OLSZTYN ECONOMIC JOURNAL
2020, 15(3), 215–228
ISSN 1897-2721 e-ISSN 2083-4675 DOI: 10.31648/oej.6541

ORIGINAL PAPER

Received: 13.09.2020
Revised: 25.10.2020
Published: 30.11.2020

INFORMATION TRANSFER IN LOGISTICS USING WIRELESS TECHNOLOGIES

Adam Wieczorek
Faculty of Economics Sciences
University of Warmia and Mazury
ORCID: https://orcid.org/0000-0001-8399-0959
e-mail: adam.wieczorek@uwm.edu.pl

JEL Classification: O330, R41.

K e y w o r d s: logistics, information logistics, wireless technologies, technologies of short-range networks, local networks, wide area networks, low-power wide area networks, global computer networks.

A b s t r a c t

The aim of the study was to indicate by the author the possibility of using wireless technologies as part of improving information transfer, with particular reference to activities in the field of logistics. The article is a review in which the theoretical aspects of logistics and information logistics are highlighted. A review and analysis of domestic and foreign literature was used as the theoretical scope. To determine the examples of the use of appropriate technologies in information logistics, an Internet database was used as the source of enterprises presenting selected technologies. The author focused on 5 main technological aspects used in information transfer in logistics, such as: short-range technologies, local networks, wide-area networks, low-power wide-area networks and global computer networks. The analysed application allowed conclusions to be drawn clearly indicating that the use of appropriate wireless technologies allows for a more effective provision of appropriate information resources in logistics.

How to cite: Wieczorek, A. (2020). Information Transfer in Logistics Using Wireless Technologies. *Olsztyn Economic Journal*, *15*(3), 215-228. https://doi.org/10.31648/oej.6541.

**TRANSFER INFORMACJI W LOGISTYCE
Z WYKORZYSTANIEM TECHNOLOGII BEZPRZEWODOWYCH**

Adam Wieczorek
Wydział Nauk Ekonomicznych
Uniwersytet Warmińsko-Mazurski w Olsztynie

Kody JEL: O330, R41.

Słowa kluczowe: logistyka, logistyka informacji, technologie bezprzewodowe, technologie sieci bliskiego zasięgu, sieci lokalne, sieci rozległe, sieci rozległe małej mocy, globalne sieci komputerowe.

Abstrakt

Celem opracowania było wskazanie możliwości wykorzystania technologii bezprzewodowych w ramach usprawnienia transferu informacji, ze szczególnym odniesieniem do działań z zakresu logistyki. Artykuł ma charakter przeglądowy. Uwypuklono w nim aspekty teoretyczne z zakresu logistyki i logistyki informacji. Wykorzystano przegląd i analizę literatury krajowej i zagranicznej z zakresu teoretycznego. Do wyznaczenia przykładów zastosowania odpowiednich technologii w ramach logistyki informacji skorzystano z bazy Internetu jako źródeł przedsiębiorstw prezentujących wybrane technologie. Autor skupił się na pięciu głównych aspektach technologicznych wykorzystywanych w transferze informacji w logistyce: technologiach bliskiego zasięgu, sieciach lokalnych, sieciach rozległych, sieciach rozległych małej mocy oraz globalnych sieciach komputerowych. Przeanalizowane zastosowanie pozwoliło na sformułowanie wniosków jasno wskazujących na to, że wykorzystanie odpowiednich technologii bezprzewodowych umożliwia efektywniejsze wykorzystanie odpowiednich zasobów informacyjnych w logistyce.

Introduction

All activities of each enterprise, especially the realization of main and logistical processes is not possible without the provision of adequate resources. In accordance with the 5R rule (aims), the logistics service aims to provide the right resources, in the right place, at the right time, with the right cost and at the right amount (Chaberek, 2002, p. 11; 2014, p. 4-6). Well-developed systems of automatization along with the common usage of the internet has led to a situation where we can encounter everywhere the information resources as new technologies and ideas. The introduction of concepts such as the Internet of Things or Internet services has disseminated the flow of information between participants of supply and logistics chains (Lasi *et al.*, 2014, p. 239-242; Ning & Liu, 2015, p. 19; Szozda, 2017, p. 403). In present times, which are dominated by e-commerce and information society, we are dealing with the evolution of modern ways of communication and information transfer. D. Weiland in his elaboration clearly points out that running a business in the era of e-commerce development has contributed to an increased demand for logistics services (Weiland, 2016, p. 97, 98).

In such a case, it may be stated that during the time of digital market sales, all the actions in the range of logistical services from the realization of supplies by suppliers up to the reverse movement of goods require adequate information as a key resource, therefore the right logistics will testify to an efficient course of the main processes (basic processes supported by the logistics processes).

