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CONCEPT OF COMMUNICATION INTEGRATION FOR AUTOMATED PRODUCTION PROCESSES REGARDING LOGISTICS 4.0

ABSTRACT

Background: Constantly changing market needs and concentration of the entire supply chain on the customer service level, forces both in the business and scientific world to search for modern solutions which improve logistic processes. This trend is leading to the transformation of current solutions towards intelligent supply chains. The use of modern technologies is aimed at improving logistics processes at the operational level by shortening the time of execution of activities, minimizing bottlenecks and errors which result from faulty information flow. Nowadays, there are numerous innovative solutions that lead the supply chains along the digitisation way.

Material and methods: Since 2016, the Institute of Logistics and Warehousing and the Poznan School of Logistics have been conducting intensive research work both in the scientific area and in the possibilities of applying individual solutions in business practice. Jointly developed long-term research methodology aims at applying the synergy effect of research work in the field of identification of innovative solutions for supply chain digitisation, with an analysis of their possible application in economic practice.

Results: The aim of this chapter is to present the concept developed to evaluate the communication integration efficiency of automated production processes as one of the key

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elements of the intelligent supply chain. The result of this work is participation in a research project L4MS, and at the end of the project work the possibility of verifying the efficiency of intelligent solutions implementation in economic practice.

Conclusions: Information technologies, wireless sensors and advanced control systems are becoming the key of the new industry. However, it should be emphasized that such high value-added products can be realized with advanced computer-controlled machines. For this reason Industry 4.0 requires equipment and has the potential to expand through. It also creates a secondary market in areas such as automation equipment, robots and special machinery in logistics.

Keywords: Logistics 4.0, automated production processes, autonomous devices, communication integration, information flow efficiency

INTRODUCTION

In the current world, as a result of progressive digitisation, we are at the beginning of the fourth industrial revolution associated with the transition to cyber-physical systems connecting machines, processes and products into intelligent business solutions and self-controllable 'Smart supply chains'. As part of the latter, cooperating Smart Factories exchange information with partners, suppliers and distribution and service networks in intelligent supply chains in an automated way. These processes have an end-to-end dimension and cover the entire life cycle of the product. Such components create the concept of Industry 4.0 as a paradigm partially defined by the use of machine to machine (internet of things - IoT) communication devices to create factories that act as intelligent production systems: a number of devices and machines are adapted to continuous communication in order to create a coherent, clearly visible system. The ultimate result is the discovery of areas of inefficiency, more accurate optimisation of some decisions and automation of some simple (or not so simple) processes. Logistics 4.0 works according to the same principles, but with a different set of components. In particular, it uses "intelligent" containers, vehicles, pallets and transport systems to create a fully networked delivery stream that offers supply chain managers, freight forwarders and other partners the necessary visibility for optimal transport management and other logistical tasks.

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RESEARCH METHODOLOGY

Research concerning the logistics processes efficiency in intelligent supply chains has been conducted since 2018 within the research and development projects of the Institute of Logistics and Warehousing and the Poznan School of Logistics. Figure 1 shows the general research methodology.

