LOGISTICS 4.0 – DIGITALIZATION OF THE SUPPLY CHAINS

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Abstract

Constantly changing market needs and the concentration of the entire supply chain on the level of customer service force both in the business and scientific world to seek modern solutions to improve logistics processes. This trend is leading to the transformation of current solutions into intelligent supply chains. The use of modern technologies is aimed at improving logistic processes at the operational level, by shortening the time of execution, minimizing bottlenecks and errors resulting from faulty information flow. With the above aspects in mind, the authors of this article have analysed in depth the structural differences distinguishing logistics 4.0 from the latest technological solutions. Concrete examples show toolkits and actions that optimise logistics processes in an enterprise, supported by intelligent cyber-physical systems providing relevant information, based on full cooperation of the Internet of Things (IoT), to achieve a significant degree of automation. Particular attention has also been paid to the immeasurably important aspect that the human element invariably remains. The basic business requirement is that the systems should be autonomous, people should not be forgotten because they have to plan and take action that cannot or should not be automated. However, in order to meet the requirements and decentralisation, an automated, intelligent and increasingly autonomous flow of assets, goods, materials and information between a point in the logistics ecosystem is crucial.

Keywords: Logistics 4.0, supply chain, digitalization, IoT, real time

1. INTRODUCTION

In today's world, with the advent of digitization, this is the beginning of the fourth industrial revolution in the transition to cyber-physical systems that combine machines, processes and products into intelligent business solutions and self-controllable 'Smart Networks and Supply Chains'. As part of the latter, cooperating Smart Factories, exchange information in intelligent supply chains, in an automated manner, with partners, suppliers and distribution and service networks. These processes have an end-to-end dimension and cover the entire life cycle of the product. Such components make up the concept of Industry 4.0 as a paradigm partly defined by the use of devices in machine-to-machine communication (internet of things - IoT) to create factories that act as intelligent production systems: a range of devices and machines are adapted to constant communication in order to create a coherent, visible system. In an ideal world, the end result is the discovery of areas of inefficiency, more accurate optimization of some decisions and automation of some simple (or not so simple) processes. Logistics 4.0 works on the same principles, but with a different set of components. In particular, it uses intelligent transport systems that offer supply chain managers, freight forwarders and other partners the necessary knowledge for optimal management of goods flows.

2. DEFINITION OF LOGISTICS 4.0

The aspects related to the attempts to define Logistics 4.0 are not entirely clear and transparent. They mainly focus on the analysis of systems managing large data flows and integration and on decentralized information management systems (Dussmann Group, 2016; Strandhagen et al. 2017; Wang; 2016; Wrobel-Lachowska, 2018). Therefore, the definition of Logistics 4.0 includes two aspects: process - supply chain processes; and technological - tools and technologies supporting internal processes in supply chains (Szymanska et al, 2017). The functional scope of technological aspects is included in the IT area, which generates many possibilities of flow optimization. These include: increasing reliability and predictability and thus minimizing risk, reducing transport costs, increasing the ability to innovate, increased agility and flexibility, e.g. for new market requirements (www.i-scoop.eu). The process aspect, on the other hand, is strictly dependent on the type and functionality of the technology used within the supply chain. Very often, it is the technology used that forces a change in processes, providing the basis for the construction of entire goods exchange systems. Here it is also faced with the definition of the so-called intelligent logistics, assuming that a certain level of technological development is temporary (Barreto, 2017; Heistermann, 2018). This concept is closely related to the concept of Intelligent Products, i.e. those that are capable of collecting, storing and sharing relevant data, while the idea of Intelligent Services is based on providing modern methods of measuring and analyzing information (Galindo, 2016; Szymanska et al, 2017). As it can be seen, these definitions include scientific aspects directed primarily at research and development areas. A slightly different definition of Logistics 4.0 in operational terms is defined, which can be clearly seen in published reports of research centers and logistics companies (Bubner, 2014; DHL, 2018; Fraunhoffer, 2014). Based on this statement, Logistics 4.0 covers a wide range of activities in the supply chain, based on modern technological solutions, fully encrypted, enabling decision-makers to make quick and accurate decisions in each of its nodes. Logistics 4.0 changes the way raw materials, semi-finished or finished products are stored and transported to the distribution point and then to the final consumer. It is worth emphasizing here that the desired goal of every enterprise is to have an integrated system, enabling the handling of all processes, providing necessary information and analysis, by as few users as possible. The following examples can be used as elements of such solutions:

- warehouses using advanced automation functions, including the use of autonomous robots, drones and material handling systems, which are supervised by advanced control systems,
- the concept of autonomous trucks or the use of platooning can improve fuel efficiency,
- the use of various sensors to obtain the necessary information in real time for optimal fleet management,
- the use of emerging technologies, such as blockchain, to implement smart contracts, authenticate the origin of goods, digitize trade flows and enable full traceability of shipments.

