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LOGISTICS 4.0 – THE CURRENT STATE AND FUTURE CHALLENGES

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Purpose: The main purpose of the paper is to present the up to date status of Logistics 4.0 and to define its future challenges.
Design/methodology/approach: The research methods used in the paper are literature studies and the case study method.
Findings: Future challenges for Logistics 4.0 were determined.
Originality/value: Results have theoretical, as well as practical implications for the management of Logistics 4.0.

Keywords: Logistics 4.0, evolution of Logistics 4.0, future trends of Logistics 4.0, RFID.

Category of the paper: technical paper, case study.

1. Introduction

The development of the logistics sector is strongly associated with the development of industry, which is now transforming production and business models according to the concept of Industry 4.0. It is the current trend of automation and data exchange in production technologies, which include cyber-physical systems (Internet of Things, Internet of Services). Logistics, which is a ubiquitous activity, consistently follows this trend and strives to implement the vision of Logistics 4.0, which contributes to the development of Industry 4.0 (Marjan, Lerher, Gajsek, 2018).

Logistics 4.0 is linked to the same terms as “Smart Services” and “Smart Products”. Thus, a technology-based approach for defining both of the aforementioned concepts is used to define “Smart Logistics”. The term “smart” may change over time, due to technology advancement. Therefore, the term “smart” depends on the time.

The most modern Logistics 4.0 system is based on the use of cyber-physical systems (CPS) that monitor and control physical processes, usually with feedback loops, in which physical processes affect calculations and vice versa. This CPS uses RFID technology to identify, detect and locate an object, and sends data to a computer that collects and analyzes all relevant information. These systems are able to communicate with other systems or people via Internet and can share data in real time, and thus processes can be coordinated (Herman, Pentek, and Otto, 2015).

Today, many transport and logistics companies use RFID systems, which are almost entirely used for distribution (shipping), receipt and control of order accuracy, in 99.5% for inventory accuracy and 30% for faster processing of orders and lowering labor costs. RFID systems position the product throughout the entire supply chain. It is an automatic method used to identify the product and where it is located. Nowadays, RFID systems are used to monitor shipments and products, manage storage and distribution, as well as to manage an enterprise using the Internet to connect systems throughout the entire supply chain and exchange data in real time (Motorola, 2014).

2. Examples of Logistics 4.0

The B&R company

One of the most innovative automotive companies in the world is B&R, which is an industry leader in the field of industrial automation and process control. The company constantly invests in personnel and services, knowing that the distribution of automation logic in the entire production system of Industry 4.0 has created an urgent need for communication networks that ensure transparency and efficiency, without compromising reliability.

The latest B&R project has optimized the production of industrial computers. Customers make their orders via PC using online tools, which then verify the feasibility of the order and the ERP system generates an invoice with a unique serial number.

Mathematically speaking, the customer has over 250 billion options to choose from various devices. The head of global industry management in B&R, Gerald Haas, claims that the goal has been achieved, because a batch in the amount of 1000 is produced as if it was a one-off, i.e. with the same accuracy. An optimized order processing schedule is planned using the ERP system, which makes logistics efficient. Parts from the warehouse are delivered just in time. The plant in Eggelsberg (Austria) is completely networked, both horizontally and vertically.

It has one homogeneous network, which includes every machine and element of building automation in the ERP system. This allows the system to control automated vehicles for storage and retrieval in the warehouse. For B&R, smart factory production using the web has been a reality since 2006. Communication in the factory network works in all directions. When the module reaches a fully-automated assembly, testing and labeling station, the real SAP query time determines which tests are required. This is possible because each product has a unique serial number, read by the RFID system. B&R collects and analyzes all production data using its own process control software.

