THE CONCEPT OF LOGISTICS 4.0

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Abstract: *The concept of Logistics 4.0 was created as a consequence of Industry 4.0, emergence of new technological solutions and the use of Internet in business systems. The aim of this paper is to present modern logistics trends, digitization of logistics and description of the concept of Logistics 4.0. The basic components of that concept are: automatic identification, real-time localization, automatic data collection, connectivity and integration, data processing and analysis and business services. The paper presents and describes some of the most important Logistics 4.0 technologies: Internet of Things, wireless sensor network, Cloud Computing, Blockchain, Big Data, robotics and automation, augmented reality, drones, 3D printing and automatic guided vehicles.*

Keywords*: Logistics 4.0, Industry 4.0, Internet, Digitization, Business.*

1. INTRODUCTION

Logistics is a field that has modified through history so that it always followed social, industrial and technological changes. Logistics 4.0 has been created in recent years as a consequence of the fourth industrial revolution and technological achievements of the 21st century. The development of ICT (Information and Communication Technologies) enabled new methods of data exchange, horizontal and vertical integration of value chains and new business models.

The aim of this paper is to describe the concept of Logistics 4.0, define its significance, components and technologies. The paper consists of six parts. The second part describes the influence of industrial revolutions on the development of logistics. Industry 4.0 is described in the third part. The fourth part covers the concept of Logistics 4.0, its basic components and technologies. The fifth part presents the advantages and challenges of Logistics 4.0. Conclusive considerations are given in the sixth part.

2. THE INFLUENCE OF INDUSTRIAL REVOLUTIONS ON LOGISTICS

Modern industry has been developing for several centuries and so far there have been four industrial revolutions, marked by innovations, changes, new production methods and influences on all other fields. Parallel to the industrial revolutions, the technological,

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social, demographic and market conditions changed in which logistics went through phases, from Logistics 1.0 to the present day Logistics 4.0. Figure 1 shows the evolution of logistics in the period from the first industrial revolution to date.

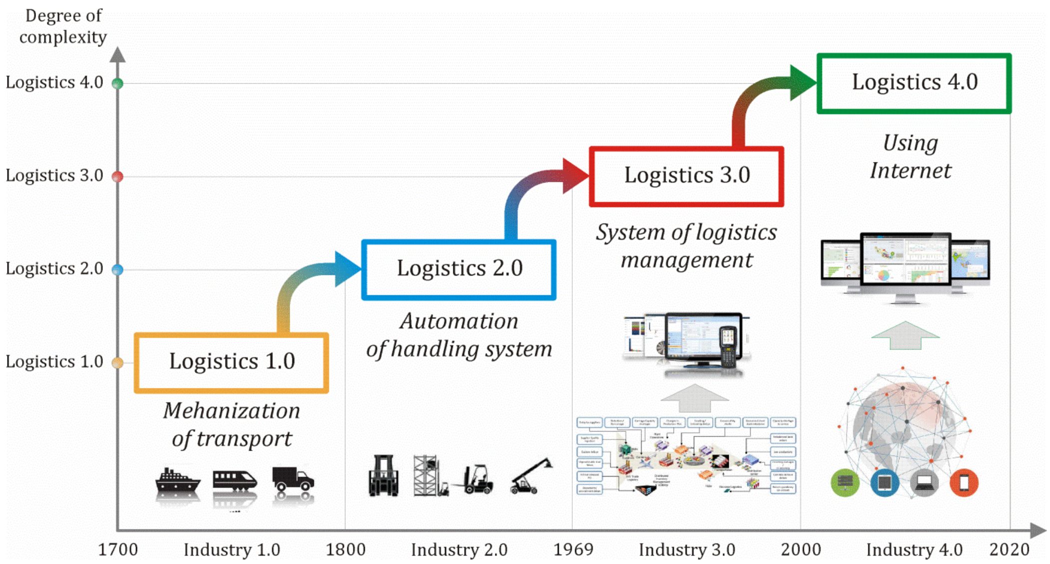

Figure 1. Evolution of logistics (adapted from Wang, 2016)

