LogForum

> Scientific Journal of Logistics <

2019, 15 (1), 7-17

http://doi.org/10.17270/J.LOG.2019.310

http://www.logforum.net p-ISSN 1895-2038 e-ISSN 1734-459X

ORIGINAL PAPER

VERIFICATION OF THE POSSIBILITIES OF APPLYING THE PRINCIPLES OF THE PHYSICAL INTERNET IN ECONOMIC PRACTICE

Waldemar Osmólski[1], Roksolana Voronina[2], Adam Koliński[3]

1) Institute of Logistics and Warehousing, Poznań, **Poland**, 2) Lviv Polytechnic National University, Lviv, **Ukraine**,
3) Poznań School of Logistics, Poznań, **Poland**

ABSTRACT. **Background:** Current supply chains, which in fact constitute full ecosystems of product trade, change in an invariably dynamic way, requiring permanent supervision and control of the goods flowing through them. One of the aspects enabling constant development of the entire logistics infrastructure is the use of the solutions of the Physical Internet, both in terms of modular transport units and real-time planning and information exchange, as well as properly designed communication infrastructure. The aim of the article is to present a concept of solutions for the application of the principles of the Physical Internet in logistics processes of various specificity.
Methods: The results of research carried out in the years 2012-2018 within the framework of research and development projects and literature studies reveal that the extent to which the basic principles of the Physical Internet are applied is unsatisfactory. Based on these results, factors directly influencing the possibility of applying the Physical Internet in a comprehensive manner, taking into consideration the specificity of various types of supply chains and networks, were selected and collated.
Results: The results of the Authors' research on the possibility of applying the principles of the Physical Internet include suggestions of solutions, which are the result of design work, aimed not only at popularising the concept of the Physical Internet, but above all at optimisation activities in logistics processes of various specificity and reach. Individual design solutions served as the methodology for verifying the comprehensiveness of the application of the principles of the Physical Internet in economic practice.
Conclusions: In spite of numerous and up-to-date literature references, the analysis of the application of the principles of the Physical Internet still has not been clearly defined. This hinders its application in the economic practice of enterprises. The article focuses on presenting dedicated solutions for individual pillars of the Physical Internet. Further research should be oriented at attempts to integrate the solutions for all the pillars of the Physical Internet.

Key words: Physical Internet, modular transport units, real-time planning, communication infrastructure.

INTRODUCTION

In the current rapidly changing reality, crystallisation of certain trends occurring in logistics can be observed, i.e.:

- economic globalisation – the flow of goods, capital, and information on a global scale,
- customisation – products and services tailored to the customer's needs,
- increased environmental awareness – environmental protection, waste logistics,
- development of information technologies – new management, assessment, and decision-making support tools.

All of these aspects have a lot of common characteristics, which need to be highlighted in an explicit way and their interrelationships parameterised and digitalised. This is particularly important from the point of view of logistics services, whose current coexistence and cooperation is highly inefficient and unsustainable, which poses a risk to the

