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CLASSIFICATION OF DIGITAL TECHNOLOGIES USED IN LIGHT INDUSTRY ENTERPRISES AND THEIR IMPACT ON IMPROVING EFFICIENCY

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Abstract
This paper explores the classification and effectiveness of digital technologies in the light industry sector. It highlights the integration of technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), Augmented and Virtual Reality (AR/VR), blockchain, and digital twins in enhancing production automation, real-time monitoring, and personalized services. The study emphasizes the strategic role of digital transformation in improving operational efficiency and advancing the circular economy model.

Introduction

In the context of the rapid development of digital technologies, the implementation of innovative solutions in practice has become an important factor in increasing the competitiveness of enterprises across various sectors. One of the industries significantly impacted by digitalization is the light industry. Light industry—which includes textile, garment, footwear, and leather production—plays a vital role in the economies of many countries. It is considered one of the most essential, multifaceted, and innovative sectors of the economy.

The use of digital technologies in light industry covers a wide range of applications. This includes the use of robotic systems and artificial intelligence for production automation; the implementation of the Internet of Things (IoT) technologies for monitoring production processes; the use of digital twins for product modeling; and the application of big data and machine learning technologies for demand forecasting and supply chain management.

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Additionally, digitalization contributes to the development of e-commerce and personalized marketing. Agriculture is the main supplier of raw materials for light industry enterprises.

Light industry is considered one of the most dynamic sectors of the economy. It was this sector that marked the starting point of the first industrial revolution. In the second half of the 18th century, the mechanization of the textile industry led to large-scale structural changes in both the economy and employment, fundamentally transforming the socio-economic landscape of many countries that specialized in this field.

Light industry is one of the most essential, diverse, and innovation-driven branches of the economy. Enterprises in this sector produce textiles, including clothing and footwear with therapeutic and preventive properties designed to restore and maintain human health, as well as workwear and specialized garments. The volume of production and consumption of consumer and medical products has a direct impact on the economic and healthy development of society.

Literature Review

Various researchers have studied the use of digital technologies in light industry enterprises. In his research, T. Sergievich notes that *"light industry is engaged in the initial processing of raw materials and the production of finished goods."* The main consumers of light industry products are individuals who use them for personal needs. Light industry refers to branches specialized in producing goods for everyday human use. At the same time, many of the additional products generated by this sector are also utilized in other fields. Light industry includes several sub-sectors, which are commonly divided into three main groups: textile, garment, and leather industries.

In their study, M. Ghoreishi, A. Happonen, and M. Pynnönen deeply analyzed the role of Industry 4.0 technologies, especially the Internet of Things (IoT), in introducing the circular economy concept in the textile sector. The authors highlighted the potential of digital transformation to reduce waste at every stage of production, extend product life cycles, and involve users in reuse processes.

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Research by R. Hassan, F. Acerbi, P. Rosa, and S. Terzi focuses on integrating life-cycle technologies with existing information systems in production companies to enhance operational efficiency. Their work investigates how these technologies can facilitate the transition of the textile industry to circular production and proposes ways to ensure the effective use of digital technologies to achieve that goal.

In the research conducted by Dennis Küsters and colleagues, the Textile Learning Factory 4.0 (TLF 4.0) project is presented as a leading initiative to prepare Germany's textile industry for digital transformation under Industry 4.0 technologies. The project's goal is to increase digital capacity in small and medium-sized enterprises and create a new production model—a smart factory—based on a complete value chain. The authors argue that digital transformation can improve competitiveness, reduce service and technical costs, and speed up the production cycle. They also address key challenges in textile digitalization: financial uncertainties, lack of qualified personnel and technical capacity, cybersecurity concerns, and resistance to rapid change.

M.M. Rahman's research analyzes how the global light industry can undergo digital transformation in alignment with the Sustainable Development Goals (SDGs). Technologies such as IoT, Artificial Intelligence (AI), blockchain, Augmented Reality (AR), and Virtual Reality (VR) are seen as crucial tools in solving the social, ecological, and economic challenges faced by the apparel sector.