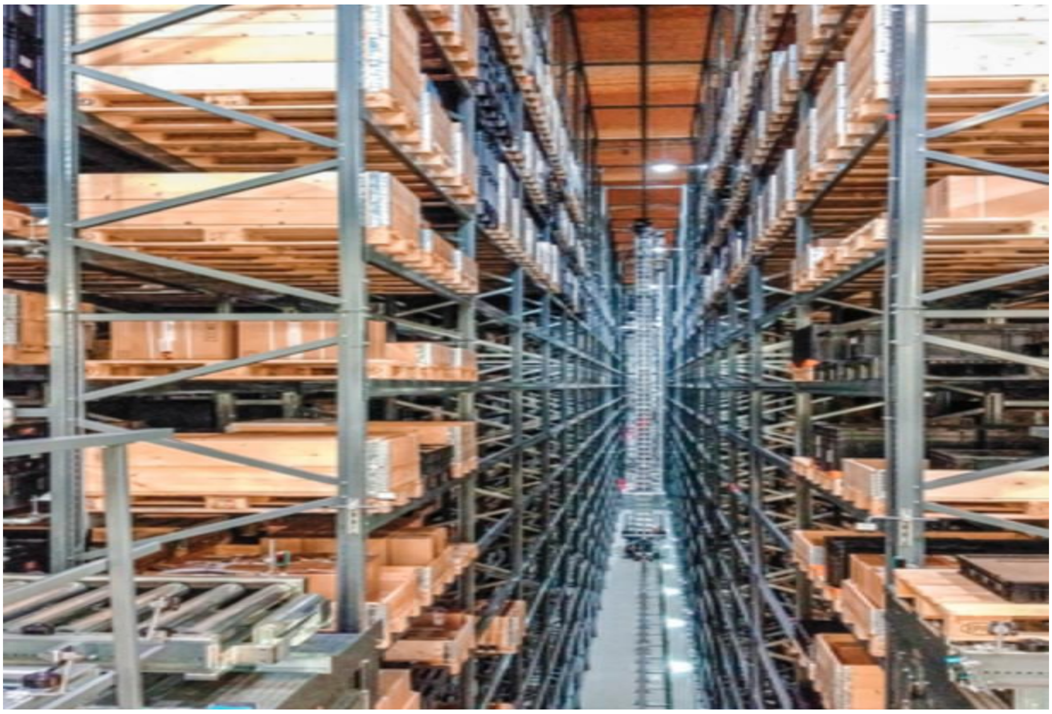

Figure 1. High bay warehouse in a factory. Adapted from: B&R (2019), https://www.br-automation.com/en/industries/automotive-industry/.

The above figure shows a high bay warehouse at the company's factory. The production halls in B&R are fully networked. The ERP system has direct control over the storage and distribution of vehicles in the high bay warehouse and automatically optimizes production logistics.

Toll Group

Toll Global Logistics needed more effective system for monitoring (tracking) goods and shipments in Singapore. An RFID system was implemented, which marked each of the 150,000 pallets in a given UHF passive area. RFID tags have been implemented, which resulted in savings in man-hours and better visibility for the company and its customers. When shipments arrive, staff members scan barcodes on boxes and then use the portal to read RFID tags on pallets, into which these boxes are loaded or distributed. The pallet identification data is then combined and sent via Wi-Fi to a software that stores the data and makes it available to both the internal users, as well as Toll Global customers. Logisticians estimate that the system will save about 6 minutes of staff time on a pallet, which gives over 600 man-hours (Motorola, 2014).

Figure 2. Storage facility in Singapore. Adapted from: Motorola (2014). Advantages of RFID in transportation and logistics.

Southeastern Plastics Corporation

The Southeastern Plastics Corporation produces forms for plastic bottles in three injection molds. Production plants located in the eastern United States send these forms in cardboard and plastic containers. Empty containers return to the molding plant to repeat the cycle. The refund process costs thousands of dollars a year due to damage and losses. The company replaced existing paper containers with more expensive plastic containers and introduced RFID technology to the market, i.e. a counting system to track the life cycle of the containers in relation to the number of cycles guaranteed by the manufacturer. Each container is permanently identified by means of an RFID tag, used to locate and track each unit in real time, giving the ability to track and extract maximum business value from each container. The company expects to achieve a return on this project in less than two years (Southeastern Plastics, 2019).

Figure 3. Southeast injection molding plant. Adapted from: Southeaster Plastics Corporation (2019). http://www.seplastics.com/index.html.

3. The evolution of Logistics 4.0

Historically, one can notice, that industrial production has been evolving periodically. These evolutionary changes took place gradually or – occasionally – they were sudden (revolutionary). During these periods, we distinguish further levels of development of Industry and Logistics (1.0, 2.0, 3.0 and upcoming 4.0). Figure 4 shows the beginning of industrial logistics development and the direction of such development in the following years.

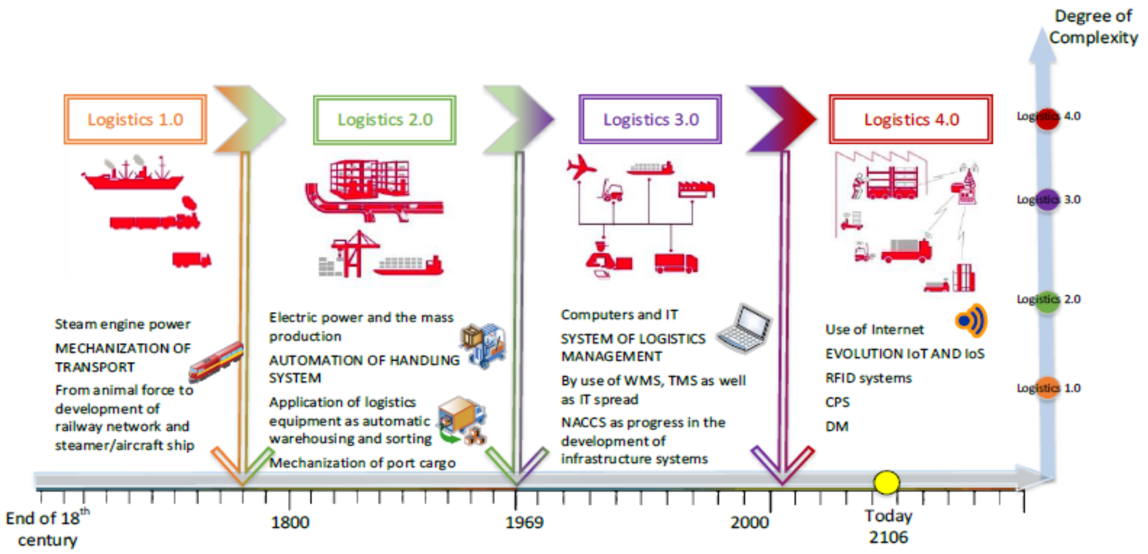

Figure 4. Logistics evolution. Adapted from: Galindo L.D (2016) The Challenges of Logistics 4.0 for the Supply Chain Management and the Information Technology, NTNU

4. Logistics 4.0 framework

The introduction of the Internet of Things and services into production initiated the fourth industrial revolution (Kangermann, Wahlster, & Halbig, 2013).