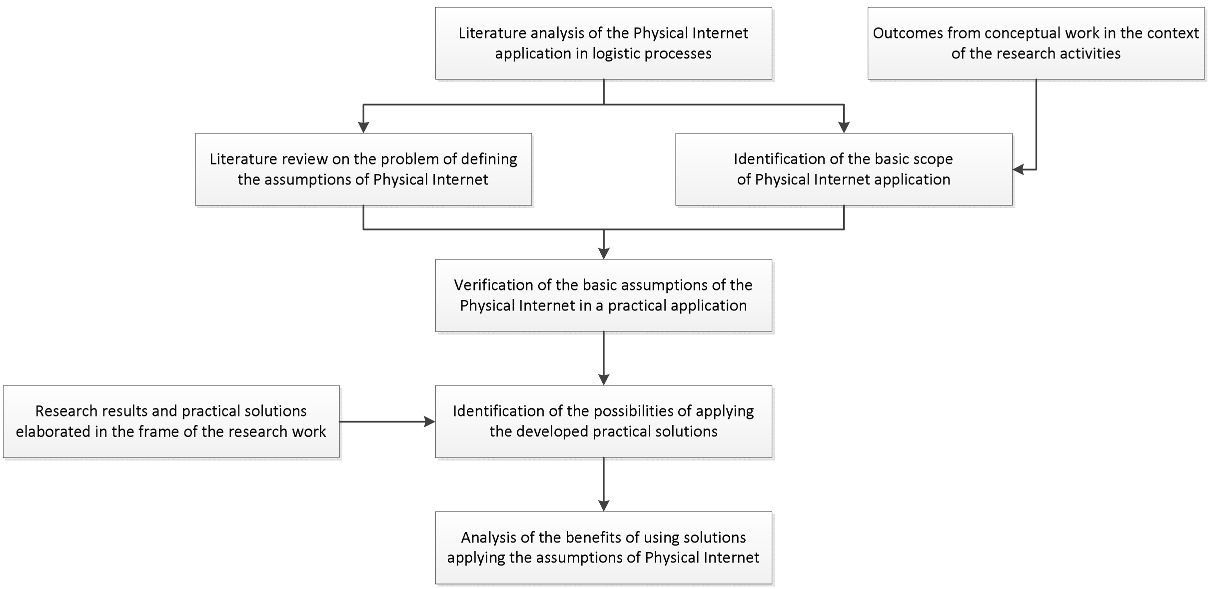
Citation: *Osmólski W., Voronina R., Koliński A., 2019. Verification of the possibilities of applying the principles of the Physical Internet in economic practice. LogForum 15 (1), 7-17,* http://doi.org/10.17270/J.LOG.2019.310
Received: 29.08.18, Accepted: 08.11.2018, on-line: 28.12.2018.

effectiveness of the processes carried out. Benoit Montreuil identified thirteen symptoms of this inefficiency and unsustainable development [Montreuil 2001]. Among them, transport constitutes a serious problem with many well-known negative side effects, such as dependence on oil, CO_2 emissions, traffic hold-ups, and even health effects. In spite of all the efforts put into improving technological, organisational, and infrastructural solutions to date, it can be said that CO_2 emissions increased by 23% within the last 10 years. This was caused, among others, by a large increase in the transport of goods on a global scale. Another aspect is the issue of the use of the available cargo space, which is estimated at no more than 60% [Pasi 2007], while so-called empty runs constitute about 25% of all the freight operations. One of the solutions aimed at reducing CO_2 emissions could be to move the volume of cargo from heavy goods vehicles to trains powered by electricity produced in the low-emission mode. However, in spite of lots of effort put into the development of multimodal transport, its share in the whole of cargo transported by way of inland transport remains low, which is yet another manifestation of the inefficiency and impermanence of logistics solutions. In general, these symptoms form a basis for defining, preparing, and implementing a logistics system which would be characterised by efficiency, timeliness of order execution, and low CO_2 emissions and which would constitute ground for combining and sharing logistics resources of numerous companies, in accordance with the principles of the Physical Internet.

RESEARCH METHODOLOGY

Taking into consideration the nature of this publication, whose primary objective is to verify the possibility of applying the principles of the Physical Internet in economic practice, the Authors decided to divide the research work into three aspects:

- a theoretical one, identifying both the definitional problem of the Physical Internet concept and the possibility of applying it in logistics processes,
- a conceptual one, identifying the basic operational scope of the application of the principles of the Physical Internet in logistics processes of various specificity,
- a practical one, presenting the possibilities of using the solutions which are the result of international research and development projects, as a proposal for the implementation of individual key scopes of application of the Physical Internet concept.



Source: own elaboration

Fig. 1. Research methodology

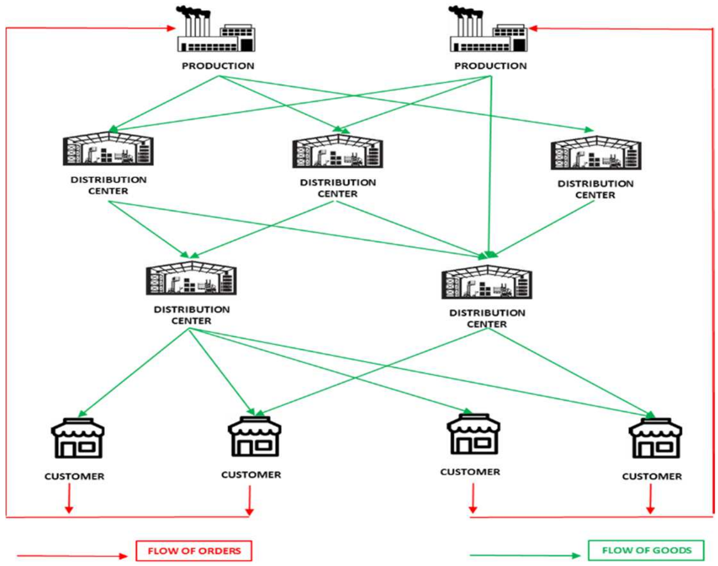
The scientific research process presented in the article results from the logic of the structural analysis of the identified research problem. The adopted research methodology aims at systematising procedures based on scientific research principles. The logic of solving the research problem was presented in Fig. 1.

