ISSN 2450-8055
eISSN 2543-8867

ZESZYTY NAUKOWE

Szkoły Głównej Gospodarstwa Wiejskiego
w Warszawie

EKONOMIKA i ORGANIZACJA LOGISTYKI

4 (3) 2019

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Selected aspects of the use, development and competitiveness of Polish transport

Redakcja naukowa
Elżbieta J. Szymańska

4 (3) 2019

Wydawnictwo SGGW
Warszawa 2019

strona www: eiol.wne.sggw.pl

Projekt okładki – Maria Zych-Lewandowska
Redaktor techniczny – Violetta Kaska

ISSN 2450-8055 eISSN 2543-8867 ISBN 978-83-7583-932-6

Wydawnictwo SGGW
ul. Nowoursynowska 166, 02-787 Warszawa
tel. 22 593 55 20 (-22, -25 – sprzedaż)
e-mail: wydawnictwo@sggw.pl
www.wydawnictwosggw.pl

Druk / Printed by: ZAPOL sp.j., al. Piastów 42, 71-062 Szczecin

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Ekonomika i Organizacja Logistyki
4 (3), 2019, 5–15

DOI: 10.22630/EIOL.2019.4.3.19

Krzysztof Tereszkiewicz, Dariusz Kusz, Łukasz Kulig
Ignacy Łukasiewicz Rzeszów University of Technology

Economic consequences of pig and poultry mortality during transport

Ekonomiczne konsekwencje śmiertelności świń i drobiu podczas transport

Abstract. The purpose of the paper is to estimate the financial losses incurred by the Polish meat industry as a result of pigs and slaughter poultry mortalities in pre-slaughter handling. The analysis showed that the total financial losses resulting from the pigs' mortality during transport to an abattoir in 2005–2018 could be estimated at about PLN 178 million. In the case of slaughter poultry, the losses in the period analysed amounted to PLN 321 million. The results obtained indicate the need for improvement measures to reduce animal mortalities in pre-slaughter handling. The most important should be the reduction of transport time, compliance with loading standards, introduction of a ban on transporting animals in conditions that may cause thermal stress.

Key words: transport of pigs and poultry, animals' mortality, economic losses

Synopsis. Celem opracowania jest oszacowanie strat finansowych ponoszonych przez polski przemysł mięsny w wyniku upadków świń oraz drobiu rzeźnego w obrocie przedubojowym. Z przeprowadzonej analizy wynika, że łączne straty finansowe wynikające z upadków trzody chlewnej w czasie przewozu do uboju w latach 2005–2018 szacuje się na około 178 mln złotych. W przypadku drobiu rzeźnego straty w analizowanym okresie wynosiły 321 mln złotych. Uzyskane rezultaty wskazują na konieczność podjęcia działań doskonalących w celu redukcji upadków zwierząt w obrocie przedubojowym. Za najważniejsze należy uznać skrócenie czasu transportu, przestrzeganie norm załadunku, wprowadzenie zakazu przewozu zwierząt w warunkach mogących wywołać u nich stres termiczny.

Słowa kluczowe: transport świń i drobiu, upadki zwierząt, straty ekonomiczne

Introduction

Transport is an important element of agro-logistics. According to Klepacki [2011], it is an activity involving the organization, planning, control and an implementation of the flow of agro-food goods from the place of production of agricultural raw materials

through channels related to their purchase, storage, production and distribution up to the final recipient, whose goal is to meet market requirements while maintaining food security, minimal costs and minimal capital involvement. Animal transport has a special place in the food sector. This branch of transport connects individual production links, it concerns farm and slaughter animals. It is a complex and multi-stage process. It covers logistics activities and operations whose purpose is to transfer farm animals to a new place of use or slaughter animals to the slaughter sector. There are three types of utility animals transport: transport of breeding material of production and breeding animals, transport of slaughter animals and transport of other farm animals. The most numerous group in transport are slaughter animals for meat production. First, pigs and poultry from large-scale fattening farms, followed by fattening cattle, sheep, rabbits and culled animals. It is estimated that in Europe over 350 million large slaughter animals are transported to slaughter annually, including about 240 million pigs, 25 million cattle, 70 million sheep, 8 million goats, 300 thousand horses [Baltussen et al. 2011]. Around 2 billion slaughter poultry are also produced annually in the EU. According to Trojanowski [2018], transported animals are classified as sensitive loads. These goods require maintaining specific transport conditions. Loads of this nature can be sensitive to many different factors. In particular, animals during transport show sensitivity to: duration of transport, light, noise, temperature and humidity as well as their changes, mechanical energy, biochemical processes.

Literature review

Adaptation of animals for transport requires considerable physical effort and usually causes effects in the form of fatigue or exhaustion. As a result, this leads to quantitative and qualitative losses, which ultimately shape the value and technological suitability of slaughter raw material delivered to the processing sector. According to Pisula and Florowski [2008], two elements should be considered in the considerations of losses arising in the meat and meat products production chain. The first are transport and storage losses related to the ones of live weight, carcasses, elements of their basic cutting, cooking and processing meat, as well as preparations during their circulation and storage. The second is related to the deterioration of the quality of raw materials, semi-finished and finished products during the production cycle as a result of endogenous and exogenous bio-physico-chemical processes occurring in meat. It should be emphasized that the negative effects of transport are transferred to the next links of the processing process, which causes a serious reduction of its efficiency.

Negative effects of adaptation to transport conditions can take many forms, such as: animal mortality, fatigue and exhaustion, weight loss, skin injuries and injuries, wounds, muscle bruises, bone fractures. The following are the post-slaughter ones: slaughter output reduction, reduced post-slaughter bleeding, quality defects in meat, confiscation of slaughter raw materials [Tereszkiewicz et al. 2017]. Studies carried out so far show that the mentioned negative transport consequences usually occur in parallel and affect a significant number of animals. Numerous factors of different nature have the impact on the volume and type of losses incurred in transport. The main ones include: genetic factors (species, breed, susceptibility to stress, sex), internal environment factors (health, condition), exter-

nal environmental factors (noise, vibrations, weather conditions, transport conditions and time, transport distance), factors social environment (interaction between animals, interaction between animals and staff). The vast majority of negative consequences are the result of transport stress, which is of polyetiological nature. The main stressors during transport are: vehicle movement, noise, vibrations, change of light and thermal-humidity conditions, hunger, thirst, foreign social environment, limitation of living space, intensive driving out [Tereszkiewicz et al. 2017]. In transport, there may also be social stress defined as a state of disturbance of the body's internal balance caused by the behaviour of other individuals of the same species. Social stress is caused by territorial conflict or rivalry within the hierarchy [Kołacz and Dobrzański 2006]. A significant threat to transported animals is thermal stress, which causes hyperthermia. Malignant hyperthermia is particularly dangerous, manifested by an increase in the body's internal temperature to life-threatening levels. Pigs and poultry are particularly vulnerable to hyperthermia.

The most drastic manifestation of losses at the same time as a measurable indicator of an extreme breach of welfare principles during transport is the phenomenon of animal mortality. In spite of various actions taken, mortality in transport has not been eliminated. However, in recent years a significant reduction in the scale of their occurrence has been achieved. The analysis carried out by Baltussen et al. [2011] shows that in the EU in 2005–2010 there was a decrease of about 15% in the number of animals reported as "dead on arrival" (DOA indicator). A significant decrease in the mortality rate was recorded in long and very long transports. The phenomenon of mortality during transport occurs in all livestock species, however, with varying intensity (Fig. 1).

The interspecies differences in mortality in transport are primarily determined by the resistance of individual species to transport stress, anatomical and physiological differences, including the structure and efficiency of the respiratory and circulatory systems, and dehydration resistance. Pigs and poultry are the species that are particularly vulnerable to mortality during transport.

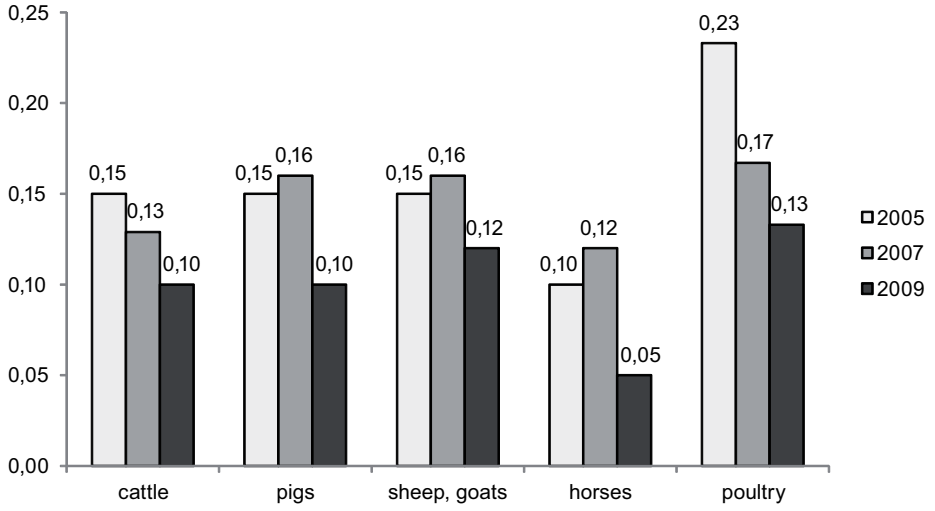

Figure 1. Mortality of animals in transport in the EU countries in 2005, 2007 and 2009
Rysunek 1. Śmiertelność zwierząt w transporcie w krajach UE w latach 2005, 2007 i 2009

Source: own study based on [Baltussen et al. 2011].

The mortality rate of pigs in transport varies widely and according to various sources [Voslarova et al. 2007, Ritter et al. 2009, Baltussen et al. 2011, Barton-Gade et al. 2012, Schwartzkopf-Genswein et al. 2012, Kephart et al. 2014, Vecerek et al. 2015] is estimated from 0.03 to 0.50%. In extreme individual cases, it can be higher and even exceed 1%. Pig mortality is characterized by a significant continental, national and regional diversity. In the EU countries, the mortality rate varies (Fig. 2) and ranges from 0.46% (Germany) to 0.03% (Denmark). However, there is no detailed statistical data showing the current scale of pig mortality in EU countries.

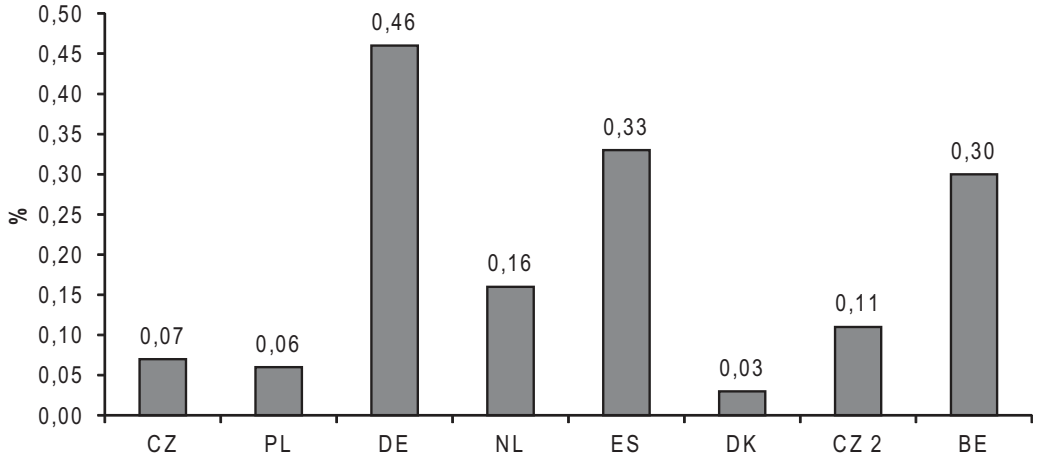

Figure 2. Mortality of pigs in pre-slaughter handling in selected EU countries in 2004–2009
Rysunek 2. Śmiertelność świń w postępowaniu przed ubojem w wybranych krajach UE w latach 2004–2009

Source: own study based on [Baltussen et al. 2011, Dos Reis et al. 2015, Vecerek et al. 2015].

