7. E-LOGISTICS

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This chapter is devoted to the most important issues related to e-logistics. The chapter not only defines this concept but also presents it in a broader context of the possibilities offered by data analysis to optimize logistics processes. The chapter includes topics such as:

- the context in which e-logistics operates, including the concept of e-business,
- basic definitions of e-logistics,
- development of e-logistics,
- modern e-logistics technologies and tools,
- practical e-logistics solutions.

7.1. Introduction

The development of digital technologies has a long history. Therefore, it cannot be said that digital solutions or sharing information in supply chains is a modern solution. On the contrary, from the perspective of time and the point of view of professionally active people, the digital aspect is already a mature solution that has become a permanent part of the course of logistics processes. In other words, we can no longer imagine, let alone operate in logistics without a parallel flow of digitally recorded information.

The modern economy is called the post-industrial economy or the digital economy. However, this does not mean that the flow of materials has been completely stopped or abandoned. It is the flow of materials that is key to economic turnover and consumption. This will continue to be the case as long as people's needs are met by material goods. Of course, some people's needs can be met by digital content, but in the foreseeable future, it will not be possible to meet all people's needs with digital goods. Thus, it seems that the coexistence of material and digital flows will constitute an inseparable tandem for the next decades. The term digital economy is intended to emphasize the role and scope of material and information flows. As will be shown in this chapter, digital flow is becoming increasingly important for building

conditions that improve the efficiency of material flow and thus improve the competitive position of specific enterprises and entire supply chains.

E-logistics is therefore a solution that fits into the mainstream of the modern economy. It is both a response to the requirements of the modern economy and a solution that provides new opportunities for doing business.

7.2. E-business

E-logistics is a solution operating within the broader concept of e-business. E-business can be loosely defined as a business process that uses the Internet or other electronic medium as a channel to complete business transactions (Jayashankar et al., 2003). Within e-business, we can distinguish such detailed activities as: e-commerce, e-advertising, e-marketing, electronic banking, electronic auctions etc. In these types of business activity, the adjective "electronic" indicates that these activities are carried out strictly in electronic (digital) form using the Internet, mobile connection etc. (Skitsko, 2016). The location of e-logistics within e-business and other concepts using data transmission via the Internet is presented in Figure 7.1.

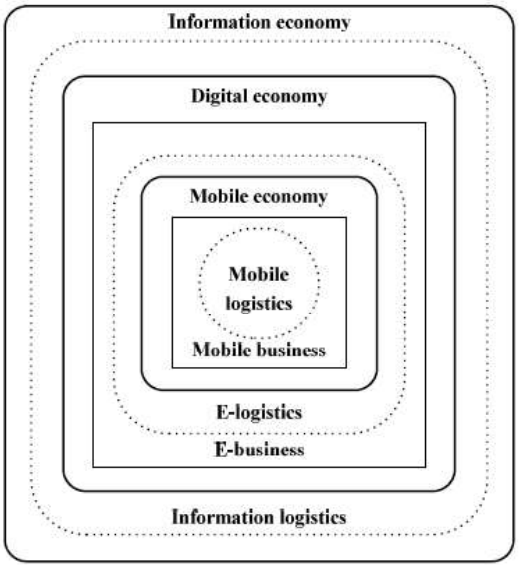

Figure 7.1 E-logistics in concept of e-business

Source: Skitsko (2016)

Within e-business, there are several basic models of communication between market participants (Shemet, 2012):

- B2B (business-to-business). In this model, there is interaction among the companies (enterprises, legal entities) intending to obtain various benefits.
- B2C (business-to-customer). In this model, the company interacts with its end consumer.
- C2C (customer-to-customer). In this model, people (physical persons) interact with each other with the help of various communication means and technology.
- C2B (customer-to-business). In this model opinions or ideas of the end consumers expressed by various means, in particular, on various Internet forums, social media, email etc. considerably influence the products making (their characteristics, features, price etc.) by the producer.
- B2G (business-to-government). In this model, the company interacts with the state administrative organs.
- C2G (customer-to-government). In this model, there is interaction between a person and state administrative organs.
- G2B (government-to-business), G2C (government-to-customer). In these models state administrative organs provide the companies (enterprises) and physical persons with information services via Internet.

The impact of the development of data processing technologies and the Internet on supply chains can be distinguished in three areas (Jayashankar et al., 2003):

- development of systems supporting enterprise management (ERP) and material flow planning (APS);
- development of systems supporting the business decision-making process that operates in real-time;
- sharing information between enterprises.

All of the areas mentioned above also occur in the context of implementing logistics processes, which became the basis for the creation of the e-logistics concept.