Therefore, this research methodology assumes both theoretical research and a verification of its principles in business practice. According to the Authors, both these aspects – complemented by the conceptual scope aimed not only at confronting the theoretical and practical considerations, but also at organising current knowledge on the principles of the Physical Internet – cannot be separated. The specificity of the research problem in question requires comprehensive research to be carried out on every plane.

The structure of the following part of the article is in keeping with the research logic presented in the research methodology.

IDENTIFICATION OF THE BASIC SCOPES OF APPLICATION OF THE PRINCIPLES OF THE PHYSICAL INTERNET

When analysing customers' requirements concerning the execution of logistics processes in the rapidly changing supply chains, a constant search for both conceptual and technological solutions aimed at improving the efficiency of the supply chain can be observed.



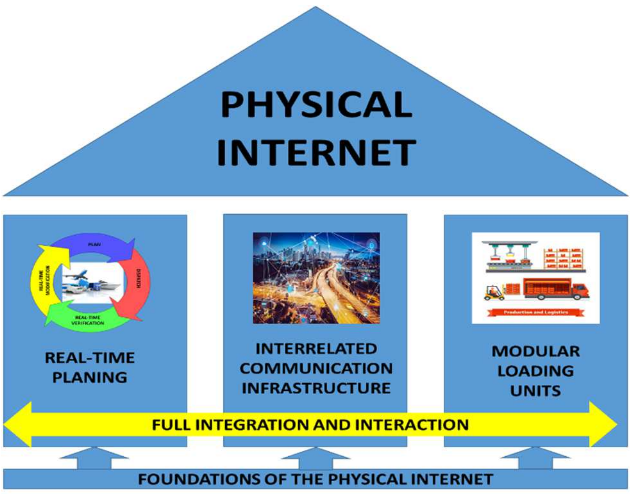
Source: own elaboration

Fig. 2. The Physical Internet concept

A response to these challenges can be the application of solutions known under the term of the Physical Internet (PI). A review of the related scientific literature reveals diverse types of research approach to the scope of application of the PI [Meller, Ellis, 2011; Ballot et al. 2012; Montreuil, et al. 2012; Trebilcock, 2012; Zhong et al. 2017; Domanski et al. 2018]. According to one of the more general definitions, PI is nothing other than the ability to provide the most efficient way of transporting goods to any given place within a certain predetermined time that will be as short as possible. Another one says that by definition, the "Physical Internet" is supposed to constitute a global logistics system which uses physical and operational, interconnected supply networks within the framework of standardised data packages and connections (interfaces), uniform protocols, and modularised container freight. The concept is reflected in a simplified manner in Fig. 2.

A Professor at Université Laval in Québec City, Canada, Benoit Montreuil, who was the first person to present the concept of the Physical Internet based on statistical analysis, came to a conclusion that a modern logistics system activates less than a half of its transport resources and for this reason, there is a need to implement a new model of this system [Montreuil, et al. 2010]. The first analytical model proved that this solution is much more efficient, decreasing transport performance by 22%, among others, while increasing load capacity by 20% and achieving better results in terms of costs, and at the same time improving service quality [Ballot et al. 2011].

The "Physical Internet" proposes a system whose users have access to an efficiently functioning, open, global logistics chain, an intermodal system (land, rail, maritime, and barge transport) using standard modules of containers used multiple times, located and identified in real time, with the possibility to coordinate the routes of cargo in a shared and widely available logistics space. In other words, all of the supply chain partners – manufacturers, transport service providers, retailers – will be able to act independently, using a common logistics network whose natural characteristic will be the ability to expand spontaneously as necessary at the given moment, should the need to change cargo size arise. This is aimed at minimising and ultimately eliminating empty runs. The implementation of the solutions of this kind requires, among others, perfect cooperation of all the links of the organisational structure based on standardised exchange of information functioning on the basis of related information infrastructure, making it possible to manage the flow of the modular units in real time. These aspects should be considered as the foundations of the Physical Internet (Fig. 3).