Mortality is observed in all groups of pigs, with particular intensification in piglets, heavy pigs weighing over 120 kg and sows defective from breeding use [Voslarova et al. 2017]. The problem of pigs' mortality during their transportation on the largest scale occurs in the group of pigs. Particularly thorough and long-term studies devoted to the issue of slaughter pig mortality and its conditions are available in American literature. A compilation of these results by Ritter et al. [2009] shows that in the period from 1933 to 2006 the mortality rate in individual years was variable and throughout the whole period fluctuated within very wide limits. However, until 2002 it did not exceed 0.22%. As the main causes of such high mortality of pigs during this period, genetic changes in the population are indicated, which resulted in an increase in the population of the frequency of stress sensitivity gene, meat index, increase of slaughter weight of pigs for fattening [Ellis et al. 2003]. The negative impact of increasing production concentration and as a result of which it was necessary to transport pigs over longer distances was also indicated. Mortality of pigs can occur both during loading, transport and unloading of animals. According to Kołacz [2010], it most often occurs during transport at this stage about 70% of all deaths recorded in pre-slaughter handling are recorded. The remaining 30% occurs

during unloading or during pre-mortem storage. Previous studies [Murray and Johnson 1998, Guárdia et al. 2009] clearly indicate that the frequency of pig mortality in transport is associated with the occurrence of the mutated *RYR1* stress sensitivity gene, which is affected by about 10% of the pig population. This load is the cause of over 50% of pig mortality in transport as well as after its completion. Elimination of the stress sensitivity gene from the pig population results in a significant reduction in mortality during transport to slaughter. Particularly positive effects of such activities were noted in Denmark. According to Barton-Gade et al. [2012], successive actions aimed at eliminating from the population of pigs used in this country specimens loaded with the halothane sensitivity gene allowed reducing pig mortality in transport from 0.12% in 1980 to 0.016% in 2002. Currently, it is the lowest rate among European countries. Denmark is recognised as a world leader in the improvement of methods of handling animals before slaughter. In recent years, as a result of other actions, mainly of a legal and organisational nature, the problem of pig mortality has also been significantly reduced in other EU countries [Baltussen et al. 2011].

Source data indicate that particularly high rates of mortality in pre-slaughter handling concern poultry, especially chicken and turkey broilers. The death of the poultry most often occurs as a result of acute stress reaction, suffocation, trampling, cardiac arrest. Numerous studies [Bremer and Johnston 1996, Petracci et al. 2006, Voslarova et al. 2007] show that the average death rate of poultry during transport in the EU is 0.35% and in selected EU countries it ranges from 0.16% (the United Kingdom) to 0.47% (The Czech Republic) – Figure 3. A higher mortality rate is found among turkeys.

Some publications state that poultry mortality may be more severe. According to Nijdam et al. [2004], the DOA rate may be 0.57%, and exceptionally it may exceed

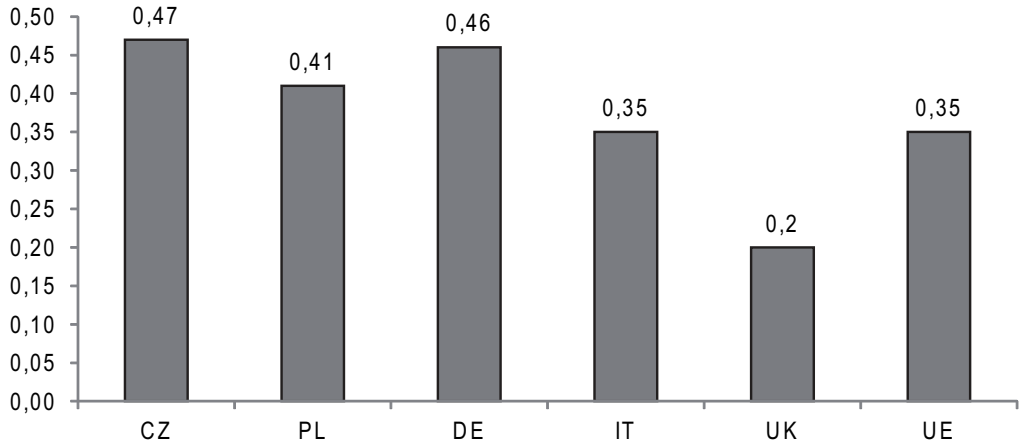

Figure 3. Mortality of slaughter poultry in pre-slaughter handling in selected EU countries in 2004–2009

Rysunek 3. Śmiertelność drobiu rzeźnego w postępowaniu przed ubojem w wybranych krajach UE w latach 2004–2009

Source: own study based on [Petracci et al. 2006, Voslarova 2007].

even 1%. According to Warriss [2006], the main factor contributing to the mortality of poultry during transport is the microclimate, and especially the high temperature. As the author shows, the temperature up to 17°C is considered to be the level of thermal safety during poultry transport. On the other hand, a higher temperature causes a significant increase in the incidence rate. Transporting poultry at temperatures above 23°C is particularly risky due to mortality. The relationship between the level of DOA indicator and transport temperature in studies on very large animal material was also confirmed by Petracci et al. [2006]. These studies show that the most poultry mortality during the summer months, with the highest mortality rates for broiler chickens observed in July and August, while the most turkeys mortality during transport carried out in June. Different results were obtained by Voslarova et al. [2007], who showed a much higher rate of mortality in the winter months when poultry was transported at a temperature not exceeding 10°C.

The global meat industry bears measurable financial losses as a result of the mortality of slaughter animals in pre-slaughter handling. According to Fitzgerald et al. [2008], animal mortality in transport is particularly severe as it affect animals when they gained market value. The economic effects of animal mortality identified in numerous studies at the stage of their transport for slaughter are characterized by considerable regional and national diversity. Brazilian studies have shown that sector losses due to mortality of pigs in the supply chain are estimated at around USD 160 thousand. Kephart et al. [2014] showed that losses due to the mortality of fattening pigs in the US in 2011 amounted to more than USD 29 million. Assuming an average mortality rate of fattening pigs in EU countries of 0.07% with an annual production of around 250 million pigs, the meat sector losses can be estimated at around EUR 26 million. Similarly, transport losses in the poultry sector, with a mortality rate of 0.35% in the EU, amount to around EUR 98 million.

Material and methods

The study attempts to estimate the financial losses incurred by the Polish meat industry as a result of mortality in poultry and slaughter pigs in pre-slaughter handling. To estimate the economic losses associated with the mortality of pigs and poultry in transport, data on the purchase of live slaughter animals in live weight published by the Statistics Poland (Główny Urząd Statystyczny – GUS) were used. It was assumed that the losses in the transport of pigs resulting from their mortality amounted to 0.137% (the average level of losses from published data for selected EU countries was taken into account – Figs. 1 and 2), while in the case of broiler chickens, the mortality rate was 0.35% [Petracci et al. 2006, Voslarova 2007]. For turkey broilers the mortality rate of 0.40% was used in the study [Petracci et al. 2006, Voslarova 2007]. To calculate the value of incurred losses, the average current purchase prices of slaughter animals published by the Statistics Poland were adopted.

Results

When analysing the purchase of pigs for the years 2005–2018 (Table 1), the value of losses for this period calculated in current prices was PLN 178 million. Assuming the improvement of pig transport conditions in Poland and the reduction of mortality during transport to the level of 0.10% (Fig. 1) and maintaining this level of the indicator, the value of losses for the analysed period would amount to PLN 129,942.8 thousand, which would give a benefit of PLN 48,778.8 on a national scale, i.e. 27% less loss.

Table 1. Economic losses resulting from mortality in transport of fattening pigs in Poland in 2005–2018

Tabela 1. Straty ekonomiczne wynikające ze śmiertelności w transporcie tuczników w Polsce w latach 2005–2018

Year	Purchase of slaughter animals for live weight – pigs (t)	Losses resulting from fattening pigs mortality (t)	Value of losses resulting from the mortality of fattening pigs (current prices) (PLN thous.)	Value of losses resulting from the mortality of broiler chickens with a mortality rate of 0.1% (current prices) (PLN thous.)
2005	1 944 447	2 663.9	10 176.1	7 427.8
2006	2 178 621	2 984.7	10 625.6	7 755.9
2007	2 228 942	3 053.7	10 565.6	7 712.1
2008	1 940 221	2 658.1	10 659.0	7 780.3
2009	1 767 687	2 421.7	11 043.1	8 060.7
2010	1 988 329	2 724.0	10 596.4	7 734.6
2011	2 085 918	2 857.7	12 916.8	9 428.3
2012	1 853 569	2 539.4	13 712.7	10 009.3
2013	2 017 210	2 763.6	14 895.7	10 872.8
2014	2 203 796	3 019.2	14 552.5	10 622.3
2015	2 250 382	3 083.0	13 257.0	9 676.6
2016	2 314 969	3 171.5	14 842.7	10 834.1
2017	2 255 405	3 089.9	15 604.0	11 389.8
2018	2 374 609	3 253.2	14 574.4	10 638.2
	Total			
	29 404 105	40 283.6	178 021.6	129 942.8

Source: own calculations based on data from the Statistics Poland.

A similar analysis was carried out for slaughter poultry – broiler chickens and turkeys. In the case of the broiler chickens, the adopted mortality rate during transport (0.41%) for the period analysed was over PLN 321 million (Table 2), while for the turkeys it was over PLN 36 million (Table 3). When adopting the assumption of improving the conditions for the transport of slaughter poultry and even a slight reduction in the losses rate would contribute to a significant reduction in the costs

Table 2. Economic losses resulting from mortality in transport of chicken poultry in Poland in 2005–2018

Tabela 2. Straty ekonomiczne wynikające ze śmiertelności w transporcie drobiu drobiowego w Polsce w latach 2005–2018

Year	Purchase of slaughter animals for live weight – poultry in total (t)	Purchase of slaughter animals in a live weight – chicken poultry in total* (t)	Losses resulting from chicken poultry mortality (t)	Losses resulting from mortality (current prices) (PLN thous.)	Value of losses resulting from the mortality of broiler chickens with a mortality rate of 0.35% (current prices) (PLN thous.)
2005	1 309 310	1 188 031	4 158	11 434.8	9 801.3
2006	1 268 794	1 152 730	4 035	10 086.4	8 645.5
2007	1 305 362	1 202 551	4 209	13 342.3	11 436.3
2008	1 486 394	1 366 099	4 781	15 156.9	12 991.6
2009	1 632 275	1 475 108	5 163	17 450.5	14 957.6
2010	1 814 344	1 667 862	5 838	18 680.1	16 011.5
2011	1 919 268	1 764 824	6 177	22 916.2	19 642.5
2012	2 099 515	1 882 792	6 590	25 436.5	21 802.7
2013	2 225 317	2 017 334	7 061	27 324.8	23 421.2
2014	2 504 521	2 276 591	7 968	29 481.8	25 270.2
2015	2 680 806	2 442 462	8 549	29 920.2	25 645.9
2016	2 949 389	2 690 836	9 418	31 455.9	26 962.2
2017	3 144 219	2 892 131	10 122	34 112.7	29 2394
2018	3 153 894	2 832 122	9 912	34 396.1	29 482.4
	Total				
	29 493 408	26 851 473	93 980	321 195.2	275 310.2

*The level of purchase of slaughter animals in a live weight for chicken poultry was estimated on the basis of the share of chicken poultry in the total poultry.

Source: own calculations based on data from the Statistics Poland.

incurred by poultry meat processing plants. Assumptions for reducing the poultry mortality rate by 0.05 p.p. would reduce losses for the broiler chickens by PLN 45,885 thousand (i.e. 14.3% lower level of losses), and in the case of the turkey broilers by PLN 4,517.5 thousand (i.e. 12.5% lower loss level).

Table 3. Economic losses resulting from mortality in transport of turkeys in Poland in 2005–2018
Tabela 3. Straty ekonomiczne wynikające ze śmiertelności w transporcie indyków w Polsce w latach 2005–2018

Year	Purchase of slaughter animals for live weight – turkeys* (t)	Losses resulting from turkeys mortality (t)	Value of losses resulting from mortality (current prices) (PLN thous.)	Value of losses resulting from the mortality of broiler chickens with a mortality rate of 0.35% (current prices) (PLN thous.)
2005	52 428	210	813.7	712.0
2006	70 776	283	1 030.5	901.7
2007	64 974	260	1 211.1	1 059.7
2008	76 151	305	1 288.5	1 127.4
2009	109 371	437	2 121.8	1 856.6
2010	93 811	375	1 726.1	1 510.4
2011	103 078	412	2 341.9	2 049.2
2012	153 263	613	3 322.7	2 907.4
2013	140 641	563	3 296.6	2 884.5
2014	155 437	622	3 655.9	3 198.9
2015	157 615	630	3 7512	3 282.3
2016	168 753	675	3 5236	3 083.1
2017	177 513	710	3 656.8	3 199.7
2018	225 394	902	4 399.7	3 849.7
	Total			
	1 749 204	6 997	36 140.1	31 622.6

*The level of purchase of slaughter animals in a live weight for chicken poultry was estimated on the basis of the share of chicken poultry in the total poultry.

Source: own calculations based on data from the Statistics Poland.

Conclusions

The analysis shows that the total financial losses resulting from the pigs' mortality during transport to an abattoir in 2005–2018 could be estimated at about PLN 178 million. In the case of slaughter poultry, the losses in the period analysed amounted to PLN 321 million. The losses shown in the results in the research are particularly bitter because they relate to animals that reached required slaughter parameters and have become an element of trade. Generating losses at this stage may evoke difficulties in determining

the subject responsible for them. The results obtained indicate the need for improvement measures to reduce the animals' mortality in pre-slaughter handling. The most important ones should include the reduction of transport time, compliance with loading standards, an introduction of a ban on transporting animals in conditions that may cause thermal stress.

