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TECHNOLOGICAL SOLUTIONS IN LOGISTICS 4.0

Tehnološka rešenja u Logistici 4.0

Abstract

Technological development, automation, digitalization, networking, new forms of communication, etc. initiated a new industrial revolution, also known as Industry 4.0. It represents a new form of organization and control of the value chain in the product life cycle. By connecting and synergizing existing and new solutions and technologies of communication, data collection, exchange and analysis, production, process management, trade, etc. a new paradigm of human action, business and living has been created. A concept that is intensively changing production processes has emerged, but its effects are also visible in other areas of human activity, primarily trade, health, agriculture, logistics, etc. By applying the solutions and technologies of Industry 4.0 in the field of logistics, the concept of Logistics 4.0 was developed with the aim of achieving greater efficiency of logistics systems and processes. New technologies and solutions appear every day, but the backbone of the development of the Logistics 4.0 concept is comprised of several key technologies, such as: Internet of Things (IoT), Autonomous Vehicles (AV) and Automatic Guided Vehicles (AGV), Artificial Intelligence (AI), Virtual Reality (VR) and Augmented Reality (AR), Big data, Data mining, Blockchain, Cloud Computing (CC), 3D printing, etc. The aim of this paper was to define and describe in detail the aforementioned technologies, as well as the possibilities of their application in the logistics systems and processes through a review of the relevant literature in this field. It can be concluded that logistics, as a multidisciplinary science, represents a fertile ground for the acceptance and further development of existing modern technologies, but also the initiator and incubator of new technologies that could easily go beyond logistics and become part of the family of Industry 4.0 solutions.

Keywords: *Industry 4.0, Logistics 4.0, technologies, IoT, AV, AI, AR.*

Sažetak

Tehnološki razvoj, automatizacija, digitalizacija, umrežavanje, novi oblici komunikacije itd. doveli su do pokretanja nove industrijske revolucije, poznate i kao Industrija 4.0. Ona predstavlja novi oblik organizacije i kontrole lanca vrednosti u životnom ciklusu proizvoda. Povezivanjem i sinergijom postojećih i novih rešenja i tehnologija komunikacije, sakupljanja, razmene i analize podataka, proizvodnje, upravljanja procesima, trgovine itd. stvorena je nova paradigma ljudskog delovanja, poslovanja i življenja. Nastao je koncept koji intenzivno menja proizvodne procese, ali čiji su efekti vidljivi i u ostalim oblastima ljudskog delovanja, pre svega trgovini, zdravstvu, poljoprivredi, logistici itd. Primenom rešenja i tehnologija Industrije 4.0 u oblasti logistike razvio se koncept Logistike 4.0 sa ciljem postizanja veće efikasnosti logističkih sistema i procesa. Svakodnevno se pojavljuju nove tehnologije i rešenja, ali okosnicu razvoja koncepta Logistike 4.0 čini nekoliko ključnih tehnologija, kao što su: internet stvari (IoT), autonomna (AV) i automatski vođena vozila (AGV), veštačka inteligencija (AI), virtuelna (VR) i proširena stvarnost (AR), Big data, Data minig, Blockchain, Cloud Computing (CC), 3D štampa itd. Cilj ovog rada je bio definisati i detaljnije opisati pomenute tehnologije kao i mogućnosti njihove primene u logističkim sistemima i procesima kroz pregled relevatne literature iz ove oblasti. Može se zaključiti da logistika, kao multidisciplinarna nauka, predstavlja plodno tlo za prihvatanje i dalji razvoj postojećih savremenih tehnologija, ali i inicijator i inkubator novih tehnologija koje bi lako mogle da izađu iz okvira logistike i postanu deo porodice rešenja Industrije 4.0.

Ključne reči: *Industrija 4.0, Logistika 4.0, tehnologije, IoT, AV, AI, AR.*

Introduction

Nowadays is considered as the era in which the fourth industrial revolution, also known as Industry 4.0, began. Like the previous ones, this industrial revolution was started and intensified by the growth of competition whose basic measures are efficiency, flexibility, speed, ability to transform, costs, etc. [41]. It is based on innovation in industry and it represents one of the key factors in the economic development of companies and countries [125]. The basic characteristics of Industry 4.0 are digitalization, automation, networking and development and application of new technologies in order to increase productivity and production in accordance with the specific requirements of the users [130]. The implications of Industry 4.0 significantly go beyond the field of production and expand into various spheres of social activity. One area that has been particularly fruitful for embracing and advancing Industry 4.0 ideas is logistics. Accordingly, in recent years the concept of Logistics 4.0 has been developed, which implies the application of solutions and technologies of Industry 4.0 in logistics. Just as Industry 4.0 has led to the radical changes in manufacturing processes, so has Logistics 4.0 transformed the way organizations buy, produce, sell and deliver goods [22]. Therefore, Logistics 4.0 has become one of the most common topics of discussion for experts in the field of logistics and supply chain management [22, 115, 137]. They strive to adequately look at existing solutions, systematically develop new ones and find ways to share them in order to achieve greater efficiency of logistics systems and processes. New thinking models, frameworks for the development of solutions and technologies and procedures for the implementation of processes aimed at establishing Logistics 4.0 as the new research area are being developed [41]. Accordingly, the subject of this paper is Logistics 4.0 as an application area of Industry 4.0, and the aim of the paper is to review the technologies of Logistics 4.0 and specific examples of application for the processes implementation and problem solving in the field of logistics.