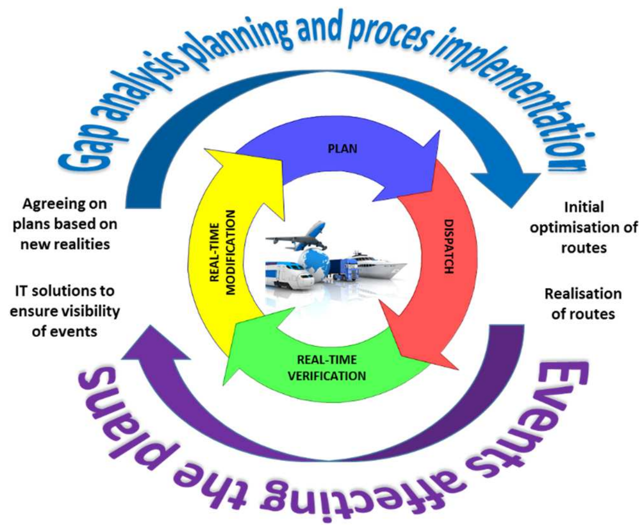
Source: own elaboration

Fig. 3. The foundations of the Physical Internet

Solutions which actually reflect the nature of the principles of the Physical Internet, thus referring to its foundations, were presented below.

REAL-TIME PLANNING

The aspects of this issue were presented in a precise manner in the solutions of the CLOUD project [http://www.project-cloud.org/], the aim of which was to create the so-called Logistic Single Window (LSW) as an ecosystem offering services and applications for all of the transport users and participants of the supply chain, making it possible to smoothly manage the flow of goods in real time (Fig. 4).



Source: own elaboration

Fig. 4. Real-time planning

The concept is based on the consolidation and full integration of three completely independent IT solutions in the following areas [Ahn, 2010]:

- management of sea shipments,
- management of the flow of goods in terminals and logistics centres,
- management of the flow of goods from the point of view of the "last mile".

It combines services offered by various branches of the transport industry and different types of logistics operations: sea, rail, water, and road ones. The CLOUD project provides a solution which streamlines cooperation in logistics through more efficient communication in the B2B, M2M, and M2B areas, while at the same time enabling development towards a more efficient, cheaper, better adjusted, and service-oriented sector, supported by full integration and synchronisation of the processes between the entities involved and the available transport resources. This allows stakeholder groups to create communities cooperating in order to combine their transport volumes and select the best transport options based on aggregated transport units. This is executed based on full integration and the principles of interoperability present in mutual system connections, offering the participants of the logistics ecosystem various types of logistics services based on the solutions of local logistics communities.

The benefits of the application of this solution include:

- joint purchasing of transport services,
- sharing intermodal connections,
- using the knowledge on intermodal transport,
- reducing empty runs of containers and road vehicles transporting goods,
- better selection of means of transport – broader use of rail transport.

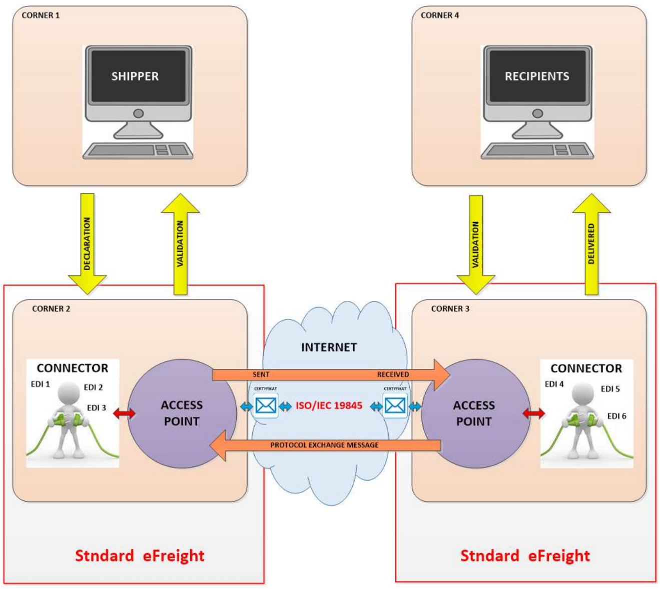
The possibility to plan logistics processes, particularly transport, in real time, directly translates into an increase in the economic and operational efficiency of the entire supply chain. It not only enables monitoring of the execution of processes in real time, but above all influences the speed of decision-making.