References

Baltussen W., Gebrensbet G., Roest K. de, 2011: Study on the impact of Regulation (EC) No 1/2005 on the protection of animals during transport.

Barton-Gade P., Christensen L., Baltzer M., Petersen J., 2012: Causes of preslaughter mortality in Danish slaughter pigs with special emphasis on transport 2007, Animal Welfare 16 (4), 459–465.

Bremner A., Johnston M., 1996: Poultry meat hygiene and inspection, W.B. Sounders, London.

Dos Reis J.G.M., Machado S.T., Santos R.C., Nääs I.A., Oliveira R.V., 2015: Financial losses in pork supply chain: a study of the pre-slaughter handling impacts, Engenharia Agrícola 35 (1), 163–170.

Ellis M., McKeith F., Hamilton D., Bertol T., Ritter M., 2003: Impact of animal handling and transportation conditions on losses of slaughter weight swine during transport, [in:] Proceedings American Association of Swine Veterinarians, Toronto, Ontario, Canada, 199–202.

Fitzgerald R.F., Stalder K.J., Matthews J.O., Schultz Kaster C.M., Johnson A.K., 2008: Factors associated with fatigue, injured, and dead pig frequency during transport and lairage at a commercial abattoir, Journal of Animal Science 87 (3), 1156–1166.

Guàrdia M.D., Estany J., Balasch S., Oliver M.A., Gispert M., Diestre A., 2009: Risk assessment of skin damage due to pre-slaughter conditions and RYR1 gene in pigs, Meat Science 81, 745–751.

Kephart R.K., Johnson A.K., Stalder K.J., Huiatt T.W., Sapkota A., McGlone J.J., 2014: Costs of bedding, trailer washout and transport losses in market weight pigs, Animal Industry Report: AS 660, ASL R2908, https://doi.org/10.31274/ans_air-180814-1192

Klepacki B., 2011: Agrologistyka – nowe wyzwanie dla nauki i praktyki, Logistyka 3, 12–13.

Kołacz R., 2010: Minimalne wymogi w zakresie transport świń, Trzoda Chlewna 10, 75–78.

Kołacz R., Dobrzański Z., 2006: Higiena i dobrostan zwierząt gospodarskich, Wydawnictwo Akademii Rolniczej we Wrocławiu, Wrocław.

Murray A.C., Johnson C.P., 1998: Impact of the halothane gene on muscle quality and pre-slaughter deaths in Western Canadian pigs, Canadian Journal of Animal Science, 78 (4), 543–548.

Nijdam E., Arens P., Lambooij E., Decuypere E., Stegeman J.A., 2004: Factors influencing bruises and mortality of broilers during catching, transport, and lairage, Poultry Science 83 (9), 1610–1615.

Petracci M., Bianchi M., Cavani C., Gaspari P., Lavazza A., 2006: Preslaughter mortality in broiler chickens, turkeys, and spent hens under commercial slaughtering, Poultry Science 85 (9), 1660–1664.

Pisula A., Florowski T., 2008: Zmiany ilościowe i jakościowe mięsa w trakcie jego pozyskiwania i przetwarzania, część 1, Gospodarka Mięsna 60 (2), 8–14.

Ritter M.J. et al., 2009: Transport losses in market weight pigs: I. A review of definitions, incidence, and economic impact, Review, Professional Animal Scientist 25 (4), 404–414.

Schwartzkopf-Genswein K.S., Faucitano L., Dadgar S., Shand P., González L.A., Crowe T.G., 2012: Road transport of cattle, swine and poultry in North America and its impact on animal welfare, carcass and meat quality: A review, Meat Science 92 (3), 227–243.

Tereszkiewicz K., Molenda P., Kusz D., 2017: Ocena warunków przewozu i dobrostanu tuczników w transporcie lokalnym, Roczniki Naukowe Ekonomiki Rolnictwa i Rozwoju Obszarów Wiejskich 104 (4), 139–150.

Trojanowski P., 2018: Identyfikacja ładunków wrażliwych oraz uwarunkowania ich przewozu. Studium na przykładzie obsługi eksportu produktów mięsnych, Autobusy 6, 973–976.

Vecerek V., Voslarova E., Malena M., Bedanova I., 2015: Mortality in pigs transported for slaughter, Journal of Agricultural Engineering and Biotechnology 3 (1), 27–31.

Voslarova E., Janackova B., Vitula F., Kozak A., Vecerek V., 2007: Effects of transport distance and the season of the year on death rates among hens and roosters in transport to poultry processing plants in the Czech Republic in the period from 1997 to 2004, Veterinarni Medicina 52 (6), 262–266.

Warriss D.P., 2006: Handling broiler chickens ante-mortem for optimal carcass and meat quality, Animal Science 1, 94–98.

Correspondence address:

assoc. prof. Krzysztof Tereszkiewicz, DSc, PhD, Eng
(https://orcid.org/0000-0001-5017-7646)
Ignacy Łukasiewicz Rzeszów of University of Technology
Faculty of Management
Powstańców Warszawy Ave. 2, 35-959 Rzeszów, Poland
e-mail: kteresz@prz.edu.pl

assoc. prof. Dariusz Kusz, DSc, PhD, Eng
(https://orcid.org/0000-0002-5643-5404)
Ignacy Łukasiewicz Rzeszów of University of Technology
Faculty of Management
Powstańców Warszawy Ave. 2, 35-959 Rzeszów, Poland
e-mail: dkusz@prz.edu.pl

Łukasz Kulig, PhD, Eng
(https://orcid.org/0000-0001-8568-3709)
Ignacy Łukasiewicz Rzeszów of University of Technology
Faculty of Management
Powstańców Warszawy Ave. 2, 35-959 Rzeszów, Poland
e-mail: lk@prz.edu.pl

Ekonomika i Organizacja Logistyki
4 (3), 2019, 17–27

DOI: 10.22630/EIOL.2019.4.3.20

Konrad Michalski[1]***, Mykolas Navickas***[2]***, Marcin Rabe***[3]
[1] Warsaw University of Life Sciences – SGGW
[2] Klaipëda University
[3] University of Szczecin

Transport in the biomass supply chain for a power plant

Transport w łańcuchu dostaw biomasy dla elektrociepłowni

Abstract. The article discusses the planning of biomass supply chain for combined heat and power plants in the context of energy security. In order to guarantee the continuity of energy and heat supplies, the biomass CHP plant must have adequate raw material reserves. Properly selected supply processes can significantly reduce the operating costs of a CHP plant. In a crisis situation, the logistics chain boils down to supply logistics. This ensures combined heat and power plant's security of energy supply continuity through proper formulation of biomass supply procedures, as well as supporting its efficiency.

Key words: transportation, supply chain, biomass

Synopsis. W artykule omówiono planowanie łańcucha dostaw biomasy do elektrociepłowni w kontekście bezpieczeństwa energetycznego. Elektrociepłownia konsumująca biomasę, aby zagwarantować ciągłość dostaw energii i ciepła, musi posiadać zapasy surowca. Odpowiednio dobrane procesy zaopatrzenia mogą zasadniczo ograniczyć koszty funkcjonowania elektrociepłowni. W sytuacji kryzysowej łańcuch logistyczny sprowadza się do realizacji procesów zaopatrzenia. Zapewnia to elektrociepłowni bezpieczeństwo ciągłości dostaw energii poprzez właściwe sformułowanie procedur dostaw biomasy, a także wspiera osiągnięcie efektywności dostaw.

Słowa kluczowe: transport, łańcuch dostaw, biomasa

Introduction

From the national security's point of view, the production and distribution of electricity is key. Transport of biomass as an alternative energy source belongs to critical infrastructure within the framework of logistics macrosystem.

The purpose of the article is to present the role of alternative energy source, which is the biomass in the supply chain for the CHP, with particular consideration for transport processes, the principles of operation of the energy sector utilizing biomass, its role in the

economy and functions. Particular attention was paid to the construction of the biomass supply chain to the combined heat and power plants. The data was illustrated using tables. The models presented in the article were made in a dedicated program using Business Process Model and Notation (BPMN). The research method used in the publication is the existing data analysis and the literary criticism. Literature, netography and statistical data show that the biomass can constitute an important energy source for industrial use. However, one must be aware of both its advantages and shortcomings.

Definition of biomass and supply chain

According to Directive (EU) 2018/2001 on the promotion of the use of energy from renewable sources, biomass means: "the biodegradable fraction of products, waste or residues of biological origin from agriculture, including plant and animal substances, from forestry and related industries, including fisheries and aquaculture, as well as the biodegradable fraction of waste, including industrial and municipal biological waste".

In connection with the entry into force of the Polish Act of 7 June 2018 amending the Act on renewable energy sources, the term biomass should be understood as "the biodegradable part of products, waste or residues of biological origin from agriculture, including plant and animal substances, forestry and related industries, including fisheries and aquaculture, processed biomass, in particular in the form of briquettes, pellets, torrefat and biochar, as well as the biodegradable part of industrial or municipal waste of plant or animal origin, including waste from waste treatment installations and waste from water and wastewater treatment, in particular sewage sludge, in accordance with waste regulations regarding the qualification of part of the energy recovered from the thermal transformation of waste".

Solarewicz [2019], on the other hand, defines biomass as "solid or liquid substances of plant and animal origin, obtained from products, waste and residues from agricultural and forestry production, as well as from parts of other waste that are biodegradable".

The supply chain is seen as a network of organizations, process or structure. It is because the supply chain is created by:

- a single enterprise – then we are talking about an internal supply chain;
- two co-operating with each other enterprises, where one is a supplier and the other is a recipient;
- network of cooperating with each other enterprises in the function "supplier–recipient".

According to Bechtel and Jayanth [1997], the supply chain is the network of producers and service providers who cooperate with each other in order to process and move goods from the raw material phase to the end-user level. All those entities are connected by flows of physical goods, information and money. On the other hand, Christopher [2001] defines the supply chain as a sequence of events on the movement of goods increasing their value. Yet another definition of the supply chain is presented by Johansson [1994], who states that it is a physical network that starts with the supplier and ends with the final customer. This network includes aspects connected to the product development, purchasing, manufacturing, physical distribution and after-sale services, as well as deliveries made by external bidders.

Essence and instruments of supply chain management

Contemporary supply chain management should focus on satisfying the requirements of the end-user; in case of energy sector, this will be the energy consumer. Combined heat and power plants should understand these needs. The process of supply chain management is related to synchronizing the physical, information and financial streams of demand and supply flowing between its participants in order to achieve their competitive advantage and create added value [Witkowski 2010]. Supply chain management processes include:

- planning, forecasting, replenishing inventory and monitoring and controlling related processes in the supply chain;
- product and network configuration;
- designing products using the knowledge potential of suppliers;
- forming production network aimed at selecting and defining manufacture tasks;
- optimization of processes in the supply chain;
- analysis and tracking of indicators and measures of business parameters' effectiveness.

The main objectives of the CHP plant in operation and functioning of the supply chain are [Witkowski 2003]:

- minimizing of total costs of product and information flow whilst maintaining required by the client level of quality of service delivery;
- ensuring shortest possible period of order implementation and the highest possible reliability, frequency and flexibility of deliveries at the assumed level of flow costs;
- optimization of the inventory level on the scale of supply chain along with flexible adjustment to the preferences within the scope of service delivery of individual market segments.

In order to achieve the best possible level of supply chain management in the CHP plant, numerous management tools and instruments can be used, such as [Szymonik 2011]:

- LM (Lean Management) – slimming management;
- AM (Agile Management) – flexible (agile) management;
- QR (Quick Response) – fast reaction;
- ECR (Efficient Consumer Response) – efficient service in the chains of customer delivery;
- TQM (Total Quality Management) – comprehensive quality management;
- JiT (Just in Time) – punctual deliveries;
- VMI (Vendor Managed Inventory) – inventory management by the supplier;
- CS (Consignment Stock) – consignment stock;
- CPFR (Collaborated Planning, Forecasting & Replenishment) – common planning, forecasting and replenishment of inventories.

Supply chain of biomass CHP plants

Supplying biomass power plants is a big challenge because energy companies are subject to the same economic laws as manufacturing or commercial companies. An important factor affecting the safety of biomass CHP plants is the need to ensure continuity of heat and electricity supply for consumer demand.

At present, one of the problems of biomass burning units in Poland is the availability of the biomass raw material on the domestic market. In Germany, biomass imported from Poland may be burned in power plants and combined heat and power plants. According to the data of the Federal Statistical Office of Germany (Statistisches Bundesamt), in 2019 the import of Polish wood to Germany reached the level of 1.17 million t, while just a few years ago it was on average about 150 thousand t per year [Centrum Informacji o Rynku Energii 2019].

Currently, for energy purposes in the enterprise you can use plants from energy crops, wood and wood waste, agricultural products and waste as well as waste wood from the wood industry (lumber, chips, bark, wood briquette, wood chips, sawdust, pellets) [Janowicz 2006].