Industry 4.0 is characterized by an increase in industrial production, compared to the previous revolutions. New production methods have been developed based on a variety of technologies (Schmidt, Hohring, Harting, Reichstein, Neumaier, and Jozinovic, 2015).

This new paradigm shift in production is the result of using the Internet, which enables machines and people to communicate with each other in real time using the so-called "Smart products and smart services" in advanced digitized factories. A "smart factory" combines all the elements involved in production processes with the use of such concepts as adaptability and interconnection of processes, as well as efficiency and ergonomics (Lasi, Kempen, Feltke, Feld, and Hoffman, 2014).

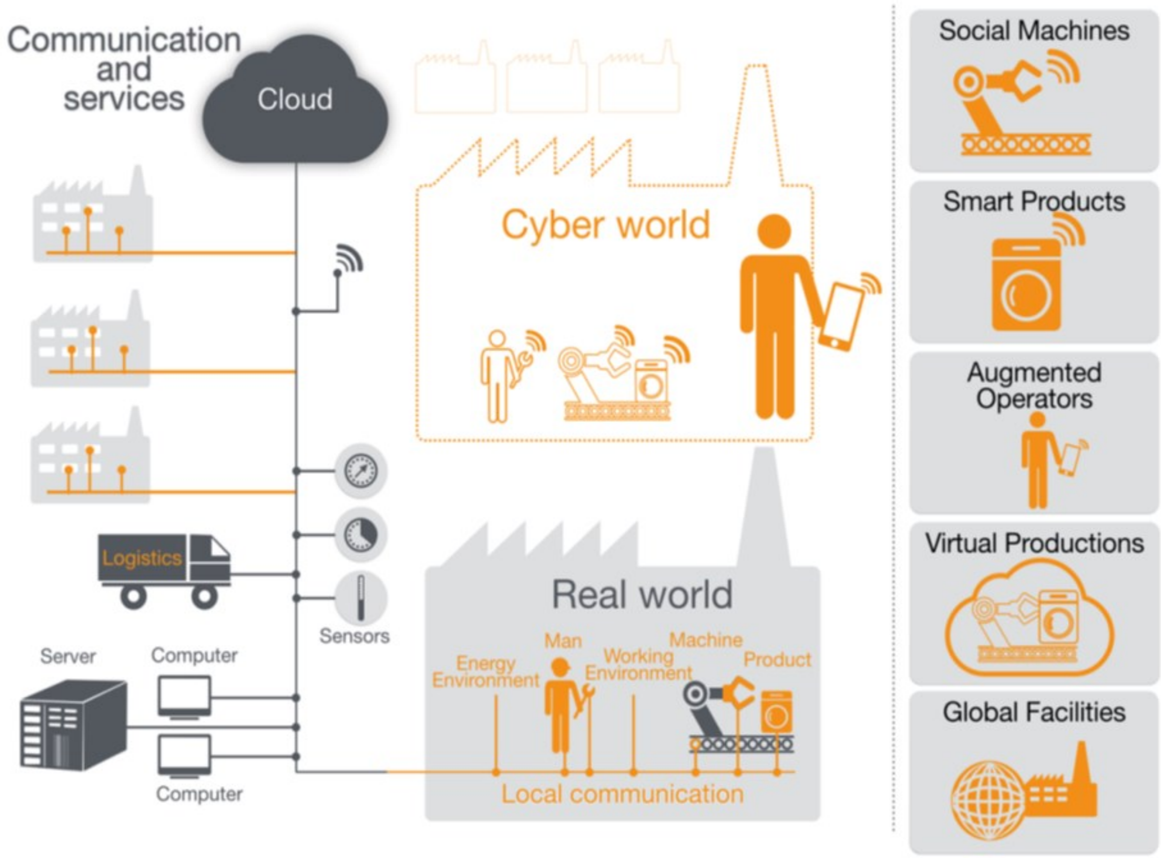

Figure 5. Combination of CPS and IoT to achieve the objectives of Industry 4.0. Adapted from: Galindo L.D (2016) The Challenges of Logistics 4.0 for the Supply Chain Management and the Information Technology, NTNU.

When it comes to Logistics 4.0, it can be said, that this is a progress in terms of "saving work, standardization through the Internet of Things". By using robots in warehouse technologies, processes carried out by humans can now be performed by machines. The purpose of such technology is a perfect balance between automation and mechanization.

