

# DIGITAL LOGISTICS: HISTORICAL BACKGROUND AND CURRENT KEY DEVELOPMENT TRENDS

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**Abstract.** *The current stage of global development is accompanied by the digital transformation of the economy, which is carried out under the influence of a significant number of digital innovations. Their result is the emergence of a new economic structure, new business practices, and new values of the business environment. This article is devoted to the study of the role and features of logistics development in the historical context and the definition of modern key trends and factors of influence in digital logistics. On this basis, a justification of the economic effects of the transformation of digital logistics is provided.*

*The methodological bases of this research are general scientific techniques and methods. In particular, a systematic approach and the synthesis, logical and predictive methods of analysis are used.*

*A systematic review of literature sources and historical references to the stable relationship between previous industrial revolutions and logistics allowed us to identify changes in the role of logistics in business processes and trace the stages of the formation of digital logistics (Logistics 4.0) within Industry 4.0. Industry 4.0 represents today's comprehensive digitalization of industrial production. In general, digital logistics is a complex system consisting of numerous new technologies that are interconnected and can influence each other. Its elements include cyber-physical systems, IP networks, the Internet of Things platform, big data analytics, artificial intelligence, predictive maintenance, advanced robotics, cloud services, immersive technologies, 3D printing, and blockchain. All of these technologies play crucial roles in the functioning of modern logistics and the formation of the supply chain, and each of them has a significant number of advantages. In particular, the advantages of using the Internet of Things in logistics are determined by: the high potential of use; no losses during transportation and storage of goods; prompt prevention of damage or loss of cargo; climate control in storage areas; identification of road situation parameters; reduction of costs; and increase of economic effect. Artificial intelligence is changing the logistics market, making it more transparent, reliable, and efficient. Cost savings and high delivery speeds are two of the main factors contributing to the spread of drone applications in supply chains. The use of immersive technologies in supply chains allows suppliers to provide on-the-job training, navigation, warehouse planning, and digital interaction with customers and partners. The implementation of 3D printing provides: the acceleration of production and the simultaneous reduction of transportation, storage, import, and export costs; customer orientation; and the reduction of negative impact on the environment. The use of digital technologies by logistics companies meets not only their business interests, but also those of society and the national and international environment. Most importantly, it improves the satisfaction of consumer needs.*

*The review of the main characteristics of key digital logistics technologies allows us to substantiate the types of effects that digital logistics have in the business environment: technological, competitive, commercial, and socioeconomic.*

**Keywords:** *Industry 4.0, digital infrastructure, digital logistics, digital transformation, digital technologies.*

## Introduction

The modern world is developing at great speed. The acceleration of the transformation of business processes in all areas of activity is constantly growing. Today, most business entities are in the process of digital transformation (digitalization) or are already implementing it. In fact, while the term *digitalization* currently has an ambiguous meaning, the phenomenon of digital transformation itself is already taking place not only at the level of individual firms (micro-level), but also at the level of national and international economic systems. The logistics sector occupies a leading position in these processes.

The development of logistics in today's globalized and digitalized economy plays a significant integrating role. This is manifested in: reducing costs; expanding transport opportunities; increasing the safety, quality, and efficiency of transport and logistics services; creating conditions for increasing the additional cost of manufactured and transported goods and services; increasing consumer service requirements; and the corresponding spread of digital technologies. Modern digital technologies have changed the sequence of interaction between material and information flows, forming three ways of their interaction. First, the information flow is ahead of the material flow, i.e., the information flow receives information about the achievement of material flows (direct direction) or it contains information about the order (the opposite direction). Secondly, information accompanies the material flow and moves simultaneously with it – that is, information about the quantitative and qualitative parameters of a material flow is received through this flow, which allows one to quickly and correctly assess its state and make the necessary regulatory decisions. Third, the information flow falls behind the material flows – that is, information serves only to evaluate results. In essence, the definition of a supply chain is interpreted as a combination of the main logistics functions of a company and its partners from the beginning of the origin of any information or commodity flow to the delivery of products or services in accordance with the requirements of the final consumers.

Digital logistics should be distinguished and presented as a process of innovative optimization of logistics processes at the micro, macroeconomic and international levels. In this context, the search for new strategic directions for the innovative development of territories and their transport and logistics systems, as well as the development of mechanisms for the formation of “smart” contracts, projects, supplies, etc., are urgent tasks today.

The aim of this study is to consider historical prerequisites and current key trends in the development of digital logistics along with the factors of their development and, on this basis, to determine the economic effectiveness of digital logistics transformation.

The methodological basis of the research is composed of general scientific techniques and methods. In particular, a systematic approach and the synthesis, logical and predictive methods of analysis are used.

The research of the topic was carried out in the following logical sequence: the essence and features of logistics development in historical retrospect were determined; the key trends of digital logistics and factors influencing its digital transformations were analyzed; and the economic efficiency of digital logistics was justified.

### **A historical background of logistics: a literature review**

The term *logistics* in Greek means the art of reasoning or calculating. As noted by G. Pavelek (1988), even during the heyday of the Roman Empire, there were employees – logistics specialists – whose duties included the functions of distributing food among the population of Rome, forming stocks, and exchanging stocks between provinces.

Historically, logistics developed as a military discipline. Even in the 9th century in the Byzantine Empire, it was believed that the tasks of logistics were to arm the army, provide it with military property, care for its needs, and, accordingly, prepare each act of a military campaign. That is to say, logistics specialists were engaged in work that was a significant component of combat success. Logistics in Napoleon's army was equally important. Historically, logistics was considered to include not only transportation, but also a wide range of issues such as planning, management and support, determining the location of troops, as well as the construction of bridges, roads, and so on. One French military specialist, historian, and theorist of the 19th century defined logistics as “the

practical art of managing an army” (Mocherny, 2001). However, as a military science, logistics was formed only by the middle of the 19th century.

Another explanation for the term *logistics* is related to mathematics. In ancient mathematics, logistics was synonymous with mathematical logic and was understood as the art of calculations and geometric measurements (Ivyt & Narushevich, 2004). In an identical sense, the concept of logistics was used by the German philosopher G. Leibniz, and was later enshrined as “mathematical logic” at the philosophical Congress in Geneva in 1904. It is the above-mentioned period that scientists define as Logistics 1.0 (Kassem et al., 2019; Shkrygyn, 2021). Since the 1950s, the term *logistics* entered the economic terminology of the USA and was considered “enterprise logistics.” The era of Logistics 2.0 then began to take shape. American scientist O. Morgenstern (1951) pointed out the possibility of applying the concepts of military logistics in economics, and defined logistics as “a part of the doctrine of the organization and economics of production, which covers procurement, production and distribution logistics.” In the 1960s, logistics was already considered a business process, but it concerned only the physical distribution of goods in space.