In order to consider biomass as a fuel for energy, we must also recognize the barriers that limit its use. The barriers include:

- relatively low heat of combustion and calorific value;
- large variation in moisture content, depending on the type of biomass and its period seasoning (up to 50%);
- high volatile matter content – problems in controlling combustion, exactly changing ignition and combustion conditions;
- difficulties in dispensing fuel resulting from the form of biomass;
- large storage area and transport difficulties due to low density bulk;
- difficulties maintaining fuel quality at a constant level;
- high content of alkaline compounds, such as potassium, phosphorus, calcium.

Most of these problems can be avoided by increasing the biomass density [Tokarska and Kościelska-Chmurko 2004].

The basis of the employed logistics solutions in the CHP plant should be systematic approach. The operation of the CHP plant using biomass remains in permanent and strong relationship with the activities of supply deliverers, distribution subcontractors, as well as recipients. The requirements of the market have a decisive impact on the process of supply and quality of importer raw materials, as well as storing processes, technology and process of electricity production, and implementation of its distribution [Krajewska and Łukasik 2012].

In order to ensure the energy security of its recipients, the heat and power plant must plan the activities relating to production and delivery of energy and heat, in practice covering a complete logistics chain, ensuring the continuity of energy supply to the recipients through planning the appropriate biomass reserves. Integration of actions in the supply chain involved in the customer service on the target market and organizational cells within enterprise requires coupling in planning of actions that have their beginning and finale on the market. This results from the necessity of adjusting the deliverance of electricity to the needs reported by the market. Fulfilling the requirements of energy security is even more difficult due to the fact that the suppliers at the same time strive to ensure the flow of energy supply and the low levels of operating costs.

Fast and uninterrupted service to recipients is not possible without information exchange between the consumers and distributor, which allows quick implementation of orders influencing planning of the production and supply, as well as informing about changes in demand.

The basic problem that needs to be resolved on each stage of electricity and heat production is obtaining the precise forecast of energy demand in the energy system and appropriate planning of fuel supplies to the CHP plant, without creating unnecessary reserves that generate costs [Szymla 2013]. Unfortunately, the problem for CHP plant may be the availability of biomass on the market, as well as the quality of the raw material itself. The tables below represent the quality requirements that should characterize various types of biomass delivered to the CHP plant.

The temperature of the supplied forest biomass in the form of chips cannot be higher than 40°C. The fraction content in the delivered biomass should be below 3.15 mm (crumble). The proportion of contamination in the form of wet sand or wet soil cannot exceed 1.2% of total mass taken to perform the test of a sample. Table 1 presents physical and chemical parameters of wood chips made of forest biomass.

Table 1. Physical and chemical parameters of forest biomass in the form of wood chips
Tabela 1. Parametry fizyczno-chemiczne biomasy leśnej w formie zrębek

External dimension (mm)	Calorific value (GJ/Mg)	Average calorific value (GJ/Mg)	Moisture content in working condition (%)	Chlorine content (%)	Ash content in working condition (%)
L = 10–63	7.1–10.3	8.7	40.0–55.0	≤ 0.008	≤ 1.5

Source: Quality requirements and conditions for the supply of biomass to PGE GiEK S.A., Dolna Odra Power Plant Complex (Elektrociepłownia Szczecin).

The temperature of the supplied biomass in the form of chips from energy crops cannot be higher than 40°C. The fraction content should be below 3.15 mm (crumble), and the proportion of contamination in the form of wet sand/soil cannot exceed 1.2% wet sand in the total mass. Table 2 presents physical and chemical parameters of chips made of energy crops.

Table 2. Physical and chemical parameters of forest biomass in the form of chips from energy crops
Tabela 2. Parametry fizyczno-chemiczne biomasy leśnej w formie zrębek z upraw energetycznych

External dimension (mm)	Calorific value (GJ/Mg)	Average calorific value (GJ/Mg)	Moisture content in working condition (%)	Chlorine content (%)	Ash content in working condition (%)
L = 10–63	5.9–10.1	8.0	40.0–60.0	≤ 0.009	≤ 1.8

Source: Quality requirements and conditions for the supply of biomass to PGE GiEK S.A., Dolna Odra Power Plant Complex (Elektrociepłownia Szczecin).

The temperature of supplied straw pellets cannot be higher than 40°C. The fraction content below 3.15 mm (crumble) cannot exceed 6% of total mass. Table 3 presents physical and chemical parameters of straw pellets.

The temperature of the supplied chips from orchards cannot be higher than 40°C. The fraction below 3.15 mm (crumble) in the supplied biomass must not exceed 8%. The fraction content below minimum external dimension of biomass (i.e. 10 mm) must not

Table 3. Physical and chemical parameters of biomass in the form of straw pellets
Tabela 3. Parametry fizyczno-chemiczne biomasy w formie peletów ze słomy

External dimension (mm)	Calorific value (GJ/Mg)	Average calorific value (GJ/Mg)	Moisture content in working condition (%)	Chlorine content (%)	Ash content (%)
L ≤ 30 D = 6–25	15.2–16.7	15.95	5.0–12.0	≤ 0.15	≤ 6.0

Source: Quality requirements and conditions for the supply of biomass to PGE GiEK S.A., Dolna Odra Power Plant Complex (Elektrociepłownia Szczecin).

exceed 15%. The fraction content of the maximum external dimension of the biomass (i.e. 63 mm) must not exceed 10%. The content of wet soil/wet sand after the carried-out test must not be higher than 0.65% of the mass of sample tested. Table 4 presents physical and chemical parameters of chips made of orchards biomass.

Table 4. Physical and chemical parameters of biomass in the form of chips from orchards
Tabela 4. Parametry fizyczno-chemiczne biomasy w formie zrębków z sadów

External dimension (mm)	Calorific value (GJ/Mg)	Average calorific value (GJ/Mg)	Moisture content in working condition (%)	Chlorine content (%)	Ash content in working condition (%)
L = 10–63	7.05–10.50	8.77	38.0–53.0	≤ 0.009	≤ 2.0

Source: Quality requirements and conditions for the supply of biomass to PGE GiEK S.A., Dolna Odra Power Plant Complex (Elektrociepłownia Szczecin).

The temperature of the supplied wood chips from the rubber tree cannot be higher than 40°C. The fraction below 3.15 mm (crumble) must not exceed 8%. On the other hand, the fraction content below the minimal external dimension of the biomass (i.e. 10 mm) must not be above 15%, and the fraction increasing the maximum external dimension of biomass (i.e. 63 mm) must not exceed 10%. The content of wet soil/wet sand after the carried-out test cannot be higher than 0.65% of the mass of sample tested. Table 5 presents physical and chemical parameters of wood chips made of rubber tree.

Table 5. Physical and chemical parameters of biomass in the form of wood chips from the rubber tree
Tabela 5. Parametry fizyczno-chemiczne biomasy w formie zrębków z drzewa gumowego

External dimension (mm)	Calorific value (GJ/Mg)	Average calorific value (GJ/Mg)	Moisture content in working condition (%)	Chlorine content (%)	Ash content in working condition (%)
L = 10–63	7.05–10.50	8.77	38.0–53.0	≤ 0.009	≤ 1.8

Source: Quality requirements and conditions for the supply of biomass to PGE GiEK S.A., Dolna Odra Power Plant Complex (Elektrociepłownia Szczecin).

Procedure of biomass delivery to a combined heat and power plant

The main goal of combined heat and power plant is ensuring the continuity of energy supply to the recipients through appropriate planning of biomass supply whilst maintaining the emergency level of reserves (security) in the warehouse. The maintained biomass supply should be sufficient to cover the assumed amounts of monthly raw material consumption. Planning of these reserves is made based on the archival usage at the beginning of the annual heating period commencing in November and ending in October of the following year. The combined heat and power plant in special cases may adjust the plan for biomass supply.

Figure 1 presents the model for supplying the combined heat and power plant with biomass, with particular emphasis on planning transport activities. Biomass can be delivered by water, road, rail and/or combined means of transport. This allows limiting the pejorative impact of transport on the natural environment and reaction to the changes in transport prices.

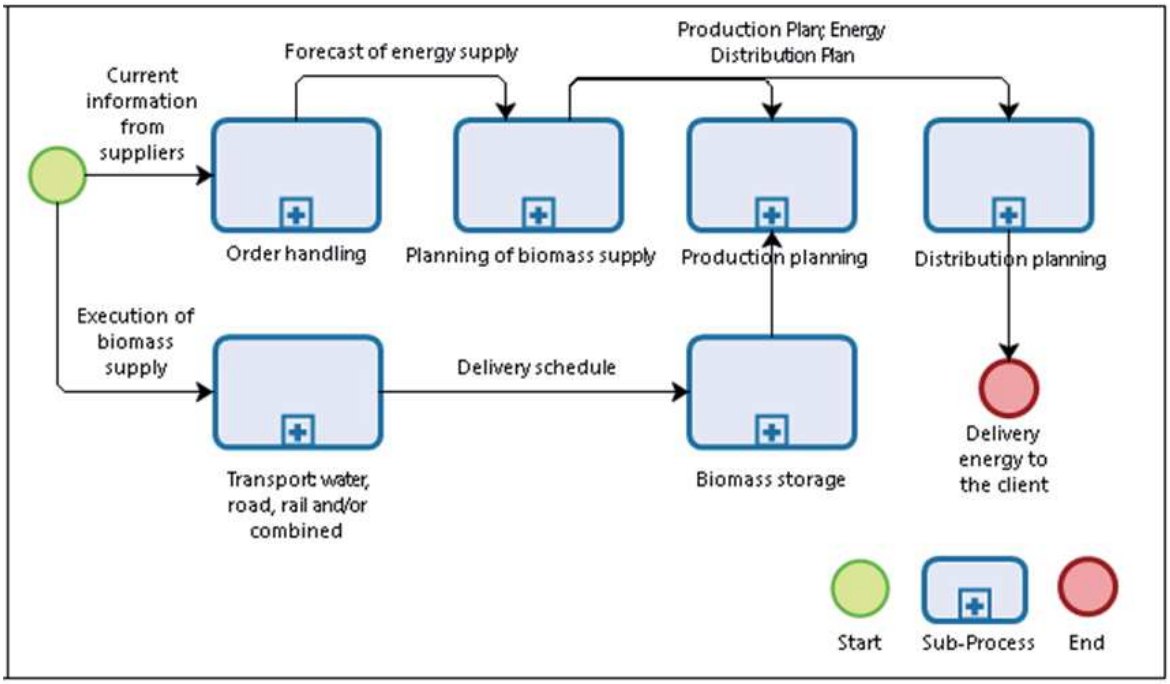

Figure 1. Model of the CHP plant's biomass supply, with emphasis on planning transport activities
Rysunek 1. Model zaopatrzenia elektrociepłowni w biomasę z uwzględnieniem planowania czynności transportowych

Source: own study.

Figure 2 shows the model of management of supplying the CHP plant with biomass. The biomass supply model aims to ensure efficient and effective procedures of planning the critical reserve for the combined heat and power plants, considering the necessity to adapt the evolving energy needs. During the heating period the procedures are initiated in