The aim of this paper was an attempt to present that using modern wireless technologies within the operations of logistics may improve the transfer of information, which should enable the increased efficiency of such operations.

Methodology

The paper is a descriptive one. Focus was put mainly on the theoretical aspects of logistics and information, as well as the chosen wireless technologies. For the theoretical description, a review of the literature was used, both domestic and foreign. The literature was criticized and analysed. Scientific article databases were also searched, including the Web of Science in accordance with the topic being elaborated. For the technology part of this paper, the broad network of the internet was overviewed as an aim to seek information about the chosen technologies. Descriptive information was used as well as practical examples provided by various enterprises, who use, produce or supply such technologies. Based on the gathered literature overview, a description, analysis and critique was prepared, which was then summed up with conclusions.

Information logistics

It is clear that any production of goods or provision of services needs the right resources, which should be supplied in accordance with the aims of 5R, and thus all of the actions (processes), of which the aim is to provide the required resources to the basic process may be defined as logistical processes. It is worth mentioning at this point that the definition of logistics may vary in different elaborations. In his work, M. Chaberek points out many problems in the process of defining this term (Chaberek, 2020, p. 89-105). Chosen definitions from the research literature prepared for this article are presented in table 1, as the proper definition is needed for further consideration.

The definitions proposed by J. Długosz and M. Chaberek (5R rule) were considered to be the most accurate in accordance with the logistics actions.

After determining what should properly be considered as logistics, the focus should now be moved to the resources of information. Information as a resource is not typical, which is mainly caused by its immaterial character. In addition, the interpretation of what information really is and how it should be understood

Table 1

Selected definitions of the term "logistics"

Author	Definition
Council of Logistics Management, 1986	logistics is the process of controlling the flow of goods from raw material producers, through all phases of production and trade to the final recipient, in such a way that the desired goods are in the right amount, place and time of demand for them, at minimum cost
European Conference of Ministers of Transport, 1987	logistics is a synchronized technique of controlling the flow of goods, moved and stored in the process of distribution (…), production (…) and supply
F.J. Beier & K. Rutkowski, 1995	logistics is generally understood as the mean of management, handling and storage operations intended to facilitate the movement of products from their origins to the places of final consumption, as well as related information to be offered to the customer
H. Zijm *et al*., 2000	logistics refers to the transport and storage of materials, parts and products along the supply chain. Logistics includes inbound and outbound processes to and from warehouses, as well as internal and external operations of handling and transport. It also covers the provision of services and the transfer of information between the various stages of the supply chain
J. Długosz, 2000	generally speaking, it can be said that logistics is about rationalizing relations in a specific system. By detailing its content a bit and referring to its various dimensions, resulting from the evolution of views, one could assume that logistics means the process of management integration by rationalizing the relationship between the elements of a given system, starting with the links involved in the time-spatial transformation of goods, through comprehensive coordination of the supply network environment, overcoming conflicts of goals on the scale of the entire system and its environment
S. Krawczyk, 2011	logistics is a term used to describe the process of planning, implementing and controlling the efficient and economically effective flow of raw materials, materials for production, finished products and relevant information from points of origin to points of consumption to meet customer requirements

Source: own elaboration based on: *Council of Logistics Management* (1966); *The role of Shippers*…, (1987, p. 31); Beier & Rutkowski (1995, p. 16); Zijm *et al.* (2000, p. 49); Długosz (2000, p. 86); Krawczyk (2011, p. 59).

is also problematic. One of the definitions of information points out that it is the name of content taken from the outside world as the senses adapt to it (Weiner, 1971, p. 152). A different definition is provided by J. Gościński who claims that information should be considered as a content forwarded by the sender who may be any item or person to its recipient, who also may be an item or a person who is a link, command, imperative or recommendation (Gościński, 1968, p. 19). As a continuation of theoretical assumptions, the most useful definition defines information as a resource, which increases knowledge about the reality which surrounds us (Falkiewicz, 1971, p. 37). Regardless of the interpretation, its nature cannot be clearly defined; which does not mean that it should be treated

in any way differently than material resources. In accordance with the definition by M. Chaberek (2002, p. 11), logistics is a process which aims to service every activity of human or enterprise by supplying the right resources in accordance with the 5R rule. With such definitions of logistics and information, it may be stated that information is a full-fledged resource without which the proper level of logistics service cannot be provided, thus the execution of the main (basic) process becomes impossible. The author would also like to develop the concept that the term „information logistics" is a new term, and that is why there are many problems with defining it. Above all, it is worth to quote the considerations of D. Weiland or P. Wierzbowski who point to the fact that the term „information logistics" is not a „new" type of logistics and it may be characterized only in terms of specific activities (Weiland & Wierzbowski, 2020, p. 13, 14). Usage of this term may be quoted as a mental shortcut, and thus the author is opting for the Sopot School of Logistics definition (Chaberek, 2002; 2011; 2020) that treats information as a full-fledged resource.