At the first European Congress on Logistics in Berlin (March 1974), it was observed that “logistics is the doctrine of planning, managing and controlling the movement of material, information and financial resources in various systems” (Rachkovskaya, 2017, p. 36). If we take into account that planning and control are management functions, their enumeration along with management is considered redundant. The definition of the subject of logistics by three types of flows was subsequently reflected in the research of many scientists.

In the 1980s, enterprises began to establish interaction in the field of coordination of physical flows both within and outside their organizations, which became a prerequisite for the term *supply chain management* (Lummus & Vokurka, 1999; Amr et al., 2018). This term considers the management of flow processes in the interaction of enterprises at various stages, from the purchase of raw materials to arrival at the final consumer.

Thus, Logistics 2.0 focused on coordinating the interaction of parties belonging to the same chain. While Logistics 1.0 focused on activities such as purchasing, manufacturing, sales, and inventory management, Logistics 2.0, along with traditional logistics, included activities such as marketing, new product development, finance, and consumer services (Farahani et al., 2009), and considered ways to optimize the interaction of process participants. At that time, such coordination of parties’ activities was considered innovative, so Logistics 2.0 is considered a revolution in the industry and a prerequisite for the formation of Logistics 3.0.

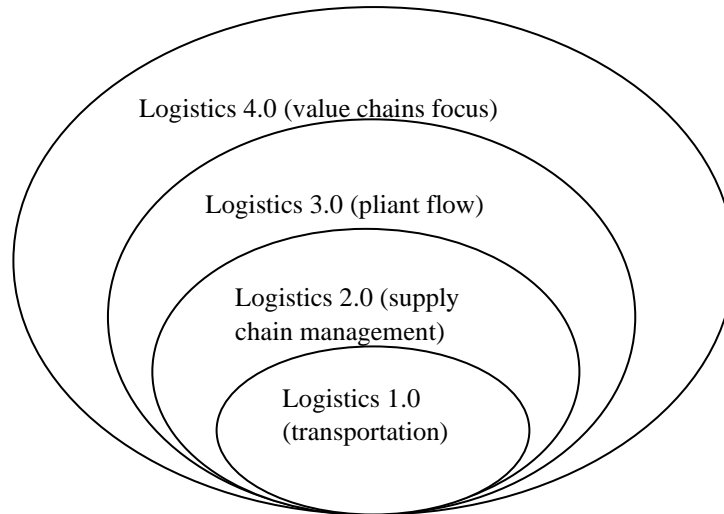
Logistics 3.0 was formed during the third industrial revolution in the early 1970s (Industry 3.0). This historical period was characterized by computerization, which enabled enterprises to quickly receive and process information flows efficiently, as well as to automate production processes. Revolutionary changes also took place in the logistics sector during this period, and supply chain management changed to flow management. Attention was then focused not only on the physical flow, but also on the processes that occur at the administrative levels of each party (cash flows, flows of services, personnel, flows of solutions and ideas, and all aspects that create value for the consumer).

Logistics forms a certain system – a network of interrelated activities, the purpose of which is to quickly manage the flow of materials and employees within the logistics channel (Stock & Lambert, 2005).

The 1980s were characterized by revolutionary changes in information technologies, the improvement of communications, and the modernization of transportation processes. In logistics, there is an understanding of the need to manage information flows on the way from the origin of the flow to the place of its consumption in order to meet the needs of consumers.

From the 1990s to the present, there has been revolutionary progress in the realm of information technologies and, in the conditions of Industry 4.0, Logistics 4.0 (Digital Logistics) is being formed.

Figure 1 shows the relationships between different epochs of logistics.



**Figure 1. The relationships between different eras of logistics**

*Source: Amr et al. (2018)*

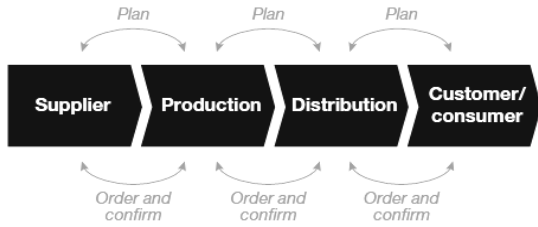
Today, Industry 4.0 involves the comprehensive digitalization of industrial production. Its elements are: cyberphysical systems, IP networks, Internet of Things platforms, big data analytics, artificial intelligence, predictive maintenance, advanced robotics, additive manufacturing, and 3D printing. There are already a significant number of scientific papers from different countries on the definition of Industry 4.0, in which logistics is explored as one of the aspects without which many of the goals of the fourth industrial revolution cannot be achieved.

The modern digital economy, in which logistics networks operate, is characterized by the global nature of using network principles to coordinate the actions of society and markets. Logistics refers to those areas that are of systemic importance for the development of any country's economy in general. Digital technologies are becoming an integral attribute of the activities of logistics companies and their partners. Digital business ultimately requires the availability of digital supply chains, which also include the digitization of logistics. The digitization process is a requirement that revolutionizes the entire process (Schrauf & Berttram, 2016). Boundaries between participants in supply systems are being eliminated as digital business and digital platforms are being integrated into the physical and virtual world (Figure 2).

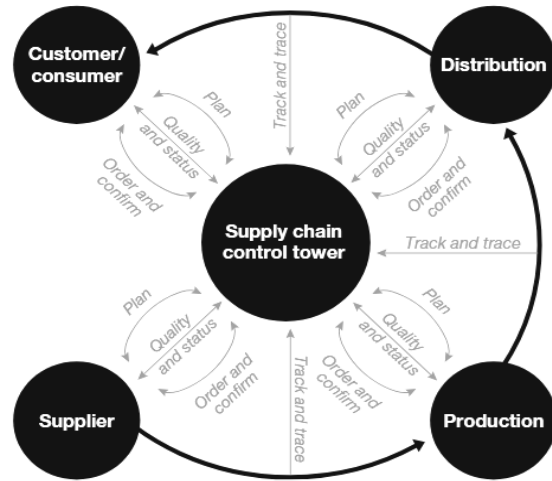
The study of literature sources made it possible to identify different approaches to the definition of the concept of "digital logistics" and its key characteristics (Figure 3).

Therefore, digital logistics are parts of the functions and operations of logistics that have undergone digital transformations using information and communication technologies. The digitization of logistics functions is considered an advantage for stakeholders, including customers and suppliers, as it provides innovative communication and information.