The paper is organized as follows. The following section presents the terminology and provides the basic definitions of Industry 4.0. After that, Logistics 4.0 was defined and its basic characteristics and conceptual framework were described. The fourth chapter describes in more detail the technologies of Industry 4.0 that have found the widest application in the field of logistics, or have the greatest potential to do so in the future. The last chapter provides concluding remarks and directions for future research in this area.

Industry 4.0

Industry 4.0 was first mentioned as a term in one of the German government's high-tech strategic projects in 2011 [65] and originally referred to the software nomenclature. Today, this is a widely accepted term used as a synonym for the fourth industrial revolution. However, there is a discussion in the literature about what this term means and what it encompasses, which is why a large number of different definitions have emerged. Hermann et al. [54] defined Industry 4.0 as a common name for the application of new technologies and concepts in the organization of the value chain. Götz & Gracel [43] defined it as a complex solution created in the sphere of common interest of engineering, computer science and management. Industry 4.0 is also defined as smart networking of machines and processes in industry using information and communication technologies [102]. What all definitions have in common is that Industry 4.0 implies the integration of computing, networks and real physical processes, thus creating a Cyber-Physical System (CPS) which is the basis for the development of new business models and solutions [41]. Various technological solutions are used for this integration, such as: Internet of Things (IoT), Cloud Computing (CC), robotics, Artificial Intelligence (AI), Augmented Reality (AR), Big Data, Machine Learning (ML), 3D printing, etc.

Most of the listed technological solutions that define Industry 4.0 already exist and are widely applied, so many authors question whether it is a revolution or evolution [1, 68, 43]. Industry 4.0 is a conglomeration of already known solutions and applications, but for the first time they are connected in a complex network of interdependent elements, so it can be viewed as an innovative concept. However, whether it represents a revolution or an evolution, Industry 4.0 has defined a new paradigm of human action, business and living.

The primary goal of Industry 4.0 is to make ordinary objects self-aware and self-learning in order to improve their performance and ability to interact with the environment [74]. The aim is to form an open smart platform for networking information applications and technologies [5]. The main needs of Industry 4.0 are real-time monitoring of data, monitoring the status and position of objects and having adequate guidelines for control of the processes that objects perform [2]. Accordingly, the basic prerequisites for the development of Industry 4.0 are the availability of real-time information through networking of all elements (objects, users, technologies) involved in the value creation, the ability to deviate at any time from the optimal way of implementing the process in accordance with the available information and data and the possibility of performing processes that create value by integrating different information [41]. Networking involves connection of the different users, communication between the objects and their components, and exchange of the information about status, position, destination, purpose, etc., allowing products or services to adapt to changing user requirements.

The effects of Industry 4.0 development are significant cost reduction of production, maintenance, logistics, energy consumption, quality improvement, etc., more rational use of resources, creation of new business models and strategies for planning and managing business processes, optimization of the entire value chain, creation of new occupational profiles, increasement of the levels of competitiveness of economic entities and the economy in general [41]. Industry 4.0 enabled the collection of large amounts of data, their adequate interpretation and multi-purpose application, connection of the different software solutions, decentralization of business process control, modularization of products and services, creation of the business process support systems, changes in the work environment, higher level of automation reflected in better cooperation of robots and humans, a high level of self-organization and autonomy in the production of products and services, etc. [41]. Industry 4.0 is mostly seen as a concept that intensively changes production processes, but its effects have far-reaching impacts on various areas of human activity such as manufacturing, trade, health, agriculture, logistics, etc.

Logistics 4.0

A new approach in the realization of production processes has defined new logistics requirements. Accordingly, Logistics 4.0 is increasingly mentioned as a concept that is strictly related to the concept of Industry 4.0 with which it shares the goals, assumptions and operating conditions [68]. In the literature, the term Logistics 4.0 is often equated with the term smart logistics [6, 68, 98]. Jeschke [61] views Logistics 4.0 as an integral part of Industry 4.0 which refers to the application of various technologies that define Industry 4.0 (IoT, CC, AI, AR, ML, etc.) in the field of logistics. Similarly, Barreto et al. [6] defines Logistics 4.0 as the realization of logistics processes with the application of innovations and applications brought by the development of CPS. Timm & Lorig [123] defined Logistics 4.0 as a transformation from hardware-oriented logistics to software-oriented logistics. Winkelhaus & Grosse [141] identified three dimensions that unite the ideas of logistics and Industry 4.0: a change of production paradigm directed towards mass customized production, changes in logistics systems and processes caused by the application of new technologies and changes in the environment and human role in industrial and logistics systems and processes. Accordingly, they formulated a three-dimensional conceptual framework (Figure 1) and defined Logistics 4.0 as a logistics system that enables sustainable fulfillment of individual customer requirements without increasing costs and with the development of the industry and trade supported by the digital technologies.