The first industrial revolution occurred in the 18th century and was marked by the invention of the steam engine and the transition from manual to machine production. This was the beginning of the massive use of transport of goods and passengers. For logistics, this period meant transport mechanization. Supply chain management was at the local level and logistics was based on push delivery flows. Warehouses were simple buildings in which raw materials and finished products were kept on the floor and movement of goods was carried out by hand carts. The owners of factories and shops dealt with the organization of production and logistic activities.

The second industrial revolution covers the period of the 19th and first half of the 20th centuries and was marked by the invention of production lines and mass production. This period is also called the technological revolution because there were many discoveries and inventions that changed civilization. Logistics started becoming more significant, new forms of transport developed, specialized transport means and systems for automatic handling of goods appeared. Supply chain management became global, logistic networks developed, new fields and companies that specialize in certain logistic activities and processes arose.

The third industrial revolution covers the period of three decades at the end of the 20th century and is marked by the development of ICT and their application in the field of production. The application of computers in production processes is the most important for this period. The Logistics & Supply Chain Management concept was introduced. Companies manage their supply chains on the global level, cooperate with suppliers, buyers, users and business partners, apply new business models and compare themselves with competition (Christopher, 2011). Logistics uses ICT, identification technologies and facilities monitoring, forms of electronic exchange of data, new technical solutions and software applications designed for managing processes and activities (Radivojević, 2016).

The fourth industrial revolution began in the 21st century and represented the integration of ICT with production processes and activities. Smart factories have automated processes and activities, digital business operations and information support on all organizational levels. The digital environment includes business partners, suppliers, buyers, users and the market with which the smart factory communicates through the Internet (Fonseca, 2018). In the new conditions, logistics has to provide visibility of real-time information flows, monitoring of market demands and direct users, personalization of products and services, decentralized autonomous management and global supply chains.

3. INDUSTRY 4.0

The term Industry 4.0 was first introduced in 2011 in Germany. Other European countries began making major changes in the same period, which were named Smart Factories, Industrial Internet of Things (IIoT) or Smart Industry (Hofmann and Rüsch, 2017).

The concept of Industries 4.0 implies connecting machines, products, systems and people that can share information and manage themselves and each other. In such a model, all objects are smart entities that have the ability to autonomously manage, control and communicate with the environment. Industry 4.0 understands complete automation and digitalization of business systems and their connections with the environment. This leads to the existence of a virtual reality model in which it is possible to monitor and manage all processes and activities. ICT, software applications and information platforms have the biggest role in the concept of Industry 4.0 because they provide connecting the virtual and physical business system.

Industry 4.0 is characterized by increased digitalization and mutual connection of products, value chains and new business models. This concept represents a new level of organization and value chain control throughout the whole life cycle of a product. The cycle begins with the idea of the product, customer request, design, production, placement of orders, delivery and ends with recycling. The value chain includes all activities of the supply chain and additional activities that are involved in creating the product value. Industry 4.0 is based on the availability of all relevant information in real time by connecting all links included in the value chain (Geissbauer et al, 2014).

The main components that form the concept of Industry 4.0 are (Santos et al., 2017; Vaidya, 2018): Cyber Physical System (CPS), Internet of Things (IoT), Internet of Services (IoS), Big data, Robotics, Cloud Computing (CC), Augmented Reality (AR) and Horizontal and Vertical Integration of the system. Various objects from the physical world are equipped with IoT devices which make them smart. In smart factories, there are smart machines, tools and equipment, and industrial robots that produce smart products. Data collection of all these objects enables the formation of a CPS in which data and process models correspond to the relations from the physical world. A virtual world is a digital version of reality in which processing and analysis of large amounts of data are performed by applying CC. The results of the analysis enable the possibility of monitoring and managing the physical world. An illustration of Industry 4.0 is given in Figure 2.