7.3. Definition of e-logistics

At the outset, it is difficult to provide a single definition of e-Logistics. This is because it is a concept very closely linked to the technical possibilities of acquiring, collecting, processing and transmitting data and information. Therefore, the definitions of this concept have changed over time and will probably continue to change.

„E-Logistics is a dynamic set of communication, computing, and collaborative technologies that transform key logistical processes to be customer-centric, by sharing data, knowledge and information with the supply chain partners." (Wang et al., 2004)

Another interesting definition, although narrow in scope, is presented by a team of authors Quirk, Forder and Bentley. *„E-Logistics is using Internet-based technologies for supporting the acquisition of material, warehousing, transportation and enables distribution through routing optimization with inventory tracking"* (Quirk et al., 2003)

Both of the above definitions focus on the aspect of data that accompanies the flow of materials in supply chains. The task of e-logistics is, therefore, to track the flow of materials to better control it and provide information about this flow in real-time to all its stakeholders, which in turn will enable the synchronization of this flow in the supply chain (Mangiaracina et al., 2015).

According to another definition, e-logistics are logistic processes implementing the flow of products purchased in electronic sales channels (Erceg & Damoska Sekuloska, 2019). An illustration of this way of understanding e-logistics is presented in Figure 7.2.

Figure 7.2 E-logistics

Source: Moroz et al. (2014)

By comparing both approaches to defining e-logistics, the basic characteristics of traditional logistics and e-logistics supporting the flow of materials in e-commerce were compared. The results of the comparison are presented in Table 1.

Table 7.1 Basic differences between traditional and e-logistics

Scope	Traditional logistics	E-logistics
Shipment type	Bulk	Parcel
Customer	Strategic	Unknown
Customer service	Reactive, Rigid	Responsive, flexible
Distribution model	Supply-driven push	Demand-driven pull
Inventory / Order flow	Un-directional	Bidirectional
Destinations	Concentrated	Highly dispersed
Demand	Stable consistent	Highly seasonal, fragmented
Orders	Predictable	Variable

Source: Song & Hou (2004)

To sum up the above definitions, their similarities should be pointed out. Logistics activities carried out for the needs of material flow are very similar to each other, regardless of whether they concern traditional flow or those carried out within e-commerce. When describing e-logistics, it should be noted that in both approaches, this concept is related to the flow of data describing the material flow. The basic functions of e-logistics are the same for both areas (Skitsko, 2016):

- formation of an information environment in which interact the participants of the logistics chain of goods supply;
- definition of characteristics of electronic information flows;
- formation of requirements and needs to the companies which provide information and communication services and corresponding connections;
- organization of the use of international standards of product identification;
- maintenance of correct and reliable operation, development of the information system of the company;
- collection, analysis, storage, transformation and organization of information transfer in electronic form;
- selection of the necessary data for management decision-making.

The implementation of these functions would not be possible without digital technologies that enable the collection, collection and analysis of data. The description of the most important of them, which had the greatest impact on the development of e-logistics, is presented in the next subsection.

7.4. Development of e-logistics

Based on the presented definitions, it can be clearly stated that the beginning of e-logistics dates back to the times when the first IT systems supporting the management of material flow, material requirement planning (MRP) and distribution resource planning (DRP) systems were created. These systems began to develop in the 1960s. They were the first solutions for the parallel flow of materials and digitally recorded information. The following years saw the dynamic development of these systems, which led to the creation of enterprise resource planning (ERP). In parallel, systems dedicated to individual logistics functions were developed: transport management systems (TMS) and warehouse management systems (WMS) (Wang, 2016). More details on IT systems can be found in Chapter 6 of this handbook.

The development of ERP systems, and especially the concentration of data and the multidimensionality of this data, allowed the creation of decision support systems (DSS) (Turbanet al., 2002). The development of the Internet and the possibility of exchanging data between the systems of individual enterprises initiated the development of ERPII class systems allowing for the integration of data between partners in supply chains (Møller, 2005). Data exchange between partners is possible thanks to the Electronic data interchange (EDI) solution (Huang, et al., 2008).

Another milestone in the development of e-logistics was the creation of electronic marketplaces (EM). The creation of platforms connecting enterprises directly with customers (and other configurations presented in the subsection on e-business) allowed for the creation of new business models and thus requirements for logistics (Wang, et al., 2007).

In parallel with the development of EM, systems for collecting and analyzing large data sets were developed, allowing for the implementation of computing processes in the cloud. The development of big data collection technology and the possibility of analyzing it and sharing analytical tools and analysis results remotely via the Internet has provided completely new possibilities, especially in the area of information supply to DSS and, consequently, the possibility of optimizing logistics processes, especially in such areas as: forecasting, inventory management, transport management and human resources management (Waller & Fawcett, 2013). To sum up the development of digital technologies used in e-logistics, we can use the observation of the authors Merali, Papadopoulos and Nadkarni (2012), who presented four-step changes in ICTs since the 1960s, which had a major influence on the e-logistics development (Merali et al., 2012):

- connectivity (between people, applications, and devices);
- capacity for distributed storage and processing of data;
- reach and range of information transmission;
- rate (speed and volume) of information transmission.