3. LOGISTICS 4.0 CHARACTERISTICS

When defining 4.0 logistics, this concept is very often linked directly to industry 4.0, the concept of the fourth industrial revolution, based on communication between machines operating in an autonomous functional area. This is most often due to one reason, namely the lack of historical experience and conditions in the field of logistics, perhaps because the new logistics paradigm is considered a fundamental development of industry 4.0. Whether this is the case or not, it becomes clear that with the advent of new times in logistics they have a huge impact on the changes in the functioning of the whole economy. At this point it is necessary to consider what really distinguishes Logistics 4.0, does it have separate elements that allow for its separate definition, while maintaining full correlation with Industry 4.0? The answer can only sound affirmative. The four most important ones are specified below:

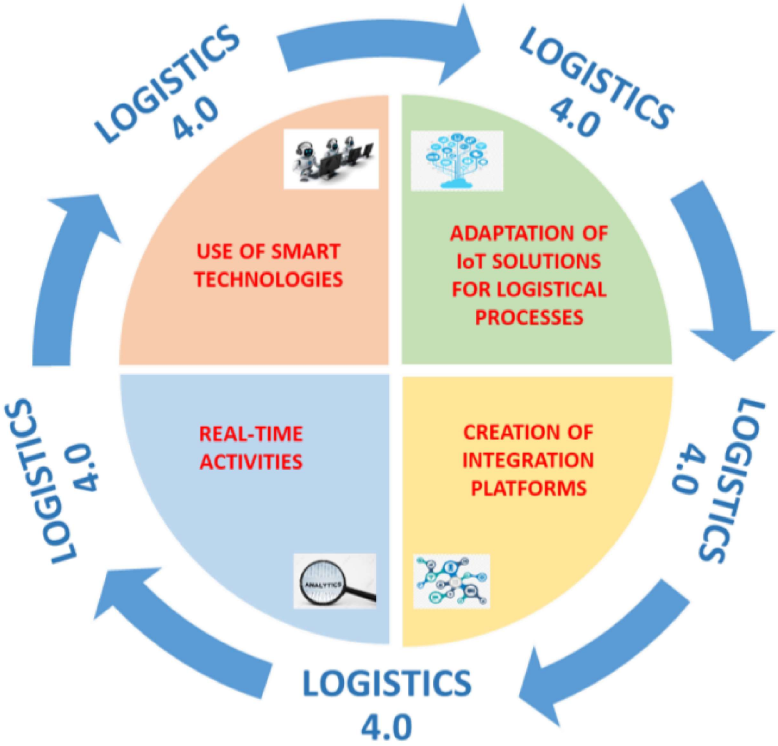
- adapting IoT solutions for logistics processes where the mobility of goods or packaging is an issue and identifying them at every location in the supply chain. Solutions used in this aspect differ from the functionalities used in modern factories, where the communication infrastructure is strictly defined. In the case of logistic solutions, a great emphasis should be placed on communication and integration systems. Proper functioning of devices in a dispersed environment absolutely requires fast communication networks and mobile solutions such as for example 5G network solutions,
- creating integration platforms, including those used in Industry 4.0, thereby creating a functional ecosystem based on full cooperation between manufacturers, freight forwarders, carriers or logistics operators. This is one

of the most important elements in terms of communication and access to necessary information. If there is a lack of access to information about the production processes of customers served to understand how their schedules overlap with transport planning, disruptions throughout the supply chain will inevitably escalate,

- real-time activities carried out in processes throughout the logistical ecosystem with full analytical capabilities. The absence of such solutions makes it difficult to predict the results of decisions taken, which means that disruptions (in the form of unexpected events) can have a significant impact on the modification of the implemented plans. One of the solutions to eliminate such problems is to use tools from the area of forecasting analyses. Using existing operational data in advanced analytical processes, it is possible to create forecasts that take into account market volatility and develop plans that reflect consumer expectations. This reduces the probability of occurrence of unexpected events (although of course it does not eliminate them completely), which in total translates into fewer disturbances,
- the use of intelligent technologies, operating throughout the supply chain, transforming traditional flows into new possibilities for collecting and processing large amounts of location information or changing physical parameters. These solutions are more often associated with industrial and manufacturing processes (as they form the basis of a modern "smart factory"), but are equally important for the development of intelligent logistics management. Among other things, they can create an environment in which all shipments can be monitored in real time and, in case of any disturbances, be they physical parameters or delivery times, appropriate corrective actions can be implemented.