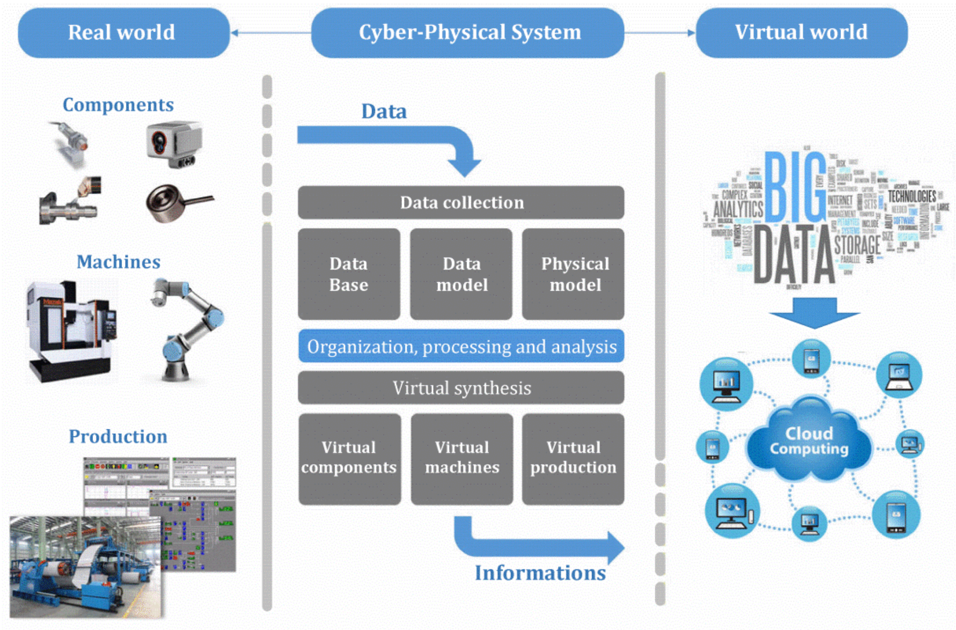

Figure 2. Illustration of Industry 4.0 (adapted from industry4.hu)

A research on the development, application and challenges of Industry 4.0 was carried out in 2015 and involved 235 German companies in the field of manufacturing, engineering, the automobile industry, electronics, information and communication (Geissbauer et al., 2014). The results of the research showed that companies will invest an average of 3.3% of their revenues in Industry 4.0 by 2020. These investments refer to the key areas in the value chain: supply chains, product development, planning, production, services and distribution. It is expected that 80% of value chains will be digitalized by 2020, productivity increased by 18% and about 110 billion Euros of revenue generated per annum (Geissbauer et al., 2014).

4. LOGISTICS 4.0

The term Logistics 4.0 first appeared in 2011 as a response and support to Industry 4.0. Today, the terms Supply Chain 4.0, Procurement 4.0, Marketing 4.0, Distribution 4.0, Warehousing 4.0, Inventory Management 4.0, Order Management 4.0, etc., can be seen. This represents the response of the logistic field to the development and requirements of Industry 4.0.

Logistics 4.0 should provide support the processes of Industry 4.0, from processing the market requirements and production planning to delivery of smart products to end users. The solution is in the digitalization of logistic activities and processes – the application of digital logistics. The characteristics of digitalization of logistic systems are (Kayikci, 2018):

- Cooperation – Digitalization enables the creation of virtual logistic associations (clusters) through which companies exchange data and information.
- Connectivity – Digitalization enables horizontal and vertical integration in supply chains and visibility of information in all chain links.
- Adaptiveness – The system of connected digital resources is flexible, as it can respond to different changes on the market (requests, users, suppliers, etc).