Undoubtedly, the above-mentioned steps in the development of ICT technologies have influenced the possibilities of the practical application of digital solutions in logistics processes. These changes also clearly present the direction in which digital technologies are developing. The technologies that are currently used in e-logistics are described in more detail in the next subchapter.

7.5. Modern technologies supporting e-logistics

The development of Industry 4.0 and Logistics 4.0 provides additional opportunities to expand the solutions and services offered within e-logistics. Among the main technologies supporting e-logistics are currently:

- Blockchain;
- Internet of Things and sensors (IoT);
- Generative Artificial Intelligence (AI);

Blockchain is a distributed database system between all participants in the same network. This system records and stores data in the form of linked blocks forming a collection of records. They are permanent and therefore cannot be deleted. It is important to know that there is no possibility of making updates or any modifications. However, it is possible to add or read a recording (Dutta et al., 2020).

Blockchain technology makes it possible to track different transactions along the whole supply chain in a secure and traceable manner. The documented transactions and data are irrevocably stored in the blockchain and cannot be used or read without consensus. Every time a consignment is being transported or handled, the transaction can be documented, creating a permanent history from the manufacturer to the trader or consumer (Aritua et al., 2021).

The Internet of Things (IoT) allows non-computer devices to communicate with each other. The concept is based on a wide range of technologies, from communication protocols through sensors collecting data, infrastructure enabling data transmission to systems analyzing the collected data (Minerva, 2015). IoT solutions are often combined with RFID (radio-frequency identification) sensors, giving the possibility of not only local identification of goods or cargo but also transferring this data to any user. IoT solutions can be created in two variants (Idrissi et al., 2022):

- Internet-centric – the main element of the system are services offered in cloud computing and the system objects are data providers;
- Object-centric – a solution in which the central point of the network is object that can be controlled using messages transmitted over the Internet.

IoT solutions are widely used in logistics. The IoT makes it possible to trace various information to control the quality of the goods such as light, humidity, temperatures, vibrations, shocks, etc. (Dash et al., 2019). For example, at Maersk, a container carrier wishes to market a service

that requires additional insurance on the whole journey. The transport conditions (vibration, temperature, humidity, magnetism, position, etc.) can be monitored in the instrumented container. This information can be also uploaded to the Blockchain to trigger partial payments during shipment AI is the simulation of human intelligence processes by machines and computer systems. Knowledge generation by artificial intelligence is carried out in three steps (Samoili et al., 2020):

- learning - the acquisition of information and its rules of use;
- reasoning - the use of rules to conclude;
- self-correction.

The AI application allows the system to give precise indications to each operator on each order. The system can do this through history-based learning. This helps achieve maximum efficiency, especially in picking-intensive warehouses, such as e-commerce (Dash et al., 2019).

The presented technologies do not constitute a closed catalogue of solutions used within e-logistics. The cooperation of these technologies within the acquisition, collection and processing of data in order to create information supporting effective managerial decisions is particularly important.

7.6. E-logistics in practice

Regardless of how e-logistics is defined, these solutions function in virtually every aspect of logistics activity, regardless of the function or material flow phase. According to the literature review presented earlier, attention should be focused on the connection between suppliers and recipients. This is where data exchange and connecting entities to improve the efficiency of material flow seem particularly important. This is currently possible thanks to the generally accessible Internet and automatic data acquisition. Practical e-logistics solutions are offered by virtually all logistics operators, especially those operating on the global market. An excellent example of solutions used within e-logistics is those offered by Dachser. This European logistics operator provides its customers with a direct connection to transport and warehouse management systems, thanks to which customers have uninterrupted real-time access to data

on the implementation of this operator's logistics processes. The functions offered by Dachser (n.d.) within e-logistics include:

- product and service analysis - this tool allows you to quickly determine the optimal or desired delivery times for shipments within Europe;
- online ordering - automatic import of data to orders saves time. The address import function from the ERP system complements address management. This functionality also allows you to send documents, save information on dangerous goods, as well as send future orders and use your own barcodes;
- control of all transport costs - allows you to quickly obtain information on the transport price without having to submit extensive inquiries;
- inventory tracking - allows you to track processes taking place in warehouses - from checking the status of order receipts to batch monitoring. This functionality allows you to immediately determine shortages and inventory levels;
- current information on the status of the shipment and its location - the Track & Trace function allows you to create an individual link for each shipment, which will inform you about the current status of the shipment. This link can then be forwarded to customers or partners;
- online invoice management - online access to all shipment data. Data is available in PDF files, Excel tables and CSV files. We can also send this data digitally via the EDI center.;
- electronic pallet accounting - manages loading equipment that requires tracking, i.e. euro pallets and racks.