RELATED COMMUNICATION INFRASTRUCTURE

The related communication infrastructure concerns one of the most important aspects of logistics, namely obtaining precise information, required in order to make proper decisions, at a precisely determined time. It is becoming very important now that huge amounts of information, based on various channels of data transfer, are exchanged between companies. Important data is often either lost in the information exchange chain or presented incorrectly or delivered with considerable delays. In order to overcome these problems and create efficient information exchange chains, focus should be primarily on the following elements:

- creating common data exchange platforms based on communication standards,
- basing their architectural structures on a well-defined, clear model,
- using standard connections in order to integrate systems in the form of access points.

These issues were subjected to full, in-depth functional analysis in the eImpact project [https://www.eimpactproject.eu/]. Within the framework of the project, a platform integrating the flow of information between the IT systems of the container terminal, the railway company, the shipowner, and the intermodal operator was created. Connections between the IT systems were based on access points precisely defined on the basis of the e-Freight standard [Pedersen, 2012; Osmolski, Kolinski, Dujak, 2018], and communication between them takes place based on the principles of the eDelivery model (Fig. 5).

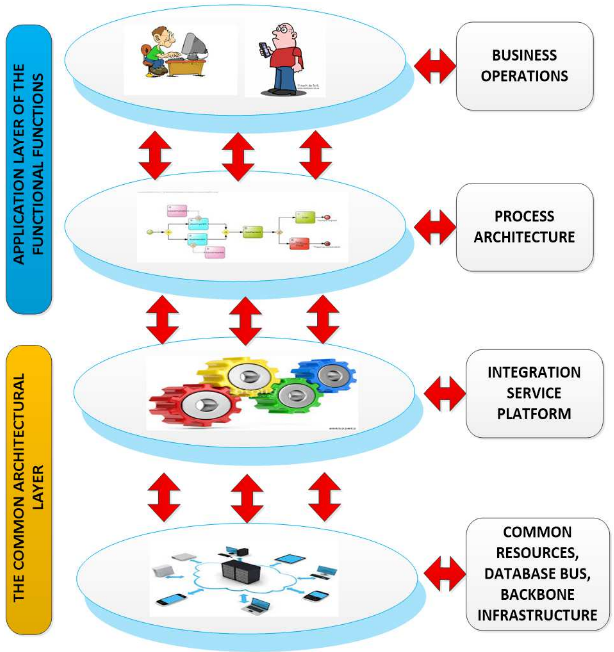


Source: own elaboration

Fig. 5. Standard e-Delivery (4-Corner model)

The access point transforms data from one standard to another for it to be unambiguously identifiable by the parties participating in the information exchange process. In this structure, each of the entities connected to the data exchange infrastructure has its profile (a role of a user of the platform). One of its elements is a format which uses the entity for electronic data exchange. In the case of using various formats of electronic documents, information transferred from the user who sends it to the platform with the use of a connector is converted by the access point to the e-Delivery standard and then passed on to the next access point which converts messages to standard data formats used by the given users.

In both of the discussed research and development projects, the component architecture solution based on the SOA model was used [Erl, 2005; Krafzig et al., 2005], as presented in Fig. 6.



Source: own elaboration

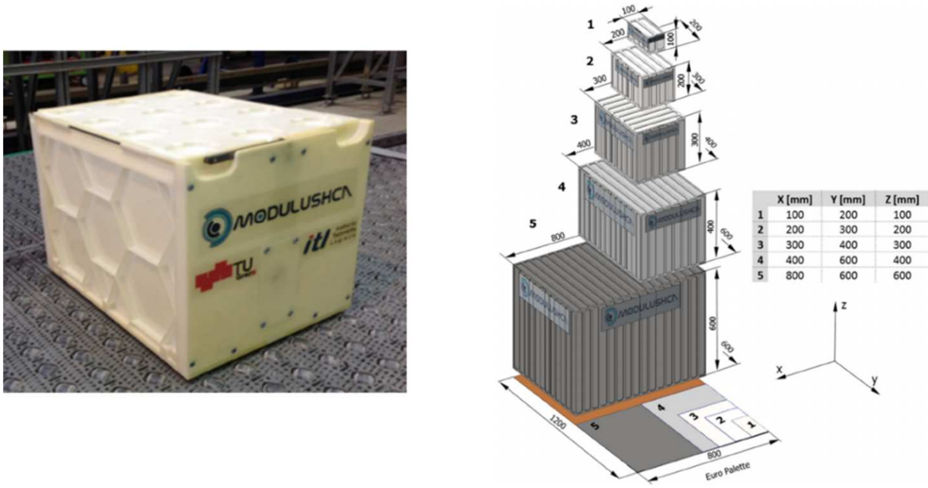
Fig. 6. Service model (SOA)