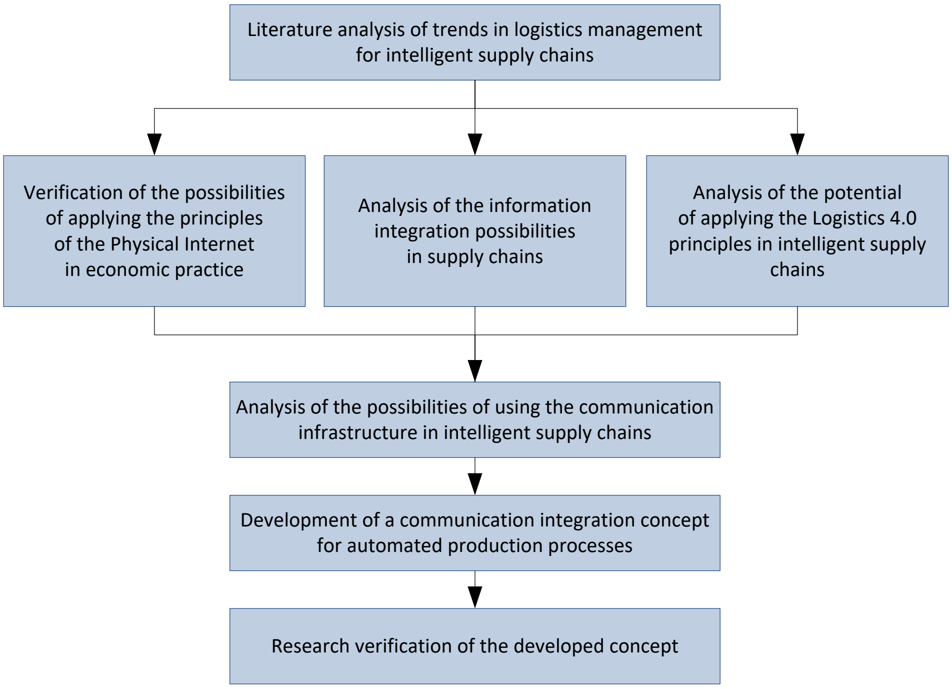

Fig. 1. Research methodology.
Source: own elaboration.

As it is a trending topic in Poland, researches in Turkey are also studying on Industry 4.0 in recent years. Moreover, there is a Ministry of Industry and Technology in Turkey. The ministry is responsible for improving the competitiveness of informatics sector, to authorize the firms that will supply public IT projects in accordance with the competencies or standards they need to carry, to cancel or to suspend authorization in accordance with technical criteria, to comply with the procedures and principles of public institutions and contractors to execute contracts related to public IT projects. To exemplify, there is a program called "University - Industry Cooperation" in Turkey and universities can be granted from the ministry up to 1 million Turkish Liras -around 152.500 Euro- (Ministry of Industry and Technology).

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The research logic includes a broad literature analysis of trends for logistics management in intelligent supply chains, as well as their application in business practice. Theoretical foundations were based on a critical review of the literature on: application of communication standards [Pedersen,2012; Sliwczynski, Hajdul, Golinska 2012], and modern integration trends in the supply chain [Speier, Mollenkopf, Stank 2008; Stajniak & Guszczak 2011; Prajogo, Olhager 2012; Kawa 2012; Leuschner, Rogers, Charvet 2013; Cyplik et al. 2014; Hadas, et al. 2015; Kawa, Zdrenka 2016; Trojanowska, Varela, Machado 2017; Domanski, Adamczak, Cyplik 2018; Dujak, Sajter 2019]. As part of the above mentioned research works, analysis of the possibilities of using the physical Internet in economic practice [Osmólski, Voronina, Kolinski 2019] and analysis of the possibilities of integrating the flow of information in supply chains [Osmolski, Kolinski, Dujak 2018; Horzela et. al, 2018; Debicki, Kolinski 2018], were carried out. This chapter focuses on the application potential of Logistics 4.0 in intelligent supply chains and the concept of communication integration for automated production processes, taking into account the logistics 4.0 principles.

THE POTENTIAL TO IMPLEMENT PRINCIPLES OF LOGISTICS 4.0 IN INTELLIGENT SUPPLY CHAINS

The advantages of information sharing and integration in supply chain management has been frequently studied in the literature. In one study done by [Zhao et al. 2002], for example, information-sharing influences supply chain performance in terms of total cost and service level. In the same manner, [Lin et al. 2002] demonstrate higher level of information sharing is related to lower total cost and make a shorter order cycle as time. However, it should be considered that while sharing of information is vital, its impact on the performance of a supply chain depends on what kind of information is shared, how it is shared, and with whom [Byrne and Heavey 2006; Holmberg 2000; Li and Lin 2006]. In terms of business, it is important not to underestimate the requirements placed on companies that hope for smarter organisation of work in logistics, but its scope is disproportionately limited compared to the countless ways in which logistics 4.0 can bring added value. In the short term, increased end-to-end visibility (E2E) and the more comprehensive view of the supply chain will almost certainly be significant added value propositions for companies that are able to achieve them. Looking to the future, Logistics 4.0 has the potential to pioneer a new, more advanced value stream concept that

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includes autonomous vehicles (i.e. vehicles without a driver), automated warehouse operations, and perhaps even completely eliminate warehouses for predicted deliveries with full, zero time integration in the intelligent production processes.

The above example shows how new paradigms can lead the way to the growth of 'anticipatory logistics', i.e. supply chain management, where intelligent technology is able to anticipate future operations, thus preventing process bottlenecks, allowing planners (and even autonomous machine processes) to adapt production schedules to future changes in demand. As anticipatory logistics will become a reality, the global value chain will become more complex, relying on advanced predictive algorithms and the integration of an increasing number of interlinked components, while being much leaner, offering a more adaptive, agile environment where lead times are significantly reduced and shortages, oversupply and disruption are becoming increasingly limited. The basic principles of Logistics 4.0 are presented in Figure 2.