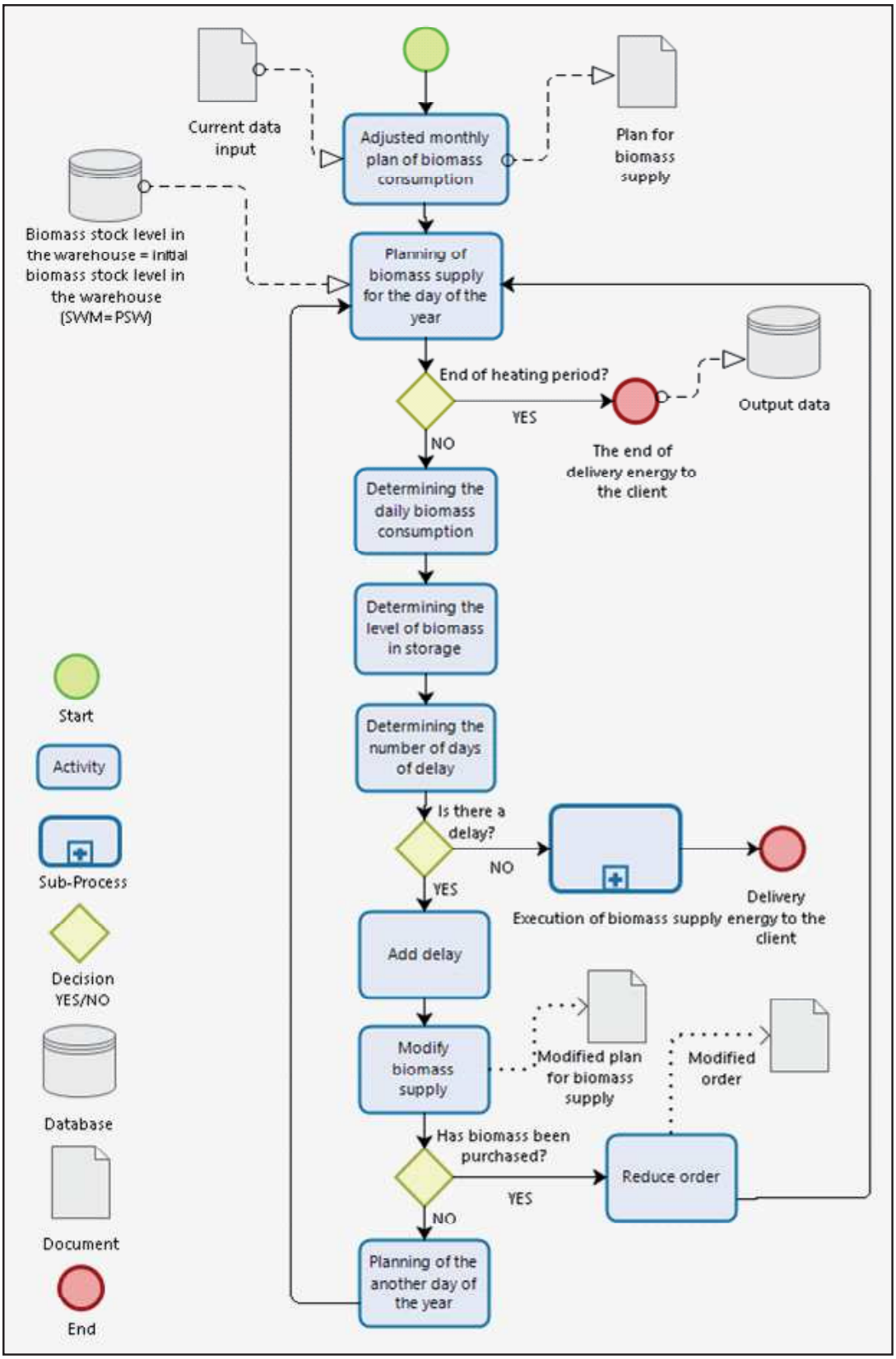

Figure 2. Model of management of the CHP plant's biomass supply
Rysunek 2. Model zarządzania zaopatrzeniem elektrociepłowni w biomasę

Source: own study.

response to the levels of biomass in storage that require purchasing extra mass or resignation from the previously contracted raw material.

The first action resulting from the model (Fig. 2) is developing the plan of monthly consumption of biomass at the CHP plant. Model gives two options for action:

- firstly, establishing the planned monthly consumption on a certain assumed level, independent of the current contractual demand;
- secondly, determining the plan based on the archival data.

The next step is determining the daily plan for supplying the CHP plant with biomass. This operation is carried out separately for each month of the year. Monthly demand for the raw material is calculated first on the n-part of the size not exceeding the maximum quantity that can be delivered daily to the warehouse. These elements are assigned to the first working days (excluding Saturdays, Sundays and holidays) in the month. The remnants of the previous day are delivered on the next working day. In each day, the amount of delivered biomass may not exceed the n-part of maximum quantity in storage. Next, the biomass amount in warehouse is calculated, which on the first day of the heating period is equal to the initial amount of raw material in the warehouse (i.e. the biomass level in the warehouse equals initial biomass level in storage). On every day of the heating year the change of inventory takes place by:

- random value of daily raw material consumption;
- volume of raw material with delayed delivery;
- daily amount of biomass delivered to the warehouse.

In addition, each day the warehouse capacity is examined, as well as daily delivery plan. Based on the analysis the decisions are made about the size of purchase and reduction of contracted biomass.

Biomass, usually after cutting, is first transported to the company that deals with the shredding of biomass into sawdust, and it is stored there. The example of such biomass is biomass from felling trees in the forest or in an inhabited area. Only the biomass obtained from plantations on which plants are cultivated that are adapted for quick processing allows shortening the period of obtaining ready fuel and its direct transport to the CHP plant.

Summary

To ensure security of continuity of energy delivery, the biomass CHP plants must have appropriate raw material reserves, which are secured in the crisis situations. Biomass can be delivered to the CHP plants with the use of different branches and types of transport. In practice, first it is transported to the enterprise which deals with shredding of biomass, and then to the CHP plant.

Energy producing companies must also consider costs that affect the profitability or losses that impact the increase of energy costs for the recipients. Keeping too large reserves of biomass cannot be explained by the lack of that raw material on the market or by significant differences of prices during the year. The CHP plants have concluded annual or long-term agreements that ensure the stability of raw material prices. Appro-

priately selected processes of supply can significantly reduce the costs of CHP plant operation. In the crisis situation the logistics chain boils down to supply. Ensuring the security of continuity of energy delivery through appropriate formulation of procedures of the biomass supply, as well as its effectiveness, is understood as optimization of the CHP plant's costs.

References

Bechtel Ch., Jayanth J., 1997: Supply Chain Management: A Strategic Perspective, International Journal of Logistics Management 8 (1), 15–34.

Centrum Informacji o Rynku Energii, 2019: Niemiecka energetyka spala coraz więcej biomasy z Polski [German power industry is burning more and more biomass from Poland].

Christopher M., 2000: Logistyka i zarządzanie łańcuchem dostwa [Logistics and supply chain management], Polskie Centrum Doradztwa Logistycznego, Warszawa.

Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources. OJ L 328/82 of 21.12.2018.

Janowicz L., 2006: Biomasa w Polsce [Biomass in Poland], Energetyka i Ekologia 8, 601–604.

Johansson L., 1994: How Can a TQEM Approach Add Value to Your Supply Chain?, Total Quality Environmental Management 3 (4), 521–530.

Krajewska R., Łukasik Z., 2012: Alternatywne dostawy paliw dla rynku energetycznego w Polsce [Alternative fuel supplies for the energy market in Poland], Technika Transportu Szynowego 9 (CD).

Solarewicz A., 2019: Odnawialne źródła energii w przemyśle [Renewable energy sources in industry], Energia 6, 2–3.

Szymla W., 2013: Efekty restrukturyzacji przedsiębiorstw sektora elektroenergetycznego a bezpieczeństwo energetyczne Polski po 1989 r. [The effects of the restructuring of power sector companies in terms of maintaining the energy security in Poland after 1989], Zarządzanie Publiczne 4 (26), 20–23.

Szymonik A., 2011: Logistyka i zarządzanie łańcuchem dostaw. Cz. 2 [Logistics and supply chain management. Part 2], Difin, Warszawa.

Tokarska E., Kościelska-Chmurko M. (Eds.), 2004: Biomasa i biopaliwa – zasoby i wykorzystanie w energetyce [Biomass and biofuels – resources and use in the energy sector], Gea, Warszawa.

Ustawa z dnia 7 czerwca 2018 r. o zmianie ustawy o odnawialnych źródłach energii oraz niektórych innych ustaw. Dz.U. 2018, poz. 1276 [Act of 7 June 2018 amending the act on renewable energy sources and some other acts. Journal of Laws of 2018, item 1276].

Witkowski J., 2003: Zarządzanie łańcuchem dostaw [Supply chain management], PWE, Warszawa.

Witkowski J., 2010: Zarządzanie łańcuchem dostaw. Koncepcje, procedury, doświadczenia [Supply chain management. Concepts, procedures, experiments], PWE, Warszawa.

Correspondence address:

Konrad Michalski, PhD
(https://orcid.org/0000-0001-6997-352X)
Warsaw University of Life Sciences – SGGW
Institute of Economics and Finance
Nowoursynowska St. 166, 02-787 Warsaw, Poland
e-mail: konrad_michalski@sggw.pl

Mykolas Navickas, MSc
(https://orcid.org/0000-0002-4734-2804)
Klaipëda University
Faculty of Social Sciences and Humanities
Department of Economics
Herkaus Manto St. 84, 92294 Klaipëda, Lithuania
e-mail: mykolas.navickas@gmail.com

Marcin Rabe, PhD
(https://orcid.org/0000-0002-4817-1971)
University of Szczecin
Management Institute
Department of Logistics
Cukrowa St. 8, 71-004 Szczecin, Poland
e-mail: marcin.rabe@wzieu.pl

Ekonomika i Organizacja Logistyki
4 (3), 2019, 29–39

DOI: 10.22630/EIOL.2019.4.3.21

Mykhaylo Hamkalo[1], ***Arkadiusz Przybyłka***[2]
[1] Ivan Franko National University of Lviv
[2] University of Economics in Katowice

Transport and infrastructure in the development of the tourist region

Transport i infrastruktura w rozwoju regionu turystycznego

Abstract. The challenges of the modern economy mean that enterprises are increasingly forced to use the solutions offered by logistics. The possibility of using such solutions reduces costs and offers better and better quality services. The article presents selected solutions related to the matter discussed in the Ukrainian ski resorts in the Carpathians. The aim of this article is to indicate how logistics management is used to increase competitiveness and better functioning of Ukrainian ski resorts in the Carpathians. The work was based on the analysis of source materials and statistical data.

Key words: logistics, logistics management, ski resorts, Carpathians

Synopsis. Wyzwania współczesnej gospodarki powodują, że przedsiębiorstwa są zmuszone coraz częściej korzystać z rozwiązań oferowanych przez logistykę. Możliwość stosowania takich rozwiązań przyczynia się do obniżenia kosztów oraz oferowania coraz lepszych jakościowo usług. W artykule przedstawiono wybrane rozwiązania związane z omawianą materią, stosowane w ukraińskich ośrodkach narciarskich w Karpatach. Celem artykułu jest wskazanie, w jaki sposób zarządzanie logistyczne jest wykorzystywane do wzrostu konkurencyjności i lepszego funkcjonowania ukraińskich ośrodków narciarskich w Karpatach. Podstawą pracy była analiza materiałów źródłowych oraz danych statystycznych.

Słowa kluczowe: logistyka, zarządzanie logistyczne, ośrodki narciarskie, Karpaty

Introduction

The Ukrainian Carpathian Mountains belong to the Eastern Carpathians located in western Ukraine. The north-eastern chain is 280 km long and over 100 km wide. The Ukrainian Carpathians occupy the territory of the Transcarpathian, Lviv, Ivano-Frankivsk and Chernivtsi regions. They occupy 4% of Ukraine and 10.3% of the total area of the

Carpathians. This region is one of the most visited in Ukraine. The advantages of this part of the Carpathians are a natural impulse for the development of tourism in this country [Wiesner and Kinash 2016]. One of the areas of tourism that has been developing dynamically in this region lately is skiing.

Nowadays, not only the product but also customer service is important for the increase in competitiveness of the services offered. The effect of this approach is the need for logistics technologies. For the efficient management of tourist services, it is necessary to use logistics as a science covering planning, control and control processes in space-time real processes in which the enterprise has its share performed with the intention of effectively achieving the objectives set. The mass nature of tourist services means that tourist services are served by specialized economic entities duplicating and improving their activities. This makes the process of providing services similar to the logistics supply chain and requires the use of logistics tools whose goal is to systematically reduce the cost of product flow in the supply chain. At the same time, it is assumed to maximize profit in every chain link company while maintaining the level of customer service expected on the market [Bentyn 2013]. Therefore, more and more often new solutions are sought that would ensure that tourism companies not only survive, but mainly develop their activities. Such opportunities give the use of elements of logistics management that will allow more efficient functioning of tourism companies.

The article was based on the analysis of facts. The research problem undertaken is aimed at systematizing knowledge about the logistics management of tourist ski resorts in the Carpathians.

Logistics in tourism

The market success of a tourist enterprise depends on the quality, characteristics and price of its product, as well as services and related marketing tasks, and especially on the level of customer service, timeliness and completeness of services offered. A well-functioning system called logistics is helpful in correcting this. Logistics itself is a scientific research field about organizing handling processes and storage of raw materials, materials and finished products in a system approach, aiming at optimization of supply chains as well as dealing with the management of post-consumer products [Abt 2001]. Logistics is the science of organizing the process of goods moving, services, resources etc. from the supplier to the final consumer. It also manages the circulation of products, services, supplies of goods. Logistics in tourism means the use of an innovative tool for managing infrastructure and tourism superstructure, bringing evident benefits both in the sphere of production and in the sphere of consumption of its services [Reczyński 2003]. Logistic infrastructure is defined in a material sense as a defined networking economic area, e.g. a national economy, in which goods and can flow information between enterprises and households [Rokicki and Roman 2011]. Logistics management of tourist services includes planning and performing services taking into account the analysis of needs, possibilities and ways of providing services throughout the entire chain, whose starting link is a producer and the final consumer. All these activities must be carried out in such a way as to ensure a cost-effective way of performing the service, and above all that it meets

the customer's requirements and expectations. Due to the characteristic features of tourist services (inability to create service reserves, immateriality, volatility, simultaneous production and consumption, diversity of place and time of service provision), their logistic management is significantly different from product management. Therefore, the choice of logistics management strategy should be based on such premises that can ensure the optimal level of meeting customer needs. The most important premises include [Gajewska 2009]:

- unity of market position, according to which services should not be provided in two differing markets;
- unity of production volume, according to which services should not be provided either on a large or on a small scale, otherwise it may lead to significant organizational difficulties and increase operating costs;
- unity of production complexity, according to which simple services should not be provided by organizations offering complicated services;
- size of companies providing tourist services should be determined in a way that technology and market allow;
- type and organizational structure of the enterprise providing tourist services, which should be tailored to the client's needs.