- Integration – In the digital world, integration of logistic systems is the process of connecting different computer systems and software applications, physically or functionally, in order to provide coordination of logistic flows.
- Autonomous – Smart objects, which have the possibility of communicating and independent decision making based on data processing of their own and environmental characteristics, are increasingly present in logistic systems.
- Cognition – Application of devices and systems for automation of tasks requiring human skills, knowledge, perception and cognitive skills (planning, reasoning and learning).

Logistics 4.0 is based on the latest ICT, software systems and the Internet which together should provide the following (Oleśków-Szłapka et al., 2019):

- Logistic management,
- Realization of commodity flows, and
- Realization of information flows.

Logistic management includes the planning, implementation and control of all logistic processes. The realization of commodity flows is a set of all activities that enable the movement of commodity flows from the source of raw materials to delivery of product to end user. Information flows are necessary to support realization of commodity flows and logistics management.

Logistics 4.0 is defined as smart logistics, because its components enable intelligent management of processes. The components of Logistics 4.0 are (Wang, 2016): Automatic identification, Real-time location, Automatic data collection, Connectivity and integration, Data processing and analysis, and Business services.

Automatic identification of all objects and participants in logistic processes, the possibility of locating them and data collection in real-time, enable quality management, planning and optimization. Data processing and analysis create new knowledge, conditions for intelligent management and new business services. There are numerous technologies that implement the stated components, and the most important are shown in Figure 3.

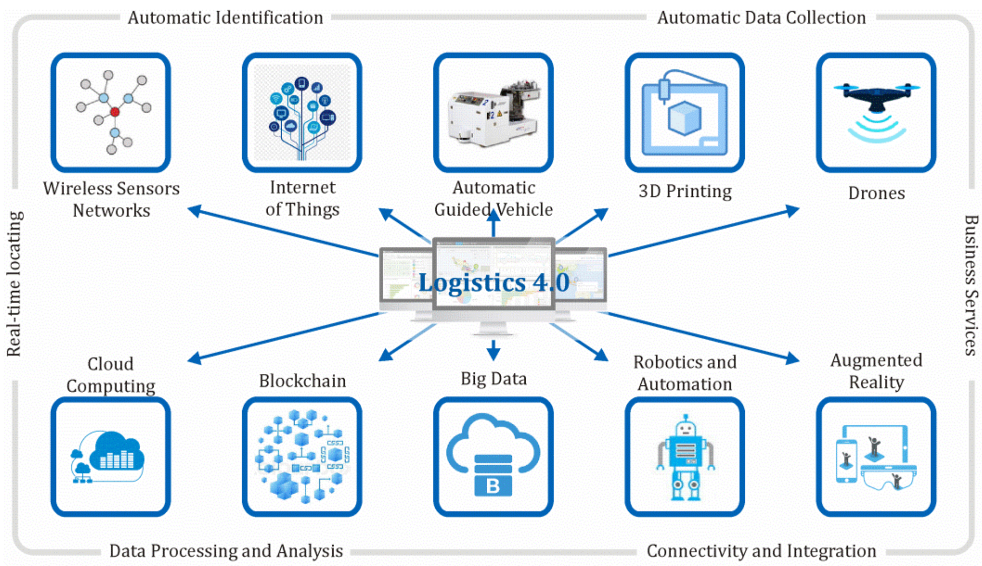

Figure 3. Components and technologies of Logistics 4.0

4.1 Internet of Things

IoT is based on the most contemporary ICT that enable marking, identification, communication and intelligent managing of things. In this concept, things become smart objects that have the ability of identification, communication and interaction. Realization of IoT enables the creation of a virtual model of virtual reality in which business models will be able to manage processes and activities in real-time on the basis of information on current state of objects. Identification technologies applied to different objects in logistics have led to the existence of smart containers, pallets, packing, packaging, vehicles, shelves, forklifts, infrastructure, ports, terminals, etc. Various models of connectivity through the Internet are present in logistic systems, which represent initial IoT solutions that lead to global connectivity of all participants and objects (Radivojević et al., 2017).