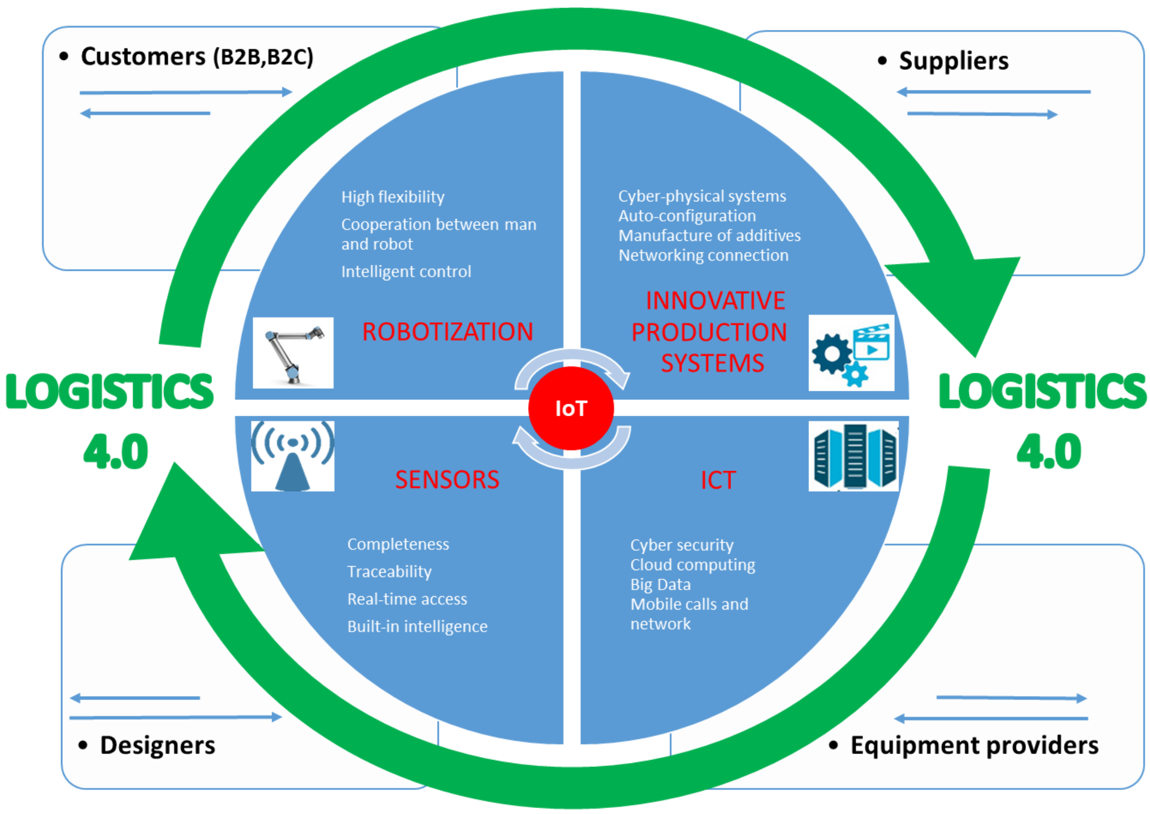

Fig.2 Principles of Logistics 4.0.

Source: own elaboration.

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Due to the nature of these links, the main challenge is the integration of cyberspace with physical objects equipped with sensory systems. The implementation of such a challenge requires the integration of business and technological competencies in order to effectively support domestic economic initiatives, and in particular the use of solutions enabling structural use of simulation platforms integrating IT solutions of many manufacturing enterprises.
Industry 4.0's Smart Companies include intelligent machines and systems that detect business needs with sensors, communicate with other devices in production via the Internet, and get the production information they need from Big Data in cloud systems. The communication and interaction between the machines in production is provided via the internet. Structures that allow the communication of objects to each other are called Internet of Things (IoT). The structure of communication and coordination between the physical world and the cyber world is called the CPS - Cyber-Physical Systems. [Alcin 2006: 20]. In order for a company to be able to use the latest technologies in the field of Industry 4.0 or Logistics 4.0, it must be characterized by a high degree of technological advancement. The seven pillars of technological advancement apply (Fig. 3):