This approach constitutes architecture for business applications created as a set of independent components organised so as to deliver services operating according to specific criteria, supporting the execution of business processes. A significant principle of the SOA is the use of existing applications and systems used by business entities, bringing them down to a uniformly functioning ecosystem. From the technical point of view, it is necessary to create universal connections between the existing and new systems, among others by using integration platforms based on specific information exchange standards. This kind of approach also requires the development of the so-called information architecture that will explicitly connect the elements operating in the areas of individual computer systems, using the available standards based on unified communication units.

The benefits of this kind of solutions include:
– decreasing workloads when modifying and combining systems,
– elimination of errors in the message exchange phase,
– easy, quick, and problem-free access to data,
– speeding up processes,
– low cost of implementing changes.

MODULAR TRANSPORT UNITS

The main objective of the Modulushca project was to develop a model and a prototype of a new standard of a logistics unit, which would make it possible to implement the idea of full cooperation and efficient organisation of logistics within a distribution network in the FMCG sector. Thanks to joint activities of the world of science and business, members of the consortium developed innovative solutions based both on research work and practical solutions of companies from across Europe [Procter & Gamble, CHEP, ITENE, ILIM, EPFL, Jan De Rejik, Poste Italiane, ARMINES, Uni. Laval Canada, PTV, MEWERE, TU Graz, TU Berlin, Kirsen Global Security]. The use of the analogy of the Physical Internet with the traditional solutions of the digital Internet became one of the basic principles of the whole solution concept. In the case of the digital Internet, information is sent, in the case of the Physical Internet – it is commodities. Information on the Internet is sent in the form of precisely specified information packages. Thanks to that, it is possible to identify the package – the name, sender, and recipients, while the content itself, the information is strictly protected and available only to the devices or people with proper authorisation. Similarly, in the Physical Internet, the flow of goods takes place based on specially designed modular transport units (Fig. 7), which make it possible to fully protect the commodities sent in them, which in turn safeguards them from unauthorised interference by outsiders, thus protecting the trade secrets of the shipments' owners.



	X [mm]	Y [mm]	Z [mm]
1	100	200	100
2	200	300	200
3	300	400	300
4	400	600	400
5	800	600	600

Source: Landschützer et al. 2015

Fig. 7. A modular transport unit

This kind of solution ultimately also requires a complete exchange of the supply system based on pallet solutions for a system of modular transport units only. Such approach also generates the need to adjust vehicles, loading equipment, and warehouses, yet the simulations carried out show that in the long term, the investments made make it possible to considerably lower the logistics costs related to the transport of goods. Modular transport units were designed in a way that enables combining elements, repeated folding and unfolding, and ultimately, easy recycling. A very important function is the possibility to use the modular units as store display – by easily detaching selected walls. Modular transport units were equipped with sensors making it possible to remain in full control during the execution of the transport process – e.g. of the temperature, humidity, pressure, shock, etc. The units are able to communicate with one another across the entire distribution network based on the installed transmitters sending information in the standardised e-Freight format, which considerably facilitates full monitoring of the condition of the goods and the course of the distribution process in real time.

Taking into consideration the above benefits, the concept of the Physical Internet with the use of standard modular units (PI-boxes) seems to be an interesting alternative to the pallet transport system, which – though well-known and established – still leaves a lot to be desired from the point of view of logistics.