**Traditional supply chain model**

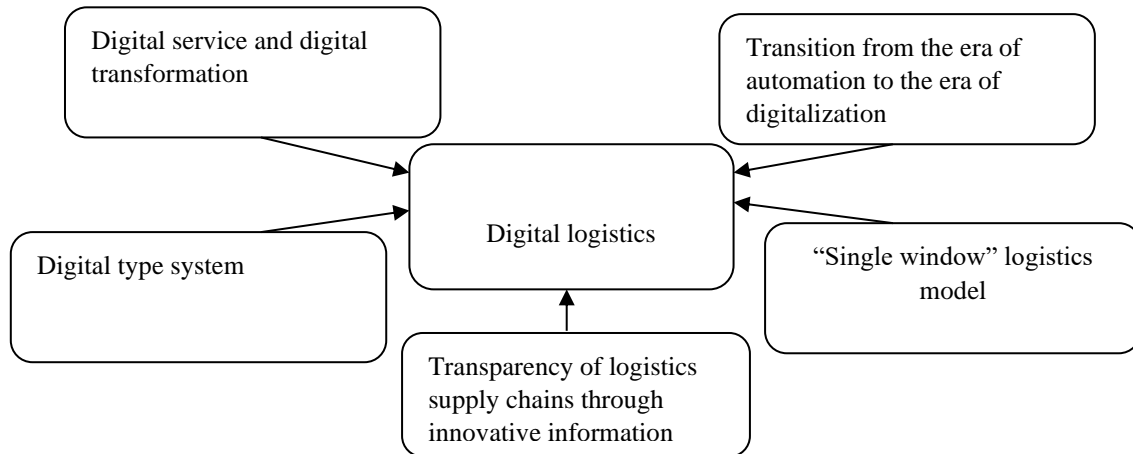


**Integrated supply chain ecosystem**



**Figure 2. The complexity of the digital supply chain**

Source: Schrauf & Bertram (2016)



**Figure 3. Key characteristics of the concept of digital logistics**

Source: Shkrygyn (2021); Schrauf & Bertram (2016); Vasilenok et al. (2020)

Such types of electronic connections are advantageous for logistics management, because modern logistics “requires the creation of interorganizational information networks and the construction of Integrated Logistics Information Systems” (Lai & Cheng, 2016, p. 274). Digital logistics platforms allow small but more innovative companies to compete with business giants.

Gunasekaran and Ngai (2003) noted that digital logistics is the transfer of goods and services through Internet communications, such as the Internet or electronic data exchange.

Digital logistics involves the search for, storage of and method of transmission of information, as well as digital technologies that provide the identification and forecasting of needs, the optimization of routes, the directions of material and information flows, and the reduction of time in supply chains (Vasilenok et al., 2020, p. 74).

Thus, digital logistics (or Logistics 4.0) requires supply chain participants to interact simultaneously. Strandhagen et al. (2017) note that sharing significant amounts of information between supply chain actors will improve companies' logistics. The digitalization of the industrial supply chain has become a prerequisite for customer orientation, the individualization of services, and the activation of logistics and the supply chain. The goal of the digital supply chain is integrated planning and management of logistics systems and networks based on digital models, methods, and tools that are built on a common information and communication platform.

The introduction of digital logistics implies the availability of a developed digital infrastructure adapted to the business conditions of a particular country as a complex of technologies, products, and processes that provide computing, telecommunications, and network capabilities and work on a digital (rather than analog) basis.

The *basic components of the digital infrastructure* include a fixed: telecommunications infrastructure (backbone, distribution and local networks; public services infrastructure (electronic customs); transactional processing infrastructure (online payments, cashless tools, FinTech services); cybersecurity infrastructure; geoinformation infrastructure (linking digital data in spatial objects); life support infrastructure (transport services); open data infrastructure; interoperability infrastructure (API); data processing and storage infrastructure (cloud or virtual infrastructure); mobile telecommunications infrastructure (3G, 4G, radio and satellite technologies, Wi-Fi); e-commerce infrastructure (B2B digital purchase and sale platforms, e-contract, e-invoicing, e-supply chain); specialized infrastructure (special networks, video surveillance, satellite engineering systems); digital television infrastructure (terrestrial, cable, satellite); and European Isa standards (Digital Agenda, 2016).

Digital logistics should take into account such components as: logistics structure (which includes participants in the logistics process, inventory storage points, distribution centers, warehouse network); logistics processes and related activities (consumer relations management, service, and procurement); and information reporting systems (design, planning, control and coordination of information via the Internet and electronic data exchange). The use of these technologies will help integrate the activities of the parties into the logistics chain.

### **Key digital logistics technologies and advantages of their application**

*Cloud computing or Cloud Software/Services* – this is a technology for providing convenient network services in the on-demand mode to a collectively used set of configurable computing resources (networks, servers, data warehouses, applications or services). The user can quickly use them for their own tasks while minimizing the number of interactions with the service provider or their own management efforts. Cloud services for businesses eliminate the need to purchase hardware and software or access external data centers at all, reducing ongoing costs. Organizations typically charge a fee for providing cloud services, but this approach allows businesses to focus on their own strategy.

A typical example of cloud services in a multimodal transport environment is the electronic logistics marketplace (ELM), which brings together ICT web systems that connect consignors, carriers, and customers for spot trade in transport services (open ELM), or for information exchange and long-term cooperation (closed ELM) (Wang, 2016)

Today, we distinguish the following service models:

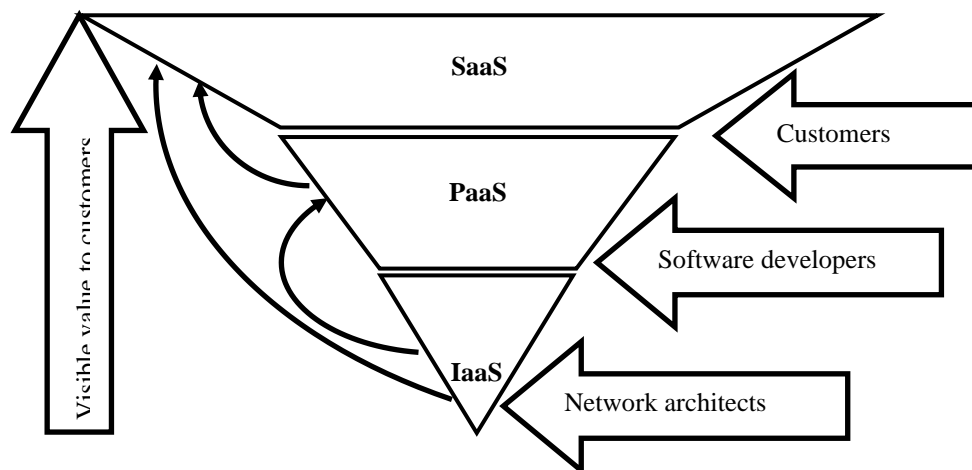
- *Cloud Software as a Service (SaaS)* – a software delivery model in which a cloud solution provider hosts customer applications. At the same time, the customer accesses their applications via the Internet. The advantage is that the customer does not spend money on maintaining their own

computing infrastructure, but uses a subscription to the service, which is paid in proportion to the volume of use;

- *Cloud Platform as a Service (PaaS)* – a model that provides customers with access to the development tools they need to create and manage mobile and web applications without investing in infrastructure support. The cloud service provider hosts infrastructure and middle-ware components, and the customer accesses these services using a web browser;

- *Cloud Infrastructure as a Service (IaaS)* – provides customers with access to on-demand infrastructure services via the Internet. The advantage of this model is that the cloud service provider provides remote access to infrastructure components that provide computing resources, storage, and network bandwidth so that customers can perform their workloads in the cloud. A cloud service provider subscriber is usually responsible for installing, configuring, protecting, and maintaining any software in the cloud infrastructure.