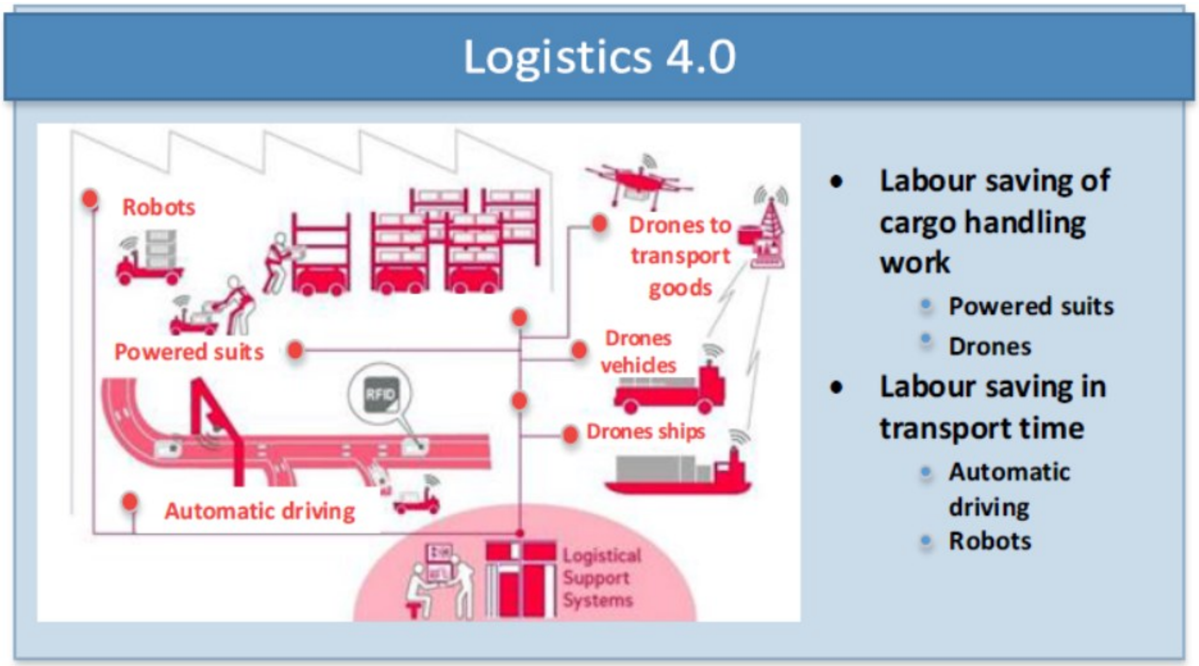

Figure 6. The previous technology characterizing Logistics 4.0. Adapted from: Galindo L.D (2016) The Challenges of Logistics 4.0 for the Supply Chain Management and the Information Technology, NTNU.

To implement a technology that turns factories into "smart factories", special training is needed, in order to improve logistics performance and cost-efficiency, as well as save time. Automatic warehouses and automatic transport are already widespread, but their scope of use is limited, as it is not compatible with the production line and with the shape and characteristics of the package of interest. Therefore, the main goal is to implement a new technology that allows to save time on work related to the transport and the transport itself, as shown in Figure 6.

4.1. Labor saving when handling cargo

With the help of warehouse robots transferring goods from the warehouse to the final means of transport, it is possible to facilitate human work. As an example of such implementation, we can use the example of Amazon, which – since 2012 – has adopted the robot manufacturer "Kiva Systems" that promotes the automation of packaging fulfillment. The robot called "Kiva" replaced "walking employees", and thus managed to increase work efficiency during each distribution task.

Hitachi, Ltd. has developed an automated guided vehicle called "Recrew", which was used in the Hitachi Transport System logistics center. Warehouse problems can be solved by automatic robots controlled by unmanned forklifts.

4.2. Saving work during the transport process

Transport determines the efficiency of product movement. Figure 7 presents the components of logistics costs, based on the estimates of the Chang Logistics Management Association of Transport, 2000).

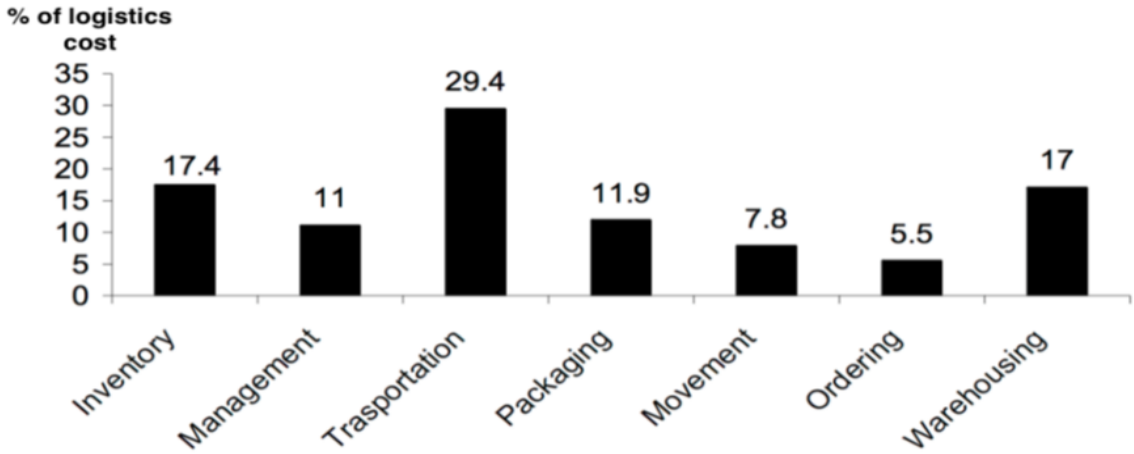

Figure 7. Components of logistics costs (Chang Logistics Management, 2000). Adapted from: Galindo L.D (2016) The Challenges of Logistics 4.0 for the Supply Chain Management and the Information Technology, NTNU.