In relation to information considered as a resource, the systems of information provision needs to be mentioned. Their goal is to process data into information. Data is influenced by various transformations, which characterize the results as individual needs of recipients working as a creation of information transmitted to this recipient. The gathered information contributes to the gaining or broadening of knowledge (also the logistic knowledge) which, as mentioned before, is necessary (Szmelter, 2013, p. 3, 4; Szmelter-Jarosz, 2020, p. 22, 23). Independent of its action, each enterprise or person who is dealing with production or services own their own supply, processing, storage and distribution of information systems. A system which is working properly allows the support of workers in a conducted activity and facilitates the process of making the decisions (Jagersma, 2011, p. 143). In addition, in a world where technological development is so dynamic it is information that becomes one of the most important resources within the enterprise, because it not only allows the production of goods or services, but its proper usage additionally enables success to be achieved in the case of gaining a competitive advantage in the market (Weiland, 2016, p. 99, 100). Information is created, stored and sold by enterprises, so it can also be a resource. However, at the same time it can be a finished product, according to the present stage of needed basic processes.

The considerations quoted clearly show that information resources have become very important in recent times, in terms of the proper functionality of any enterprise. Furthermore, they are needed for a fully effective logistics service. Technological development has not led only to the formation of an information society, but also to the fact that its plurality and presence in every aspect of human life and enterprise may be problematic. In case of such a challenge, it is worth considering some potential options which may improve information transfer.

Chosen technologies supporting the transfer of information in logistics

Information has become one of the most important resources of the XXI century, and is in constant movement. Technological solutions have improved in a significant way the transfer rate which has contributed to many effects, both positive and negative. At present almost in every place on earth, conducting any type of economic activity, as well as regular living seems to be impossible without wired or wireless access to the global network. This is the result of a dynamic development in the tech sector which has been initiated by the introduction of first phones operating on a 3G network (transmission of data with high speed) in 2002 and next the inauguration of a process which may be referred to as the smartphone revolution in 2007 with the case of the first iPhone (Vorhees, 2017). Wireless technology has become something convenient. It turns out that it is cheap and easy to introduce a way to help communicate between people or to conduct economic activities. In accordance with DHL Trend Research, it turns out that connectivity has become one of the basic needs of humans, which is presented in Figure 1 (Heutger & Kuckelhaus, 2020, p. 4).

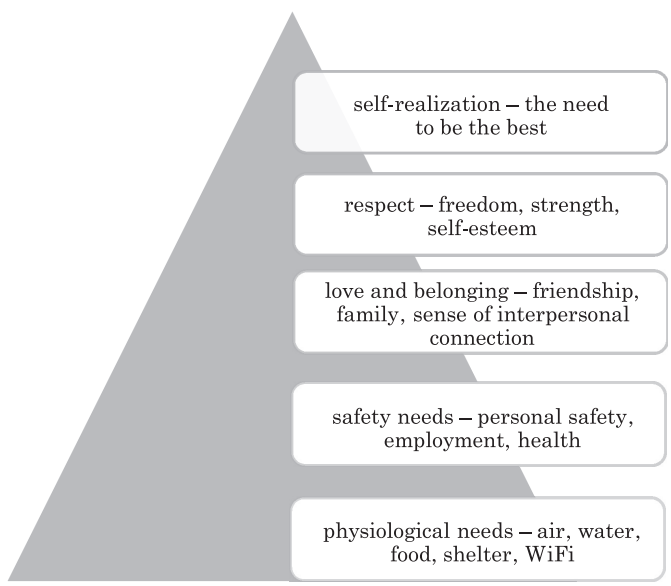

Fig. 1. „Updated" pyramid of needs
Source: based on Heutger & Kueckelhaus (2020).

The usage of wireless technology has helped to not only improve the availability of the Internet to all people in the world, but it has also allowed the adjustment of various elements to the network functionality within many industries. As an example, in the case of logistics such usage may be observed in the positioning of vehicles and goods during transport and on live demand (Mrozek, 2019). In some cases, there is also the idea of creating virtual supply chains operating in an automated way due to the usage of connectivity (Szozda, 2017, p. 404, 405). New generation wireless connectivity is defined as a series of various technologies allowing communication and data transfer without using any wires. Among such technologies, some examples may be: Wi-Fi, Bluetooth or new standards like 5G which is in the process of implementation around the world. It is also worth mentioning the less popular solutions which are low-power wide area networks (LPWANs) (Ismail *et al.*, 2018, p. 1-3) and satellites of low Earth orbits (LEO) (Ritchie & Seal, 2020). The presented technologies represent significant progress and the further development of world „connection".