The first is external, the so-called pull dimension, which includes paradigm shift due to user demands for high quality personalized products, development of Industry 4.0, globalization, demands for sustainable development, social change, etc. [55, 70, 141]. The second is technological, the so-called push dimension, which encompasses the various technologies of Industry 4.0 that enable paradigm shift and drive the transformation of traditional logistics operations [70, 141]. The third is the logistical dimension defined by competencies, functions and human factors. Competencies relate to management activities [59] and task execution [47]. These activities are implemented within four basic functions in terms of flows: procurement logistics, production, distribution and logistics of returnable and waste materials [47]. Human factors, such as knowledge, skills, physical limitations, psycho-social interaction, decision making (subjectivity), motivation, etc. significantly affect the quality and efficiency of logistics activities. Human labor will never be completely replaced by machines in Logistics 4.0, but their labor will be strongly influenced by new technologies. In addition, people are the ones who make the final decision on accepting or rejecting a technology, which directly shapes the further development of Logistics 4.0 [127].

Various Industry 4.0 technologies that can be applied in logistics have been identified in the literature, and some of them are shown in Table 1. The technologies that have the greatest potential for wide application in logistics are described in more detail below.

Figure 1. Conceptual frame of Logistics 4.0 (adapted from [141])

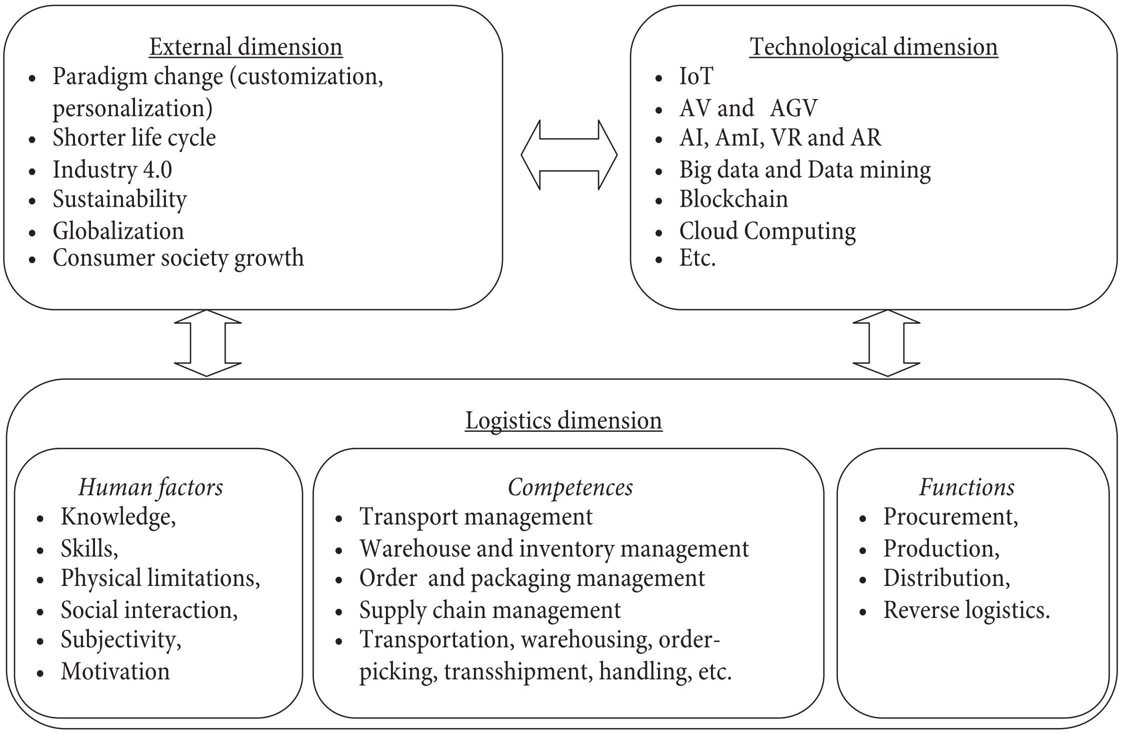

Table 1. Overview of the most common technological solutions in Logistics 4.0

	Kostrzewski et al. [68]	Tang & Veelenturf [120]	Lee et al, [72]	Lin & Yang [78]	Schmidtke et al, [109]	Horenberg [56]	Pesti & Nick [100]	Barreto et al, [6]	Wagener [135]	Galindo [37]	Juntao & Yinbo [64]	Mussomeli et al, [92]
Internet of Things (IoT)		x	x	x						x	x	
Autonomous and Automated Guided Vehicles (AV and AGV)	x	x		x		x	x				x	x
Artificial (and Ambient) Intelligence (AI and AmI) and Augmented (and Virtual) reality (AR and VR)		x	x	x								x
Big data and Data mining (BD and DM)					x					x		
Data security and Blockchain (BC)		x				x		x				
Management and control support systems and Cloud Computing (CC)	x		x		x		x	x	x	x	x	x
E-Marketplace and M-Marketplace						x			x			
3D printing						x						
Advanced robotics	x	x										

Technological slutions in Logistics 4.0

At the level of application, prototype or concept, there is a large number of technological solutions that are associated with Industry 4.0, and new ones appear every day. Some of them are more or less applicable in the field of logistics, and below are described in more detail those that have had the greatest impact so far, or have the potential to greatly affect logistics systems and processes in the future.