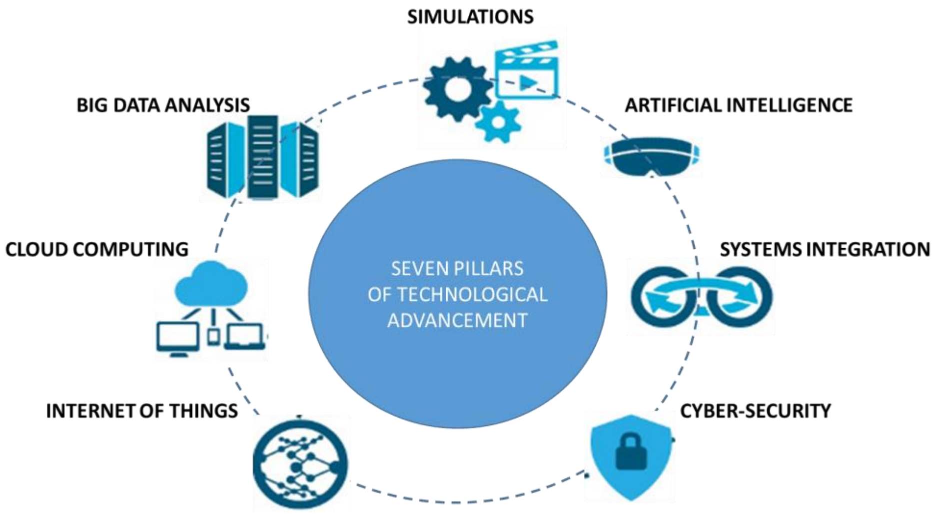

Fig. 3. Seven pillars of technological advancement.

Souce: ILiM research.

- **Simulations** - the use of simulation tools both in the design processes of structural, sales or process solutions,
- **Artificial intelligence** - to fully automate and support decision-making processes,

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- **System Integration** - integration of services available in the network, offered by different suppliers, which can be used in a dynamic way ensuring different components of the value chain and implementation of new business models - includes services such as Smart Mobility and Smart Logistics,
- **Cyber-security** - application at every stage of IT systems construction (from design to operation) of methods of assessing and ensuring security of cyberspace and information and hardware infrastructure of enterprises and their cooperators, which is of key importance in the transformation to Logistics 4.0,
- **Internet of Things (IoT)** - building wireless sensory networks and controllable management models,
- **Cloud computing** - using cloud computing and digital services,
- **Big Data** - acquisition and processing of large amounts of data for analysis - modelling - simulation - forecasting - prototyping - implementation.

RELATED COMMUNICATION INFRASTRUCTURE - INITIAL OBJECTIVES

The related communication infrastructure concerns one of the most important aspects of logistics, i.e. obtaining precise information within a precise time frame necessary to be able 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 is either lost, in the information exchange chain, or misrepresented or received with a long delay. In order to overcome these problems and create effective information exchange chains, it is necessary to focus in particular on the following elements:

- create common platforms for data exchange based on communication standards,
- their architectural structures should be based on a well-defined, clear model,
- use standard links to integrate systems in the form of access points,
- use simulation platforms to monitoring and control logistics processes.

These issues have been subjects to a full and in-depth functional analysis in the L4MS project ('Logistics For Manufacturing SMEs', Grant agreement ID: 767642, Funded under: H2020-EU.2.1.1.1), which created a platform integrating the information flow between IT systems used in production logistics, enabling full coordination of autonomous devices control.

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This approach is an architecture for business applications created as a set of stand-alone components organized to provide services operating according to specific criteria, supporting the implementation of business processes. An important premise of this solution is the use of existing applications and systems, which are used by economic entities, reducing them to a standard functioning ecosystem. On the technical side, it is necessary to create universal links between existing and new systems, including through the use of integration platforms based on specific standards of information exchange. Such an approach also requires the development of the so-called information architecture, which will combine elements operating in the areas of individual computer systems, using available standards based on unified communication units. This type of activity leads to a full optimisation of logistics as shown in Figure 4