Such solutions are one of the key aspects of building intelligent value streams, as a basis for increasing efficiency and complexity of logistics compared to previous solutions. This is about aspects or concepts of so-called "anticipatory logistics" with the ability to predict future events, thus preventing bottlenecks in logistics or production processes. This state of affairs will enable planners (and even autonomous machine processes) to adapt production schedules to future changes in demand. As the pre-logistics become a reality, the global value chain will become more complex, based on advanced predictive algorithms and the integration of more and more interlinked elements, while at the same time being much leaner, offering a more adaptive, agile environment in which lead times are significantly reduced and shortages, excesses and disruptions of all kinds are becoming less frequent - Figure 1.

Figure 1. Logistics 4.0 characteristics



Source: own study

Due to this nature of links, the main challenge is to integrate cyberspace with physical objects equipped with sensory systems. The realization of such a challenge requires the integration of business and technological competences in order to effectively support national business ventures, and in particular the use of solutions enabling the structural use of integration platforms combining IT solutions of multiple enterprises.

4. ADAPTATION OF IoT SOLUTIONS FOR LOGISTICS PROCESSES - INTELLIGENT LOADING UNITS

4.1. Definition of the issue

The Internet of Things (IoT) is an idea in which every computer device, machine, building, animal, and human being has unique identifiers and has the ability to collect and then transfer data between them through the Internet. The concept of the Internet of Things was first mentioned in 1999, when Kevin Ashton presented it with the whole concept. Based on this concept, and in particular based on logistics aspects, it can be conclude that intelligent devices can offer support for warehouse management, order handling, supply chain management and distribution. In the case of tracking shipments, only IoT solutions, which replace phased scans (loading, subsequent points of travel), will help to determine the exact location of the goods during the order. This is made possible by wireless connectivity via cellular networks, Wi-Fi and Bluetooth technology, which enable the exchange of information between readers, scanners and computers. As a result, the percentage of shipments delivered the first time increases. The ability to monitor the status of the delivery in real time not only allows you to react to emergencies, but also allows for previously unavailable activities - such as automatic temperature control when transporting human organs, live animals or food.

The development of information and communication technologies has led to innovations in data capture technologies such as RFID and information processing systems such as EPCIS (Electronic Product Code Information Services), BI (Business Intelligence) and more advanced ERP systems. RFID and related information systems provide access to a large amount of real-time information about material flows and events in the supply chain. As today's RFID tags become better and cheaper and EPC standards evolve, new opportunities are available to use the information acquired through RFID to plan and control operations in the supply chain in real time. For supply chain control activities, this may mean a paradigm shift towards real-time control and decision making, filling the time gap between the occurrence of events and their corrective actions.

A real revolution in identification has been introduced by the use of beacons, which emit a constant radio signal thanks to an energy-saving Bluetooth Low Energy solution. Readable devices (e.g. smartphones) then process these data to determine, among other things, the ID, purpose and exact location of the goods bearing the beacon. This simple device has an infinite number of applications - it can, for example, show the user a place at a mass event or activate when the customer enters the store with the phone and, based on the customer's shopping history, recommend the right products and provide the seller with the necessary information about the habits of buyers. In logistics, beacons can help, among other things, with marking of goods and inventory - in this case, the products will report themselves when the appropriate computer is within reach. This technology is already used to track and locate transported goods.

4.2. Examples of applications - warehouses

Warehouses have always served as an important node in the flow of goods within the supply chain. However, in the current economic climate, they also serve as a key source of competitive advantage for logistics service providers, who can manage them quickly, cost-effectively and increasingly flexibly. This is not an easy challenge. With thousands of different types and forms of goods currently stored in an average warehouse, every square meter of warehouse space must be optimally used to ensure the fastest possible receipt, processing and delivery of specific goods. The result is a fast, technology-based environment that is ideal for IoT applications. From pallets and forklift trucks to the building infrastructure itself, modern warehouses contain many assets that can be combined and optimized through IoT. In the warehouse, the widespread option of marking pallets or products with low-cost miniature identification devices such as RFID paves the way for intelligent warehouse management. Among other things, in the goods receipt process, wireless readers capture data transmitted from each pallet, which can include product information such as volume and dimensions, which in turn can be aggregated and sent to the WMS for further use. This capability eliminates time-consuming manual pallet counting and scanning tasks. The cameras attached to the gates can also be used for damage detection. Once the pallets have been moved to the right place, the tags send signals to the WMS to provide real-time insight into inventory levels, thus preventing costly re-verification situations. If any stock item has not been loaded, sensors can alert the warehouse manager, who can track the exact location of the item for corrective action. With regard to the quality of the accepted assortment, the sensors monitor its condition and in case e.g. temperature or humidity reaches a critical level, they immediately inform the warehouse staff about it. This enables immediate corrective action to be taken, thus eliminating the possibility of losses. During the dispensing process, pallets are scanned through the shipping gate to ensure that the correct assortment has been loaded. Stock levels are then automatically updated in the WMS.