In this elaboration, the main focus was put on the usage of 5 technologies used in logistics, concerning data transfer and information. Such a choice was deliberate and concerns these possibilities which are most popular and have the broadest spectrum of usage. These technologies also tend to be the most important link between the connection of places characterized by the biggest limitation. The chosen technologies are:

– technologies of short-range networks,
– local networks,
– wide area networks,
– low-power wide area networks,
– global computer networks.

In the case of short-range networks, examples would need to be RFID, NFC and Bluetooth. RFID represent an interesting option as an older technology, but its versatility makes it a popular solution even in the present day. What is more interesting is the fact that this type of technology does not require an external source of power. Mainly it is used in logistics in order to identify cargo, transport or trucks and makes the picking, storage and identification processes easier (Mašek *et al.*, 2016, p. 232, 233; Chudy-Laskowska, 2018, p. 222-224). It contributes mainly to the introduction of the automatization of processes of inventory management[1]. A much newer technology is Near Field Communication (NFC) which may also be described as an innovative example of RFID. It has much broader usage, as its functionality is present in almost every model of smartphone, which allows for many applications, ex: contactless payments. Of direct use for logistics, NFC is used to monitor the state of cargos

[1] The author refers to the functioning of RFID technology in a large extent in his other study (Wieczorek, 2015).

during transport, especially the fragile ones such as pharmaceuticals. Of key importance for NFC, since it is displacing RFID, is the growing popularity of devices which can operate it, and thus this is the cause of lower costs, which may be present with the implementation of RFID (Heutger & Kuckelhaus, 2018, p. 16-18). Another popular technology is a network also used within mobile phones but not exclusively: Bluetooth. In terms of logistics, it is mainly used to monitor and track shipments and trucks. Suitable adapters are adopted to shipments and works similar to RFID tags, but they are also characterized by improved data transfer and a better working range. Proper transmitters may be used within warehouses to improve the movement of robots or workers and thus automate certain related processes (*Automation of…*, 2020, p. 4-6). Bluetooth labels may also be used to monitor fragile cargo (as in the NFC example), especially for pharmaceuticals as mentioned previously (Chou *et al*., 2013, p. 1, 2).

Another point of interest is the usage of local networks and, in this case, Wi-Fi should be the starting point. Mainly, this network is used in warehouses, places where goods are sorted, but also within the enterprises where access to the internet is needed. In addition, Wi-Fi 6 technology will provide the users a larger capacity for data and information. At present, enterprises such as DHL are using autonomous robots for shipment completion, and for them it is necessary to use a wireless network. Beside this example above, all types of wearable devices also need access to a network, due to the fact of allowing better transfer of information which may contribute to increased efficiency of work in warehouses and in transport processes (McGuire, 2017). Some types of Wi-Fi development may be Li-Fi which is a type of network based on the usage of LED light, which eliminates some of the limitations in information transfer, such as immunity to radio interference which is a problem in the case of Wi-Fi (Subha *et al*., 2020, p. 2403-2409). Implementation of Li-Fi, besides improving information transfer, also leads to a reduction in material costs and necessary wiring (*High-speed Internet…*, 2020). Broadband network as a development of Wi-Fi and a complementary network may be used in logistics especially for the tracking of products in real time and the optimization of space used to store cargo. It is a highly effective solution, especially with the complementary use of Wi-Fi in accordance with processes connected with managing the warehouse space (*Real-time Locating…*, 2020).

Another aspect of wireless network usage concerns the wide range of access. The most important examples are mobile phone networks and the wireless networks 4G, LTE and fresh 5G. Development of these networks has been present since 2009 at least, and it is guaranteeing increased data throughout, improved transfer and what is one of the most important points in the case of 5G, i.e., additional bandwidth for users (approx. 10 times more than in the case of 4G) (Rejeb & Keogh, 2020, p. 3, 4). The application of 5G in logistics may be described based on few examples. Above all, firstly 5G connectivity may be a solution

