digital transformation and IoT in the automotive industry in the future.

The implementation of IoT can have a significant impact on the economic strategy of automotive enterprises. One of the main benefits of IoT is that it enables car manufacturers to collect real-time data on various aspects of their business, from production processes to supply chain activities to customer preferences and behavior.

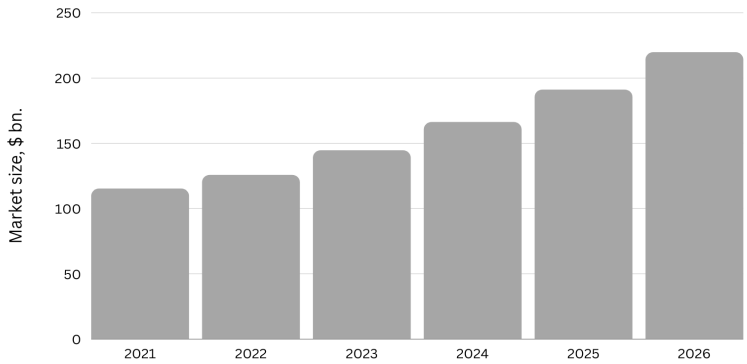

Figure 2. Market size of the automotive IoT in 2021, with a forecast through 2026 [5]

This data can be used to develop more advanced and personalized services for customers, which can help automotive enterprises to differentiate themselves from their competitors and build brand loyalty. For example, by collecting data on vehicle usage and maintenance needs, car manufacturers can offer proactive maintenance services and personalized recommendations to their customers, which can help to reduce the cost of ownership and improve customer satisfaction. In addition to improving customer experiences, IoT helps automotive enterprises to improve their operational efficiency and reduce costs. By using real-time data analytics, car manufacturers can optimize their production processes and supply chain activities, identify areas of waste and inefficiency, and make adjustments in real-time to improve efficiency. Furthermore, IoT can help automotive enterprises to improve their product development processes. By collecting data on customer preferences and behavior, car manufacturers can gain insights into which features and services are most important to their customers and use this information to develop more innovative and compelling products.

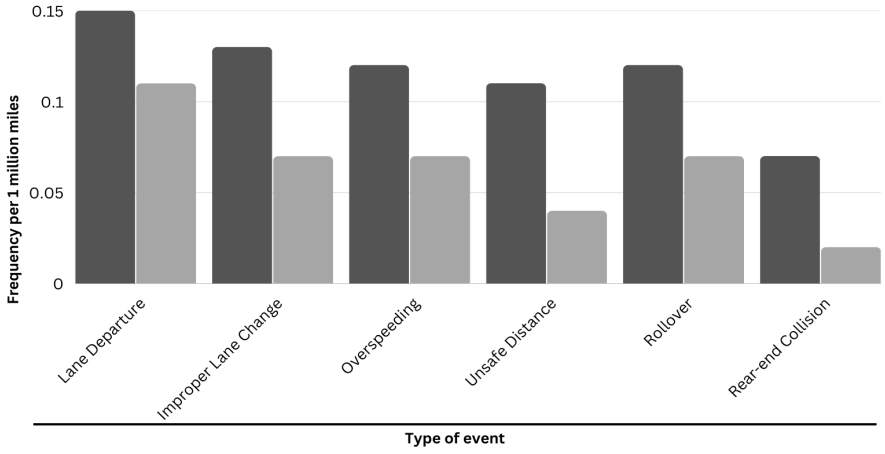

Figure 3. Reduction in US crashes between trucks with vs. without IoT safety systems [6]

The implementation of IoT can help automotive enterprises to improve their competitiveness, reduce costs, and improve customer satisfaction, all of which can have a significant impact on their economic strategy. By leveraging the power of IoT, car manufacturers can stay ahead of the curve in an increasingly competitive and rapidly evolving market:

• **Production efficiency:** According to a report by McKinsey & Company, IoT can help automotive manufacturers achieve up to 10% improvement in production efficiency [7]. This is achieved through the use of real-time data analytics to optimize production processes, reduce downtime, and improve quality control.

