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DEVELOPMENT OF INDUSTRIAL LOGISTICS IN THE CONTEXT OF ARTIFICIAL INTELLIGENCE AS AN ACTIVE FLEXIBLE APPLICATION COMPONENT

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Abstract. The main objective of this report is to clarify what changes will occur in the functioning of industrial logistics systems using artificial intelligence. In addition, the global development and impact on logistics with its particularities in the various stages of technical development will be specified. The analysis so far shows that the logistics industrial systems will continue to function as subsystems of the industrial system because they are interconnected with certain interrelationships characterizing their structural systematicity and logistical security. Or the logistics system will be in equilibrium when the interconnections between these subsystems create conditions for the normal functioning of the entire industrial logistics system, providing logistical support to production. This essentially means that the interrelationship between the three types of subsystems, material, financial and informational, will form optimal relationships between them and those in the field of external industrial services. A subsystem of the logistics system with artificial intelligence is a part of this system that will allow solving tasks of the logistics system and at a higher level in a separate logistics activity or sphere of the business organization. The components of the logistics system with artificial intelligence, arranged in certain levels, ways and interrelationships, will form the logistics subsystems of a higher level, or logistics systems with artificial intelligence.

Keywords: artificial intelligence; highly automated logistics activities; artificial intelligence in logistics; levels of automation of logistics activities; logistics areas with artificial intelligence

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Introduction

Artificial Intelligence (AI) is to some extent treated as a controversial topic (Sohrabi 2023) in terms of the possible threats it may pose to humans and their current

place and role in the functioning of the industrial system as a whole. However, in recent times, artificial intelligence-based systems have been integrated into more and more areas of industrial production (Limna 2023; Wollschlaeger et al. 2017). And although enterprises still have a long way to go for their overall digital transformation, we are already witnessing how they are revolutionizing the way they operate and generating increased added value for all participants in the logistics chain (Treleaven & Batrinca 2017; Singh et al. 2020; Lu 2019). We can conclude that regardless of the large-scale changes it causes for business and people, artificial intelligence also provides exceptional opportunities for solving more complex tasks with greater effect. All this helps enterprises that are able to successfully integrate artificial intelligence in their activities to achieve higher competitiveness and resistance to environmental changes (Angelova & Ivanova 2023).

In this publication, the focus of attention is placed on the integration of artificial intelligence in industrial logistics systems. As the goal set by the authors is to clarify what changes will occur in the functioning of industrial logistics systems using artificial intelligence. In addition, the global technological development and impact on logistics with its particularities in the various stages of technical development will be specified.

Features of Technical Development and its Impact on Logistics

Technical development plays a crucial role in shaping the logistics industry by introducing innovative features and capabilities that enhance efficiency, accuracy, and speed in the supply chain. Some key features of technical development impacting logistics include:

– Automation: Automation technologies such as robotics, artificial intelligent (AI), and machine learning streamline warehouse operations, inventory management, and transportation, leading to faster and more cost-effective logistics processes.

– Internet of Things (IoT): IoT devices enable real-time tracking and monitoring of goods, vehicles, and equipment, improving visibility and transparency throughout the supply chain.

– Data Analytics: Advanced analytics tools help logistics companies analyse large volumes of data to optimize routes, predict demand, and identify areas for improvement in their operations.

– Cloud Computing: Cloud Computing: Cloud-based solutions provide scalability, flexibility and availability of data that supports decision making.

– Blockchain Technology: Blockchain enhances security and traceability in logistics by creating an immutable record of transactions, reducing fraud, and ensuring the authenticity of goods.

Logistics systems with artificial intelligence include the management and control of material, financial and information flows from the supplier to the consumer. Or

in general requirements integrate the following: purchase and delivery of materials; raw materials and semi-finished products; production storage; production; distribution; consumption and others (Li & Li 2023). At the same time, all of them must be secured financially and informationally to create a normal functioning of the logistics system considered as a whole with the industrial system. This means that the material, financial and information flows, or also called logistics chains (Fig. 1) in their nature can also be considered as logistics subsystems, but with new qualities, because they are characterized by the property of systematicity and after the application of artificial intelligence.