Models of working with the cloud environment for different consumer groups are shown in Figure 4.



**Figure 4. Cloud environment models for different consumer groups**

*Source: developed by the authors*

Cloud services are widely used by IT companies and system integrators such as SAP, Oracle, Infor, IBM, GenerixGroup, and Visagio.

For example, GenerixGroup uses the Generix Supply Chain Hub SaaS platform, which combines the capabilities of processing physical cargo flows, digitalizing information flows and processes of interaction between companies and their partners in real time. Infor is a global provider of business software that creates sets of cloud solutions and deploys easy-to-use technologies that apply data analytics and are easily integrated into existing systems. Oracle offers PaaS solutions with ready-made software components that enable developers to add new features to applications (in particular, artificial intelligence, chat-bots, blockchain, and the Internet of Things). This also includes solutions for analysts, end users, and administrators of Internet technologies, database management, system management, and security.

Cloud logistics is rapidly becoming popular: 50% of logistics service providers already use cloud services, and 20% plan to do so. As data is transferred to the cloud, logistics services become available as part of payment on demand. This means that small businesses no longer need to spend money on comprehensive IT solutions – they only pay for what they need, when they need it.

Services such as Shipwire and Freightly provide real-time cloud-based transport management systems. They cover all logistics processes from purchasing to billing, making the whole process easier and cheaper for companies.

The *main advantages* of the use of cloud technologies in logistics are as follows:

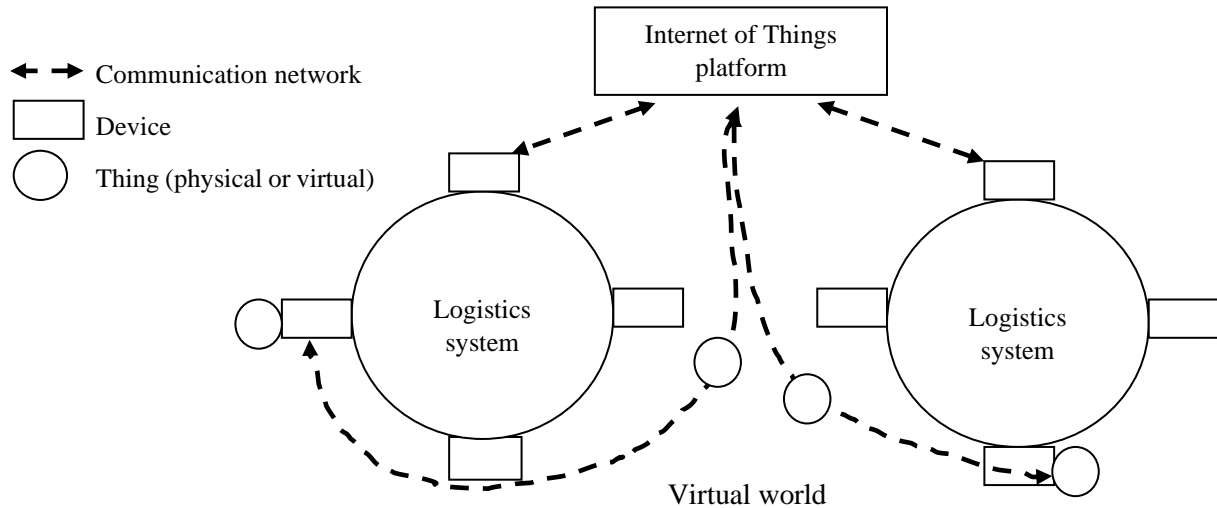
- cloud services make the automation of business processes in the supply chain more accessible;
  - cloud technologies enable supply chain participants to improve the speed and accuracy of implementing basic logistics business processes. In the case of an IT system failure, companies that do not use cloud services are forced to spend their own time on data backup and recovery, and this affects the speed of business processes;
  - TMS systems provide automated operational accounting of the current location of vehicles and the condition of the road and cargo, as well as data on the facts of delivery and shipment. This allows users to optimize routes and load vehicles online, provide operational and final reports on the implementation of logistics operations, and generate indicators for evaluating their effectiveness;
  - using cloud technologies, a single platform can be created for cargo owners and carriers. When placing an order, the cargo owner sets the main criteria (route, cargo type, weight, car type, etc.) and immediately sees offers from carriers that are members of the cloud platform;
  - the availability of complete, reliable, up-to-date information on all inventory flows in the supply chain;
  - accelerated turnover of goods, increased reliability of delivery, and increased level of service;
  - cloud services are hosted on remote servers, so if the central supply chain company (or any of its counterparties) develops and its branches open, then there is no need to buy software – one can work in the cloud from anywhere in the world;
  - cloud technology providers take care of the smooth operation of the IT system, providing automatic updates and rapid restoration of functionality in case of malfunction. Users of such services need not worry about the safety of information in case of failure (Antipina, 2018, p. 36).
- Compared to other technologies, *cloud computing* is the most conscious technology of cargo transportation. For small and medium-sized businesses, it offers a high level of security and provides an opportunity to experiment and launch new services and products much faster.

The *Internet of Things (IoT)* is a dynamic network system where each technological device has an identity, physical attribute and virtual personalization, with self-tuning capabilities based on standard and communication protocols (Kramp et al., 2013, p. 2). The IoT makes it possible to connect technologies to a conventional device (home appliances, microwave, home theater, car, etc.) and use them online (Whitmore et al., 2015). It also offers significant potential for the public and private sectors, enabling innovative applications to overcome common problems that exist in many industries. Furthermore, it is able to collect and transmit information from all devices capable of connecting to the Internet via Wi-Fi, sensors, Bluetooth, GPS, cellular networks, technologies using radio frequency identification (RFID) chips, etc. Ben-Daya et al. (2019) define the IoT as “a network of digitally connected devices that can communicate with each other and facilitate the planning, control, and collaboration of supply chain processes and chain between partners.”

In essence, the IoT is a combination between a technological innovation and a person’s desire for constant and ever-increasing connection with everything that happens in the internal and external environment, as everything is concentrated in one device that extends to the entire environment.

Logistics was one of the first industries to use IoT technology to implement intelligent, networked and automated logistics operations, where the Internet acts as a necessary tool.

A model of association of logistics systems based on the IoT is shown in Figure 5.



**Figure 5. A model of the interconnection of logistics systems based on the Internet of Things**

*Source: Morozova (2021)*

The IoT allows intelligent logistics management and combines transportation, storage, packaging, loading, unloading and other components of the logistics process into an integrated system with the lowest cost.