Internet of Things (IoT)

The term Internet of Things originated in 1999, and was coined by Kevin Ashton while working on promoting RFID technology [82]. The very idea of connecting devices was present much earlier, since the 1970s, and was then generally called "embedded internet" or "pervasive computing" [68]. However, it has gained wider application and popularity only in the last decade, and it has been widely used since 2014 [82]. There are many different definitions of IoT in the literature. Uckelmann et al. [128] define it as a set of sensors and actuators built into physical objects that are interconnected by wired or wireless networks and typically use the same Internet Protocol (IP). A similar definition is given by Gubbi et al. [46] and Hozdić [57], which under IoT imply a global network of interconnected objects that communicate with each other through standard protocols. A somewhat more general definition is given by Lu et al. [81] which define IoT as a technological paradigm whose goal is to connect everything and everyone, anytime and anywhere. In line with the latter definition, some researchers are expanding the concept of IoT and calling it the Internet of Everything (IoE), which integrates Internet of Services (IoS), Internet of Manufacturing Services (IoMs), Internet of People (IoP) and Information and Communication Technologies (ICT) into a single system [95]. Thus, IoT is used as an umbrella term to cover various aspects of the expansion of the Internet and networks into the physical environment.

Xu et al. [145] state that IoT consists of four basic layers: sensors that integrate different types of "things", a network that enables information transfer, services that integrate different applications and software solutions, and an interface that presents information to the user and interacts with the system. Similarly, Lee & Lee [73] define the structure of IoT as a combination of radio frequency identification (RFID) technologies, wireless sensor networks (WSN), middleware, cloud computing (CC) and IoT applications. RFID enables the identification, tracking and transmission of information through various types of tags, from completely passive to active [80]. WSN is a network of interconnected sensors that track and monitor the status of various objects, such as location, movement, temperature, pressure, noise, air quality, humidity, speed, etc. [104]. Indirect software allows developers to communicate with various devices via sensors, actuators, RFID tags, etc. [8]. It is the link between the hardware and the interface. CC is a platform that uses the Internet to enable sharing and use on demand of various computing resources (such as various computing components, networks, storage capacity, software, etc.) [73]. The result is the ability to store large amounts of data, process them quickly and make efficient decisions in real time. IoT applications form an interface that allows people and objects to interact, present information in an intuitive and understandable way, identify problems, and suggest solutions [73].

Kim & Kim [66] point out that logistics is one of the areas that has benefited the most from the application of IoT. This is made possible by connecting over 26 billion facilities (vehicles, transport units, handling equipment, infrastructure facilities, etc.) worldwide in 2019, and it is estimated that by 2025 that number will go over 75 billion [68]. IoT has found application in all subsystems of logistics. In the ordering subsystem, it is used for order management and information exchange (e.g. [103]), creating a digital bill of lading (e.g. [144]), etc. In the transport subsystem, it has found application for locating and routing (e.g. [79]), fleet maintenance and fault prevention (e.g. [10]), fleet management (e.g. [118]), establishment of the autonomous vehicles systems (e.g. [60]) and drones (e.g. [9]), transport quality control (e.g. [111]), monitoring of various transport parameters in real time (e.g. [19]), increasing transport safety (e.g. [71]), protection of cargo from damage, alienation, etc. (e.g. [116]), etc. In the storage and inventory subsystems, it is used for the management of storage processes (e.g. [118]), warehouse security (e.g. [124]), inventory (e.g. [121]), etc. Within the packaging subsystem the IoT technology enabled the development of the systems for the organization and control of automatic packaging (e.g. [77]) and labeling (e.g. [139]), as well as the design of smart packaging with the ability to monitor various parameters (e.g. [53]) etc.

Autonomous (AV) and Automated Guided Vehicles (AGV)

Although the terms autonomous vehicles and automated guided vehicles are similar and are sometimes used with the same meaning in the literature, there are differences between them. AGVs are an older invention. They first appeared in the United States in the 1950s, and ten years later in Europe (Germany) [129]. They imply vehicles that are remotely controlled or that are self-controlled following a predefined path, where radio waves, cameras, magnets, lasers, etc. are used for their guidance [63]. Autonomous vehicles, also called in the literature Fully Automated Vehicles, Self-driving Cars or Driverless Cars, have been developing more intensively since 2009 and presentation of the Google self-driving vehicle [134]. They imply adaptable and self-learning vehicles that are able to "feel" the environment and move safely in it with little or no help from people [119]. It can be said that autonomous vehicles are a type of automated guided vehicles that do not have a fixed, predefined path, but decide on the path independently based on information from the environment and algorithms and software solutions that are part of their operating system.