In addition to the goods stored in the warehouse, IoT also ensures optimal use of resources. By linking machines and vehicles to the central system, IoT enables warehouse managers to monitor all resources in real time. Managers can be notified when assets are over-utilized or when unused assets should be used for other tasks. For example, different sensors can be used to monitor warehouse equipment, determining its state of use. Data analysis determines the optimal performance and tasks for these assets. One such innovative solution is Swisslog's "SmartLIFT" technology. This solution combines both forklift sensors with directional barcodes placed on the warehouse ceiling as well as data from WMS to create a specific, internal GPS system. The system provides the forklift driver with the ability to determine the optimal route to a strictly defined storage location. It also provides information for managers on the speed, location and productivity of resources in real time. Thanks to this solution, Bobcast has recorded a 30% increase in the number of pallets transported per working hour, without making any mistakes in identifying the goods.

The combined devices, equipped with appropriate sensors, also enable the use of so-called predictive maintenance, e.g. storage transport systems. For example, sensors can be placed on a sorting machine to detect the level of physical stress by measuring the throughput or temperature of the machine. All these data are collected and combined for the purpose of predictive maintenance analysis, the timing of which can be planned ahead of time and the expected life of the machine at its current level of use calculated. Any anomaly is signaled to staff so that it can be eliminated before causing serious damage.

5. CREATING INTEGRATION PLATFORMS

5.1. Definition of the issue

The concept of integration platforms refers to one of the most important aspects of logistics, which is to obtain precise information within a specific time period necessary to make the right decision. This becomes very important at a time when huge amounts of information are exchanged between companies, based on different data transfer channels. Very often important data are either lost, in the chain of information exchange, or misrepresented or arrive with a long delay. In order to overcome these problems and to create effective information exchange chains, the following elements should be the main focus:

- create common platforms for data exchange based on communication standards,
- their architectural structures are based on a well-defined, clear model,
- use standard links to integrate systems as access points.
- use simulation platforms to control logistic processes.

The essential thing in this whole concept is to minimize the activities that need to be done to transmit the necessary information, or the clarity and uniformity of the processes taking place in a given ecosystem. One of the pillars of such a solution is the application of the integration platform concept. It allows the parties involved in trading in goods to provide standardized information and documents in one place in order to meet all formal and legal requirements. It is worth noting that this concept is recognized and promoted by several global organizations dealing with trade facilitation. These include the United Nations Economic Commission for Europe (UNECE) and its Centre for Trade Facilitation and Electronic Business (UN/CEFACT), the World Customs Organization (WCO), the United Nations Network of Paperless Trade and Transport Experts in Asia and the Pacific - UNNExT (Ahn, 2010), SITPRO Limited in the United Kingdom and the Association of Southeast Asian Nations (ASEAN).

The basic value of a given solution for individual ecosystem stakeholders is to increase the efficiency of handling the procedures of trade in goods, which are customs clearance or obtaining various permits, by shortening the time of their implementation and reducing service costs. Therefore, the implementation of the solution makes it possible to introduce information into a given ecosystem at one time without the need to duplicate this activity many times in different parts of the decision-making chain.

5.2. Examples of applications

An example is the innovative approach to customs clearance processes, which has been implemented in Portugal, based on the creation of a national one-stop-shop system, enabling traders to transmit all information on import, export and transit through a single electronic gateway. The logic of this approach is clear and obvious, but its implementation must take into account the complexity and specificity of the whole solution. Such an approach can be seen primarily in the IT systems operating in some European ports. An example of a solution can be the structure created in the WiderMos project (widermos, 2020), and implemented in Portuguese ports, called LSW (Logistics Single Window). The processes implemented in a defined ecosystem integrate a number of services, solutions and applications to a common ecosystem of logistics, reservation, planning and management. All process stakeholders were keenly interested in creating such a project and using it in their daily work. This group included shippers, container terminal operators, multimodal operators, road operators, rail operators and air transport operators.

The main objectives of the LSW were:

- promoting interoperability solutions for the TSL industry in Portugal,
- optimization of connections and synchronization of information flow,
- application of standards both in the construction of the solution as well as in the exchange of messages occurring in the process of information relocation.

The development of a given solution took into account, among other things, the need to rely on an open and interdisciplinary structure that can contribute to more architecturally complex ecosystems for the exchange of information, an example of which is Port Community System (www.epcsa.eu). LSW was created based on the results of many different European projects in the field of logistics interoperability, including e-Freight (e-Impact) and e-Delivery (CEF Digital Connecting Europe). Thanks to the applied solutions, the project was ranked at the level of one of the most modern IT solutions implemented on a European scale.