At the same time, the IoT not only allows different systems to be combined into a single whole, but also to effectively interact through various communication networks, creating elements of intelligent logistics. The IoT is expected to be a prerequisite for profound changes in the global supply chain through intelligent cargo movement. This will be achieved through the continuous synchronization of supply chain information and the smooth tracking of objects on the road in real time.

The areas of application on the IoT in logistics are as follows:

- connected transport (full transparency of movement, control of the driving mode, increasing the utilization of vehicles, and strengthening driver discipline);
- fleet management (adaptation of service to operating conditions, automatic dispatching, and integration with ERP systems);
- autonomous transport (driver support assistants, self-driving metro, autopilot of traffic on the highway, and promising systems of full autonomy);
- ensuring security (friend-foe identification, the prevention of fuel theft and misuse of vehicles, and the availability of data for investigation of events);
- asset tracking (control of the location and movement of goods, instant inventory of the warehouse and sales area, and visibility of goods throughout the entire supply chain);
- smart infrastructure (centralized management, monitoring the condition of pipeline elements, and monitoring the load and wear of an axle);
- warehouse automation (robots that move racks of goods, fully automatic warehouse systems, and promising autonomous forklifts);
- asset monitoring (tracking key parameters, instant responses to status changes, and data availability throughout the entire supply chain).

Logistics is the most promising area for IoT implementation. This is confirmed by the successful practice of using the IoT. In this vein, IBM and Colombian logistics operator AOS have

implemented a platform that uses the IoT to track and obtain information about each vehicle that transports goods. IBM Blockchain, Watson IoT, and IBM Cloud technologies were used to develop this system. AOS trucks are equipped with special IoT sensors for assigning RFID tags. Each label contains information about the carrier, cargo, location at a specific time, and availability of space in the truck – this is how the IoT improves transportation. The necessary information is recorded on the blockchain, which allows the company to quickly receive it, while providing the company with reliable protection against unauthorized access. This IBM solution reduces the impact of the human factor and significantly speeds up the processing of handling information (Ardas, 2019).

Thus, the *advantages of using the IoT* in logistics are:

- optimizing the use of company resources, as personnel, machinery and equipment are used more efficiently and economically, which reduces costs;
- reducing the negative impact of the human factor. Unfortunately, people cause most accidents. Losses, theft, forgery, and replacement of products during delivery – all of these problems threaten not only the company’s revenue, but also its reputation. The IoT will improve delivery security and create a new job market;
- controlling transport. Through the use of the IoT in transportation, companies have information about the location of a particular cargo at any time, which allows them to accurately determine the delivery time, as well as monitor the condition and change the parameters of the cargo depending on the current situation.
- identifying road situation parameters, as monitoring weather conditions, roadway cover, and temperature allows companies to avoid problems with the loss of goods or irrational time spent on cargo delivery;
- controlling climate in storage areas;
- its high usage potential. Thanks to the introduction of the IoT in logistics, the field has experienced a revolutionary breakthrough in recent years.

*Artificial intelligence (AI)* is a set of related technologies that make machines do things that mimic the human thinking process. AI can expand and strengthen human abilities and skills, and its technologies are a valuable business resource in today’s environment of information technology. The use of AI helps to meet the demand of ordinary citizens for better-personalized goods and services and allows officials to save time on routine tasks, ensuring the search for creative and innovative approaches to improve services (Khmarska et al., 2021, p. 46).

Studying AI is based on the results of research on the theoretical principles of the functioning of neural networks, signal recognition, and images which were developed several decades ago. Technologies in the field of neurocybernetics were created by American scientists U. McCulloch, V. Pitts, and F. Rosenblatt (1958). The first successful results of neurocybernetics allowed scientists to move forward in the direction of solving individual problems of modeling human functions. The most significant breakthrough in the development of AI research occurred in the global scientific society in the mid-2000s. This was due to some factors: first, progress in the performance of information processing algorithms due to the development of deep learning technologies; secondly, the powerful growth of data of various types (text images, map data, etc.) and technologies, which provided almost unlimited opportunities for storing and accessing such data. Today, AI is increasingly penetrating various business models and processes of national and global economies. “These innovative digital technologies become more efficient and productive as they are together incorporated into new products and services. AI integrated services modify the job done, improves productivity and work conditions while minimizing human intervention during

the operation” (EGE 2018). In the near future, the use of AI technologies for the analytics of service solutions in the business and social spheres is expected to increase.

The key directions in the development of AI technologies in the modern world are reflected in Table 1.

**Table 1. Key areas of the development of artificial intelligence**

*Source: developed by the authors*

<b>Direction</b>	<b>Explanation</b>
Intelligent data management solutions	More and more business applications and VI systems have created advanced opportunities for the development of artificial intelligence, and the popularity of business solutions based on artificial intelligence is increasing every year.
Automating connected devices	Autonomous systems in industry, agriculture, and mining will continue to be expanded with partially or fully robotic systems that connect people, machines, and businesses.
Natural language management platforms	The ability of user interfaces to interact with humans will gain popularity in every type of business application. The main focus will be on increasing the understanding of human language and its generation.
Event-driven business systems	The enterprise will gradually implement event-driven business models. In these models, the cloud, IoT, and mobile communications will use artificial intelligence technologies.
Chat bots	Numerous companies are already moving towards AI chat bots and other virtual assistants to solve daily work tasks, quickly analyze customer and supplier requests, and be able to respond to customer requests in a timely manner.
Automation of business processes	The steady growth of data generated by the IoT will force companies to engage in machine learning for data processing and analysis.
Deep processing of big data	Artificial intelligence technologies allow companies to conduct a deep quantitative and qualitative assessment of large amounts of data at a high professional level and without human intervention. The mass use of such technologies will significantly change basic science.
Neuro-crowdsourcing and networking communities	Due to the unique market and the Neuromation synthetic data platform, market participants are expected to migrate from an open, unorganized market to an organized and automated platform service in the near future. In partnership with Neuromation, companies will develop the consumer, retail, medical, manufacturing and robotic sectors
Computer vision	Image analysis based on regular image decomposition (segmentation), using the example of deep learning or AI for object recognition. The main growth factors of the computer vision market are the need for quality control in absolutely all areas of activity, including for the development of national security. Computer vision algorithms are designed to detect behaviors (patterns), recognize emotions and relationships, identify differences, and understand intentions. Once this is achieved, cameras will be able to provide real-time visual data for analysis for various purposes.

In logistics, AI is already widespread thanks to the introduction of advanced technologies such as Amazon automated warehouses, Einride autonomous trucks, Zipline drones, Starship last-mile delivery robots, and others. These types of technologies can potentially replace some types of manual work that do not require complex skills (for example, sorting in a warehouse, delivering the last mile, driving trucks, etc.)

In its current state, AI helps logistics specialists in real-world logistics operations by using intelligent alerts based on predictive analysis. For example, from sources such as MarineTraffic, companies can get real-time and estimated arrival time (ETA) status information for each vessel in the world based on satellite data (Swan, 2015).