Differences between AV and AGV also exist from the aspect of application in logistics. AGVs are mainly used in storage and transshipment subsystems, while in the transport subsystem their application is mainly limited to internal transport. On the other hand, AVs are currently used exclusively in the transport subsystem. In the literature, a distinction is usually made between the application of AGVs indoors for horizontal (e.g. [117]) and vertical transport (e.g. [58]), transshipment (e.g. [27]), storage/retrieval (e.g. [30]) and order-picking (e.g. DHL, [27]), and outdoors in the strictly controlled environment (such as terminals, logistics centers, ports, airports, industrial complexes, mines, etc.) for horizontal transport (e.g. [15]) and transshipment (e.g. [45]). Road AGVs are predominantly used, but there are examples of the application of both rail (e.g. [25]) and air (e.g. [138]) vehicles. On the other hand, the literature has identified applications of AVs in short-haul transport (for the realization of the last mile) (e.g. [91]), as well as in long-haul transport (e.g. [90]). They are also predominantly used in road transport, but their application in rail (e.g. [97], waterway (e.g. [76] and air transport (e.g. [35]) is also possible.

In line with the applicability, the main areas of research for AV and AGV are technological solutions, responsibilities and regulations, ethics and the human factor [131]. Research on technological solutions deals with the basic components of the system in charge of observation and modeling, localization and mapping, path planning and decision making, and motion control [112]. Simply put, the ability of a vehicle to collect and interpret data from the environment and plan and execute activities based on them, is investigated [4]. The need to change regulations in this area and to define responsibilities are the main obstacles to wider application, primarily of the AVs, which is why this is the subject of frequent discussions and research [131]. Considering that driving involves constant risk assessment and decision-making that can be legally but also morally ambiguous, Goodall [42] points out that significant attention needs to be paid to ethical issues in research. Finally, although both AV and AGV systems tend to involve humans minimally, their direct or indirect impact on the operation of these systems is inevitable, which is why the human factor is a particularly important area of research [126].

Artificial (and Ambient) Intelligence (AI and AmI) and Augmented (and Virtual) reality (AR and VR)

The term Artificial Intelligence was first officially used in 1956 at the University of Hanover (USA) [107]. There are many different definitions of AI in the literature. Bellman [7] defines AI as the automation of activities related to human thinking, such as decision making, problem solving, learning, etc. Kurzweil [69] defines it as the art of creating machines that realize functions that require intelligence when realized by humans. Winston [142] under AI implies the study of calculations that enable observation, reasoning and action. Luger & Stubbllefield [83] define it as a field of computing that deals with the automation of intelligent behavior. All definitions can be classified into those whose focus is on thinking and reasoning and those with a focus on behavior, as well as those according to which AI achieves rational thinking or human thinking [107]. According to today's modern understandings, AI in the broadest sense implies the ability of a computer to perform tasks that are usually performed by intelligent beings, above all observation, reasoning, problem solving, learning and communication [21].

Artificial Intelligence has enabled the development of some new technologies, including Ambient Intelligence (AmI), Augmented Reality and Virtual Reality. AmI is essentially associated with AI and actually represents AI in the environment [38]. The term originated in the last years of the 20th century [48], and implied an electronic environment that is sensitive to the presence of people and enables interaction with them [38]. Later, the meaning of the term was expanded to include an environment without the presence of people. According to the modern definition, AmI implies a multidisciplinary approach that aims to improve the way the environment and people interact in order to create new opportunities to use the space in which people live and work [38]. Some of the new ways to achieve this interaction have enabled the development of augmented and virtual reality technologies.

AR is defined as a direct or indirect view of the physical environment in real time, which is enhanced/expanded by the addition of computer-generated virtual information [16]. VR, on the other hand, involves a computer-generated simulation in which interaction with artificial three-dimensional space is possible [89]. Milgram et al. [88] defined the so-called Milgram's Real-Virtual Continuum, which encompasses the space between the real and virtual environment in which AR and VR are located, where AR is closer to the real and VR to the virtual environment. AR provides users with an enhanced real-world experience, while VR enables the creation and experience of a virtual environment. Both technologies use various types of glasses, helmets, gloves, mobile devices (phones, tablets), etc. as media.

The aforementioned technologies have found wide application in the field of logistics. They can be used to process purchase orders (e.g. [148]), in the storage subsystem for the implementation of transshipment operations, storage/retrieval, locating/allocating goods and handling equipment, (e.g. [99]), loading and unloading of transport units/means, order-picking (e.g. [114]), management and control of warehousing processes (e.g. [105]), etc., in the inventory subsystem to optimize inventory levels (e.g. [99]), in the transport subsystem for monitoring the status of goods and vehicles in the fleet management systems (e.g. [49]), vehicle routing (e.g. [62]), vehicle navigation in conditions of reduced visibility, primarily in water transport (e.g. [13]), driving skills improvement (e.g. [84]), transport safety improvement (e.g. [96]), etc.