for some enterprises to connect. Expectations concern its common implication in advanced logistical hubs ex. harbour, airport, and warehouse complexes. The adoption of 5G will allow not only a more efficient flow of information, but will also make it easier to cover large usable spaces while using only one network, which will definitely improve the efficiency of information transfer and the introduction of additional technologies such as augmented reality (*Lufthansa Technik and…*, 2020). Other enterprises point out that 5G will be the only network which will allow the connection of every element in the transhipment port (containers, cranes, vehicles etc..), which will enable some degree of automation of loading, the completion processes, and the level of safety; hence, a more efficient logistics service (*Port of Antwerp…*, 2020). Another application of 5G directly concerns the processes of transport. The implementation of 5G in a system of traffic control allows the limiting of traffic congestion and shortens the time needed for the provision of transport services, while simultaneously decreasing fuel costs. Besides implementing different levels of connectivity and transparency in the logistics process (especially in accordance with information), 5G will be a key element in the case of growth and development and implementation of autonomous (and may be in the future fully automatic)[2] systems of truck driving systems, in particular for road and long-haul transport (Külaots, 2019). Another case of use refers to the functionality of supply chains. One proposed solution concerns the creation of digital copies of chosen elements in a supply chain. Such an example allows one to maintain control and affect not only digital parts but also physical attributes, such as resources or any other element of the supply chain. Such a creation has already been used in harbours or within large warehouses in order to design, plan or manage their future operations. It is obvious that such a solution is not a simple one, it generates many costs and it requires high precision and high quality data. Wireless technologies headed by 5G may be a solution for such requirements. The presentation of information about the state in harbours 1:1, localization, and the availability of products needs high capacity and reliability of links which may be provided by the common usage of 5G. In addition, its adaptation may enable the connection of other networks and the transfer of data from various devices without any problems concerning compatibility, which is very important in case of the introduction of new technologies, thanks to which it will be possible to collect almost any stream of information transfer (*Lift your cranes to…*, 2020).

The next section concerns wide networks of low power (LPWAN). These are somewhat like a main competitor of 5G networks in that this is a present innovation concerning data transfer. Often, they are defined as narrowband and as for their construction they should provide functionality similar to Bluetooth (BT) or RFID while at the same time possessing the ability of data transfer over long distances (in accordance with small distances such as in BT or RFID).

[2] The author refers to the conceptual difference discussed in his study (Wieczorek, 2017).

This should also generate a smaller cost of introduction than 4G or 5G. Their main advantage is above all availability due to the fact that some of them are already in commercial use, and their implementation is fast and cheap (Heutger & Kuckelhaus, 2020, p. 24). They are perfect for places where a small amount of data is transferred in one period. In relation to logistics, their adoption can be seen mainly as a tracking and monitoring of resources flowing through various supply chains. An example of such an adoption may be airports, which are using them for the identification of cargo and the coordination of ground equipment and other vehicles. The system allows the localization of luggage equipment, vehicles and all other moving resources and in addition it may positively influence the level of safety (*Semtech's LoRa…*, 2019). Another positive example of LPWAN usage is indirectly connected to information transfer, because proper aspects of monitoring and tracking, especially in the case of postal services, allow the reduction of mistakes and losses. Such use of advanced information transfer enables improved efficiency of postal enterprise activity, but it may also contribute to the lowering of costs (*Deutsche Post DHL…*, 2019). Another adoption may be observed in the case of fleet or shipyard management. One such shipyard is using this network for the improvement of management. They are using special sensors which transmit data to the main desktop of central place management, which significantly improves the effectiveness of coordinating drivers and vehicles. An exact view of what is happening in the harbour or in the work place allows increased safety and reduces the need for a workforce as well as shortening the working distance of some machines, devices or vehicles. Such a solution may be used in each type of reloading yard, distribution centre or any other industry complex. Another adoption may be compared to the tracking of vehicles based on GPS. Chosen technologies of LPWAN allow the tracking of vehicles with a lower energy consumption and at the same level of telemetric data transfer. In addition, such a module is characterized by small dimensions, which enables its usage in case of unpowered resources (ex. containers), as well as for rental fleets or ones used by third parties (*Omnitracs Volvo…*, 2020; *Real-Time…*, 2020).

Finally, it is worth describing the global area networks, because even the newest wireless technologies have their limitations. It is obvious that the ranges of various types of networks are getting better and better, yet this is caused by the operators who are investing in their base stations etc., however, in a situation where the provision of proper infrastructure is not possible then another solution should be considered. One solution may be the XXI century satellites that are also sharing access to the internet network. Satellites used by such solutions are those that move in a low orbit around the Earth (such a solution reduces delays and allows global access to the service compared to geostationary satellites). This technology is at present not too expensive and this is thanks to implementations by enterprises such as SpaceX in relation to the functionality of commercial markets (Seemangal, 2017). Many other enterprises are also planning

to extend their activity to provide access to global networks by using Earth satellites (*How O3b mPower…*, 2020). The technology of satellite connectivity is an attractive offer for enterprises who are dealing with the logistics service. It would allow the constant tracking of shipments around the world, while at the same time eliminating the so-called black spots of connectivity, ex. ships on the open ocean. Such functionality could be implemented commonly and should provide improved monitoring of goods flow and resources within supply chains in a place where no other technology could access (Skylo, 2020). In addition, Earth satellites may positively influence remote control and management of machines and devices of various enterprises which are not operated directly by humans, no matter where they are (*Satellite Technology…*, 2020).