4.2 Cloud Computing

CC means the use of various computer services through the Internet. The main characteristics of CC are: providing services at the request of the user, broad network access, mutual using of resources, flexibility in use and measured use. This means the users can use computer resources when and however much they need; they can access the Internet through different devices; a large number of users can use the same resources; cloud systems automatically monitor and measure the use of resources for each user (Mladenović, 2018). CC provides numerous advantages to logistic companies as it enables quick, efficient and flexible access to IT (Information Technology) services and innovative solutions in supply chains. Logistic companies no longer need to invest in the procurement of software applications and hardware infrastructure, develop their own IT sectors and coordinate integration with business partners.

4.3 Big Data

Big Data include technologies for storing, transmitting, processing and analysis of large amounts of data that cannot be stored, processed and analyzed by traditional tools and data base technologies. The application of different analytical methods enables the formation of new information and knowledge from such data sets, which can influence management and decision-making in the business system (Jeske et al., 2013). Logistics 4.0 implies a significant increase in the amount, diversity and speed of data processing. By applying Big Data analytical methods and Data Mining (DM), companies can create additional values and apply new business models. DM enables finding hidden information, relations, relationships, rules and logic that exists among the data. By using DM, it is possible to predict market trends, user behavior, find causes of disorders, etc (Radivojević, 2016).

4.4 Blockchain

Blockchain technology can be described as a decentralized and distributed system of all transactions in a certain segment of work. One block represents a set of data and information on one transaction and it is added to the previous block, forming a chain. The blockchains can be found with all participants in business transactions, enabling visibility and availability of information. The possibilities of blockchain technologies in logistics are faster and more reliable logistics in global trade; improved monitoring and visibility of goods in supply chains; automation of commercial contracts between business partners through smart contracts based on blockchains; etc. Blockchain in logistics and supply chains provides security, protection and tracking of information, transparency of data for all partners and users, financial savings through smart contracts, development of new business models, etc (Kückelhaus and Chung, 2018).

4.5 Wireless Sensor Network

Wireless Sensor Networks (WSN) are systems consisting of a sensor and wireless communication network. WSN enable collection and transfer of data between sensor nodes, access devices and network users. Sensors are used to identify objects and their physical characteristics – characteristics of goods, transport and transshipment means, containers, locations in warehouses and sales facilities, equipment and traffic infrastructure, etc (Radivojević, 2016). Some examples of the use of WSN in logistics are (Kückelhaus and Chung, 2018): measuring vehicle load is based on WSN and 3D cameras; quality control of goods based on analysis of data obtained from sensors; sensors are installed in transport and transshipment equipment, infrastructure and facilities in logistics; work clothes with built in sensors improve safety and health conditions of workers; etc.

4.6 Robotics and Automation

Applying robotics and automation in production processes enables: improved quality of finished products and safety levels, reduction of errors, necessary labor and costs, improving quality standards, etc. Development of robotics suggests that robots, in the future, will be faster, more precise, flexible and affordable, which will accelerate their use. The contemporary market sets faster demand, efficiency and faster responses to users' requests to logistic companies. There are numerous examples and possibilities for applying robots in logistics (Kückelhaus and Chung, 2018): a fleet of intelligent robots for collecting, commissioning and sorting of goods; robots for unloading containers based on OCR (Optical character recognition) technology and intelligent control; robots used for sorting goods in delivery vehicles or self-delivery of goods to the point of collection, etc.

4.7 Augmented Reality

Augmented Reality (AR) enables elimination of borders between the physical and digital world, providing users with a view of reality expanded by information from the digital world. Digital layers of information are shown on the device, creating a picture of enlarged reality to the user. The devices may be glasses, tablets, laptops, mobile phones and similar. AR provides the right information at the right time and in the right place. Some possibilities of AR application in logistics are: application of smart goggles in warehouses for collecting, sorting and packing operations; smart handling of forklifts and vehicles; smart delivery of goods to the end user using smart goggles, etc. Research and development of AR devices, the possibility of recognizing images and connecting devices with software applications will create conditions for application of AR in all logistic processes (Kückelhaus and Chung, 2018).