Big data and Data mining

Industry 4.0 implies the application of technologies based on the collection, processing and analysis of large amounts of data, so in this context, the term Big data appears increasingly. Wu et al. [143] define Big data as the process of collecting large amounts of data from heterogeneous and autonomous sources, with shared and decentralized control, with the goal of finding complex and variable relationships between them. Similarly, Sagiroglu & Sinanc [108] define Big data as massive data sets that have a large, volatile, and complex structure that is difficult to store, process, and visualize for further processing or obtaining the results. The goal is to obtain useful information that companies or organizations can use to better understand various aspects of business and gain a competitive advantage in the market [108]. Big data is determined by the basic so-called 3V characteristics: velocity of change and increase in the amount of data, variety of types, shapes and formats of data and the volume of data generated every second [113].

The process of research into large amounts of data to determine hidden patterns and correlations is called Big data analytics [108]. Researchers from various scientific fields are making great efforts to develop new, fast and dynamic Big data analytics technologies that would also be easy to use [113]. These technologies are actually tools for finding, collecting, transforming, analyzing and visualizing data to make them applicable for efficient decision making, with acceptable resource consumption (time, finances, energy, etc.) [143]. These technologies are collectively called Data mining, or Knowledge Discovery in Databases, and are most commonly created by combining different statistics tools, AI, and database management [20]. The process of determining patterns and relationships in large data sets takes place in five steps: selection, preprocessing, transformation, data research, and interpretation/evaluation [34].

Ghosh [40] identified logistics as one of the main areas of application of Big data and Data mining. They are applied in all subsystems of logistics, i.e. wherever the data applicable to the improvement of the logistics services can be collected. Their application in logistics creates conditions for managing orders (e.g. [17]), transportation (e.g. [136]), warehousing operations (e.g. [18]), inventory (e.g. [44]), packaging processes (e.g. [149]), as well as for capacity planning of available resources, last mile optimization, customer loyalty management, supply chain risks management, etc. [26].

Data security and Blockchain

Technology of the cryptographically protected chain of data blocks was defined by Haber & Stornett [50]. However, the practical application of the name Blockchain, under which it is known today, was introduced only in 2008, when a group of authors under the pseudonym Satoshi Nakamoto [93] used this technology to create a cryptocurrency known as Bitcoin. It implies a decentralized digital register of data sets, i.e. blocks, which are mutually identified and connected on the basis of encrypted information, thus forming chains [94, 101]. These chains are formed within computer networks that represent nodes, which record, share and simultaneously synchronize transactions, thus creating a decentralized database [125]. The basic characteristics of Blockchain technology are: decentralization, verifiability and consistency (invariability) [51]. Decentralization is a consequence of the fact that the network within which the chains are formed is completely managed by its users, without relying on a body that would have centralized competencies over the infrastructure or transactions within the network. In order to add a new block of data to the registry, it is necessary to share it with all users within the network and all users keep their copy of the entire registry. Verification is performed by the digital signature of the network user when adding new data, which is encrypted using a public-private cryptographic key. The application of the cryptographic key enables anonymity in the network because digital signatures are not connected to the identities of people in the real world. Consistency is ensured by the application of consensus algorithms that allow data verification only if consensus is reached by all network users. If a consensus is reached the block is accepted and becomes part of the chain, otherwise it is rejected. Blockchain technology practically prevents any manipulation, which ensures a very high level of data security.

Intensive exchange of a large amount of data has generated a demand for improving the security of these transactions, which is why Big Data is considered to be one of the main drivers of the development of Blockchain technology [122]. Accordingly, Blockchain technology, like Big data, can be applied in all subsystems of logistics, i.e. for the implementation of all processes and activities that require secure data exchange. However, despite the importance and potential, the literature describes only a few fields of application of Blockchain technology in logistics [51, 122, 146]: processing of documentation (purchase order, bill of lading, customs documents, etc.), control of goods (identification of counterfeit products, monitoring of dangerous or high-value products, monitoring of traceability, etc.), support for the application of IoT in logistics and supply chain management.

Management and control support systems and Cloud Computing (CC)

Management and control support systems in this paper imply software solutions that aim to provide support in the management and control of the execution of various processes and activities in all logistics subsystems. Some of the most commonly used solutions are: Enterprise Resource Planning (ERP), Warehouse Management System (WMS), Inventory Management System (IMS), Electronic Data Interchange (EDI), Transport Management System (TMS), Intelligent Transport System (ITS), telematics systems, Package Management System (PMS) etc.