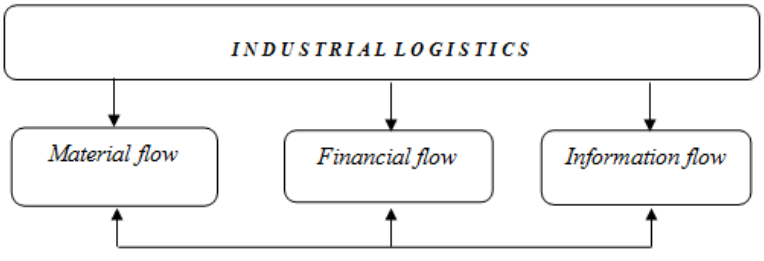

Figure 1. Components of the industrial logistics system

In this context, one of the requirements of particular importance is to create conditions for control both along the value chain of the manufactured product and for its entire life cycle. This is especially characteristic and necessary for industrial products that belong to the category of complex material assets controlled by artificial intelligence (He et al. 2020). Thus, when determining the value of industrial products, which have the character of complex durable material assets, different management approaches, characteristic of highly automated systems, are used. However, all of them are related to the logistics chain, and it changes throughout the entire life cycle of the product, because it is affected by various factors at different stages of its formation and operation (Li et al. 2023).

The impact of technical development on logistics is profound, leading to increased efficiency, reduced costs, improved customer service, and enhanced sustainability. By embracing these technological advancements, logistics companies can stay competitive in a rapidly evolving industry and meet the growing demands of modern supply chains.

1. The Place of Artificial Intelligence in Industrial Logistics

The future of industrial development brings to the fore the problem of searching for approaches and ways for quick and total application of the principles of new technical solutions. The difficulties in achieving these results come from the fact that these technical solutions are affected by many and

different factors. The need to react quickly in the time course of these stages, affecting their essence and their saturation with novelties, can be considered as innovation density (Rahman et al. 2021). What is the duration and their importance in the stages of industrial activities is of utmost importance for the development of logistics processes? Various proposals are made to specify logistics resources by grouping them into only two groups, material and informational, and to propose approaches and ways for their more effective use. Special attention is paid to the preparation and qualification of new specialists to realize this process of intellectual development. However, the truth should be sought in the analysis of the development of this process over time. Thus, it is accepted that the industrial development is considered in stages, and the change of these stages takes place with the so-called industrial revolutions, which form the industrial concepts in logistics (fig. 2).

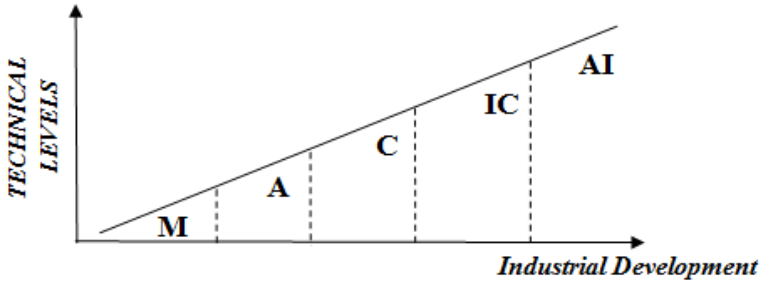

Figure 2. Industrial concepts in logistics

Where: **M** is **M**echanization;
A is **A**utomation;
C is **C**omputerization;
IC is **I**ntegrated **C**oncepts;
AI is **A**rtificial **I**intelligence.

The nature and scope of industrial logistics evolve significantly during the various stages of industrial development, influenced by several key factors:

– Early Industrialization: During the early stages of industrial development, logistics primarily focus on basic transportation and storage of raw materials and finished goods. The emphasis is on establishing efficient supply chains to support manufacturing processes.

– Mass Production Era: With the advent of mass production, logistics become more complex, requiring coordination of large-scale production, inventory management, and distribution networks. Standardization and optimization of processes become crucial to meet growing demand.

– Globalization and Technological Advancements: In the era of globalization and rapid technological advancements, industrial logistics expand globally, necessitating efficient coordination of supply chains across borders. Automation, digitalization, and data analytics play a significant role in enhancing efficiency and visibility in logistics operations.