The benefits of this kind of solutions include:

- preventing the spreading of the competitors' business information such as the volumes transported or new packaging for special offers,
- increasing the willingness to share the given means of transport and warehouse resources in the distribution processes by competitors – lowering operating costs,
- full monitoring of the storage and transport conditions and geolocation across the entire distribution process (particularly important

in the case of fresh products or those sensitive to temperature/humidity changes),
- simplified identification of responsibility for damage to products thanks to access to data in real time (e.g. compensation from the carriers),
- the possibility to easily consolidate freight thanks to the modularity of the units – more efficient use of cargo space – lowering transport costs.

CONCLUSIONS

The concept of the Physical Internet is a relatively young issue, both in practical and scientific terms. A constant search for the possibility to increase the competitive advantage not only of single enterprises, but also entire supply chains causes the Physical Internet to gain significance, also from the point of view of the customer. Not just business partners in the supply chain, but also end customers want to have the option to access up-to-date information about their product and the history of its journey from the manufacturer to the customer. All this points to further opportunities of technological development of the solutions and tools used to date.

The use of the solutions described in the individual projects and referring to the idea of the Physical Internet generates numerous benefits in the optimisation of the integrated logistics ecosystem, primarily including:
- a universal approach to the creation of information exchange platforms in various sectors of the economy, based on international standards,
- unification of business processes,
- improvement of the functioning of enterprises, shortening handling times, and lowering the costs of business activity,
- creating an integrated ecosystem based on the transparency of the processes taking place between the entities involved,
- the possibility for the companies to immediately react to any disruptions occurring within the supply chain in order to be able to fully model them, creating real-time scenarios and processes, thus focusing on predicting events,
- combining various business applications created as a set of independent components into one ecosystem.

It should be noted that each of the research and development projects presented in this article contains a solution focused mainly on one of the pillars of the Physical Internet. According to the Authors, the Physical Internet will be successful in economic practice when it is based on existing technical and technological solutions. The direction for further research and development work should be the development of solutions that will enable the use of the already existing standards and tools used in enterprises. In the long term, we should search for the possibility of integrating the solutions currently dedicated separately for the individual pillars of the Physical Internet.

ACKNOWLEDGMENTS AND FUNDING SOURCE DECLARATION

This work has been fully supported/funded by Connecting Europe Facility TRANSPORT under Grant No. 2014-EU-TM-0686-S "e-Freight Implementation Action (e-Impact)".

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, https://ieeexplore.ieee.org/xpl/mostRecentIssue.jsp?punumber=5707966

Ballot E., Montreuil B., Fontane F., 2011, Topology of Logistic Networks and the Potential of a Physical Internet, in International Conference on Industrial Engineering and Systems Management IESM' 2011, Metz-France, 585-594, http://www.i4e2.org/iesm11/free_access_documents/proceedings_outlines.pdf

Ballot E., Gobet O., Montreuil B., 2012. Physical Internet Enabled Open Hub Network Design for Distributed Networked Operations. In: Borangiu, T., Thomas, A., Trentesaux, D. (eds.) Service Orientation in Holonic and Multi-Agent Manufacturing Control, Springer, Heidelberg, 279–292. https://link.springer.com/bookseries/7092

Erl T., 2005. ERL, Thomas. Service-oriented architecture (SOA): concepts, technology, and design, Pearson Education India. http://www.soabooks.com/

Krafzig D., Banke K., Slama D., 2005. Enterprise SOA: service-oriented architecture best practices. Prentice Hall Professional

Landschützer C., Ehrentraut F., Jodin D., 2015. Containers for the Physical Internet: requirements and engineering design related to FMCG logistics. Logistics Research, 8(1), 8. http://doi.org/10.1007/s12159-015-0126-3

Meller R.D., Ellis K.P., 2011, An investigation into the physical internet: Establishing the logistics system gain potential. In Proceedings of the International Conference on Industrial Engineering and Systems Management, 575-584, http://www.i4e2.org/iesm11/free_access_documents/proceedings_outlines.pdf

Montreuil B., 2011, Towards a Physical Internet: Meeting the Global Logistics Sustainability Grand Challenge, Logistics Research, 3(2-3) 71-87. http://doi.org/10.1007/s12159-011-0045-x

Montreuil B., Meller R.D., Ballot, E., 2010. Towards a Physical Internet: the impact on logistics facilities and material handling systems design and innovation, In: Gue, K., et al. (eds.) Progress in Material Handling Research, Material Handling Institute, 305–327, https://digitalcommons.georgiasouthern.edu/pmhr_2010/40

Montreuil B., Rougès J.-F., Cimon Y., Poulin D., 2012. The Physical Internet and Business Model Innovation, Technology Innovation Management Review, 2(6), 32–37

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.