Optimization of the transport process will have a large impact on the structure of logistics costs. To achieve "driving automation", it is required that the transport process takes place in several parts. First of all, an automatic highway should be designated, then it will be necessary to adapt car insurance regulations and systems, as well as technical considerations to fully automatic operations, overcoming various obstacles. With partial highway automation, the impact on logistics costs will depend on personal costs of truck drivers and will be lower.

Another application of the new logistics technology is the use of drones. The world's largest logistics company, DHL, plans to use drones as a means of emergency transport. Employees developed the "Parcelopter", which is a drone capable of flying for about 45 minutes. Work is underway to expand this form of transport. Some companies are interested in using this drone to transport and control equipment on campus. Another example is the use of drones in material and inventory management at Chiyoda Corporation – a leading engineering company that works in material management with drones. The use of drones in inventory management is expected to increase in the future.

Rolls-Royce is working on the development and commercialization of drone ships. The ship can be full of goods. However, there is a risk of pirate attack, so an insurance system must be developed.

4.3. Logistics network

The basis of this 4.0 evolution is the IoT (Internet of Things), which, by optimizing logistics processes, allows to combine all functions and information in real time. We can say that Logistics 4.0 is the standardization of the logistics infrastructure. For example, Bosch introduced virtual tracking to provide information to the company's production, distribution and commercial partner. The use of RFID tags introduces automation of data management of incoming goods and optimization of stocks.

In this way, a flexible review of production planning and logistics is possible in relation to changes in supply and demand in the transport environment. If several companies use this system, they can share data in real time. In addition, DHL has developed integrated management through the Agheera platform, available to a lot of logistics companies in real time. Therefore, future smart factories will act as a "big brain", sharing information in real time between all stakeholders, which provides an optimization of logistics processes. With such use of IoT in logistics, it will be necessary to use a secure data protection system. Figure 8 is a forecast of the future in the field of logistics technology, already referred to as Logistics 4.0.