Summary

The presented technologies and their implementation in logistics are an example because there are many other possibilities allowing the improvement of data transfer using wireless technology. The selection of presented technologies was because they represent the real functions and examples from existing enterprises who are dealing with production, services or logistics. Information is one of the most important resources of logistics, and must be provided in accordance with the 5R rule. It is an indispensable element of the proper functioning of any type of enterprise, therefore it is very important to support data transfer with modern technologies. On one side, they allow the conduction of various activities, and from the other they improve existing processes (as part of providing 5R with relations to information) allowing faster, more accurate transfer, thus contributing to the increased effectiveness of activities performed, within the processes connected with logistics service, when providing information. The logistics industry requires the effective coordination of human and material resources. The more and more common introduction of wireless technologies has the chance to find its application in logistics activities. RFID can be further used in warehouses or other environments that require control to improve tracking processes. NFC may be more commonly used, allowing for secure transmission of information for logistical needs. Bluetooth technology will enable local logistics structures to communicate without any problems, and therefore it will enable the more efficient operation of warehouses based on simple automation processes. 5G will allow for a global network connection of large producing factories and corresponding logistics centres and may also be a key factor in the development of autonomous (or automatic) transport. Extensive low-power networks will enable basic connectivity with most parts of the world. Low-power global networks using satellites will extend the range of access to the internet in most remote corners of the world. In view of such consideration, it can be easily noted that

wireless technologies are a point of interest with regards to logistics, especially information logistics. It is obvious that enterprises will have many challenges with matching the proper devices and infrastructure with the right costs, yet even now the logistics sector is taking serious action in the development of wireless connectivity and trouble-free usage of its benefits.

Translated by Author
Proofreading by Michael Thoene

References

3 Ways Mobile Workstations Eliminate Waste and Improve Warehouse Efficiency. (2017). Miles Data Technologies. Retrieved from https://www.milesdata.com/blog/3-ways-mobile-workstations--eliminate-waste-and-improve-warehouse-efficiency/ (10.12.2020).

Automation of Internal Transportation. (2020). Mobile Industrial Robots. Retrieved from https://www.mobile-industrial-robots.com/media/3777/white-paper_what_every_business_owner_needs_to_know_about_amrs.pdf (10.12.2020).

Beier, F.J., & Rutkowski, K. (1995). *Logistyka*. Warszawa: Szkoła Główna Handlowa.

Chaberek, M. (2002). *Makro- i mikroekonomiczne aspekty wsparcia logistycznego*. Gdańsk: Wydawnictwo Uniwersytetu Gdańskiego.

Chaberek, M. (2011). Praktyczny wymiar teorii logistyki. *Roczniki Naukowe Wyższej Szkoły Bankowej w Toruniu*, *10*(10). Retrieved from http://yadda.icm.edu.pl/yadda/element/bwmeta1.element.ekon-element-000171209797 (10.12.2020).

Chaberek, M. (2014). Theoretical, regulatory and practical implications of logistics. *LogForum Scientific Journal of Logistics*, *10*(1), 3-12. Retrieved from https://www.logforum.net/pdf/10_1_1_14.pdf (10.12.2020).

Chaberek, M. (2020). *Ład logistyczny w gospodarowaniu*. Gdańsk: Wydawnictwo Uniwersytetu Gdańskiego.

Chou, P.H., Lee, Ch-T., Peng, Z.-Y., Li, J.-P., Lai, T.K., Chang, Ch.-M., Yang, Ch.-H., Chen, Y.-L., Nien, Ch.-Ch., Chen, L.-H., Lai, L.-Y., Lu, J.-Ch., & Hung, S.-Ch. (2013). *A Bluetooth-Smart Insulating Container for Cold-Chain Logistics*. Conference: 2013 IEEE 6th International Conference on Service-Oriented Computing and Applications, p. 1-7. http://dx.doi.org/10.1109/SOCA.2013.46.

Council of Logistics Management. What is it All About? (1986). Oak Brook. Illinois. Quoted after M.C. Cooper, D.M. Lambert, & J.D. Pagh. (1997). Supply Chain Management: More Than a New Name for Logistics. *The International Journal of Logistics Management*, *8*(1), 1-14. Retrieved from https://www.researchgate.net/publication/235278234_Supply_Chain_Management_More_Than_a_New_Name_for_Logistics (22.09.2020).

Deutsche Post DHL, ALPS Electric Europe GmbH and Sigfox launch innovative tracking solution for roll cages. (2019). Sigfox. Retrieved from https://www.sigfox.com/en/news/deutsche-post-dhl-alps-electric-europe-gmbh-and-sigfox-launch-innovative-tracking-solution (10.12.2020).

Chudy-Laskowska, K. (2018). Factors Influencing the Decision to Implement an RFID System. *LogForum Scientific Journal of Logistics, 14*(2), 221-233. http://dx.doi.org/10.17270/J.LOG.2018.279.