In order to improve the efficiency of the logistics business, AI technologies can: extract the relevant part of data and link it with internal data, which can be very complex due to its poor quality;

determine what events matter from a huge amount of data; formulate decision-making proposals and inform specialists regarding planning the proposed solution at the right time and place; predict the arrival time of trucks depending on traffic conditions; predict container repair requirements based on impact detection GPS trackers; predict damage to cargo and insurance requirements based on temperature sensors; predict the illness days of warehouse employees based on public holidays and weather conditions, etc.

Therefore, the use of AI in logistics aims to speed up all processes, ensuring their accurate and smooth execution. The use of paper, office supplies, opaque supply chains, remote cargo transportation – all of these are the realities of our time, which lead to significant costs in energy, materials, money, and time. AI changes the logistics market, making it transparent, more reliable, and efficient.

*Robots, drones, and autonomous systems.* The concept of robotics was defined by Brady (1985) as a reasonable relationship between perception and action. Since this connection is reasonable, the role of AI in robotics is very important, because it is AI that solves the problem of working with real objects in the real world of robotics research. Brady (1985) noted that “robots have vision, strength, and tactile sensation, proprioceptive senses of the robot’s inner state. The arms, wheels, grippers, and legs are the mechanical parts that allow the robot to function.” That is, from a technical point of view, a robot consists of two components: a mechanical one that performs certain work operations, replacing a person in production processes; and a software one that controls the robot in automatic or automated mode.

Until recently, robotics technology did not have a sufficient impact on logistics, but today, in the context of the COVID-19 pandemic, the use of robots has significantly intensified. The main economic reason for the introduction of robots in various production operations is that their execution without direct human participation is cheaper when comparing the timing and quality of work performed.

In logistics, robots have come to be used to perform common and repetitive tasks that require complex programming to configure and implement. Over time, the areas of application of robots in logistics operations and supply chain management have expanded. Most of this work is in such functional areas of logistics as warehouse logistics and production. Numerous warehouse and shipping companies are taking advantage of IT and implementing robotics, automated systems, and AI in their business models. If this is the use of robots at logistics infrastructure facilities (logistics centers, public warehouses, distribution centers, cross-docking in terminals, etc.), then robotic equipment is very diverse: from fully automatic and highly mechanized warehouses to robots that perform individual operations of warehouse cargo handling.

Unlike the manufacturing sector, logistics copes more effectively with the problem of adapting various orders from a large number of customers. Since orders in the delivery sector are unique in terms of sorting, packaging, and delivery, the process equipment must be equipped with intelligent functions. This helps firms to better focus on delivery, take into account the requirements of each customer, and improve the level of service by delivering the necessary goods to the right place at the right time. Furthermore, large order volumes encourage companies to use automated and intelligent systems for delivery in order to reduce lead times (Wen et al., 2018).

The rapid development of artificial intelligence and robotics has created prerequisites for the use of intelligent warehousing in logistics and drones for the delivery of goods. Due to this, companies are able to reduce the time spent on delivering goods and significantly improve the quality of customer service. Among the companies that produce drones for industrial use, including logistics, are DJI, Delta Drone, Flytrex, Flirtey, Matternet, Project Wing and others. Well-known companies such as Amazon, Google, Dodo, DHL, UPS, etc. are implementing drones in logistics. They are

mainly used at present for delivering parcels weighing up to 8–10 kg and over short distances, on a segment of the route which is called the last mile in logistics, but they do not stop there.

For example, Amazon, the largest e-commerce company in the USA, has acquired a patent for a large, high-flying airship that can be used to dispatch drones and then deliver goods to Amazon customers. Since 2013, work has been carried out on the Amazon Prime Air project, which provides for the delivery of goods to customers using octocopters (drones with 8 propellers).

Additionally, 3PL provider Geodis, together with Delta Drone, has developed a fully automatic inventory replenishment and inventory kit using drones. The kit consists of a ground robot and a silent ATV drone with four high-definition cameras. This intelligent solution allows users to calculate and report data on product balances in real time, as well as process data and integrate it with the warehouse information system.

Along with this, the use of drones has a number of disadvantages:

- privacy and security. Using drones to deliver goods around a city (first and last miles) is the most tangible and impressive future benefit for logistics, but it is also a source of problems. Due to the fact that privacy and security issues are growing in densely populated cities, the most difficult aspect, from a moral point of view, is creating the necessary conditions for logistics infrastructure and integrating them into the urban transport network;

- legislation. There are a number of bills that restrict drone flights in different airspace;

- “issues in the air.” There are cases when drones collide with birds in the air, which fall into their blades.

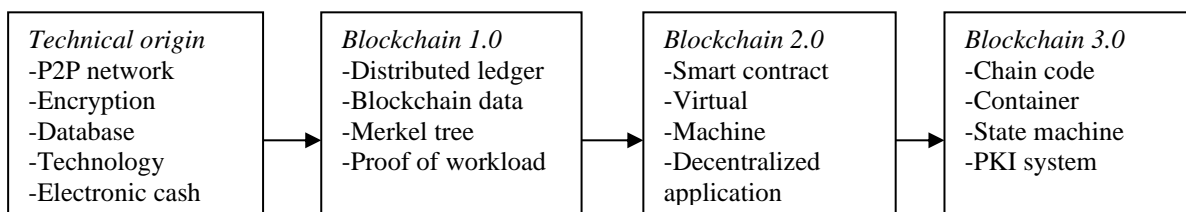
- “issues on earth.” States today face the problem of vandalism and theft of drones. In addition, users can track the drone only by its last location, since there are always blind zones if cameras are used;

- “fighting with nature.” A car, train, or person can withstand weather conditions to some extent, but the weight of drones is too small to withstand wind or rain.

Despite a number of challenges in using drones, cost savings and high delivery speeds are two of the main factors contributing to the spread of drone use in supply chains. Commercial drones are still being developed and used, but they are already considered a technology that will disrupt the usual order of operation of product delivery services in the future.

*Blockchain technology* was first proposed by Nakamoto (2008) in his work “Bitcoin: A Peer-to-Peer Electronic-Cash System.” At the heart of the creation of blockchain technology, the idea is that there should be no centralized control of information or even censorship at the network level, but at the same time, networks should be open to everyone, and all users should be able to make anonymous transactions. Blockchain is a distributed database where data storage facilities are not connected to a general server. This database stores an ever-growing list of ordered records, called blocks. Each block has timestamps and a link to the previous block. The use of encryption ensures that users can only change those parts of the blockchains that they own – in the sense that they have private keys, without which writing within a file is impossible. In addition, encryption ensures that copies of the distributed blockchain are synchronized across all users. Thanks to the wide application possibilities of blockchain technology, many large companies have improved their business models or operating modes and received many new features. Currently, blockchain technology has passed four stages in its development (Figure 6).