6. REAL-TIME ACTIVITIES

6.1. Definition of the issue

Nowadays, planning and control is often carried out on the basis of previous demand and event information such as past sales and budgets in combination with control concepts such as MRP and MRPII. This leads to a time gap between sudden events and corrective actions. In this way, this 'delayed' planning and control environment has significant potential for improvement depending on the speed of response, inventory turnover and lead time. In addition, inefficient information exchange and lack of visibility in the supply chain can lead to poor quality forecasts and additional adjustment and operational control loops. The consequence is that control and decision making is based on a basis that may be information from a few weeks ago, rather than on the current real time situation. Therefore, the aspect of managing information in a precise, quick and efficient way becomes extremely important. Below are a few phrases of a given issue used by logistics practitioners:

- real-time information means that relevant data, for decision making, is available without delay,
- real-time action means that decisions on actions to be carried out can be communicated without delay in time.
- real-time simulation means that different alternative scenarios can be simulated in real time.
- real-time supply chain planning is the process of thinking and organizing activities to get the right product, on time, in quality, in the right place and at the lowest cost to meet customer requirements.
- real-time supply chain identification is the process of organizing all activities around collecting data without time delay, analyzing it and making real-time

decisions based on facts. By instantly detecting and detecting changes in demand, supply and business conditions while using advanced analysis, true integration between planning and execution is achieved.

6.2. Examples of applications

An example of real-time supply chain planning is the development of brokerage platforms for digital freight services. According to GUS data, 21% of all transports are empty runs. On the other hand, loaded vehicles often do not use the entire cargo space. Utilizing the global scale of smartphone users, freight broker platforms enable real-time data flow and communication between all participants in the transport processes, thus ensuring that orders are efficiently matched to available capacity. Benefits include real-time communication, GPS tracking of shipments, secure payment and documentation handling via a mobile application. One such example is the freight brokerage platform launched by Amazon, based on Freight Waves. The online service, which is currently in beta in Connecticut, Maryland, New Jersey, New York and Pennsylvania, allows shippers to instantly quote and match the freight service. Amazon does not provide the capacity of its own vehicles within the platform, but rather mediates access to transport partners within its network. The company has long had the infrastructure to mediate in the flow of these goods without significant investment. This enables it to offer significantly lower costs than its competitors. According to Freight Waves analysis, Amazon services are offered at prices between 26% and 33% lower than market prices.

Another very important aspect of real-time identification is wireless communication, which is becoming increasingly important in Intelligent Transport Systems (ITS). From 2022, all newly sold vehicles will be connected to the internet. However, the limitations of current network standards (3G and 4G) do not allow full integration of the entire transport system. Although specific solutions related to 5G technology are still under investigation, it is already clear that the future network will not only have to offer much higher data transfer rates, but will also have to support multiple, simultaneously connected devices (up to one million devices per km2), offer total reliability and minimum delays. In addition, these objectives must be met with similar cost and energy consumption levels to those of the standards currently in use. However, the biggest advantage offered by 5G is the possibility to use multiple communication channels and access points within one session (including the possibility to connect between devices without access to the central infrastructure), which will increase flexibility of connections and services offered. It works well in the Vehicle-to-X (V2X) concept, where X can be other cars, buildings, traffic lights and even pedestrians, referring to the Intelligent Transport System, where all vehicles and transport infrastructure are interconnected. This connectivity allows for much more precise monitoring of the entire transport network, which ultimately leads to:

- optimize traffic flow and reduce congestion on the roads through communication between vehicles and the transport infrastructure (Vehicle to Infrastructure V2I),
- improving road safety (Vehicle to Vehicle V2V, Vehicle to Pedestrian V2P),

- less pollution,
- automation of transport systems (Vehicle to Network V2N),
- implementation of autonomous vehicles (Vehicle to X V2X).