4.8 Drones

Unmanned Aerial Vehicles (UAVs) – drones will not replace the traditional method of transport but they can be used for safe operation in remote and potentially dangerous locations. Commercial use of drones has been in the phase of testing in recent years in some large companies (Amazon, Google, DHL). The greatest application of drones is expected in intralogistic processes, monitoring of logistic activities and delivery of goods to end users. Intralogistic operations can be simplified by using drones for transport between production units, urgent delivery of spare parts or for transfer of goods from warehouses to retail sections within the same facility. Drones can be used for checking the state of facilities and equipment, stock control and checking incoming vehicles on receiving gate. Drones for delivery of goods to end users may transform the existing methods of delivery in large cities and rural areas (Kückelhaus and Chung, 2018).

4.9 3D Printing

3D Printing is a contemporary technology for creating three dimensional objects which has started to be applied in various fields, from the pharmaceutical industry and production of medical devices to production of spare parts and aircraft parts. 3D printing will considerably impact logistic processes and services: regional logistic networks will become more complex, new supply chain strategies will be developed; companies will be able to offer new logistic services in the field of spare parts supply; logistic providers can define a global 3D platform with a digital model base; personalization of products and services, in conformity with users' requirements, is realized by 3D printing in the nearest distribution center. 3D printing allows delivery of goods at the request of the user, an increase in delivery and decrease in stock costs (Kückelhaus and Chung, 2018).

4.10 Automatic Guided Vehicle

Automatic Guided Vehicles (AGV) have been in use for more than 60 years in various fields of industry, production processes and warehouse facilities. AGVs are unmanned vehicles based on sensor and video detection technologies, artificial intelligence and other ICT. AGV vehicles that are used in logistic processes may be: tractors for towing trailers, vehicles for unit loads, pallet trolleys, trolleys with additional forks, light load vehicles, assembly line vehicles, special vehicles, etc. These vehicles are used for traditionally demanding tasks; they enable automatic handling of freight and equipment. The application of AGVs in logistic processes decrease expenses and labor, increase reliability, productivity, safety and quality of work, reduce the risks of human errors and damaged, etc (Kückelhaus and Chung, 2018).

5. ADVANTAGES AND CHALLENGES OF LOGISTICS 4.0

The introduction of Logistics 4.0 is becoming an imperative for all companies that want to stay on the market. This requires large investments, changes in the methods of work and decision-making, contemporary education and employee training. There are no concrete data on the effects of applying the concept of Logistics 4.0, but various papers state numerous possibilities and improvements which may be realized by logistic companies and users. Some advantages of Logistics 4.0 are (Oleśków-Szłapka et al., 2019):

- Complete integration of the physical and virtual world;
- The possibility for users, machines and systems to have communication in real-time and possibilities of independent decision-making of all participants in logistic processes;
- Improvement of all processes in supply chains, reduced risk of structural or organizational errors during realization of a process and possibility of decreasing the process realization time in accordance with users' requests;
- Accessibility of contemporary technologies for processing and analyzing large quantities of data;
- Improvement of business performance and access to all resources;
- Increased visibility and flexibility of supply chains, etc.

The disadvantages of Logistics 4.0 are primarily the consequence of high demands relating to organizational, technical and software solutions. A company has to change the way it operates, its organization of management and apply the latest IT solutions so that it could meet the preconditions for introducing a new concept of smart logistics. The challenges facing Logistics 4.0 are: high introduction and implementation costs, strict requirements in view of hardware infrastructure, requirements for application of process-oriented management methods, etc. The solution to the stated challenges are good implementation, the commitment of the whole company to changes, motivation of employees for further training and development of their own intellectual resources that support changes (Oleśków-Szłapka et al., 2019).