Długosz, J. (2000). *Relacyjno-jakościowa koncepcja logistyki w zarządzaniu*. Poznań: Zeszyty Naukowe – seria II, Prace habilitacyjne.

Falkiewicz, F. (1971). *Podejmowanie decyzji kierowniczych*. Warszawa: PWE.

Gościński, J. (1968). *Elementy cybernetyki w zarządzaniu*. Warszawa: Polskie Towarzystwo Cybernetyczne.

Heutger, M., & Kueckelhaus, M. (2019). *Rethinking Packaging. A DHL perspective on the future of packaging in the logistics industry*. Powered by DHL Trend Research. Retrieved from https://

www.dhl.com/content/dam/dhl/global/core/documents/pdf/glo-core-rethinking-packaging-trend--report.pdf (10.12.2020).

Heutger, M., & Kueckelhaus, M. (2020). *Next-Generation Wireless in Logistics. A DHL perspective on the evolution of wireless networks and the future of IoT in logistics*. Powered by DHL Trend Research. Retrieved from https://www.dhl.com/content/dam/dhl/global/core/documents/pdf/next-generation-wireless-in--logistics.pdf (10.12.2020).

High-speed internet through your lights with LiFi. (2020). Signify. Retrieved from https://www.signify.com/global/innovation/trulifi (10.12.2020).

How O3b mPOWER Challenges the Conventional Wisdom of Satellite Networks. (2020). Via Satellite. Retrieved from https://www.satellitetoday.com/long-form-stories/how-o3b-mPOWER-challenges--conventional-wisdom-satellite-networks/?utm_source=VSDigitalEdition&utm_medium=DE--Redirect&utm_campaign=SES-O3bContent2019 (10.12.2020).

Ismail, D., Rahman, M., & Saifullah, A. (2018). *Low-power wide-area networks: opportunities, challenges, and directions*. Workshops ICDCN '18: Proceedings of the Workshop Program of the 19th International Conference on Distributed Computing and Networking, p. 1-6. https://doi.org/10.1145/3170521.3170529.

Jagersma, P.K. (2011). Competitive information Logistics. *Business Strategy Series*, *12*(3), 136-145. http://dx.doi.org/10.1108/17515631111130103.

Krawczyk, S. (2011). *Logistyka: teoria i praktyka*. Warszawa: Difin.

Külaots, M. (2019). *MWC 2019: 5G Will Bring New Tech Revolution Fleet Complete*. Retrieved from https://blog.fleetcomplete.com/mwc-2019-5g-will-bring-new-tech-revolution (10.12.2020).

Lasi, H., Fettke, P., Kemper, H.-G., Feld, T., & Hoffmann, M. (2014). Industry 4.0. *Business & Information System Engineering*, *6*, 239-242. http://dx.doi.org/10.1007/s12599-014-0334-4.

Lift your cranes to the next level. (2020). Siemens. Retrieved from https://new.siemens.com/global/en/markets/cranes.html (10.12.2020).

Lufthansa Technik and Vodafone Business launch 5G private network. (2020). Vodafone. Retrieved from https://www.vodafone.com/business/news-and-insights/company-news/lufthansa-technik--and-vodafone-business-launch-5g-private-network (10.12.2020).

Mašek, J., Kolarovszki, P., & Čamaj, J. (2016). Application of RFID Technology in Railway Transport Services and Logistics Chains. *Procedia Engineering*, *134*, 231-236. http://dx.doi.org/10.1016/j.proeng.2016.01.064.

Mrozek, A. (2019). *4 Key Benefits GPS Trailer Tracking Provides Fleets*. Samsara. Retrieved from https://www.samsara.com/blog/gps-trailer-tracking-for-fleets (10.12.2020).

Ning, H.S., & Liu, H. (2015). Cyber-physical-social-thinking space based science and technology framework for the Internet of Things. *Science China Information Sciences*, *58*. http://dx.doi.org/10.1007/s11432-014-5209-2.

Omnitracks. (2020). Volvo Trucks USA. Retrieved from https://www.volvotrucks.us/our-difference/uptime-and-connectivity/fleet-management/omnitracs/ (10.12.2020).

Port of Antwerp to develop private 5G network. (2020). Port Technology. Retrieved from https://www.porttechnology.org/news/port-of-antwerp-to-develop-private-5g-network/ (10.12.2020).

Real-Time Locating System (RTLS). (2020). Kinexon. Retrieved from https://kinexon.com/technology/real-time-locating-system-rtls (10.12.2020).

Real-Time, All the time. (2020). Volvo Trucks USA. Retrieved from https://www.volvotrucks.us/our-difference/uptime-and-connectivity/ (10.12.2020).