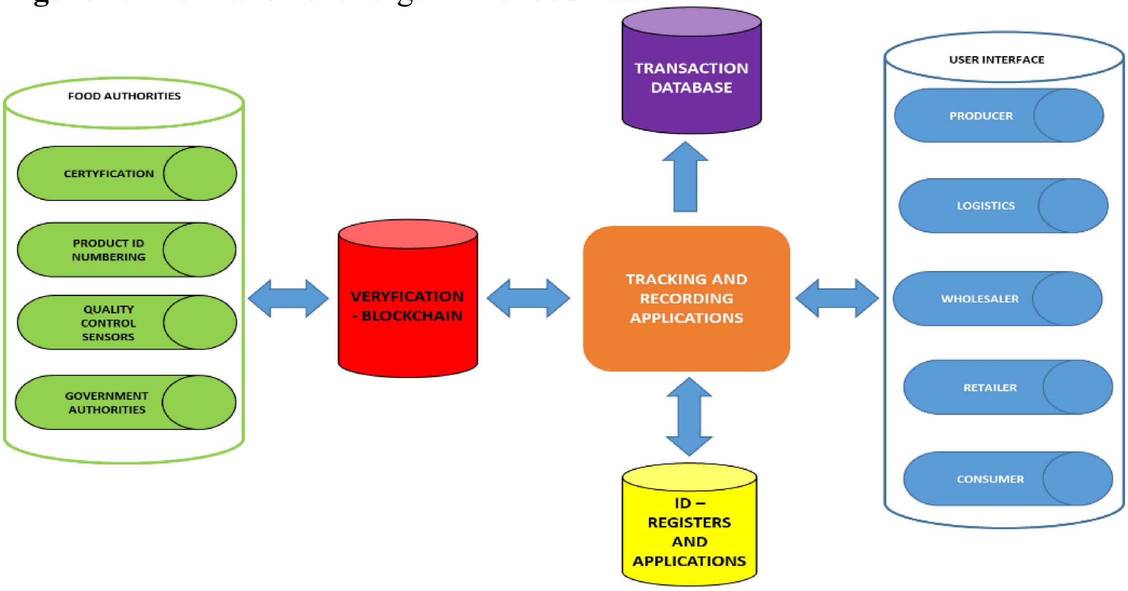
Also using short-range radio technology, vehicles capable of V2X communication transmit information such as vehicle speed and direction of travel to each other, for example to avoid collisions. The radio technology behind V2X is called Dedicated Short Range Communication (DSRC), designed specifically for car-to-vehicle communication. DSRC is based on the Wi-Fi 802.11 standard, but is optimized for very low latency and ad-hoc connections, allowing cars to communicate at high speed while travelling. With V2X communication, cars have a much better, more precise picture of the speed and position of the vehicles in the environment, even outside the driver's line of sight. Information about surrounding road conditions can be collected in a variety of circumstances, such as poor visibility at night or dense fog, which would be impossible to measure using vision technology. For a long time, the main obstacle to the development of this technology has been the problem of too few vehicles using it. V2X is more effective the more vehicles use it. Fortunately, thanks to the Cadillac CTS 2017 and the Mercedes E-Class 2017 with V2X communication to help prevent accidents, this solution has come to market. With the advent of more and more DSRC chips on the market, this nascent, potentially life-saving technology may soon become widespread.

7. REAL-TIME ACTIVITIES

7.1. Definition of the issue

For the first time, Blockchain technology was used to control the cash flow of Bitcoin payments (Foroglou, 2014). To understand why this kind of technology is considered so important, it is necessary to first explore its secrets. The increased demand for transparency in the supply chain is causing increased interest in Blockchain technology, which breaks down every movement per block and documents transactions every time a shipment changes ownership (Dujak, Sajter, 2019). Merging blocks together creates a record for the parties involved in the process and provides detailed information related to each traffic to which all parties have access. This creates a permanent, digital history as products pass through the entire supply chain from the original source to the final stage of the journey. The aim is to produce a single version of the truth, link information, ensure transparency for all parties involved in the supply chain and determine how they have participated in the movement of goods or services. In addition, the digital story is not owned or controlled by any of the trading partners, so it can be accessible to all verified chain players. No party may modify, delete or attach any records without the consent of the other parties in the network. Data generated using block technology can provide a greater chance to analyze information, which is becoming increasingly important in today's supply chain. This is best reflected in Figure 2.

Figure 2. Information exchange in the food trade



Source: own study

The key problem solved by Blockchain technology is how it can build a basis of consensus for secure information transactions without worrying about sensitive data when no node across the network can be trusted. This technology can guarantee security by using a mathematical algorithm mechanism (Steiner et al, 2016). Thanks to it, all nodes in the system can exchange data in an autonomous and secure manner, without exposing the entire flow to any interference or misrepresentation in the information exchange.

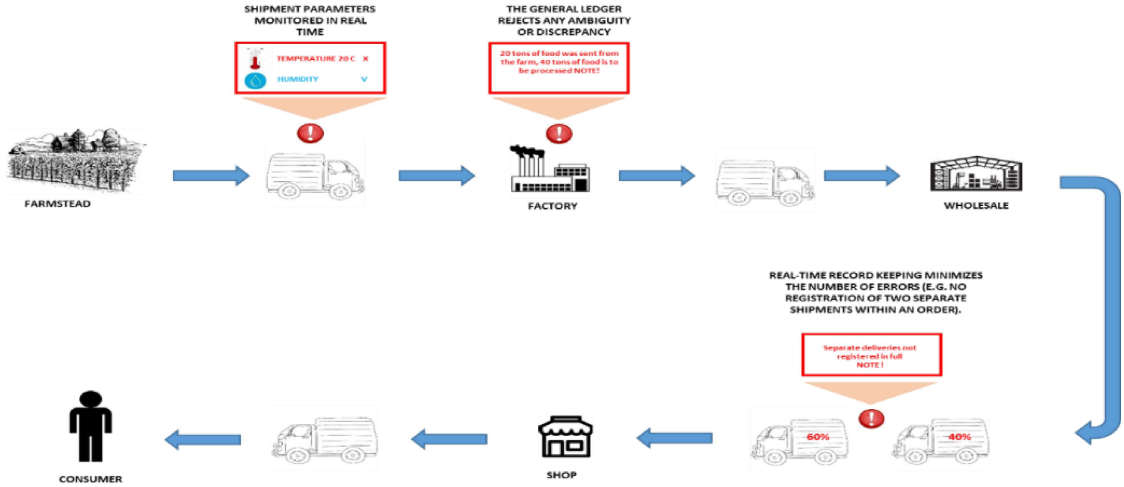
One of the key questions in the current market situation is: is Blockchain technology able to help solve problems in supply chains and if so, to what extent does it work? Looking at the issue from the perspective that it is nothing more than an encrypted digital ledger, shared by many supply chain partners, providing sustainable transparency and validation of transactions, it can clearly state that it is the ideal solution for a global supply chain. It allows anyone who has access to the network to see what is happening at any given time or to follow any changes in real time. The reality is that Blockchain reflects a very decentralized and fragmented world binding its data, flows and activities into something that people can recognize as a record of the truth. It is accessible to all participants recording all kinds of information, protected by cryptographic tools that simultaneously protect the privacy of participants in the chain.