An ERP system is defined as a comprehensive software package that integrates a wide range of business processes and functions with the goal of providing a holistic business overview and company resource planning accordingly [67]. ERP involves the integration of information from all business areas of the company using common databases and has a modular structure [23]. One of the most important ERP modules is WMS. It is an information system for managing and controlling physical and information flows in a warehouse [110]. It collects and stores information on goods and storage resources and processes and forwards it to other modules of the ERP system [132]. Based on the functions it implements, WMS itself can be divided into seven basic modules for: yard management, storage assignment, storage/retrieval, inventory management, order-picking, shipping and workforce and task management [52]. Of the mentioned modules, the inventory management module stands out, for which special software solutions known in the literature under the common name IMS are being developed. They are in charge of accurately keeping records of the quantities of goods in stock, determining the time and quantity of goods to replenish stocks, recording the time of sale of products and predicting future demand based on that, etc. [3]. Significant inventory reduction can also be achieved by applying EDI systems that are a form of e-commerce within organizations in which one partner (buyer or seller) establishes communication with one or more other partners using various methods of electronic data exchange [75]. EDI enables the formation of a strategy of cooperation between suppliers, distributors and retailers with the aim of faster response to the requests of end users (customers) [133]. Another important module of the ERP system is TMS. It is a platform that combines software solutions, information and communication technologies in order to plan, implement and optimize the physical movement of goods and related activities [106]. The functioning of TMS can be observed through four key processes: planning and decision-making based on real-time information, implementation of transport plans with automated dispatching and carrier selection, improving the visibility of the transport chain for all participants and monitoring key performance indicators [106]. A significant segment of TMS is telematics systems. The term telematics was coined by combining the terms telecommunications and informatics and was initially used exclusively to denote the sending of information via telecommunications systems, while today it also encompasses the fields of computer and electrical engineering, digital technologies and traffic engineering [36]. It is used for information collection about vehicles, navigation, diagnostics, safety improvement, communication between vehicles, etc. [12]. In recent years, with more intensive development of information and communication technologies, IoT, AV, AI, etc., the ITS solutions are also developing. These are the systems for automatic and autonomous traffic and mobility management that is realized by managing transport means, infrastructure, traffic participants, and by connecting and communicating between transport means of different transport modes [33]. PMS includes software tools for the design and production of packaging and marking labels, optimization of dimensions, stacking methods, enlargement, etc. There are many different solutions of these software tools on the market [14].

Most of these solutions are not new and have been applied in practice for much longer than the existence of the Industry 4.0 concept. However, in the Industry 4.0 environment, these solutions are experiencing a renaissance, especially in terms of wide availability and easy application made possible by the concept of cloud computing. CC implies wide and easily accessible network access that allows the use of shared computing resources (e.g., servers, storage capacity, applications, services, software, etc.) that can be quickly occupied and released with minimal service provider engagement [87]. CC defines five basic characteristics, three service delivery models and four application models [87]. The main features are the provision of service at the request of the user (the user independently selects and launches computer resources when they need them), wide network access (resources can be accessed from any location using various types of devices that can connect to the network), pooling resources (total available resources are created by combining resources of a large number of providers and users who are physically located in different locations), resilience (required resources can be quickly and easily adjusted to user requirements) and service quantification (resource use can be measured as a prerequisite for billing and wide application) [87]. Service delivery models are software as a service (use of programs and applications located in the cloud infrastructure), platform as a service (use of development environment and tools in the cloud to develop own applications) and infrastructure as a service (use of computer infrastructure and resource management for processing and data warehousing, networking, etc.) [87]. The basic deployment models are private cloud (deployment within an organization), shared cloud (deployment within the community with the same or similar interests), public cloud (fully open access for all users) and hybrid cloud (any combination of the aforementioned deployment models) [87].

E-marketplace and M-marketplace

The Internet has made it possible to create e-commerce platforms called Electronic Marketplace (E-marketplace) [32]. E-marketplaces enable automated transactions, trade, or collaboration between business partners [24]. They may differ in relation to sales mechanisms (direct, stock market), ownership (buyer, seller, third party), number of owners (one or more), primary activity (trade, industry, logistics, etc.), participants (private or public, Business-to-Business - B2B, Business-to-Customer - B2C, etc.), type of goods or services and industry orientation (horizontal, vertical, diagonal) [29, 39]. E-marketplace enables simpler, faster and more reliable shopping, information exchange, contract management, market research, order management, orders integration in time and space, development of information systems for tracking inventory and finances, easier promotion and advertising, etc. [31]. With the evolutionary development of the E-marketplace platform, mobile marketplaces (M-marketplace) have emerged and include platforms on which trade is realized using mobile devices (mobile phones, tablets, laptops, etc.). Social trends have influenced Internet users to increasingly turn to mobile technologies, therefore many of the activities they once carried out on personal computers are now carried out via mobile devices, anywhere and at any time. Like some of the technologies described above, these platforms were developed well before the Industry 4.0 concept was defined, however with the development of smart mobile devices they are becoming part of the Industry 4.0 paradigm. Smart mobile devices combine telecommunications and computing technologies and use technologies such as Bluetooth, Zigbee, NFC (Near-Field-Communication), Wi-Fi (Wireless Fidelity), Li-Fi (Light Fidelity), WiMax (Worldwide Interoperability for Microwave Access), 4G and 5G, etc., to connect to other devices or networks.