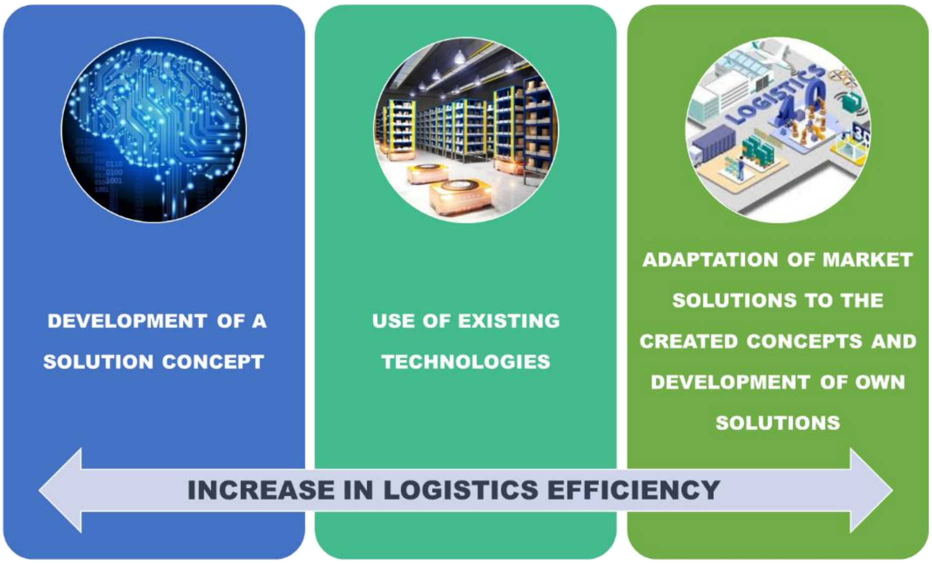

Fig.4. Increased logistics efficiency.
Source: own elaboration.

The benefits of such solutions are as follows:

- reducing the amount of work involved in modifying and merging systems,
- elimination of errors in the messaging phase,
- easy, fast and trouble-free access to data,
- acceleration of processes,
- low cost of implementing the changes,
- time saving,
- less cost production,

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- using less resources,
- high speed reliability,
- increase in income and profit level.

THE CONCEPT OF COMMUNICATION INTEGRATION FOR AUTOMATED PRODUCTION PROCESSES

The purpose of the research is both to analyze the possibilities of integration of the communication information platform with autonomous devices used in the production process, as well as to identify the benefits of using automation of logistic and production processes in small and medium-sized enterprises. We can talk about 3 types of integrations during production process (http://www.akillifabrika.org):

- Vertical Integration: It increases the capacity of the system, computer, machine, work terminal, devices and tools in the company system.
- Horizontal Integration: The subsidiary companies outside the enterprise, suppliers, logistics companies, financial institutions, insurance companies, distributors, manufacturers, etc. integration that provides similar interaction over internet.
- End to End Integration: It is the end-to-end integration of engineering systems across the entire supply chain to support the enterprise to offer customized, more qualified products and services to people.

The analysis will cover the process of folding, internal transport of materials to production stands and finished products to the stands of packing and packaging gluing, which consists in dynamic buffering of materials based on the production plan, taking into account the use of AGV. Application of the solution will allow the company to achieve tangible benefits in the form of shortening the time of process completion, generation of cost savings, increase in the productivity of the implemented process. A measurable achievement, which is difficult to be clearly defined at the conceptual stage, is the improvement of operational efficiency through the optimization of process execution thanks to the use of 3D simulation visualization.

Currently, the analyzed process of packaging folding and gluing is partly automatic, based on the hybrid method assuming segmented automation of the production process and the use of human labor. Although the configuration of AVGs allows for partial automation of deliveries of finished products to the packing stand it is limited by the lack of communication between

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them, which generates a limitation in the form of the capacity of the process of material buffering. This limitation has a direct impact on the productivity of the entire production process - the introduction of communication integration using the communication platform will increase the information flow efficiency, which will minimize errors in material collections, the number of empty trolley runs and their unnecessary storage movements. The expected outcomes of implementation of this solution are as follows: greater availability of materials in the buffer, shorter time of the buffer process, elimination of waiting time of the production machine for the material to be processed, increased efficiency of the production process and reduction of production costs.