Achieving excellence in the organization of the supply chain involves cooperation with a large number of parties, as well as complex information and financial flow. This leads to a delay in cost, non-transparency of agreements, and non-standard situations. Such problems can also arise due to processes that are manually regulated by control authorities.



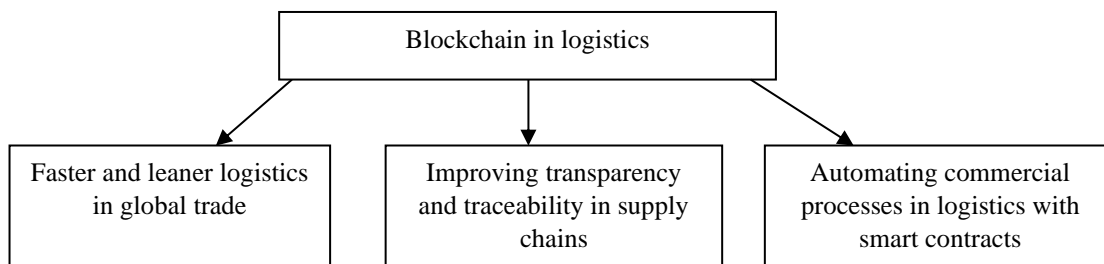
**Figure 6. The development stages of blockchain technology**

*Source: Swan (2015)*

For example, logistics companies often have to draw up paper documentation when passing through customs processes. Accordingly, this makes it difficult to track the passage of goods along the supply chain, check the goods that are being transported, and be able to quickly respond to unforeseen circumstances, causing issues in the organization of international trade. Blockchain technology can help to overcome a large number of logistics issues and improve the efficiency of the logistics process. Being a transparent public register, blockchain is able to offer clients and auditors simple and effective tools for tracking the entire route.

A significant number of companies around the world have already implemented and are using blockchain technology in their work. For example, the BASF Corporation, together with the blockchain startups Quantom and Ahrma, created, on the basis of blockchain technology, platforms for tracking cargo delivery and commissioning smart containers that send information about the status and integrity of the order and the loading process. Kuovala Innovation has implemented smart contracts on its own Kinno platform (a computer algorithm designed for concluding and maintaining commercial contracts in blockchain technology). This approach assumes that the user places an order for sending cargo equipped with an RFID tag, and that other system participants set delivery terms. The winner of the contest receives a contract, which is registered and tracked in the blockchain. Payment based on smart contracts is made automatically. Smart contracts are able to provide better reliability of the agreement than lawyers and traditional law, as well as completely eliminate ambiguity in the interpretation of the terms of the agreement. The Ukrainian online platform A2B Direct is the so-called “cargo Uber,” which allows users to track cargo movement around the clock and provides a full cycle of electronic document management.

One of the most important aspects of blockchain is that it can only provide its advantages provided that all participants in the logistics chain have access to the network (Figure 7).



**Figure 7. Key blockchain use cases in logistics**

*Source: developed by the authors*

The main features of the implementation of blockchain technology are the following: ensuring the uninterrupted supply of information between partners and improving the quality of processes at the

same time; increasing the degree of trust among all elements of the chain; and simplifying the process of making and transmitting decisions at each stage, mainly through providing single access to digital information, which provides an opportunity to collectively predict the process and activities.

The *advantages of implementing of blockchain technology in logistics* include:

- the ability to track goods from the place of production to the final consumer and protect buyers of products from non-original goods and deception, which allows the buyer to be confident in the decision to purchase goods;
- dispersal, which allows all elements of the logistics chain to participate in real time by tracking the movement of transport or purchased goods, processing the necessary package of documents in the form of smart contracts, and destroying illegal elements during the delivery process;
- security, due to the use of cryptography and the absence of the possibility of making changes to the delivery process by elements.

*Immersive technologies and 3D printing.* Immersive technologies blur the line between the physical and digital world, creating a sense of immersion.

Related terms are:

- Virtual Reality (VR) – creating a virtual environment that is provided to the human senses in such a way that the human perceives the environment as if they are in it;
- Augmented Reality (AR) – a type of virtual reality in which virtual objects are superimposed on a real environment (Azuma et al., 2015). AR must meet three requirements: combine virtual and real objects in a real environment, work interactively, and register real and virtual objects in real-time;
- Mixed Reality (MR) – a technology that combines VR and AR. This allows a person not only to navigate in the surrounding space, but also to create this space, filling it with important or useful information.

The main differences between VR, AR, and MR are shown in Table. 2.

Immersive technologies work in conjunction with cloud storage and the Internet of Things (IoT). Those devices that are worn by humans (for example, glasses, helmets) generate large amounts of IoT-related data, which must be stored and processed in real-time. This requires the use of cloud storage and cloud computing. Augmented reality devices should also read information about the environment and send it to a cloud-based analytical system.

**Table 2. Key differences between VR, AR and MR**

*Source: McMillan et al. (2017)*

	<b>Virtual Reality (VR)</b>	<b>Augmented Reality (AR)</b>	<b>Mixed Reality (MR)</b>
Display device	Special headset or smart glasses	Headsets optional	Headsets optional
Image source	Computer graphics or real images produced by a computer	Combination of computer-generated images and real-life objects	Combination of computer-generated images and real-life objects
Environment	Fully digital	Both virtual and real life objects are seamlessly blended	Both virtual and real life objects are seamlessly blended
Perspective	Virtual objects will change their position and size according to the user's perspective in the virtual world	Virtual objects behave on basis of the user's perspective in the real world	Virtual objects behave on basis of the user's perspective in the real world

Presence	Feeling of being transported somewhere else with no sense of the real world	Feeling of still being in the real world, but with new elements and objects superimposed	Feeling of still being in the real world, but with new elements and objects superimposed
Awareness	Perfectly rendered virtual objects cannot be distinguished from the real deal	Virtual objects can be identified by their nature and behavior, such as floating text that follows a user	Perfectly rendered virtual objects that cannot be distinguished from the real world

Currently, research on the use of immersive technologies in logistics is quite limited. However, their impact on logistics is obvious. Prospective areas of the application of immersive technologies in supply chains are: providing on-the-job training, real-time instruction, navigation, warehouse planning, warehouse order acquisition, dynamic traffic support, and digital interaction with customers and partners. The integration of augmented reality with technology such as voice selection makes it possible to increase labor productivity and change the way we perform official tasks (Merlino & Spröge, 2017).