There is no data on logistic companies which completely encompassed the process of implementing Logistics 4.0 in available literature, but there are many examples of the application of some components of Logistics 4.0 (Figure 4). Most often this refers to large and successful companies that have their own IT sectors or cooperate with IT companies through innovation centers, open laboratories or projects (Kückelhaus and Chung, 2018).

Amazon's warehouse robots | AR in DHL warehouse | AGV in port Hamburg

Figure 4. Examples of applying some components of Logistics 4.0

6. CONCLUSION

Throughout history, the field of logistics has developed and continuously adapted to the needs of the population, current technological trends and industry. This paper described the concept of Logistics 4.0 which represents the response to the requirements of Industry 4.0. Logistics 4.0 includes the latest ICT, software applications, new business models and concepts that together enable complete digitalization and automation of logistic processes and activities.

This concept imposes numerous challenges to companies: large financial investments, implementation risks, strict infrastructure requirements, new levels of education and skills of the employees, etc. At the same time, this concept has not been fully defined because new technologies are continuously being developed and new solutions applied. Applying the Logistics 4.0 concept for companies is not a matter of choice (*should it be applied?*) but a matter of time (*when do we start?*).

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REFERENCES

[1] Christopher, M. (2011). Logistics & Supply Chain Management, 4th ed. Financial Times Prentice Hall, London.
[2] Fonseca, L.M. (2018). Industry 4.0 and the digital society: concepts, dimensions and envisioned benefits, Sciendo, 12(1), pp. 386–397.
[3] Geissbauer, R., Schrauf, S., Koch, V., Kuge, S. (2014). Industry 4.0 – Opportunities and Challenges of the Industrial Internet, PwCIL, Germany. Retrieved from www.pwc.de/industry4.0. (Accessed 25.01.2019)
[4] Hofmann, E., Rüsch, M. (2017). Industry 4.0 and the current status as well as future prospects on logistics, Computers in Industry, 89, pp. 23–34.
[5] industry4.hu. (Accessed 21.01.2019)
[6] Jeske, M., Grüner, M., Weiß, F. (2013). Big Data in Logistics. Retrieved from www.dhl.com. (Accessed 23.12.2018)
[7] Kayikci, Y. (2018). Sustainability impact of digitization in logistics, Procedia Manufacturing, 21, pp. 782-789.
[8] Kückelhaus, M., Chung, G. (2018). Logistics Trend Radar, DHL Customer Solutions & Innovation, Germany. Retrieved from www.dhl.com. (Accessed 23.12.2018)
[9] Mladenović, T. (2018). Cloud Computing in logistics, Master Thesis, Faculty of Transport and Traffic Engineering, University of Belgrade.
[10] Oleśków-Szłapka J., Stachowiak A. (2019). The Framework of Logistics 4.0 Maturity Model. In: Intelligent Systems in Production Engineering and Maintenance. ISPEM 2018. Advances in Intelligent Systems and Computing, 835. Springer, Cham.
[11] Radivojević, G. (2016). Information Management in Logistics, Faculty of Transport and Traffic Engineering, University of Belgrade.
[12] Radivojević, G., Bjelić, N., Popović, D. (2017). Internet of Thing in Logistics, Proceedings of the 3th Logistics International Conference – LOGIC 2017, pp. 185-190, Belgrade, 25-27 May 2017.
[13] Santos, C., Mehrsai, A., Barros, A.C., Araujo, M., Ares, E. (2017). Towards Industry 4.0: An Overview of European Strategic Roadmaps, Procedia Manufacturing, 13, pp. 972-979.
[14] Vaidya, S., Ambad, P., Bhosle, S. (2018). Industry 4.0 – A Glimpse, Procedia Manufacturing, 20, pp. 233-238.
[15] Wang, K. (2016). Logistics 4.0 Solution New Challenges and Opportunities, Proceedings of the 6th International Workshop of Advanced Manufacturing and Automation – IWAMA 2016, pp. 68-74, Manchester, UK, 10-11 November 2016.