For example, the company that manages the ripening process of the products is linked to refrigerated warehouses, transport companies and ultimately to the buyers to ensure that the products are optimally fresh when they are needed. Using Blockchain technology you can monitor how this process is approved. It provides the ability to segregate or capture data and control its availability in order to confirm the process as defined, from sourcing the product from the producer to tracking transport to delivery to the consumer. Given the transparency of data, it can be concluded that Blockchain technology is used to digitally track and store, at all stages of the food chain, all product information:

- data on agricultural activities, growing and rearing conditions,
- factory/processing plant,
- series numbers and expiry dates,
- temperature and storage conditions,
- shipment data, etc.

These relationships are illustrated in Figure 3.

Figure 3. Blockchain in the food supply chain



Source: own study

In this system, governmental organizations and regulators do not have a central role in overseeing the exchange of information in the supply chain, but are one of its links and perform a similar role to all other members. However, they also have their own obligations, such as imposing and applying strictly regulated rules of conduct to the whole supply chain, and checking the authenticity of the information sent by each member. If a food safety risk is identified, they can immediately take remedial measures to eliminate it. This approach of decentralized traceability is becoming a new approach that increases transparency in the supply chain, reinforces the reliability of information, allows real-time tracking of food products and thus enhances security of supply.

7.2. Examples of applications

As the largest exporter of tuna in the world, the Thai Union group in Bangkok operates within many complex supply chains. First of all, it is about fighting the fishing industry against illegal fishing and human rights violations. The company has implemented a traceability system to monitor and manage the exclusion of illegal fish from the supply chain. The Union Group was the first company in the world to introduce a canned tuna tracking device so that consumers can analyze the route of their products from the moment they are caught in real time by verifying the species, the catch area, the trip number or the fishing vessel. The company's management is also considering using digital traceability to improve communication between employees and fishing vessels. It also envisages the use of Blockchain technology as an opportunity to secure supply chains through the use of cryptographic signatures or a common demand and supply chain and to ensure security at every stage of the chain from supply to production to consumer. Another very important aspect is the use of technology in cross-border payments to identify the payer and beneficiary, which contributes to promoting safe and legal migration of workers.

The Thai Union launched a pilot digital traceability program under which the maritime telecommunications service provider Inmarsat installed Fleet One terminals on fishing vessels in Thailand. The program is testing the use of scalable platforms for electronic exchange of catch data and traceability systems that use mobile applications and satellite communications. In another pilot program, crew members, captains and fleet owners have been trained in the 'Fish Talk' chat room developed by Xsense, which provides digital communication between fishing vessel crews and land-based units.

Cargill announced that in the run-up to Thanksgiving (November 2017), consumers were able to track Honeysuckle White turkeys from the family farm to the table. Consumers in selected markets can simply text or enter a code from the packaging at HoneysuckleWhite.com to access the location of the farm, view the history of the family farm, view photos from the farm and read the message about the producer.

8. CONCLUSION AND FURTHER RESEARCH

Analyzing the concept of Logistics 4.0, it can certainly state that it is nothing more than a set of tools and optimization processes that take place at different stages of the company's activity. They are based on modern IT systems, enabling full cooperation of the technical infrastructure, operating in the field of the Internet of Things, thus leading to full automation of work. Moreover, the application of such solutions undoubtedly leads to shortening of the decision-making chains, thus enabling to make the right decisions in a much shorter time, and this in turn leads to building a competitive advantage of the company. It should be noted that modern supply chains, which operate on the basis of integrated cyberphysical systems, generate huge amounts of data, which, when used in an appropriate way, can be used as a basis for activities aimed at increasing the level of visualization of processes, their continuous improvement leading to self-improvement or as significant assets of the company. Appropriate and skillful application of digital solutions, such as machine learning or artificial intelligence, will be the basis for the advancement of enterprises, thus increasing the level of service at every stage of the supply chain.