Rejeb, A., & Keogh, J.G. (2020). 5G Networks in the Value Chain. *Wireless Personal Communications*, *117*, 1577–1599. https://doi.org/10.1007/s11277-020-07936-5.

Ritchie, G. & Seal, T. (2020). Why Low-Earth Orbit Satellites Are the New Space Race. *The Washington Post*, 10.07.2020. Retrieved from https://www.washingtonpost.com/business/why-low-earth-orbit-satellites-are-the-new-space-race/2020/07/10/51ef1ff8-c2bb-11ea-8908.

Satellite Technology powered by the Globalstar Satellite Network. (2020). Globalstar. Retrieved from https://www.globalstar.com/en-us/about/our-technology.

Seemangal, R. (2017). SpaceX Launches Its 12th Resupply Mission to the ISS. *Wired*, 08.14.2017. Retrieved from https://www.wired.com/story/spacex-launches-its-12th-resupply-mission-to-the--iss/(10.12.2020).

Semtech's LoRa® Technology Connects Thousands of Assets at Istanbul Airport. (2019). IoT Business news. Retrieved from https://iotbusinessnews.com/2019/06/20/06031-semtechs-lora-technology--connects-thousands-of-assets-at-istanbul-airport (10.12.2020).

Subha, T.D., Subash, T.D., Elezabeth Rani, N., & Janani, P. (2020). Li-Fi: A Revolution in Wireless Networking. *Materialstoday: Proceedings*, *24*(4), 2403-2413. https://doi.org/10.1016/j.matpr.2020.03.770.

Szmelter, A. (2013). Business Intelligence jako element systemu zaopatrzenia informacyjnego. *Torun Business Review*, *12*(12). Retrieved from http://yadda.icm.edu.pl/yadda/element/bwmeta1.element.ekon-element-000171294035 (10.12.2020).

Szmelter-Jarosz, A. (2020). *Logistyczne aspekty racjonalnego wykorzystania systemów informatycznych*. Gdańsk: Wydawnictwo Uniwersytetu Gdańskiego.

Szozda, N. (2017). Industry 4.0 and its impact on the functioning of supply chains. *LogForum Scientific Journal of Logistics*, *13*(4), 401-414. http://dx.doi.org/10.17270/J.LOG.2017.4.2.

The role of Shippers and Transport Operators in the Logistics Chain. (1987). European Conference of Ministers of Transport. Retrieved from https://www.oecd-ilibrary.org/transport/the-role-of--shippers-and-transport-operators-in-the-logistics-chain_9789282105818-en (22.09.2020).

Vorhees, J. (2017). *10 Years Ago, the iPhone Redefined Mobile Computing*. MacStories By Frederico Viticci & Friends. Retrieved from https://www.macstories.net/news/10-years-ago-the-iphone-redefined-mobile-computing (10.12.2020).

Weiland, D. (2016). Logistyka informacji jako podstawowy element w budowaniu przewagi konkurencyjnej w e-commerce. *Studia Ekonomiczne. Zeszyty Naukowe Uniwersytetu Ekonomicznego w Katowicach*, *306*(6). Retrieved from http://cejsh.icm.edu.pl/cejsh/element/bwmeta1.element.cejsh-f09a1162-46b0-469c-91f0-9430370af7ec (10.12.2020).

Weiland, D., & Wierzbowski, P. (2020). *Logistyka informacji w gospodarce 4.0*. Gdańsk: Wydawnictwo Uniwersytetu Gdańskiego.

Weiner, N. (1971). *Cybernetyka, czyli sterowanie i komunikacja w zwierzęciu i maszynie*. Warszawa: Państwowe Wydawnictwo Naukowe.

Wieczorek, A. (2015). *RFID Technology in Transport*. The 5th Multidisciplinary Academic Conference in Prague 2015. Retrieved from https://books.google.pl/books?id=5Ty5CgAAQBAJ&pg=-PA302&dq=Adam+Wieczorek+RFID&hl=pl&sa=X&ved=2ahUKEwi9naeyvdLtAhUJ6aQKHSwsAxAQuwUwAHoECAMQCQ#v=onepage&q=Adam%20Wieczorek%20RFID&f=false (10.12.2020).

Wieczorek, A. (2017). The influence of self-driving transport vehicles on the field of Logistics. *Research Journal of the University of Gdańsk. Transport Economics and Logistics*, *66*, Modelling of logistics processes and systems, Part XVII, p. 107-114. http://dx.doi.org/10.5604/01.3001.0010.5602.

Zijm, H., Klumpp, M., Regattieri, A., & Heragu, S. (2000). *Operations, Logistics and Supply Chain Management*. Springer Nature, Switzerland AG. http://dx.doi.org/10.1007/978-3-319-92447-2.