The apparel industry is one of the most significant manufacturing sectors, generating a $3 trillion economy and contributing 2% to global GDP. It plays a vital role in the design, production, and sale of garments and fashion items. Moreover, it encompasses various branches, including raw material preparation, fashion design, commerce, and marketing communication.

According to the United Nations, the apparel sector does not pay sufficient attention to social and environmental issues. It produces 8–10% of global CO_2 emissions, consumes 79 trillion liters of water annually, contributes to 35% of microplastic pollution, and generates over 92 million tons of textile waste each year.

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AR technology allows users to assess product compatibility, size, and color, enabling them to "experience" the product from any location via mobile devices. VR technology helps develop products in a virtual environment and enhances the retail experience.

Blockchain is a distributed ledger technology that ensures transparency, security, and immutability. In the fashion supply chain, it addresses issues of information asymmetry, trust, and traceability. It also facilitates circular economy practices by enabling the recycling of used garments as raw materials.

AR (Augmented Reality) refers to a technology-enhanced version of reality enriched with digital visual elements, sound, or other sensory inputs. VR (Virtual Reality) allows users to interact with a three-dimensional (3D) virtual environment through computer modeling and simulations. AR helps customers try products, while VR supports customized product development based on customer needs.

Smart clothing is created by integrating smart devices into light industry products, offering a promising interface between the physical and digital worlds. These garments may supplement or replace smartphones and other portable connected devices.

Wearable devices play a crucial role in smart clothing. Currently, Wearable 2.0 technology is used, enabling connectivity to various devices and access to cloud services to enhance users' quality of life.

Methodology

The article uses the methods of comparative analysis in the organization of production, Content analysis of academic studies, industry reports, and international best practices to identify key digital tools such as IoT, AI, AR/VR, blockchain, and digital twins; Systematic classification of digital technologies based on their functional roles in production automation, supply chain integration, product personalization, and sustainability enhancement. Conceptual modeling, drawing on the principles of Industry 4.0 and the circular economy, to frame a digital transformation roadmap tailored to the light industry.

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Analysis and Results

The light industry consists of several narrowly specialized sub-sectors. These specialized branches within the light industry are illustrated in Figure 1.