Pasi S., 2007. Average loads, distances and empty running in road freight transport–2005, Statistics in focus, Eurostat, 117. https://ec.europa.eu/eurostat/web/products-statistics-in-focus/-/KS-SF-07-117

Pedersen J.T., 2012. One common framework for information and communication systems in transport and logistics: Facilitating interoperability. In Golinska P., Hajdul M. (eds), Sustainable transport, Springer Verlag, Berlin Heidelberg, p. 165-196, http://doi.org/10.1007/978-3-642-23550-4_8

Trebilcock B., 2012. Physical Internet Initiative: Pipedream or possibility?. Modern Materials Handling, 67(3), 22-29, https://www.logisticsmgmt.com/article/physical_internet_initiative_pipedream_or_possibility

Zhong R.Y., Xu C., Chen C., Huang G.Q., 2017, Big data analytics for physical internet-based intelligent manufacturing shop floors. International journal of production research, 55(9), 2610-2621, http://doi.org/10.1080/00207543.2015.1086037

WERYFIKACJA MOŻLIWOŚCI ZAŁOŻEŃ FIZYCZNEGO INTERNETU W PRAKTYCE GOSPODARCZEJ

STRESZCZENIE. **Wstęp:** Obecne łańcuchy dostaw, a właściwie możemy mówić o pełnych ekosystemach obrotu produktami zmieniają się w sposób niezmiernie dynamiczny, wymagający stałego nadzoru i kontroli towarów w nich przepływających. Jednym z aspektów umożliwiających stały rozwój całej infrastruktury logistycznej jest wykorzystanie rozwiązań z zakresu Fizycznego Internetu, zarówno w ujęciu modularnych jednostek transportowych, planowania i wymiany informacji w czasie rzeczywistym, czy też prawidłowo zaprojektowanej infrastruktury komunikacyjnej. Celem artykułu jest przedstawienie koncepcji rozwiązań zastosowania założeń Fizycznego Internetu w procesach logistycznych o różnej specyfice.

Metody: Wyniki badań przeprowadzonych w latach 2012-2018 w ramach projektów badawczo-rozwojowych oraz badań literaturowych, świadczą o niezadowalającym stopniu wykorzystania podstawowych założeń Fizycznego Internetu. Na ich podstawie dokonano wyboru i zestawienia czynników wpływających bezpośrednio na możliwość zastosowania Fizycznego Internetu w sposób kompleksowy, uwzględniający specyfikę różnych rodzajów łańcuchów i sieci dostaw.
Wyniki: Wynikiem prowadzonych badań nad możliwością zastosowania założeń Fizycznego Internetu są propozycję rozwiązań, będące wynikami prac projektowych, które mają na celu nie tylko rozpowszechnienie koncepcji Fizycznego Internetu, ale przede wszystkim działania optymalizacyjne w procesach logistycznych o różnej specyfice i zasięgu. Poszczególne rozwiązania projektowe posłużyły jako metodologia weryfikacji kompleksowości zastosowania założeń Fizycznego Internetu w praktyce gospodarczej.
Wnioski: Analiza zastosowania założeń Fizycznego Internetu pomimo licznych i aktualnych odniesień literaturowych, wciąż jest niejednoznacznie zdefiniowana. Utrudnia to jej wykorzystanie w praktyce gospodarczej przedsiębiorstw. W niniejszym artykule skoncentrowano się na prezentacji rozwiązań dedykowanych dla poszczególnych filarów Fizycznego Internetu. Kierunkiem dalszych badań powinna być próba integracji rozwiązań dla wszystkich filarów Fizycznego Internetu.

Słowa kluczowe: Fizyczny Internet, modułowe jednostki transportowe, planowanie w czasie rzeczywistym, infrastruktura komunikacyjna

Waldemar Osmólski
Institute of Logistics and Warehousing, Poznań, **Poland**
e-mail: Waldemar.Osmolski@ilim.poznan.pl

Roksolana Voronina
Lviv Polytechnic National University, Lviv, **Ukraine**
e-mail: roksolanavoronina@gmail.com

Adam Koliński
Poznań School of Logistics, Poznań, **Poland**
e-mail: adam.kolinski@wsl.com.pl