While making a thorough and in-depth analysis of the issue of digitization of supply chains, or aspects of Logistics 4.0, let's not forget that behind every action there is a person and it is the person who is supposed to benefit from these solutions. They are supposed to support work and provide necessary information in the shortest possible time, leaving the final decision to man. This does not mean, of course, that all optimization activities must be controlled directly by a human being. Of course, it would be a denial of the sense of digitization or automation of work. However, it should be strongly emphasized that the final decision in the whole complexity of supply chains must be left to man. Thanks to digitization and process automation understood in this way, it is able to maintain the full balance of cyber-physical ecosystems, enabling us to make rational decisions in real time, thus moving from a central and planning approach to actions that meet the requirements of buyers in real time. In this way, it will be able to create the future without unnecessary risk of our actions. The perspective of further research at the Institute of Logistics and Warehousing and at the School of Logistics is the efficiency analysis of the autonomous solutions in logistics processes, including the digitalization of supply chains.

9. REFERENCES

Ahn K., (2010), The study of Single Window model for Maritime logistics. In Advanced Information Management and Service (IMS), *6th International Conference on IEEE*, 106-111.

Barreto L., Amaral A., Pereira T., (2017), Industry 4.0 implications in logistics: an overview, *Procedia Manufacturing*, 13, pp.1245-1252.

Bubner N., Helbig R., Jeske M. (2014), *Logistics trend radar, Delivering insight today. Creating value to-morrow!*, Pub. DHL Customer Solutions & Innovation, Troisdorf.

CEF Digital Connecting Europe. [available at: https://ec.europa.eu/cefdigital/wiki/display/CEFDIGITAL/eDelivery access April 22, 2020]

DHL, (2018), *Internet of Things in Logistics*. [available at: www.dhl.com/content/dam/Local_Images/g0/New_aboutus/innovation/DHLTrendReport_Intemet_of_things.pdf. access May 22, 2018]

Dujak D., Sajter D. (2019), Blockchain Applications in Supply Chain, in: Kawa A., Maryniak A. (eds.), *SMART Supply Network*, Springer International Publishing AG.

Dussmann Group , (2016), *Logistics 4.0*. [available at: https://news.Dussmanngroup.com/en/multimedia/news/logistics-40/ access May 22, 2018]

Foroglou, G., Tsilidou A. (2014), Further applications of the blockchain, *Columbia University PhD in Sustainable Development 10 Year Anniversary Conference*.

Fraunhoffer (2014), *Logistics 4.0 and challenges for the supply chain planning and IT.* [available at: https://www.iis.fraunhofer.de/content/dam/iis/tr/Session%203_5_Logistics_Fraunhofer%20IML_Akilar.pdf access April 21, 2018]

Galindo, L.D. (2016), *The challenges of Logistics 4.0 for the supply chain management and the information technology*, Norvegian University of Science and Technology, master thesis.

Innovation and Networks Executive Agency Connecting Europe Facility; 2015; *Project : e-Freight Implementation Action (e-Impact)*; [available at: https://ec.europa.eu/inea/en/connecting-europe-facility/cef-transport/projects-by-country/multi-country/2014-eu-tm-0686-s access May 25, 2018]

Heistermann, F., Hompel M., Mallée, T., (2018), *Digitisation in logistics*, BVL International, [available at: www.bvl.de/en.

Strandhagen J.O., Vallandingham L.R., Fragapane G., Strandhagen J.W., Stangeland A.B.H., Sharma N., (2017), Logistics 4.0 and emerging sustainable business models , *Advances in Manufacturing*, 5 (4), pp. 359-369.

Steiner J., Baker J., Wood G., Meiklejohn S., (2016*), Blockchain: the solution for transparent in product supply chains*, Project Provenance Ltd.

Szymanska O., Cyplik P., Adamczak M., (2017), Logistics 4.0 a new paradigm or a set of solutions, *Research in Logistics and Production*, 7(4), pp. 299–310.

Wang K. (2016), Logistics 4.0: New challenges and opportunites, *Conference: 6th International Workshop of Advanced Manufacturing and Automation*.

Wrobel-Lachowska M., Wisniewski Z., Polak-Sopinska A. (2018), The role of the lifelong learning in logistics 4.0, *Advances in Intelligent Systems and Computing*, 596, pp. 402-409.

I-scoop (2018). [available at: www.i-scoop.eu/industry-4-0/supply-chain-management-scm-logistics/ access March 21, 2018]

www.epcsa.eu/pcs

www.modulushca.eu

www.project-cloud.org

www.widermos.eu