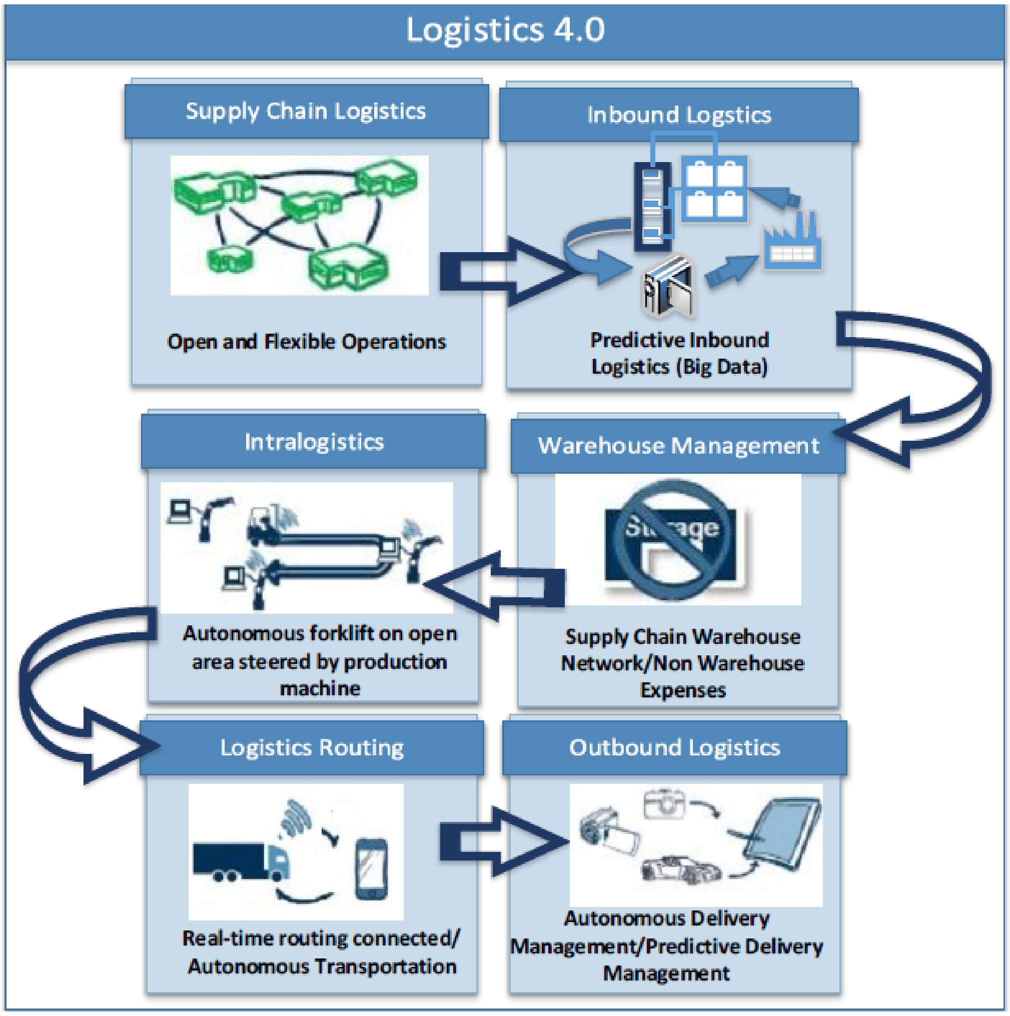

Figure 8. Supply chain management process in Logistics 4.0. Adapted from: Galindo L.D (2016) The Challenges of Logistics 4.0 for the Supply Chain Management and the Information Technology, NTNU.

Supply chain management will consist in a creation of a large network of stakeholders (clients and suppliers) gathered within an online platform, where all orders from clients and suppliers will be implemented in real time.

The flow of goods within a factory, i.e. internal logistics, will be fully compatible with an automated forklift and its routes, which will be programmed according to inbound logistics and information received from an online platform used by all interested parties.

As a result of such actions, warehouse costs will be reduced to a minimum or disappear altogether because all customer and supplier orders will be foreseen. Fleet vehicles will have a route programmed according to the internet platform, while customers and suppliers will be able to track vehicles using GPS data, showing their location in real time. It should be noted that the automation will not replace people in their work entirely. The aim of introducing automation processes is to help people in their work and provide them with a more secure workplace.

5. Technical elements of Logistics 4.0

Logistics 4.0 can be defined as Smart Logistics. The term "smart" depends on the technology used to identify, locate, detect, process and act to promote smart logistics.

5.1. Identification (RFID systems)

The first step is to identify products in the virtual and real world. The RFID system can be used to identify logistic objects marked with an RFID tag. The reader identifies the object when it passes by and sends product information via radio waves to the computer that processes the data.

The RFID system is an important technology that revolutionizes a wide range of applications, including supply chain management. It offers a convenient way of identifying objects by marking "the right thing", "the right time" and "the right place", confirmed by the identification number provided by the RFID tag (Uckellmann, 2008).

The benefits of using RFID technology include lowering labor costs, simplifying business processes and reducing inventory inaccuracies, as well as providing transparency in logistics processes.

5.2. Location (RTLS)

Identification is associated with the registration of an identified location using real-time locating systems (RTLS).

RTLS systems combine object identification and real-time localization. Some real-time locating systems provide a physical position (e.g. GPS coordinates), while others refer to a symbolic position, e.g. goods issue.

In addition to internal location systems, such as radio frequencies, infrared, ultrasound and magnetic systems, optical technologies are also one of the most widespread radio frequency identification technology (RFID system). We can distinguish the following methods of localization:

- Cell of origin (transponder-of-origin).
- Time of flight climb systems.
- Time Difference of Arrival (TDoA).
- Angle of Arrival (AoA).

The cell of origin only indicates that the transponder is in the reading range. Generally, any RFID reader or label attached to a fixed location means the location of a cell of origin. For example, to track pallets, floor transponders are used, that have low frequency readers attached to them, in order to indicate their position when the forklift passes them.

Another way of locating in real time is by using the strength of the received signal, where any equipment is located by measuring the strength of the received signal. The RFID systems enable the location of an object while the tag is within the range of multiple antenna readings and the amplitude can be used to locate the tag.

TDoA systems use algorithms for regulation and location estimation, taking into account the degree of synchronization between readers when measuring exact times.

AoA systems are used at airports, where rotary radar antennas for aircraft location are located. The antennas rotate, in order to find the direction of the highest signal strength. Antenna arrays are also used to measure angles.

There are hybrid methods that combine all of the above technologies. For example, in case of a combination of GPS and passive RFID in hybrid personal data, the terminal is used to track location. An RFID system with several antennas, used to locate an object depending on the frequency received for each antenna, is an indoor location system. For an external location system, GPS is the most commonly used technology.

5.3. Detection (CPS)

Detection is a system that provides the function of the proper state of the logistics system. The condition of the goods is essential in many areas, such as the cold chain and fresh food logistics.

CPS are automated systems that actually allow to combine physical operations with computer and communication structures. The system usually consists of a unit of one or more microcontrollers used to control sensors and actuators that interact with the environment. The data obtained can be exchanged with other CPS using a communication interface. CPS consists of two main functional components:

- Advanced connectivity used to gather real-time data in the physical world and feedback from the computational world (RFID system).
- Intelligent data management, analytical and calculation functions (software).

Obtaining accurate and reliable data from the machines about their components is the first step in the development of CPS. Such data can be measured directly from sensors or obtained from controllers or production systems of the enterprise, such as ERP, MES, SCM and CMM. All this data is continuously and permanently sent to a central server.

Another main issue to develop CPS is to choose the right sensors (type and specifications) (Lee, Bagheri, and Kao, 2014).

In short, sensors and actuators, together with computer software, create CPS, which enables product detection and comparison of information from sensors and actuators with a virtual model to verify if the product adapts to the model and the appropriate state has been achieved.