Another global logistics operator that uses e-logistics solutions on a large scale is DHL. In addition to the very similar functions presented above for another operator, DHL also uses solutions from the field of machine learning, augmented reality and artificial intelligence to a large extent. Augmented reality is used to optimize the warehouse infrastructure and logistics operations conducted there. Machine learning and artificial intelligence are used to increase the efficiency of the business and increase the organization's resilience by focusing the actions taken on proactive instead of reactive actions. Taking proactive actions is possible thanks to the analysis of large data sets and searching for relationships between causes and effects in them. It is therefore possible to predict the formation of future phenomena based on past events. Such actions also have an impact on increasing the value of services directed to DHL customers and increase their competitive position (DHL, 2017). This shows that a logistics

operator can offer not only classic logistics services in the form of transport, storage or order handling but also advanced services in the field of data analysis and recommending solutions resulting from these analyses. E-logistics solutions are therefore becoming a source of competitive advantage, and the services resulting from them are a natural element of cooperation between the links of the supply chain.

7.7. Summary

The solutions operating within e-logistics are as diverse as the definitions of this concept. Two main trends in defining this concept can be distinguished. In a broader sense, e-logistics are all kinds of digital solutions that accompany the flow of materials. In a narrower sense, e-logistics is defined as the implementation of logistics processes accompanying e-commerce. Of course, both approaches are not mutually exclusive. The presented history of development, the presented expansion of the scope in which e-logistics functions and the expected directions of development clearly show that regardless of the way in which this concept is defined, it will be the object of interest of both business practitioners and researchers.

Although, as noted in the introduction to this chapter, material flow will not be replaced by information flow, information flow largely determines the efficiency of material flow. Supporting information processes implemented within e-logistics with methods and data analysis tools seems to be particularly important in this respect. Modern technical solutions allow for the collection of large sets of data and the search for relationships between these data in order to prepare information useful in making managerial decisions.

Detailed solutions in the field of data analysis, data preparation for making managerial decisions have been discussed in the remaining chapters of this manual. They present not only business analytics concepts but also ERP systems that allow for data collection, BI tools that allow for data analysis and visualization, as well as modern issues related to the use of machine learning in data analysis and data security.

The lack of a clear context for defining the concept of e-logistics is caused by the rapid development of the subject and the blurring of the boundaries between individual solutions supporting the implementation of information flow.

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8. GIS IN LOGISTICS

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Geographic Information Systems (GIS) have revolutionized the logistics industry by providing powerful tools for spatial analysis and decision-making. As businesses increasingly operate in a globalized environment, the ability to visualize and analyze geographical data is essential for optimizing supply chains, managing transportation networks, and enhancing overall efficiency. GIS technology enables logistics professionals to map routes, track shipments, and analyze spatial patterns, leading to more informed decisions and improved resource allocation. This chapter explores the integration of GIS in logistics, highlighting its applications, benefits, and future potential. By understanding how GIS can be leveraged in logistics, businesses can gain a competitive edge, reduce costs, and enhance customer satisfaction.

8.1. Geographic Information Systems (GIS)

A Geographic Information System (GIS) is a computer-based tool that integrates, stores, analyzes, and visualizes geographic data. It connects spatial data with descriptive information to help users understand and interpret spatial relationships, patterns, and trends. GIS is used across various industries for mapping, analysis, and decision-making, providing valuable insights into the spatial dimensions of data (Jonker, 2023; GisGeography, 2024a; Esri, n.d.a; National Geographic, n.d.).

According to Esri (n.d.b) and GisGeography (2024b), the history of Geographic Information Systems (GIS) dates back to the early 1960s when the first computerized GIS was developed by **Roger Tomlinson**, often referred to as the "father of GIS". This initial system was created for the Canada Land Inventory to assist in land-use management and resource planning. Throughout the 1970s and 1980s, advancements in computer technology, remote sensing, and spatial analysis led to the development of more sophisticated GIS software. In 1969, Esri (Environmental Systems Research Institute) was founded and became a pivotal player in the GIS industry, introducing the ArcGIS platform, which significantly enhanced the capabilities and accessibility of GIS technology. By the 1990s, GIS technology had evolved to include a wider range of applications, from urban planning to environmental management. The integration of GIS with GPS (Global Positioning Systems) and the advent of the internet further