– Sustainable Development: In the current stage of industrial development, there is a growing emphasis on sustainability and environmental responsibility in logistics. Companies are adopting green practices, optimizing transportation routes, and reducing carbon footprint to align with global sustainability goals.

The development of industrial logistics requirements is most strongly influenced by technological advancements, globalization, market demands, and regulatory changes. Companies that adapt to these evolving requirements by embracing innovation, collaboration, and sustainability practices are better positioned to thrive in the dynamic landscape of industrial logistics (Zhang 2021). Theoretical and practical concepts are also developed for the complete automation of production along the flow of details. After it, the stage of the fourth industrial revolution begins and is characterized by integrated concepts based on cyber-physical systems. It is characteristic that now the marks and signs of a new fifth industrial revolution are beginning to appear. Analysis of this development shows that each subsequent stage of the industrial revolutions has a shorter time period than the previous one. This is also accepted as a regularity in technical development (Wang et al. 2023). The other characteristic feature is that at the beginning and end of each of these stages it overlaps with novelties that create saturated innovation zones (Ft), that form a new regularity. This innovativeness is characterized by the fact that for each subsequent stage it is shorter in time (Ft >….>....) and more saturated with novelties (FN <….<….), or:

$$Ft_1 \, f \, Ft_2 \, f \, Ft_3 \, f \, ... Ft_i \, f \, Ft_n \tag{1}$$

$$FN_1 \, p \, FN_2 \, p \, FN_3 \, p \, ... FN_i \, p \, FN_n \tag{2}$$

Therefore, each of these sub-stages defines the reached technical level of the current stage and the levels of the new innovation components of the next stage. Or it is the change in the innovation curve over time. In fact, it is the transition by stages from one industrial revolution to the next, and in this case also with the manifestation of logistical changes.

Artificial intelligence plays a crucial role in industrial logistics by optimizing supply chain management, enhancing operational efficiency, and improving decision-making processes. AI technologies such as machine learning, predictive analytics, and natural language processing can help in demand forecasting, route optimization, inventory management, and real-time tracking of goods. By leveraging AI in industrial logistics, businesses can reduce costs, minimize errors,

and streamline their operations to meet customer demands effectively. Overall, AI is transforming the way logistics operations are managed and executed in the industrial sector.

2. Nature and Scope of Industrial Logistics During the Various Stages of Industrial Development

The development of these requirements is most strongly influenced by technical decisions and impacts, leading to a change not only to the essence and content of the concept of industrial logistics, but also to the formation of new signs and marks of this concept. In this sequence, based on the analytical study of this process and the prognostic data for industrial development after the fourth industrial revolution, comes the stage of artificial intelligence (Wang et al. 2023; Shu & Xing 2021). For more overview, a concept will be used, as a flexible given, benefiting by fully automating the types of labour used in logistics, namely: industrial development of logistics is automation of all types of labour used in logistics activities. (Fig.3) through the different stages of development.

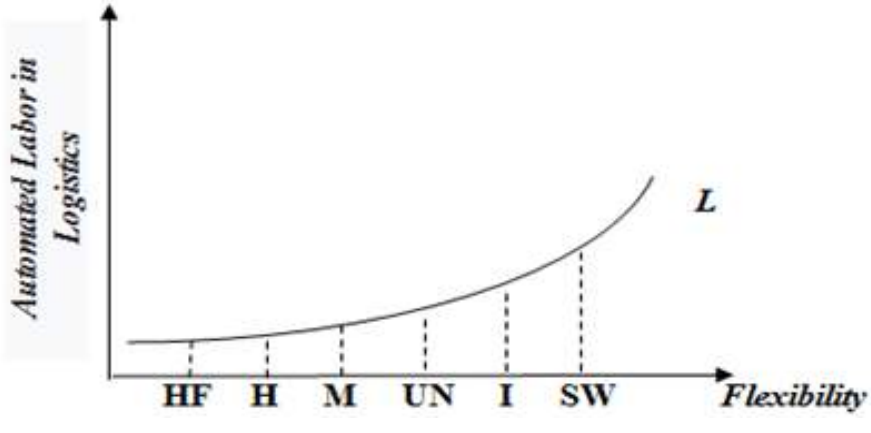

Figure 3. Logistics activities in the stages of industrial revolutions

Where: **HF** is **H**armful Labour;
H is **H**ard Work;
M is **M**onotonous Work;
UN is **Un**attractive Work;
I is **I**ntellectual Work;
S is **S**mart Work.