5.4. Internet of Things (IoT) networks

Thanks to IoT, enterprises can supervise and manage each of their products in real-time in logistics architecture. They not only supervise information in the supply and stock chain, but can also analyze data generated from each procedure and forecast. By forecasting information about your products from the current procedure, you can predict the future, as well as trends or the likelihood that an accident might occur, when you would need to assess and take remedial measures that could be prepared in advance. This improves the ability of companies to react early to the market.

The Internet of Things and services make it possible to create networks that contain the entire supply chain process, which – in turn – transforms it into Smart Logistics. CPS consists of smart storage systems, machines and production equipment using digital ICT-based integration, combining production, marketing, service and distribution logistics (Group, 2013).

IoT can be defined as a network of unique cyber-physical systems cooperating to achieve common goals, which is why IoT is understood as one of the main parts of CPS.

The "things" in IoT are sensors, actuators (which form CPS), as well as communication modules, i.e. devices that can work with smart components, in order to achieve the goal, without which they would not be able to achieve. IoT is, therefore, a network, in which CPS can communicate and cooperate with each other through a common goal.

CPS often uses human-machine interfaces to enable communication between users and production facilities in a network environment (Creation, 2015).

In short, the Internet of Things is present in the entire supply chain. First, it optimizes supply chain management; secondly, it ensures efficient use of resources; thirdly, it makes the entire supply chain visible and transparent, in which information on the supply chain can be improved; fourthly, the supply chain is managed in real time, which provides high supply chain flexibility and full integration (Sun, 2012).

In supply chain management, the Internet of Things manifests in a production connection with storage, as well as transport and sales links. This means that enterprises are comprehensively stocked and are able to adapt quickly (Obitko and Jirkovski, 2015).

Leading industrial companies are digitizing and combining value chain functions both vertically and horizontally. They include a digital conversion process with automated product data transfer, combined with a planning and production system, as well as integrated customer service, including horizontal integration of inventory and planning data from suppliers, customers, as well as value chain partners. All this optimizes the flow of product information from the customer through their own company to the supplier and back (Wegener, 2015).

5.5. Data collection and analysis (Big Data and data search)

Logistics 4.0 means a huge increase in diversity, volume and speed of data creation. Previously, only simple data types were collected and measured, e.g. temperature, now big data is obtained in real time, such as images or films. This type and amount of collected data has increased with the development of the sensors (Schmidt, Möhring Härting Reichstein, Neumaier and Jozinavić, 2015).

Over 90% of the surveyed companies believe that the effective analysis and use of data is of great importance, and the ability to analyze this data will be decisive for their business model in five years (Wegener, 2015). This processing and analyzing of large amounts of data will be fundamental to this industrial revolution, i.e. the Internet of Things.

5.6. Business services (IoS, ERP, invoicing, marketing, CMS)

IoS is a term used to describe the concept of offering services over the internet. These can be services offered by different suppliers that can be combined by value. IoS is based on a service provider that provides the services themselves, the nature and infrastructure of the services, as well as business models. The services created are, therefore, available to customers. For example, it may be the creation of virtual production technologies, as well as the possibility of combining individual services necessary to perform a complex task during the process (Obitko and Jirkovsky, 2015).

The IoS idea has already been implemented in the Smart Face project under the name "Autonomics for industrie 4.0" initiated by the German Federal Ministry in the field of economics and energy affairs. This project is based on a service-oriented architecture, enabling the use of modular assembly stations that can be flexible, modified and expanded as needed. Transport between the stations takes place via automated vehicles. Both assembly stations and automatic vehicles offer their services using IoS. The vehicles have customer-specific configurations and can autonomously decide which stages of work are necessary. Therefore, one can compose processes individually using IoS (Herman, Pentek, and Otto, 2015).

The technological processes described above enable the implementation of the Logistics 4.0 concept. This concept consists of smart identification (e.g. using RFID and tags), product identification and location (with RFID antennas working as RTLS), then the information collected in the tag (Big Data and Data Mining) is sent via the network to the Database. This system creates CPS, which allows the object to track itself without human intervention, communicating with itself via the Internet on the CPS network.

The main principles for the design or implementation of all technical components are as follows:

- Interoperability – in which normalization and semantic descriptions are important, as companies, people and CPS are connected by IoT and IoS. The German Electric, Electronic and Information Committee indicated DIN and VDE Technology for the need of standards and published the “German Standardization Plan” in 2013.
- Virtualization – thanks to CPS, where the physical world can be connected with the virtual one. The physical data from the sensors is combined with virtual and simulation models. Thus, a virtual copy of the physical world is created, that allows CPS to physically monitor processes.
- The ability to work in real time – providing continuous data analysis to react immediately, when needed, to any changes in the environment.
- Decentralization – i.e. providing autonomy, resources and responsibility to the lower levels of the organizational hierarchy. Individual agents make their decisions in person and pass them on to the higher levels in the event of failure or complex situations. Because of this, it is difficult to centrally control systems by nature. This requires an enterprise to analyze hierarchical planning and a more decentralized coordination concept.
- Modularity – in order to be flexible in this changing environment, it is necessary to adapt or add and use new modules.
- Service orientation – the structure should be service-oriented (SOA), which is an architectural model in computer software design, in which the application provides services to other components via network communication.