The automation of the production process will be based on the use of AGVs, which can be integrated into the functionality of the communication platform. The technological solution of the buffer area itself is based on the installation consisting of 350 chain conveyors, operated by two horizontal elevators. Next stages of the production process are linked to the automatic buffer area through two autonomous AGVs. This way of buffer automation is aimed mainly at compensation of differences resulting from the production plans of individual processes (production plans are adjusted to the tool or product, compensation of differences has a significant impact on the efficiency of individual production stages). In the subsequent stages of the production process there is a conflict between the opposite strategies of material and stock management - push and pull. Another important aspect of using such a buffer system is the fact that the sensitive production process is secured and made independent by dynamic and flexible buffering of 350 pallets with materials according to an approved production plan. This solution allows us to combine different material delivery strategies in one buffer area. The buffer is able to collect the material according to the push strategy from the previous production operation and to forward it to the next stage according to the pull strategy. The ERP system is responsible for the management of the buffer area and the sequence of executed tasks, as AGVs and Automatic Buffer Area do not have their own visualization and simulation system for processes or individual operations. Integration with the ERP class system can be exchange of text files in standardized format (XML) or by means of direct access to the database and database views available. Selection of the method of integration depends on the capabilities of the ERP system provider. The application managing the buffer operation has its own database

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based on which all transactions are performed, and their result is transferred to the ERP system with the use of an integrating application.

An important aspect of buffer automation and intralogistics between processes is also the fact that there is no need to produce long series of individual products. Products can enter the buffer area in any configuration, regardless of shape, color, size and value. The buffer will automatically adjust and optimize the allocation of goods in individual areas according to the data provided by the ERP system, so that the release to the next stage of the process (order) is performed as fast as possible. The buffer has the functionality of shuffling and rotating the material inside its 350 areas without the intervention of employees. In this way, the burden of intralogistics has been significantly reduced thanks to elimination of unnecessary forklift truck runs, searching for material with the right index, much shorter time of preparation for the next order. An additional advantage of implementing this solution is the clear and precise organization of the storage area - the buffer area is planned in detail and the goods are arranged there, which increases safety in the warehouse, compared to the situation when the same number of pallets is left on the floor on the intermediate storage area.

THE STAGES OF COMMUNICATION INTEGRATION

The stages of research work in the field of communication integration include as a first step, an analysis of the current state of the automatic solution used in the process of folding and gluing the packages, with particular reference to the identification of limitations. This analysis will identify the precise indications and functional conditions of the possibilities for implementation of the integration of AGV devices with the OPIL platform. Data showing the actual state will be collected, moreover, the expected outcomes of this implementation will be determined, which in the last stage will serve as a norm (target/desired value) of the obtained results of the implementation. After implementation of the analytical part and identification of integration possibilities (in organizational and technological terms), the OPIL platform will be implemented in the analyzed process. The prepared preliminary business model will provide for verification of the possibilities of application of integration in the studied area together with the possibility of its implementation in other areas of the studied process. Then, the implementation and technological validation of the platform integration with autonomous devices and IT system used to monitor processes in the company will be carried out. The next

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task will be to conduct a process analysis after the implementation of the integration platform, compare the results obtained with the status before the implementation and the planned outcomes, as well as to set out further possibilities of implementation and process improvements.

The conceptual assumptions presented above can be defined as the basic research stages, which are shown in Figure 5.

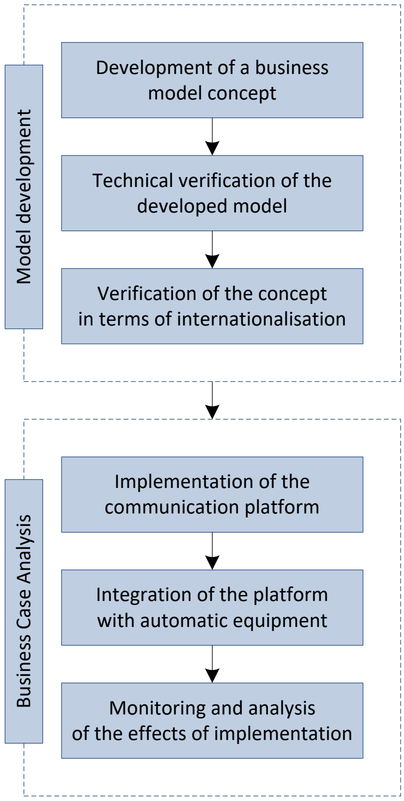

Fig. 5. Basic research stages of communication integration.
Source: own elaboration.

The main objective of the first stage is to develop a detailed business model, including an analysis of the effectiveness of implementation of communication platform integration with autonomous devices. The development of this model requires cooperation both in technological terms of the implementation and from the perspective of internationalization of the results obtained. This kind of cooperation at this stage will guarantee that the developed business model meets both technological requirements and is universal enough to be used not only in the realities of Polish business, but also the international business.