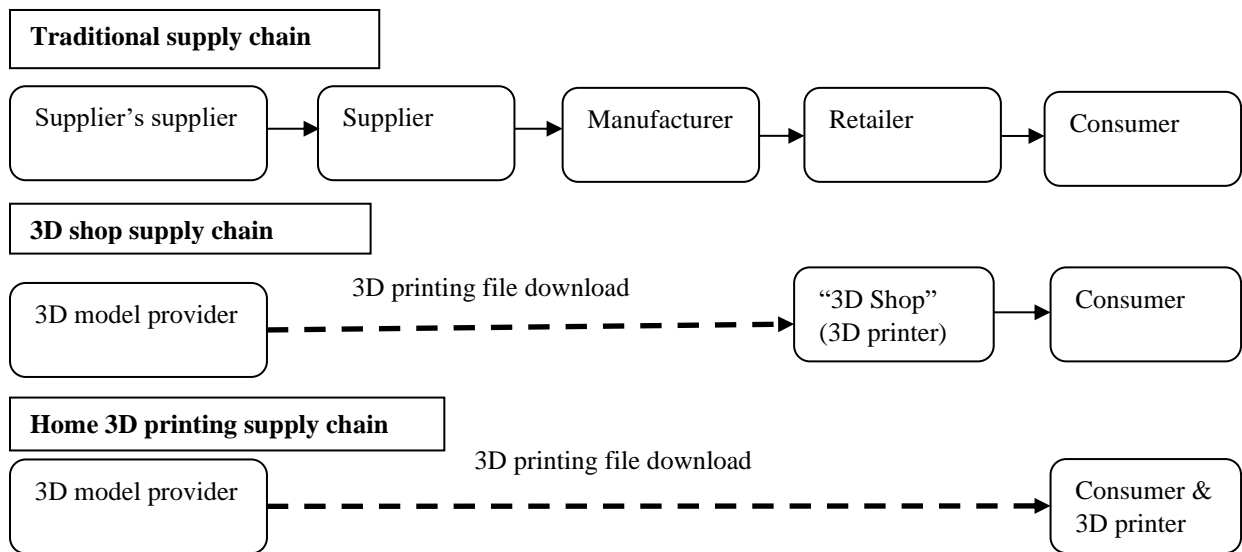
*3D printing* is a process used to create a three-dimensional object using various materials via a highly specialized printer. It can be carried out in various ways, but is based on the principle of the layer-by-layer creation (growing) of a solid object from the bottom up.

More than a hundred materials can be used for 3D printing today, including plastic, glass, metal, wax, various adhesive mixtures, clay, human tissue, and so on. This technology can be used for the production of spare parts, bio-structures, and jewelry. Expanding the possibilities of using different materials allows the scope of application of 3D printing to be expanded.

Currently, the usage volumes of 3D printing on a global scale are very small – only 0.02% – meaning that this technology does not have a significant impact on the logistics sector. However, according to a study published on the website of the German company Ernst & Young Global Limited, the degree of penetration of 3D printing technology worldwide has grown from 24% to 65% in recent years. The market leaders are currently South Korea and China where, respectively, 81% and 78% of companies use 3D printing. Third place in the world in terms of the penetration of 3D printing technology is Canada, with 77%.

Recently, there have also been warnings that the rapid development of 3D printing and especially its spread in industry can negatively affect the logistics and transport industries. In the near future, 3D printers will become more accessible to everyone. Due to the fact that many goods can be produced at home, there will be a reduction in the volume of cargo transportation that uses different types of transport, and the need to use warehouses will decrease. However, it is possible that these warnings will not be justified, because 3D printing requires a special working material that serves as the basis for making these objects. This material will still need to be delivered using a logistics chain – whether from the manufacturer to the retailer or directly to the customer. The disappearance of the logistics sector may not be discussed, then, but changes will occur in any case.

Wieland (2014) showed how much shorter the supply chain becomes when 3D printing is applied (Figure 8).



**Figure 8. Supply chain with 3D print shop**

Source: Wieland (2014)

The *advantages of using 3D printing* in logistics are numerous:

- accelerating production and at the same time reducing transportation and storage costs;
- potentially reducing import or export costs, sea freight, and brokerage costs due to localized production;
- avoiding large and expensive equipment in factories;
- retaining a customer focus. The consumer can individually modify the desired product and sometimes participate in prototype testing, at no additional expense;
- improving production efficiency by reducing material and energy costs;
- reducing the negative impact on the environment. The number of trucks on the roads that carry goods to customers will decrease and, accordingly, the number of emissions into the atmosphere will decrease.

The economic benefits of the mass implementation of *3D printing* in logistics are quite significant. This technology can significantly affect the relationship between manufacturers and sellers, which in some sectors may cease to exist altogether, or may lead to the creation of warehouses for manufacturers who don't have their own inventory. The manufacture of products for individual orders directly on the spot and close to the consumer will reduce inventory and transit costs.

As a result of direct communication with the consumer via digital technologies, significant business expansion, the development of the ability to model human behavior, and the direct interaction of companies with the consumer will allow logistics to function most effectively within the three-component environment-business-person interaction.

## Conclusions

The digital transformation of logistics can be characterized as a new mechanism for the accelerated systemic development of economic systems, built on effective information connections and optimized, value-based data flows necessary for solving operational and strategic business tasks

The economic efficiency of logistics today depends on the use of digital technologies that allow us to apply new technological solutions, optimize the technological process, and improve economic performance by implementing previously unattainable measures. Logistics processes during all periods of development have been accompanied by information flows, but only digital logistics has allowed us to move to a new stage of relations between the parties in the supply chain. Fast information exchange, computerized business solutions, and the ability to process and analyze large amounts of information in real time provide a new level of business relations and customer orientation.

Ultimately, digitalization increases: the efficiency of logistics processes in the field of customs and border clearance (speed, simplicity, and predictability of formalities); the quality of infrastructure related to trade and transport; the simplification of the organization of international transportation at competitive prices; the quality and competence of logistics services provided by market operators; and the tracking of the passage and timeliness of cargo delivery. The integration of ge-positioning systems that allow users to monitor the location of vehicles and radio frequency coding (RFID) systems into logistics creates a new arena for digital logistics. Internet of Things technologies based on data received from sensors allow users to reload containers in time and to select the best transportation routes.

The transformation of conventional logistics systems into smart (digitally visible) logistics systems and the optimization of logistics processes creates various effects.

*Technological effects.* Digital logistics increases the level of progressiveness of the technologies used. Due to the improvement of the quality of the technological processes of the logistics business, the service time and speed of cargo delivery are reduced.

*Competitive effects.* Those logistics companies that use digital technologies to service the supply chain are well above other companies, have a larger share of the logistics market, and, accordingly, attain increased profits. The customer base increases due to the high quality of service, reduced waiting times for documentation processing, and so on.

*Commercial effects.* Thanks to the digital transformation of logistics, traffic volumes are increasing, new information services are emerging, productivity is increasing, resources are being saved, and the share of logistics costs are being reduced.

*Socioeconomic effects.* Thanks to digitalization, the organizational structure of companies is being improved, working conditions are being improved, the volume of paper documentation and the number of management personnel are being reduced, and transportation management decisions are becoming more efficient.

Thus, this study shows that digital transformation has opened up significant opportunities for the development of digital logistics and the optimization of the supply chain.

Prospects for further research are to determine the factors of influence and the impact of digital logistics on the innovative development of business processes at the regional, national, and international levels.

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