These services should be hermetically guarded and, when combined, facilitate use via ICT (Obitko and Jirkovsky, 2015). The following table shows the design principles required for each technical component.

Table 1.
Design principles for each Logistics 4.0 technical component

	Identification	Locating	Sensing	Networking	Data collection and analysis	Business services
Interoperability	X	X	X	X	X	X
Virtualization	X	X	X	X	X	-
Real-time capability	X	X	X	X	X	X
Decentralization	X	X	X	-	X	X
Modularity	-	-	-	-	-	X
Service Orientation	-	-	-	-	-	X
Security	-	-	-	X	X	X

Adapted from: Galindo L.D (2016) The Challenges of Logistics 4.0 for the Supply Chain Management and the Information Technology, NTNU.

6. Conclusion

The main challenges arising from digital technology and automation are significant investments in software and machines, as well as the transformation of companies to successfully implement this technology. Thus, unclear economic benefits and high investments are the two most important obstacles arising from this technology. Figure 9 shows the major challenges faced by companies in relation to the integration of technology and the business model that marks the fourth industrial revolution.

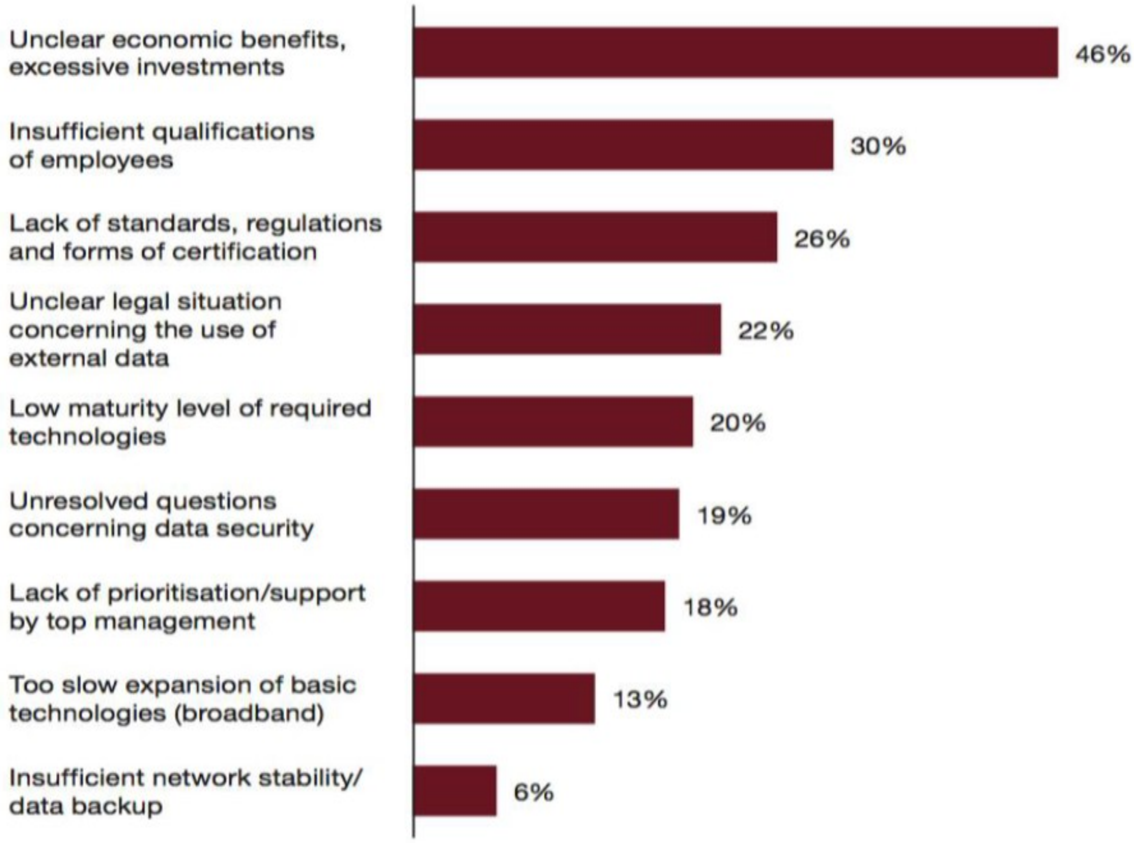

Figure 9. Challenges for the successful implementation of the technology and business model of the fourth industrial revolution. Adapted from: Wegener D. (2015). Industry 4.0 – vision and mission at the same time. Industry 4.0 – Opportunities and challenges of the industrial Internet.

Changing the requirements for employees at all stages of the supply chain value is another challenge in terms of insufficient qualifications of employees in the field of digital technology. The Internet of Things and growing digitization requires employees competent in the topic of data science and information technology. Hence, the foundation for the education needed for digital technology should be created through incentives and enthusiasm from an early stage. Due to the wide range of complex challenges and the simultaneous lack of agreed standards, with the meaning that enterprises alone cannot face the challenges, but also require joint efforts of industrial associations, trade unions and employers' associations. Industrial policy makers can provide support that promotes uniform industry standards and regulations.

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