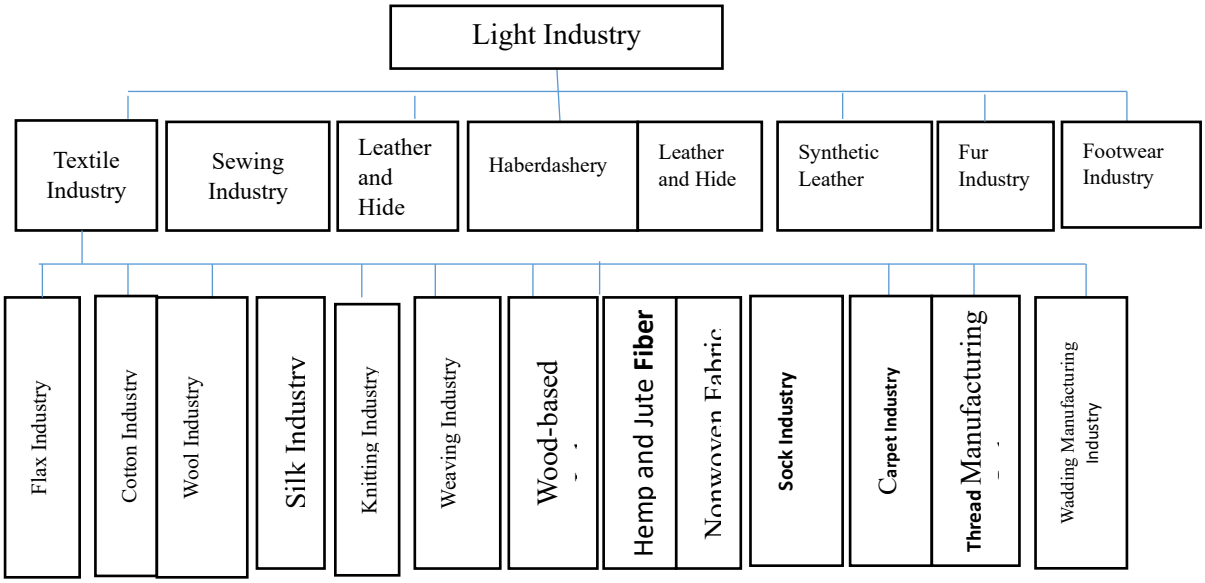

Figure 1. Structure of the Light Industry Sector

The possible directions for applying digitalization in the fashion sector can be seen in Figure 2.

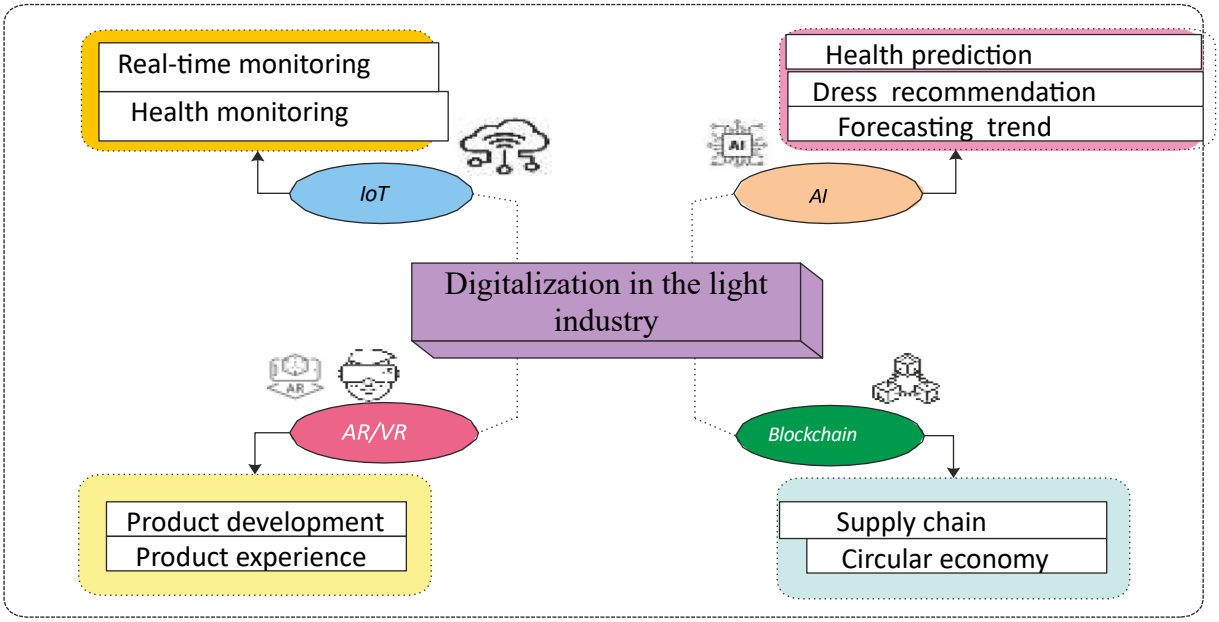

Figure 2. Digitalization in the Light Industry [19]

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IoT (Internet of Things) refers to physical devices equipped with sensors and computing power that can communicate with other devices via the Internet or wireless networks [20]. In the fashion sector, IoT enables real-time monitoring of operations (such as product tracking and feedback systems), health monitoring for individuals (e.g., athletes, patients, the elderly, and infants), and the implementation of safety systems.

Figure 3 illustrates an IoT-based tracking architecture for the fashion industry proposed by Stauffer et al. This architecture consists of the following six stages:

1. **Create**
2. **Read**
3. **Communicate**
4. **Aggregate**
5. **Consult/Trace**
6. **Analyze**

In the **Create** stage, textile products are integrated with sensors and tags, enabling their tracking within the supply chain.