The main element of logistics that gives meaning to its activities and processes is, as already mentioned, customer service. Customer service is usually treated as a tool of one of the marketing mix instruments – distribution. The distribution of tourist services takes place through various distribution channels. A two-tier channel containing a tourist operator and agent is a classic resulting from high specialization in the provision of services. Due to the emerging organizational possibilities and the need to reduce costs, such a channel is often reduced to one intermediary, which is an agent also called a travel agency [Bentyn 2013]. However, this concept has changed over time. According to the theory of logistics, the separate operations of enterprises should be connected by supply chain management mechanisms. As far as marketing is focussed on "creating the consumer", logistics is on efficiently satisfying his needs. Logistics focuses on methods to improve consumer service in order for the company to gain a competitive advantage and ensure customer satisfaction. At the heart of marketing tourism are three components: quick response to customer needs, reliable service and good relationships. Customer service is therefore seen as the ability to meet customer expectations [Kempny 2001].

Supply chain relationships allow for better coordination of tourist services and minimise conflicts between individual links of the tourist supply chain. The characteristics of tourist services affect the dynamic of the supply chain coordination process. Offering partial services requires coordination between their individual suppliers in order to shape the tourist product appropriate for the final customer. The inability to store services and the need to leave at your disposal for their provision is associated with specific costs of securing the service potential. The presentation and evaluation of a tourist product effect of its popularity. Thus, it creates the need to understand the essence of information services related to the sale of a tourist product. In addition, the complexity of the tourism product means that its management must be based on the cooperation of individual links in the tourist supply chain.

Uncertainty associated with the variable, associated with many economic factors of countries generating tourism demand and the seasonal nature of demand increases the risk of providing tourist services [Bentyn 2013]. In the case of tourist enterprises, a significant problem is also the selection and simultaneous definition of criteria of logistic customer service. For some companies, tourist customer service is the time that the tourism organizer needs to build an attractive tourist offer. For another group of enterprises, this is mainly the availability of tourist products. Still another group will perceive this problem as a minimization of damages and losses that may occur during the service of a tourist event or an indicator of the response of a service seller to customer complaints [Wiktorowska-Jasik 2010].

Therefore, companies from the tourism industry face numerous problems related to logistics activities that can support the overall development strategy of the enterprise. These strategic logistic problems may include [Gajewska 2009]:

- the selection of strategic suppliers of materials (food, fuel, spare parts, equipment, etc.) and services (e.g. communications, access to utilities, cleaning services);
- decision on own or external transport service of logistics processes;
- development of own distribution network or using the network of other enterprises (e.g. reservation systems, sale of airline tickets, holidays, etc.);
- shaping the subjective structure of sales of tourist services (or tourist goods).

The proper solution should result in the fact that the criteria that the logistic customer service meets should provide the service in such a way that it is timely, of adequate quality, reliable, flexible and adequate to the order placed. This can guarantee that the customer will again use the services offered and not those offered by competitors.

Historical aspects of the development of transport routes in the region

The emergence and development of ski resorts in the 19th and 20th century resulted from the development of transport infrastructure. A popular means of transport within the investigated area in the second half of the 19th century became a narrow-gauge railway, which led the intensive development of the forest industry (harvesting and primary processing of raw materials). The first steam locomotive traction railway was built in 1873 by the Austrian timber manufacturer Leopold Popper on the territory of Eastern Galicia between the towns of Dolyna and Vygoda, with a length of 8.6 km [Klapczuk 2012].

The construction of railway lines along the route Khyriv–Drohobych–Stryi (1872), Stryi–Skole (1885) and Skole–Lavochne (1887) has played a significant role in the development of tourism in the mountainous part of the Lviv region [Klapczuk 2012].

In the second half of the 1930s, the ski resort Slavske had a direct railway connection with Warsaw, Lódź, Gdynia, Poznań, Vilnius, Kraków and Lviv. Slavske was the main point of four special ski trains of the League for the development of tourism, which for two days allowed visitors to use the ski areas of the Eastern Beskids. In the early 20th century, the Sambir–Syanky railway was laid, which contributed to the development of the ski resort of Syanky [Quirini-Popławski 2017].

For the purpose of serving the growing flow of tourists in 1932, popular tourist trains were introduced, which ran on the route Lviv–Slavske and Lviv–Skole in summer and winter. Based on the experience of transportation on the route Kraków–Zakopane, in the second half of the 1930s on the route Lviv–Stryi–Lavochne high-speed trains "lux-torpeda" with a maximum speed of 108 km/h were used. With the development of highways, the role of individual transportation grew [Quirini-Popławski 2017].

Since 1884, the tourist development of the mountainous part of Ivano-Frankivsk region began. This was supported by the opening of the Stanislaviv–Vorokhta–Voronenka railway. In 1922, a ski-jump was built in Vorokhta by specialists from Zakopane (Poland), which is currently used with certain modifications. During the interwar period, a special train with the unofficial name "Narty, dancing, brydż (Skies, dancing, bridge)", ran from Warsaw to Vorokhta. Next to the sleeping cars there were cars in which musicians performed and dance parties were held; there were gaming tables for fans of bridge. As a rule, steam locomotives of such trains were decorated with wreaths of spruce in winter, they had inscriptions on the front part "Ski raid to Vorokhta" [Łoziński and Łozińska 2010].

Logistics of air transport

The military conflict in eastern Ukraine had a significant impact on the tourist flow. This is clearly reflected in the number of flights performed in the airspace of Ukraine. The largest number of flights – 534,581 were served by the State company UkSATSE in 2013, a substantial proportion of the flights were performed by foreign airlines (81%). Over the next years (2014–2016), there was a decrease in the number to 214,262 [UkSATSE 2019]. The sharp decrease in the number of flights relates to the closure of part of the airspace over the temporarily occupied territory of Crimea, with the territorial waters, the closure of the environmental protection zone, including the buffer zone, as well as the termination of air traffic between Ukraine and Russia.

From 2017 to 2019, a positive tendency was being observed. From January to November 2019, UkSATSE provided 313,195 flights, which is 11.8% more than the corresponding period of the last year. Ukrainian airlines performed 102,889 flights, while foreign airlines made 210,306 flights. Both indicators have a positive trend compared to the same period of the last year – an increase of 3.4 and 16.4% [UkSATSE 2019].

Ski resorts in Ukraine may expect the arrival of domestic and foreign tourists at the airports of Lviv, Ivano-Frankivsk and partially Uzhgorod and Chernivtsi. As shown in Table 1, the ski resorts Slavske and Play are the closest to the Lviv airport. The Ivano-Frankivsk airport has the most optimal location in relation to the ski resorts of the region, but the airport infrastructure does not allow to receive a large number of flights, especially from abroad. The effective functioning of the Uzhgorod airport can significantly improve the transport accessibility of the Krasiya resort.

Currently, Bukovel is the only ski resort in Ukraine, which is actively improving its transport accessibility by airline services. Skorzonera LLC, which deals with the development and management of the resort of Bukovel, since 2010 obtained the concession of the Ivano-Frankivsk International Airport. Despite the economic crisis, transportation is carried out in two directions within Ukraine: Kyiv–Ivano-Frankivsk, Dnipro–Ivano-Frankivsk. A new flight from Bucharest has been introduced on 27 December 2019. The

Table 1. Distance from airports by main roads in Ukraine
Tabela 1. Odległości od lotnisk głównymi drogami na Ukrainie

Ski resort	Distance (km)			
	Lviv	Ivano-Frankivsk	Uzhgorod	Chernivtsi
Bukovel	239	89	264	168
Dragobrat	259	112	246	189
Slavske	137	168	177	304
Play	136	165	136	303
Krasiya	189	264	65	397
Pylypets-Podobovets	200	153	124	291

Source: actual study on the basis of the Google maps website https://www.google.com.ua/maps [access: 30.12.2019].

flights operate twice a week, on Monday and Friday, by Windrose company. The usual price for a one-way ticket is about EUR 100 [IFO 2019].

In recent years, Lviv International Airport named after Daniel Galitsky ranked among the three largest airports in Ukraine in terms of passenger flows. During 2018, passenger traffic amounted to 1.6 million people, 12 new flights were opened. As at December 2019, the airport accepts flights from 14 airlines that cover 29 countries in Europe, as well as Israel and Azerbaijan. In the summer, the number of flights is growing. In January––November 2019, passenger traffic at Lviv airport amounted to 2.05 million passengers – this is 39.4% more than in the same period of 2018, when the airport served 1.27 million passengers. For 11 months of 2019, passenger traffic on international flights totaled 1.86 million (+45.5%) tourists, on domestic flights – 188.6 thousand (–1.6%) tourists; during this period, the airport served 17,540 flights, which is 24% more than a year earlier, when this number was 14,148 [Fel'metsher 2019].

Logistics of railroad transportation

Railway transport in Ukraine is the leading industry in the road transport complex of the country, which provides almost 82% of freight and 36% of passenger traffic carried out by all means of transport. The operational railway system in Ukraine is approaching almost 19.8 thousand km (excluding the occupied territories, the network of which is not currently in operation), of which more than 47.2% is electrified. In terms of freight traffic, the railways of Ukraine occupy the fourth place on the Eurasian continent, second only to the railways of China, Russia and India. The load capacity of Ukrainian railways (annual traffic volume per 1 km) is 3–5 times higher than that of developed European countries [Ministry of Infrastructure of Ukraine n.d.].

Within the Carpathian region, Ukrainian railways interact with the railways of Poland, Romania, Slovakia and Hungary. Forty international railway crossings have been organized for international traffic. Most railway checkpoints (freight and passenger) are located on the border with Poland (7), the fewest number (3) – on the border with Slovakia and Hungary. International passenger rail transport is carried out on the routes: Kyiv–Lviv––Przemyśl, Lviv–Wrocław, Mukachevo–Budapest. In December 2019, the international

route Lviv–Przemyśl–Berlin – a joint project of Ukrzaliznytsia JSC and Polish State Railways Inc. was implemented [Kravtsov 2019].

Regional branch Lviv railway serves the territory of seven Ukrainian regions: Lviv, Ivano-Frankivsk, Volyn, Zakarpattya, Chernivtsi, Ternopil, Rivne. For domestic passenger traffic, Lviv railway serves 49 pairs of trains that provide connection with all regions of Ukraine.

The only major element of the transit transport infrastructure of Ukraine, which was created during the years of independence of Ukraine is the Beskid tunnel with length of 1,764 m. The project was financed by loans from the European Bank for Reconstruction and Development and the European Investment Bank. Construction lasted from 2013 to 2018, and it allowed to increase the turnover to 100 pairs of trains per day at a speed of up to 70 km/h [Kravtsov 2018].

The best railway connection has Slavske ski resort, on the territory of which there is a railway station. This resort has a railway connection with Slovakia (Kyiv–Lviv––Slavsko–Kosice), Austria and Hungary (Kyiv–Lviv–Slavskoe–Budapest–Vienna) – Table 2. Every day the railway station Slavskoe takes 16 trains on internal routes, which allows to provide connection with the cities: Kyiv, Lviv, Odessa, Kryvyi Rih, Lysychansk, Zaporizhia, etc. The worst railway connection has the Krasiya resort, because of the small number of trains (2) and inconvenient (night) time of arrival and departure.

Table 2. Aspects of railway connection of ski resorts in Ukraine
Tabela 2. Aspekty połączenia kolejowego ośrodków narciarskich na Ukrainie

Ski resort	The nearest station	Distance (km)	The number of trains in international traffic	Number of passenger trains per day
Bukovel	Tatariv/Vorokhta	16/22	–	16
Dragobrat	Yasinya	14	–	8
Slavske	Slavske	0	2	18
Play	Scole	27	1	11
Krasiya	Kostryna	6	–	2
Pylypets-Podobovets	Volovets	15	1	19

Source: actual processing based on data from Lviv Railway (Lvivska Zaliznytsya) website http://railway.lviv.ua [access: 30.12.2019].

Logistics of road transportation

The public highways system in the western region of Ukraine reaches 42,308.2 km, 98.2% of which are hard-surface roads. The longest length of public roads in the region has Lviv, the shortest roads are in Zakarpattya region. Within the study area, 13.7% are state roads, 86.3% are local roads. The maximum length of international roads is typical for the Lviv region (547.9 km), and the length of national roads typify Ivano-Frankivsk (352.4 km) and Lviv regions (347.1 km) [Derzhstat 2019].