The essence of this industrial development for all stages until now has been to increase social productivity at the expense of reducing physical labour as hard,

harmful, unattractive, monotonous and intellectual. At the end of the third industrial revolution, however, with the application of the principles of automation, some elements considered as such from the sphere of intellectual labour begin to be solved. These are self-regulating systems as the primary norms of artificial intelligence and others, with which in the fourth stage (Fourth Industrial Revolution) this goal is complemented and with the programmed development of artificial intelligence (Joshi 2023). However, there are still unclear moments about the global goal of industrial development and industrial logistics, how far it will continue, what future awaits us, and whether it will end. So far, only vague forecast components of development have been given. It is expected for the fifth stage of industrial development (Fifth Industrial Revolution) to include research related to changes in the functional essence of man. One hypothesis is proposed for the continuity and flexibility of the goals of industrial revolutions, and the fifth is predictive. It can be assumed that the goals of the industrial revolutions so far have a flexible continuity, but after the third revolution there is no clearly formulated global goal as a result of a new stage of technical development. How far it will go and how long it will affect logistics flows is too vague a problem.

Automation Saturation of Industrial Logistics

Each of these temporal sub-stages or phases of technical saturation passes through different levels of technical development and change. These are the levels of quantitative accumulation over time (QA) and the levels of qualitative changes (QC), at which the regularities of both the current and the future industrial revolution (IR) operate, or:

$$IR = QA + QC \tag{3}$$

As an upper limit of industrial development with human participation, the occurring quantitative and qualitative changes in industrial logistics with and without human participation are considered. The special thing about this dependence is that the area between them defines the possibilities for the participation of human intellectual labour in industrial development. This is the exhausted human resource of novelties. Therefore, it can be assumed that man as a biological species has exhausted his possibilities to generate novelties. And here is the big question, will it not stop the progress of development, or will there be a new type of functionally acceptable human or will it be replaced by artificial intelligence. This is not within the power of scientists involved in the process of industrial development of logistics but is a complex global issue and problem. Our view is that the industrial development of logistics will not stop, but will change, and we need to explore and analyse these innovation zones by looking for new ways and means to more efficiently extract the resource from their application (Soumpenioti & Panagopoulos 2023). In the future, in E-Logistics, the "financial flow" component will have to be transformed into the concept of "virtual

reality" and the necessary information will be taken over by the "information flow" component. In fact, only two flows will be preserved: material and informational. Many examples from practice can be cited: application of artificial intelligence in the management of production processes and activities; the use of information modules in technological concepts with strict financial control, the creation of smart factories, etc. The special thing about these innovation zones is that so far, few people know this environment and can transfer their knowledge and experience to others. That is why one of the questions that humanity is facing and looking for a solution is to try to formulate a clear goal of industrial logistics development. This means not only a targeted use of the available resources, but also a restructuring of the approaches and ways of their use, including those of the logistics areas.

Automation saturation in industrial logistics refers to the extent to which automated technologies have been implemented in various aspects of the logistics process. This includes the use of robotics, autonomous vehicles, automated warehouses, and other technologies to streamline operations and reduce manual labour. As automation continues to advance, industrial logistics companies are increasingly adopting these technologies to improve efficiency, accuracy, and speed in their operations.

However, it is essential to consider the potential challenges and limitations of automation saturation in industrial logistics. These may include high initial costs of implementation, the need for specialized training for employees, potential job displacement, and cybersecurity risks. Finding the right balance between automation and human intervention is crucial to ensure optimal performance and adaptability.