The development of the E-marketplace and M-marketplace platforms has led to the intensive development of the logistics market. Logistics services markets have actually become part of electronic markets because the customer now automatically buys the logistics service with the purchase of products. Logistical requirements are changing, the number of deliveries is growing, the size of deliveries is decreasing, and the requirements from the aspect of delivery quality are becoming stricter (reliability, flexibility, accuracy, etc.). In the literature, the problems of logistics that are related to the electronic and mobile markets are mostly observed from the aspect of creating new models of logistics business and development of the logistics market through expanding the offer and improving services using new technologies, etc. [147].

3D printing

3D printing is a form of additive production that has its roots in stereo lithography created in the mid-80s of the twentieth century [86]. It involves the production of three-dimensional objects by repeatedly adding layers of material. This technology, along with the development of computers and the Internet, has been identified as one of the biggest drivers of radical change in global industry since the establishment of the first production lines in America in the early twentieth century [85] and a herald of the new industrial revolution [11]. The visions of various authors and companies have shown that there are almost no restrictions on what can be printed. There are examples of 3D printing in almost all branches of industry, from aircraft production, over medical equipment to food [140]. Unlike traditional forms of industry, 3D printing enables easy and fast establishment and start of production lines, locating production plants much closer to end consumers, greater flexibility in relation to changing user requirements, etc. [85]. The impacts of this new production technology are noticeable in many areas, but logistics stands out among them [85].

Mass use of 3D printing could lead to a reduction in international trade flows, especially from Asia, as products could be cheaply produced much closer to the point of consumption. The great variety of products that would result from custom production would lead to a reduction in the level of goods in stock, as well as the need for long-term storage of goods. Logistics providers would be significantly less involved in logistics activities for the procurement of semi-finished products, installation parts and spare parts because they would be produced on site. On the other side, their engagement in the procurement of raw materials and materials for 3D production would increase significantly. There would also be significant changes in distribution logistics, especially in the relations of manufacturers, wholesalers and retailers [85]. In some branches, retail trade could disappear completely or be transformed into showrooms that would not have stocks or sell goods. The sale would be made by the manufacturer himself and the goods would be delivered directly to the home address. The volume of flows in home deliveries would be further increased with the mass use of 3D printers as each house could become a mini production facility requiring raw materials for production [85].

Advanced robotics

The tendency of people to be replaced by machines in work is longer than 500 years and dates back to the period of Leonardo da Vinci. Today, the application of robots in the realization of many complex activities is a reality. In industry, they participate in the production and assembly of products, in medicine they perform complex surgical procedures, in households they perform daily household chores such as mowing the grass or vacuuming, etc.

In addition to the obvious motives for the application of robots, such as a high level of reliability, efficiency, precision, flexibility, etc., the lack of manpower is especially emphasized in logistics [28]. This is a consequence of higher demand for labor due to the intensive development of e-commerce and the demand for frequent deliveries of small quantities of goods, as well as the reduction of labor potential due to lower population growth in developed countries, and migration in the less developed ones. However, despite the need, so far the application of robots in logistics has been limited, primarily for technological reasons. Robots are predominantly stationary, “blind” and relatively unintelligent [28]. They perform the same operations over and over again with a high level of precision and accuracy, which is suitable for some simpler, but not more complex logistics processes. The application of robots in logistics would imply the possibility of performing an unlimited number of combinations of different operations with different objects. Robots must be able to see their environment and objects, to be able to capture them, to move and relocate them freely, and to be able to “think” and coordinate all these processes [28]. With the advent of Industry 4.0 technologies, such as IoT, AV, AI, AiM, etc. all this became possible.

So far, in practice, advanced robotics in logistics has been applied in warehouses for the realization of storage and retrieval processes [28]. At the prototype level are the robots for loading/unloading transport units and means, stationary and mobile robots for order-picking and realization of various VAL (Value Added Logistics) services such as palletizing, de-palletizing, packaging, repackaging, labeling, finishing, processing, etc. [28]. At the concept level are the solutions of fully automated systems of distribution centers, cross-dock terminals and the realization of the last mile in which advanced robots would realize all the processes of handling and transporting the goods [28].

Conclusion

With the spread of the effects of the new industrial revolution, the need of various fields for the adoption and application of new technologies becomes clear. As logistics is one of the fields in which Industry 4.0 has a great influence, this paper explores the implications and possibilities of applying Logistics 4.0 technologies in real circumstances through a review of relevant literature in the field. It can be concluded that the end of this revolution is not in sight and that with new scientific breakthroughs in almost all areas, it will continue to change all areas of human activity. Logistics as one of these areas, not only represents a fertile ground for the ideas of Industry 4.0, but also acts as a driver of many changes aimed at further development of existing, but also development of new technologies and opportunities in industry and logistics. This area of research is very dynamic, new technologies and solutions appear every day or new possibilities of applying existing ones are found. Accordingly, this paper is a cross-section of the current situation and it can be said that its main shortcoming is the inability to comprehensively consider all technologies and solutions and their possible application in the field of logistics. However, the paper represents a good basis for further research of application of the described technologies in the specific organizations, regions, areas of logistics and logistics systems, analysis of the mutual influence of technologies, decision-making on the priority of technology depending on expected effects, etc., as well as for the development of new technologies.

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