Over the past five years, there has been an improvement in the quality of roads in the western region of Ukraine, which affects the transport accessibility of ski resorts. For passenger transportation to the ski resorts of the Lviv region (Slavske, Play), the international

road M-06 Kyiv–Lviv–Chop is used. This road crosses the territory of Kyiv, Zhytomyr, Rivne, Lviv and Zakarpattya regions. In Hungary, it continues as highway 4. Territorial road T-1424 connects the resort Slavske with the highway M-06, which is 23 km long. These roads are in good condition. The resort Slavske has a regular bus service to Lviv (126 km).

Bukovel and Dragobrat ski resorts are located next to the national highway N-09, which runs through the territory of Lviv, Ivano-Frankivsk and Zakarpattya regions: Mukacheve–Rakhiv–Ivano-Frankivsk–Rohatyn–Lviv (423.6 km). The road condition within the Lviv and Ivano-Frankivsk regions is good. In order to relieve pressure on the road, an additional road was built from the Yablunytskyj Pass, which combines the resort of Bukovel with the H-09 highway, Bukovel ski resort has regular bus service to Ivano-Frankivsk, Lutsk, Kolomyia, Zbarazh. In winter, bus services are provided from Lviv, Kyiv, Odessa, etc.

In many ski resorts, there is a problem with the condition of the roads, on which travelers get directly to the ski areas. Especially important is the problem of comfortable internal resort routes in Slavsk. The main ski area, where the best and longest ski runs run, is located on the hillside of Trostyan mountain at a distance of 2–4 km from the village Slavske It is possible to drive there only with four-wheel-drive cars. Local residents informally provide paid transport services with their own four-wheel drive cars to car owners who do not have such cars.

A similar situation is observed in the resort of Dragobrat, which is located at an altitude of 1,400 m a.s.l. From the international highway N-09, the distance to the resort is more than 8 km, which can only be reached by four-wheel-drive cars. Adverse weather conditions can cause landslides fully or partially destroying the road.

Ski resort infrastructure

Modern ski resort infrastructure is typical for the resorts of Bukovel and Play. These resorts continue to develop, but a wide range of accommodations, food, and appropriate ski infrastructure were formed in 2010–2011, during the first 8 years of existence.

Bukovel ski resort is located near the village Polyanytsya (Ivano-Frankivsk region) within the altitudes of 850–1,372 m a.s.l. The ski season lasts from December to the end of April. According to the complexity of the skiing runs, there are 14 blue runs (easy for beginners), 41 red runs (medium in complexity, for experienced skiers), 7 black runs (for athletes and experts). The total length of the runs is 68 km, artificial covering with snow is carried out on all runs. The main means of transport within the resort are 15 chairlifts and 1 T-bar lift. Most of the installed lifts are of the new generation of well-known world manufacturers Doppelmayer and Leitner. The total carrying capacity of the lifts is over 33 thousand passengers hourly[1].

Bukovel ski resort is characterized by high-quality information logistics, which is due to the mobile Internet of the fourth generation (4G), the ability to track the load of lifts in the online mode, information schemes and signs on the tracks, printed information materials.

[1] http://bukovel.com [access: 30.12.2019].

As can be seen from Table 3, the Dragobrat ski resort is characterized by a high-altitude position among the studied resorts. On the main slope of Stig mountain there are two T-bar lifts, each about 1 km long; there are also several old short lifts, which are located on mild slopes for children and beginners. Top of the Carpathians tourist complex belongs the T-bar lift and chair-ropeway (commissioned in early 2010), which are located in the right part of the natural boundaries of Dragobrat. Another chair-ropeway Leitner (1,200 m) belongs to the Carpathian Seagull tourist complex, has been put into operation in the 2010–2011 season. For professionals, free-ride tours are offered from the top of Blyznytsia (1,883 m) – the length of the route is more than 3 km. Dragobrat does not differ significantly from the existing ski resorts of Ukraine in terms of length and variety of trails, in particular in their latitude. The maximum length of the skiing run is 2,080 m. The difference in altitude is the smallest among the studied resorts and is 355 m high.

Table 3. Characteristics of skiing infrastructure in Ukraine
Tabela 3. Charakterystyka infrastruktury narciarskiej na Ukrainie

Resort	Lifts		Snow generation system	The highest lift station (m a.s.l.)	Maximum trail length (m)
	T-bar lifts	chair lifts			
Bukovel	1	15	+	1 372	2 353
Slavske	13	2	+*	1 232	1 800
Pylypets-Podobovets	9	1	–	1 160	2 000
Play	1	2	+	1 060	1 200
Dragobrat	4	1	–	1 704	2 080

*Skiing runs on the Pogar mountain.

Source: author's development on the basis of data from ZymaGhory.com portal http://zymaghory.com [access: 30.12.2019].

The oldest ski resort Slavske leave behind all existing Ukrainian resorts in the number of lifts and the length of runs. However, the main problems of the resort remain poor quality of skiing runs preparation, outdated skiing infrastructure, short ski season due to the lack of artificial covering with snow most of the runs, etc. A single snow generation system is installed on two runs on Pogar mountain. For transportation of tourists, chair lifts are used, which were installed about 40–50 years ago. The main source of water for snow generation in Slavske resort are the rivers Slavka and Opir. However, it is necessary to build artificial reservoirs. Most routes have no information schemes and pointers and 4G Internet capability is not fully used.

The nearby location allows to combine the skiing areas of Pylypets and Podobovets into a single resort. The most developed skiing infrastructure is typical for the Pylypets ski area, the total length of the skiing runs is more than 20 km. The runs are provided with 7 lifts: 1 chair lift (double) and 6 T-bar lifts. The total carrying capacity of the lifts is over 5 thousand passengers hourly. The resort's runs are of all types of complexity, there are significant opportunities for freeride skiing. Organized groups are offered for snowcat trips to the Hymbu mountain (1,491 m). Within Podobovets 4 km of runs are laid which are served by three T-bar lifts with length of 400–1,250 m. Most of the lifts are outdated.

Summary

Transport logistics plays a crucial role in the development of ski resorts. Tourist development of this region was associated with the development of the railway network in the 19th century. In the 1930s, the speed of rail transport has increased significantly and the number of transported tourists has increased. Given the realities of the Ukrainian railway, the speed of trains has not changed significantly over the past 80 years. The highest logistics potential among the studied ski resorts has Bukovel. This is due to high-quality transport infrastructure, well-targeted passenger transportation logistics, information support, and modern skiing infrastructure. Despite the good transport accessibility of the Slavske and Pylypets-Podobovets ski resorts, they do not provide quality logistics in general. This should lead to the introduction of new solutions that will eliminate these inconveniences.

References

Abt S., 2001: Logistyka w teorii i praktyce [Logistics in theory and practice], Wydawnictwo Akademii Ekonomicznej w Poznaniu, Poznań.

Bentyn Z., 2013: Logistyka w gospodarce turystycznej [Logistics in the tourist economy], Wydawnictwo Uniwersytetu Ekonomicznego w Poznaniu, Poznań.

Derzhavna Sluzhba Statystyky Ukrayiny – Derzhstat, 2019: Transport i zv'yazok Ukrayiny – 2018. Statystychnyy zbirnyk [Transport and communication of Ukraine – 2018. Statistical Journal], Kyiv.

Fel'metsher M., 2019: Z pochatku roku pasazhyrs'kyy aeroport „L'viv" zris mayzhe na 40% [Since the beginning of the year, passenger traffic at Lviv airport has grown by almost 40%]. Ekonomichna pravda of 02.12.2019, [electronic source] https://www.epravda.com.ua/news/2019/12/2/654358 [access: 30.12.2019].

Gajewska M., 2009: Logistyczne ujęcie zarządzania przedsiębiorstwem turystycznym [Logistic approach to tourist enterprise management], LogForum 2, 8–9.

Ivano-Frankivsk International Airport – IFO, 2019: Bucharest – Ivano-Frankivsk flight announced. News of 03.12.2019, [electronic source] https://ifo.aero/en/news/101 [access: 30.12.2019].

Kempny D., 2001: Logistyczna obsługa klienta [Logistic customer service], PWE, Warszawa.

Klapczuk W., 2012: Galicia Railways, Visnyk Prykarpats'koho universytetu. Istoriya 22, 10–20.

Kravtsov Y., 2018: Beskyds'kyy – tse pershyy zaliznychnyy tunel', zbudovanyy u nezalezhniy Ukrayini [Beskidsky is the first railway tunnel built in independent Ukraine, [electronic source] http://railway.lviv.ua/info/press-center/news-archive/news/article/2018/february/1534 [access: 30.12.2019].

Kravtsov Y., 2019: Z 15 hrudnya pochne funktsionuvaty peresadkovyy marshrut L'viv – Berlin [From December 15, Lviv – Berlin interchange will start operating], [electronic source] http://railway.lviv.ua/info/press-center/news/article/2019/december/2021 [access: 30.12.2019].

Łoziński J., Łozińska M., 2010: Narty-Dancing-Brydż w kurortach Drugiej Rzeczypospolitej [Ski-Dancing-Bridge in the resorts of the Second Polish Republic], Wydawnictwo Naukowe PWN, Warszawa.

Ministry of Infrastructure of Ukraine, n.d.: General information about railway transport, [electronic source] https://mtu.gov.ua/en/content/informaciya-pro-ukrainski-zaliznici.html [access: 30.12.2019].

Quirini-Popławski Ł., 2017: Miejscowości turystyczne w dolinie Oporu w Beskidach Wschodnich do 1939 roku [Tourist resorts in the Opor valley in the Eastern Beskids until 1939], [in:] Ł. Quirini-Popławski, M. Hamkało, M. Rutynskij, N. Kudła (Eds.), Człowiek i jego działania. Spojrzenie geografa [Man and his actions. Geographer's look], Wydawnictwo Uniwersytetu Jagiellońskiego, Kraków, 255–272.

Reczyński R., 2003: Logistyka w przestrzeni turystycznej [Logistics in tourism space], Logistyka 4, 9–12.

Rokicki T., Roman M., 2011: Infrastruktura logistyczna w turystyce (na przykładzie gospodarstw agroturystycznych) [Logistics infrastructure in tourism (on the example of agritourism farms)], Logistyka 6 (CD).

Ukrainian State Air Traffic Service Enterprise – UkSATSE, 2019: UkSATSE has serviced more than 300,000 flights during 11 months of 2019, [electronic source] http://uksatse.ua/index.php?act=Part&CODE=247&id=505 [access: 30.12.2019].

Wiesner W., Kinash M., 2016: Możliwości uprawiania różnych form turystyki aktywnej w ukraińskich Karpatach [Possibilities of practicing various forms of active tourism in the Ukrainian Carpathians], Rozprawy Naukowe Akademii Wychowania Fizycznego we Wrocławiu 54, 110–121.

Wiktorowska-Jasik A., 2010: Znaczenie logistyki w rozwoju gospodarki turystycznej Polski [The importance of logistics in the development of tourism in Poland], Folia Pomeranae Universitatis Technologiae Stetinensis. Oeconomica 61, 159–166.

Correspondence address:

Mykhaylo Hamkalo, PhD
(https://orcid.org/0000-0002-0019-7400)
Ivan Franko National University of Lviv
Geography Faculty
Department of Tourism
Doroshenka St. 41/4, Lviv 79000, Ukraine
e-mail: hamkalo.m@gmail.com

Arkadiusz Przybyłka, PhD
(https://orcid.org/0000-0001-9427-6232)
University of Economics in Katowice
Department of Labour Market Forecasting and Analysis
1 Maja St. 50, 40-287 Katowice, Poland
e-mail: arkadiusz.przybylka@ue.katowice.pl

Ekonomika i Organizacja Logistyki
4 (3), 2019, 41–53

DOI: 10.22630/EIOL.2019.4.3.22

Sławomir Stec
Ignacy Łukasiewicz Rzeszów of University of Technology

Innovative processes in passenger transport in Poland and Europe

Procesy innowacyjne w transporcie pasażerskim w Polsce i Europie

Abstract. The subject of research were innovative processes of a technological, organizational, structural, market or sociological nature. The starting material for developing the studied subject was the analysis of the dynamics of changes in expenditure on research and development in the field of transport infrastructure in Poland and the European Union. It has been found that in the last two decades, innovations in passenger transport have been successively implemented in Poland and Europe, the aim of which is to effectively meet the existing needs in the field of passenger transport, and above all to effectively encourage car drivers to use public transport. Introduction of the new solutions in transport is possible due to the growing level of budget expenditure on research and development in the field of transport, telecommunications and other infrastructure. The selected presented innovations in passenger transport effectively improve the quality of travel, increase the efficiency of infrastructure use and contribute to reducing the negative impact of transport on the environment.