3. Restructuring of resources in the conditions of E-environment (material, biological, intellectual-human, information)

To solve the resource problem in the logistics areas in the future, different types of funds will be needed, but the main ones will be material, human (intellectual labour) and financial (Minchev et al. 2023). The material will be expressed in allocation and inclusion in the national budgets of the countries with a large intellectual and monetary resource for use mainly in the field of new technologies, artificial intelligence, cyber-physical systems, experimental research, experimental conclusions and others. These resources will also include the financial means for building or restructuring the material base intended for experiments and trials of new innovative logistics solutions, new research laboratories, etc. Biological Resources: Promoting sustainable agricultural practices to preserve biodiversity and ecosystems. Leveraging biotechnology for eco-friendly solutions such as biofuel production or genetic engineering for sustainable agriculture. Ensuring responsible management of natural resources to maintain ecological balance.

Human resources will cover the retraining of specialists who will be trained in new educational programs to work in an intellectual environment. Essentially,

this means that a fundamental restructuring of the essence of industrial logistics and its accompanying activities is necessary in the following directions: training of specialists mainly for work in an intellectual environment, well-versed in addition to conventional technologies and their job opportunities, as well as cyber-technologies, investing in continuous learning and upskilling programs to prepare the workforce for the digital age, fostering a culture of innovation and creativity to harness the intellectual potential of employees, implementing remote work policies and digital collaboration tools to optimize human resource management in the E-environment. Or this will require a radical restructuring of the essence of the concept of industrial logistics.

Information Resources: Implementing robust data management systems to ensure the security and privacy of information assets. Leveraging data analytics and artificial intelligence to extract valuable insights from information resources. Integrating information systems for seamless communication and collaboration in the digital environment. By restructuring these resources in the E-environment, organizations can achieve greater sustainability, efficiency, and competitiveness. Embracing digital technologies and sustainable practices can drive innovation, optimize resource utilization, and create a more resilient business model that is well-equipped to thrive in the digital era.

Conclusion

We have entered a century of accelerated development, built on the basis of fundamentally new technologies, electronic management, computer-integrated activities and the drive to minimize or replace intellectual labour with artificial intelligence. Based on new communication and computer achievements, nanotechnology and other technical solutions, the structure of the economic world has not only changed, but also created new components of development. In the future, industrial activities will be considered as a whole, including both technological, information and management processes, as well as functionally integrated intellectual components in one system. In this sense, industrial logistics is a subsystem of the industrial system. It is part of this system, which allows solving tasks of the logistics system at both a high and a lower level in a separate logistics activity or sphere of the business organization. The components of the logistics system, arranged according to new levels, ways and interconnections, form the logistics subsystems, including those that have adapted artificial intelligence. The logistics system includes management and control of material and information flows from the supplier to the consumer. In general requirements it contains the following: purchase and delivery of materials; raw materials and semi-finished products; production storage; production; distribution; consumption and others. At the same time, all of them must be secured financially and informationally in one "E-information" flow, in order to create a normal functioning of the logistics system

considered as a whole. This means that the material, financial and information flows will be contained in two E-chains "material and information". They are also called logistic chains in their nature they can also be considered as complex subsystems because they are characterized by the property of systemicity in an E-environment.

If we trace the various directions of realized benefits from the use of artificial intelligence, we will find that we will accelerate the process of implementing the principles of the current and next industrial revolutions in practice, we will extract the unrealized effect from the intellectual zones, we will introduce a differentiated distribution of public benefits from the effective zones, we will create a new type of specialists, we will create conditions for choosing a person functionally adapted to work in an intellectual environment.

The development of industrial logistics in the context of AI is a significant trend that is reshaping the way supply chains are managed and optimized. AI technologies, such as machine learning, predictive analytics, and natural language processing, are being increasingly utilized in industrial logistics to enhance efficiency, accuracy, and decision-making processes.

AI enables industrial logistics companies to automate repetitive tasks, improve demand forecasting, optimize route planning, and enhance inventory management. By analysing vast amounts of data in real-time, AI systems can identify patterns, trends, and anomalies that human operators may overlook, leading to more informed and data-driven decision-making.

Furthermore, AI-powered predictive maintenance systems can help prevent equipment failures and downtime, leading to increased operational efficiency and cost savings. Overall, the integration of AI in industrial logistics is driving innovation, improving productivity, and enabling companies to stay competitive in today's fast-paced and dynamic business environment.

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