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The main objective of the second stage is to implement the communication platform in the business case as well as monitoring and evaluation of the results obtained. The main result of this stage will be integration the communication platform with automatic devices that have been previously implemented in the analyzed process. The next element of this research will the monitoring of implementation effects, both in technical terms (outcomes of system integration) and business terms (outcomes of improvement in the logistics processes implementation).

The proposed KPIs concern both the analysis of the effectiveness of integration of the platform with automatic devices, and the impact of the implementation on logistics processes in the analyzed business case:

a) Analysis of integration efficiency:

- operational efficiency (influence of information management on productivity growth),
- efficiency of monitoring process (influence of visualization of the arrangement of pallets with goods on the efficiency of organization of autonomous transport operation).

b) Analysis of the impact of the implementation on logistics processes:

- cost and operational efficiency of autonomous transport (costs generated in the process and time of implementation of processes with the use of automatic equipment),
- efficiency of warehouse space development,
- efficiency of logistics processes implementation (number of errors).

CONCLUSION AND FURTHER RESEARCH

Information technologies, wireless sensors and advanced control systems are becoming the key of the new industry. However, it should be emphasized that such high value-added products can be realized with advanced computer-controlled machines. For this reason Industry 4.0 requires equipment and has the potential to expand through. It also creates a secondary market in areas such as automation equipment, robots and special machinery in logistics. Automation of logistic and production processes is a poorly implemented area among SME sector enterprises due to the financial barrier concerning high costs of implementation of these solutions. The use of autonomous internal transport equipment and the OPIL platform will make it possible to improve production and logistics processes on a large scale, which should be considered a breakthrough given the current state of technical preparation of small and medium-sized production enterprises in Poland. An innovative product of this project will be the

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development of a simulation model based on the automation of the processes of delivery of semi-finished products to the intermediate storage area, their delivery to work cells and collection of finished products by autonomous AGVs and delivery to a fully automated packaging cell. Such simulations will be carried out based on the use of the OPIL platform together with existing production management systems. A new business model will also be developed, which concerns not only the efficiency of the solution application in the automated production process in terms of process optimization but will also include an analysis of the technical possibilities of implementation of this solution, taking into account the specificity of the SME sector and the possibilities of project financing.

This chapter presents a conceptual framework of research in the field of communication integration for automated production processes, on the basis on which scientific and development research is carried out at the Institute of Logistics and Warehousing and the Poznan School of Logistics. This concept made it possible to start research work in this area. The next stage of research will be the development of a business model and its business verification.

REFERENCES

Alçin S., 2016, Üretim için yeni bir izlek: sanayi 4.0, Journal of Life Economics, 3(2), 19-30.

Byrne P.J., Heavey C., 2006, The impact of information sharing and forecasting in capacitated industrial supply chains: a case study, International Journal of Production Economics, 103(1), 420-437, DOI: 10.1016/j.ijpe.2005.10.007.

Cyplik P., Hadas L., Adamczak M., Domanski R., Kupczyk M., Pruska Z., 2014, Measuring the level of integration in a sustainable supply chain. IFAC Proceedings Volumes, 47(3), 4465-4470, DOI: 10.3182/20140824-6-ZA-1003.01907.

Debicki T., Kolinski A., 2018, Influence of EDI approach for complexity of information flow in global supply chains. Business Logistics in Modern Management, 18, 683-694.

Domanski R., Adamczak M., Cyplik P., 2018, Physical internet (PI): a systematic literature review. LogForum 14(1), 7-19, DOI: 10.17270/J.LOG.2018.269.

Dujak D., Sajter D., 2019, Blockchain Applications in Supply Chain, in: Kawa A., Maryniak A. (eds.), SMART Supply Network, Springer International Publishing AG, 21-46, DOI: 10.1007/978-3-319-91668-2_2.

Osmólski W., Koliński A., Kilic Z., Concept of Communication Integration for Automated Production Processes Regarding Logistics 4.0 [in:] Adamczak M. et al., Digitalization of Supply Chains, Spatium, Radom 2019, p. 85-100. https://doi.org/10.17270/B.M.978-83-66017-86-3.7

Hadas L., Cyplik P., Adamczak M., Domanski R., 2015, Dimensions for developing supply chain integration scenarios. Business Logistics in Modern Management, 225-239.