In the **Read** stage, data from the sensors and tags are captured by special devices, including geographic location and environmental parameters recorded during tracking.

In the **Communicate** stage, the tracked data is transmitted to the relevant systems using a communication protocol embedded in the device. The protocol is selected based on the size and distance of the transmitted data.

In the **Aggregate** stage, diverse data collected from various sources is consolidated into a unified database—such as a time-series database or a data warehouse.

In the **Consult/Trace** stage, business operations management—such as supply chain, monitoring, production, and human resources—is integrated with the tracking and verification processes.

In the **Analyze** stage, the collected data is processed through analytical modules, generating the most valuable insights. These indicators, supported by enhanced visual analytics strategies, help evaluate business processes, develop strategies, and increase profitability.

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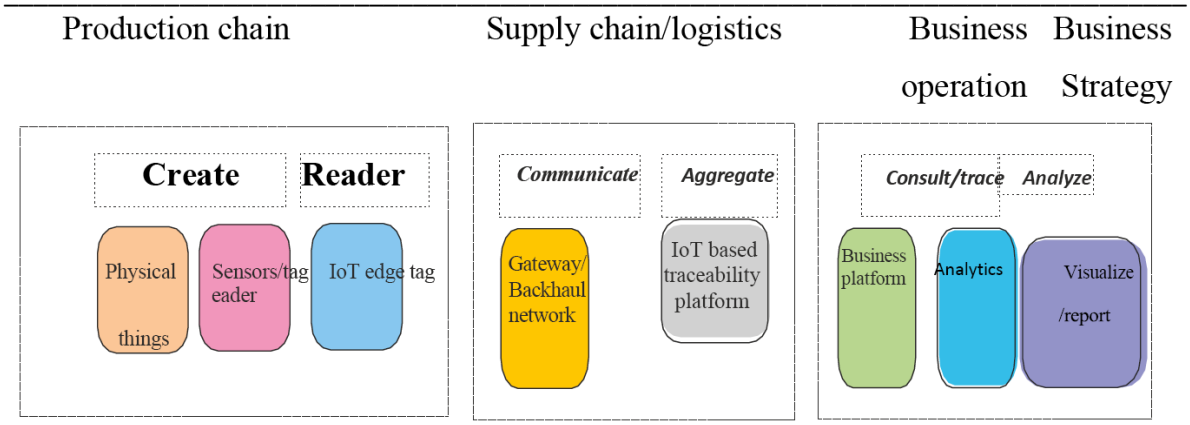

Figure 3. IoT traceability architecture for fashion supply chain[21].

As noted by Ghoreishi and Happonen (2019), Industry 4.0 technologies connect and provide real-time data related to product design (e.g., resource optimization), enabling enterprises to make effective decisions during the production process. In addition, monitoring products using digital technologies allows companies to predict maintenance needs and avoid unnecessary costs. Maintenance can then be performed precisely when and where it is needed.
Digitalization ensures information exchange between organizations and customers through platforms and applications that link supply and demand data [22].

Conclusion

The integration of digital technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), Augmented and Virtual Reality (AR/VR), blockchain, and digital twins in light industry enterprises has the potential to significantly transform production efficiency, innovation, and sustainability. These technologies not only facilitate automation and real-time monitoring but also enable personalized product development and improved supply chain coordination.
The theoretical insights and empirical evidence presented in this study underscore the importance of building a comprehensive digital ecosystem rooted in the principles of Industry 4.0. Such an ecosystem empowers enterprises to

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transition from conventional manufacturing processes toward "smart" production systems that maximize efficiency and customer value.

To remain competitive in the modern industrial landscape, light industry firms must embrace digital transformation not merely as a technological upgrade, but as a strategic imperative that drives innovation, reduces environmental impact, and aligns with the circular economy model.

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