• **Revenue growth:** Another study by McKinsey & Company found that companies that adopt IoT can experience up to 10% revenue growth, thanks to improved customer experiences, more efficient operations, and the development of new revenue streams. [8]

• **Cost savings:** According to a report by Deloitte, companies that implement IoT can achieve cost savings of up to 30%. This is achieved through the optimization of supply chain and production processes, the reduction of maintenance costs through predictive maintenance, and the reduction of energy and material costs. [9]

• **Customer satisfaction:** A study by Accenture found that companies that implement IoT can improve customer satisfaction by up to 20%. This is achieved through the development of personalized products and services, proactive maintenance, and improved communication and engagement with customers. [10]

The following Internet of Things solutions have become popular on the mass car market:

• **Connected car technology:** This includes features such as telematics, which allow for remote monitoring of vehicle performance, and in-car connectivity, which enables passengers to access the internet, media, and other services from within the vehicle.

• **Advanced driver assistance systems (ADAS):** features use sensors, cameras, and other IoT technologies to improve driver safety and reduce the risk of accidents. Examples include automatic emergency braking, lane departure warning, and adaptive cruise control.

• **Predictive maintenance:** IoT sensors can be used to monitor vehicle performance and detect potential maintenance issues before they become major problems. This can help to reduce downtime and maintenance costs, as well as improve overall vehicle reliability.

• **Smart infotainment systems:** Modern infotainment systems use IoT technologies to provide drivers and passengers with personalized content and services, such as music streaming, navigation, and voice control.

IoT-enabled technologies can improve the efficiency of automotive manufacturing and supply chain operations, resulting in cost savings and increased productivity. ADAS features and other IoT-enabled safety technologies can reduce the number of accidents and associated costs, such as medical expenses and lost productivity. IoT-enabled infotainment and connectivity features can improve customer satisfaction and retention, leading to increased sales and revenue. As for the manufacturer, these technologies can enable the development of new revenue streams, such as data analytics services or connected car services. Thus the adoption of the new-edge technologies in the automotive

industry can have a significant impact on the economy, driving innovation, improving efficiency, and creating new opportunities for growth and profitability. [11]

General Motors has assessed the impact of IoT on the manufacturing process according to research conducted by Frost & Sullivan. They found that the implementation of IoT can reduce the production time per unit of goods by 10 to 15% compared to standard production methods. In 2010, on average, the production of one car took about 30-35 hours. And already in 2020, thanks to the use of IoT technologies, the production time was reduced to an average of 20-25 hours. This shows that the use of IoT can have a significant impact on production efficiency and timescales [12].

While digital transformation can bring many benefits to the automotive industry, there are also some potential challenges and risks to consider [15]. Some of the problems that may arise with the implementation of digital technologies include:

• **Security risks:** as more devices and systems become connected, there is an increased risk of cybersecurity threats, including data breaches and cyberattacks.

• **Skills gaps:** the adoption of new digital technologies may require new skills and training for employees, which could create skills gaps and labor shortages.

• **Integration challenges:** integrating new digital technologies with existing systems can be a complex and time-consuming process, which may require significant investments in IT infrastructure and resources.

• **Data privacy concerns:** as more data is collected and analyzed through IoT devices, there are growing concerns around data privacy and how this information is used.

• **Cost implications:** implementing digital technologies can be expensive, especially for smaller automotive businesses that may not have the same financial resources as larger companies.

There are many case studies that highlight the potential challenges of digital transformation in the automotive industry. For example, the 2018 data breach at British Airways, which compromised the personal and financial data of over 400,000 customers, was linked to vulnerabilities in the company's IoT systems [13]. Another example is the recent supply chain disruptions caused by the global chip shortage, which has highlighted the risks associated with relying on a limited number of suppliers for critical components. To address these challenges, automotive businesses may need to consider a range of strategies, including investing in cybersecurity measures to protect against cyber threats and data breaches, providing training and development opportunities for employees to upskill and develop the necessary digital competencies, collaborating with other businesses and organizations to share resources and knowledge around digital transformation, developing clear data privacy policies and ensuring compliance with relevant regulations, diversifying supply chains to reduce dependence on a single source of critical components. While digital transformation presents many opportunities for the automotive industry, it is important to consider and address potential challenges and risks to ensure successful implementation and adoption of these new technologies [14].

Conclusion. The digital transformation of the automotive industry has had a significant impact on business development strategies, as well as on production efficiency, revenue, and customer experience. The implementation of IoT has led to improvements in supply chain management, predictive maintenance, and quality control. However, there are also challenges that arise with digital transformation, such as cybersecurity risks and

the need for new skill sets. To overcome these challenges, companies must develop a comprehensive digital strategy and invest in their employees' skills and training. With proper planning and execution, digital transformation can help automotive companies stay competitive and meet the evolving demands of the market.

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