Holmberg S., 2000, A systems perspective on supply chain measurements, International Journal of Physical Distribution & Logistics Management, 30(10), 847-68, DOI: 10.1108/09600030010351246.

Horzela A., Kolinski A., Domanski R., Osmolski W., 2018, Analysis of use of communication standards on the implementation of distribution processes in Fourth Party Logistics (4PL). Business Logistics in Modern Management, 18, 299-315.

http://www.akillifabrika.org reached on 03.06.2019

Kawa A., 2012, SMART logistics chain. In Asian Conference on Intelligent Information and Database Systems. Springer, Berlin-Heidelberg, 432-438, DOI: 10.1007/978-3-642-28487-8_45.

Kawa A., Zdrenka W., 2016, Conception of integrator in cross-border e-commerce. LogForum 12(1), 63-73, DOI: 10.17270/J.LOG.2016.1.6.

Leuschner R., Rogers D., Charvet F.F., 2013, A meta-analysis of supply chain integration and firm performance, Journal of Supply Chain Management, 49(2), 34-57, DOI: 10.1111/jscm.12013.

Li S., Lin B., 2006, Accessing information sharing and information quality in supply chain management, Decision Support Systems, 42(3), 1641-1656, DOI: 10.1016/j.dss.2006.02.011.

Lin F., Huang S., Lin S., 2002, Effects of information sharing on supply chain performance in electronic commerce, IEEE Transactions on Engineering Management, 49(3), 258-268, DOI: 10.1109/TEM.2002.803388.

Osmolski W., Kolinski A., Dujak D., 2018, Methodology of implementing e-freight solutions in terms of information flow efficiency, In Interdisciplinary Management Research XIV-IMR 2018, Osijek, 306-325.

Osmolski W., Voronina R., Koliński A., 2019, Verification of the possibilities of applying the principles of the Physical Internet in economic practice. LogForum 15 (1), 7-17, DOI: 10.17270/J.LOG.2019.310.

Pedersen J. T., 2012, One common framework for information and communication systems in transport and logistics: Facilitating interoperability. In Golinska P., Hajdul M. (eds),

Osmólski W., Koliński A., Kilic Z., Concept of Communication Integration for Automated Production Processes Regarding Logistics 4.0 [in:] Adamczak M. et al., Digitalization of Supply Chains, Spatium, Radom 2019, p. 85-100. https://doi.org/10.17270/B.M.978-83-66017-86-3.7

Sustainable transport, Springer Verlag, Ber-lin Heidelberg, 165-196, DOI: 10.1007/978-3-642-23550-4_8.

Prajogo D., Olhager J., 2012, Supply chain integration and performance: The effects of long-term relationships, information technology and sharing, and logistics integration, International Journal Of Production Economics, 135(1), 514-522, DOI: 10.1016/j.ijpe.2011.09.001.

Sliwczynski B., Hajdul M., Golinska P., 2012, Standards for transport data exchange in the supply chain–pilot studies. In KES International Symposium on Agent and Multi-Agent Systems: Technologies and Applications. Springer Berlin Heidelberg, 586-594, DOI: 10.1007/978-3-642-30947-2_63.

Speier C., Mollenkopf D., Stank T.P., 2008, The Role of Information Integration in Facilitating 21(st) Century Supply Chains: A Theory-Based Perspective, Transportation Journal, 47(2), 21-38.

Stajniak M., Guszczak B., 2011, Analysis of logistics processes according to BPMN methodology, in: Golinska P., Fertsch M. and Marx-Gomez J. (eds.), Information Technologies in Environmental Engineering – new trends and challenges, ESE. Springer, Berlin Heidelberg, 537-549, DOI: 10.1007/978-3-642-19536-5_42.

Trojanowska J., Varela M. L. R., Machado J. 2017, The tool supporting decision making process in area of job-shop scheduling, In: World Conference on Information Systems and Technologies. Springer, Cham, 490-498, DOI: 10.1007/978-3-319-56541-5_50

Zhao X., Xie J., Zhang W.J., 2002, The impact of information sharing and order-coordination on supply chain performance, Supply Chain Management: An International Journal, 7(1), 24-40, DOI: 10.1108/02635570110386625.

Osmólski W., Koliński A., Kilic Z., Concept of Communication Integration for Automated Production Processes Regarding Logistics 4.0 [in:] Adamczak M. et al., Digitalization of Supply Chains, Spatium, Radom 2019, p. 85-100. https://doi.org/10.17270/B.M.978-83-66017-86-3.7