Key words: transport, innovations, technological innovations, innovative processes, transport strategies

Synopsis. Przedmiotem badań były innowacyjne procesy o charakterze technologicznym, organizacyjnym, strukturalnym, rynkowym lub socjologicznym. Materiałem wyjściowym do opracowania badanego przedmiotu była analiza dynamiki zmian wydatków na badania i rozwój w zakresie infrastruktury transportowej w Polsce i Unii Europejskiej. Stwierdzono, że w ostatnich dwóch dekadach sukcesywnie wdrażano innowacje w transporcie pasażerskim w Polsce i Europie, których celem było skuteczne zaspokojenie potrzeb w dziedzinie transportu pasażerskiego, a przede wszystkim skuteczne zachęcanie kierowców do korzystania z transportu publicznego. Wprowadzenie nowych rozwiązań w transporcie jest możliwe dzięki rosnącemu poziomowi wydatków budżetowych na badania i rozwój w dziedzinie transportu, telekomunikacji i towarzyszącej infrastruktury. Przedstawione innowacje w transporcie pasażerskim skutecznie poprawiają jakość podróży, zwiększają efektywność wykorzystania infrastruktury i przyczyniają się do zmniejszenia negatywnego wpływu transportu na środowisko.

Słowa kluczowe: transport, innowacje, innowacje technologiczne, procesy innowacyjne, strategie transportowe

Introduction

The developing economies of individual countries, the intensive development of cities and the improvement of the financial situation of the population shows enormous transport demand, which means that traditional investment in infrastructure, services and transport organization does not guarantee satisfying this demand in a satisfactory manner. In many areas around the world you reach the border of traffic and transport intensity, which contributes to significant road congestion and lack of space for new transport infrastructure. In many places around the world the limit of traffic and transport intensity is close, which contributes to significant traffic congestion and lack of space for new transport infrastructure. In addition, energy resources are slowly depleting, on which the majority of mechanized transport technologies are based [Burnewicz 2010].

Eurostat data for 2016 shows that among various means of transport, travellers most often choose traveling by car. As much as 71% of travels were conducted by car. And this number has been steadily increasing over the past two decades. Since 1996, it has increased by over 20%. This causes a significant civilization threat, because the preference of individual car trips over collective transport has a negative impact on the environment. This contributes to air pollution, water pollution, noise emissions and occupying an increasing area of land. Moreover, the increasing land traffic causes a greater number of road accidents, the consequence of which is the threat to human lives.

These worrying effects of transport development lead to the creation and dissemination of modern technologies and a new organization of transport services in a limited economic, natural and social space. The process is easier because we are living in a time of great innovations that are implemented in almost every industry and in every area of life, both in production and in services. The implementation of innovations in transport allows to meet institutional, commercial, individual and group needs, thanks to which it is possible to increase the efficiency and functionality of transport systems, reduce energy demand, reduce harmful effects on the environment and contribute to the development of alternative forms of transport, as well as meet the transport needs of individuals and legal [Burnewicz 2010].

In view of the above, it is important to strive to increase the intensity of research and development in the development of innovative solutions that contribute to increasing efficiency, throughput, reducing unreliability and preventing the loss of time and resources, as well as reducing operating costs. New solutions improve the quality and efficiency of transport and significantly reduce local air pollution and greenhouse gas emissions, contributing positively to the quality of life of residents.

Research goal and methodology

The publication provides a concise description of innovation related activities in passenger transport to identify and evaluate the most promising innovations. The subject of research were innovative processes of a technological, organizational, structural, market or sociological nature. The starting material for developing the studied subject was the analysis of the dynamics of changes in expenditure on research and development in the field of transport infrastructure in Poland and the European Union. A synthetic review of

strategic documents related to the development of transport at national and EU level was also carried out.

The taken up subject is extremely extensive, which is why selected concepts, prototypes and inventions in the field of passenger transport were presented. This way of presenting this issue is helpful in spreading technological knowledge and spreading useful innovations. The analyses were conducted on the basis of source materials presented in publications, scientific articles and internet portals, as well as on the basis of previous research and mass statistics data provided by Eurostat. Methods of processing and interpretation of optional knowledge were used using the descriptive method, the method of descriptive analysis and graphic presentation, as well as literature studies.

Innovation in transport in the light of theoretical considerations

Threats resulting from the intensive development of passenger communication make it necessary to search for new concepts and new means in transport. Therefore, it becomes necessary to intensify innovative activities, which in transport are understood as actions consisting in improving existing ones or introducing new solutions or processes regarding all aspects of changes and contributing to the increase of economic, financial, technical and technological efficiency, the natural environment as well as systems of transport in order to maximize social effects and management results by the public and private sectors [CATI 2012].

Transport innovations should be considered in several areas. They relate to transport technique and technology; planning, organization and management of transport systems, as well as transport financing in the scope of maintaining and modernizing existing resources, as well as new investments in infrastructure and means of transport [Bąk 2016]. From the technology point of view, Bąk [2015] indicates that innovations concern the following areas: automation in road transport, fuel and propulsion technologies, improvement of means of transport, intelligent transport systems, innovations in the field of services and organization as well as infrastructure.

When discussing the types of innovations in transport, the most common is innovation in a technical context. Among them are product and process innovations. In transport, product innovation is understood as the introduction on the transport market of a product whose technological features or purpose are significantly different from previously proposed and supplied products or whose operation has been significantly improved, and at the same time it can provide the recipient (user) with objectively new or increased benefits. In turn, process innovation in transport is defined as the adoption of new or significantly improved methods of operation (processes) in various aspects of transport services, production of means of transport or other transport products, transport management, etc. This may involve changes in the organization, technology, human resources, working methods, equipment or a combination of such changes [Wiszniewski 1999]. Recently, non-technical innovations have also been included in transport innovations. According to the Oslo Manual [2005], non-technical innovation is any innovation activity of individuals that is not associated with the development and introduction on the market of new or significantly changed products or services, and the implementation of new or significantly changed processes. According to this division, we can speak of organiza-

tional and marketing transport innovations. In the case of organizational innovations, we can talk about the implementation of new or significantly improved methods of transport organization. In turn, in the case of marketing innovations, we talk about implementation of new concepts or transport strategies that differ significantly from the methods used so far [Mazur-Wierzbicka 2015].

In some countries, innovation in transport is also considered in the context of more economical use of financial, management and organizational resources. This is due to the increasing transport needs with limited resources [CATI 2012]. In this case, innovations in transport reduce transport costs and time, which causes the users to experience positive emotional feelings, which in turn affects the usefulness of transport products and services, which in turn increases the efficiency of resource use [Lakshmanam and Anderson 2009].

In accordance with Christenssen [2010], who divided innovation into groups, in transport, as in other sectors of the economy, continuation innovations predominate, which mainly contribute to the modernization, improvement of processes and products, e.g. by using batteries in trolleybuses enabling the vehicle to travel along a road section without electric traction. There are also innovations introducing completely new products or processes that can even displace the current technology or product from the market. This is known as innovation that interrupts development. An example would be the introduction, in the past, of internal combustion and electric drives at the expense of steam drives.

Transport innovations are characterized by specific features. Geerlings [1999] emphasizes that transport innovations are focused on individual or collective clients, are quite large and expensive, and in the future will affect other investment projects. This is influenced also by sustainable development as well as they have cooperative character, which means that they do not appear in only one unit. They include institutions and their networks, scientific and research units, public and local administration, government as well as non-governmental organizations and civic initiatives.

In order to develop innovations, innovative activities are carried out through all scientific, technical, organizational, financial and commercial activities. Some of them are innovative in themselves, while others are not new, but they are necessary to implement innovation. Innovative activity is associated with research and development (R&D), which is necessary to develop all innovations [GUS 2018]. Research and development activity is defined as creative work, carried out in a methodical way, undertaken to increase knowledge resources and to create new applications for existing knowledge, which in consequence leads to the introduction into the economy of a "new or significantly improved product, service or process, including the implementation of a new marketing or organizational method that redefines the way the company works or its relations with the environment" [Bukowski et al. 2012]. Conducting R&D activity allows measuring the innovation and innovativeness of the economy of a country, region, industry, sector or a given entity. One of the ways to measure innovation and innovativeness is the analysis of expenditure indicators for research and development activities. The measures of the above R&D indicators include two main groups of indicators [Godecki 2008]:

- cash expenditure on research and development;
- number of persons employed in the R&D sphere.

The above-mentioned indicators inform about how intensively innovative activity is conducted. On the economic scale, the Frascati methodology is most often used to meas-

ure innovation, and the measure used is GERD – gross expenditures on research and development, i.e. the sum of internal expenditure incurred in a given year on R&D by all units conducting this activity in a given country. This is because the Frascati methodology enables multidimensional analyses and comparisons. According to Frascati methodology, expenditure on R&D is classified according to the distance to the economic application of conducted research divided into basic research, applied research and development works, as well as into other classes (according to the criteria: sector in which research is conducted – business, government, higher education, private non-profit; according to the source of funds: domestic and foreign; according to socio-economic goals; according to research areas, etc.) [Bąk 2016].

The place of innovation in passenger transport in Polish and EU strategic documents

An efficient and well-functioning passenger transport system is essential for the inhabitants of the European Union. The EU's transport policy aims to promote clean, safe and efficient traveling across Europe, providing the basis for citizens' right to travel freely throughout the EU (both at work and for recreation). The implementation of this policy is intended to make transport effective, sustainable, safe, reliable and constitute homogeneous European transport area by improving regulation, ensuring a high degree of implementation of EU transport legislation and open and fair competition both in the EU and in relations with key partner countries. This allows creating a modern European transport infrastructure –ensuring effective implementation of the Trans-European Transport Network (TEN-T) financing under the Connecting Europe Facility (CEF) and using innovative financial instruments (such as the European Fund for Strategic Investments (EFSI). The assumptions of the EU transport policy are also an innovative transport sector, which is possible thanks to the effective implementation of funding for research and innovation in the field of transport under the Horizon 2020 program [Eurostat 2019], whose priorities are [European Commission 2019]:

- more sustainable transport: resource-efficient transport that respects the environment;
- improving transport and transport systems: better mobility, less congestion, more safety;
- maintaining transport competitiveness: the European transport industry as a global leader;
- making transport research responsive: socio-economic research and forward-looking activities in policy making.

The key goal of EU policy, however, is to reduce citizens' dependence on private cars to achieve cleaner and more efficient transport in urban areas. The issued document entitled "White Paper on transport" [DG MOVE 2011] emphasized the need to withdraw vehicles fueled with conventional fuels and replace with vehicles with lower emission. In addition, the White Paper contains a strategy for near-zero urban logistics in the EU by 2030. The EU supports a price and market approach towards greener transport, including a new green public procurement system.

Poland, which has been investing significant financial resources in innovative transport from many years, prioritizes the increase of transport accessibility while improving the safety of traffic participants and the efficiency of the sector. This is possible thanks to the implementation of the assumptions of the Strategy for Sustainable Transport Development until 2030. Implementation of the strategy requires undertaking, among others, activities such as: building an integrated and interconnected transport network for a competitive economy or improving the organization and management of the transport system. Public transport is promoted and the safety of traffic participants is increasing. Implementation of the strategy also requires limiting the negative impact of transport on the environment and improving the efficiency of the use of public funds allocated to transport projects.

The strategy also points to modern solutions that facilitate the functioning of the entire transport sector and reduce its negative impact on the environment and climate, so that it is possible to create a sustainable transport system for the country by 2030. Activities in this area should be limited to, among others for the development of innovative ITS technologies, development of intermodal transport infrastructure, digitization of transport services, the introduction of autonomous buses to the market, the use of innovative noise-absorbing road surfaces, with increased strength, less susceptible to abrasion [Ministerstwo Infrastruktury 2019].

In addition to the above-mentioned most important documents supporting the development of innovative transport, there are a number of other treaties, strategies, memoranda, and policies in force within the union, country, voivodship, poviat or commune. All of these documents direct their records towards activities related to the desire to build and operate sustainable and modern transport.

Innovative activity in passenger transport in Poland and the EU

Above, it has been pointed out that one of the ways to measure innovation and innovativeness is to analyse expenditure indicators for R&D. When using the data presented by Eurostat for the analysis, it is necessary to take into account the collective method of presentation of results for transport connected by telecommunications and other infrastructure. Figure 1 presents the share of Poland's budget expenditure against the background of 28 EU countries on R&D in the field of transport, telecommunications and other infrastructure. The data are presented in the calculation of the euro spent per capita. In two decades in the EU, expenditures on research and development in transport is steadily increasing. Since 2000, these expenses have more than tripled, from 1.8 to 5.7 GBP per inhabitant. It should be noted that the most was spent in 2008–2010 form 6.7 to 7.1 GBP per inhabitant.

A similar situation occurs in Poland. Here, the increase in expenditure was even more significant, as research expenditure in the transport sector increased fivefold from GBP 0.75 per inhabitant in 2000 to GBP 4.2 per inhabitant in 2016. However, in the period of 2004–2007 there was a decrease in expenditure in this up to GBP 0.2 per inhabitant.

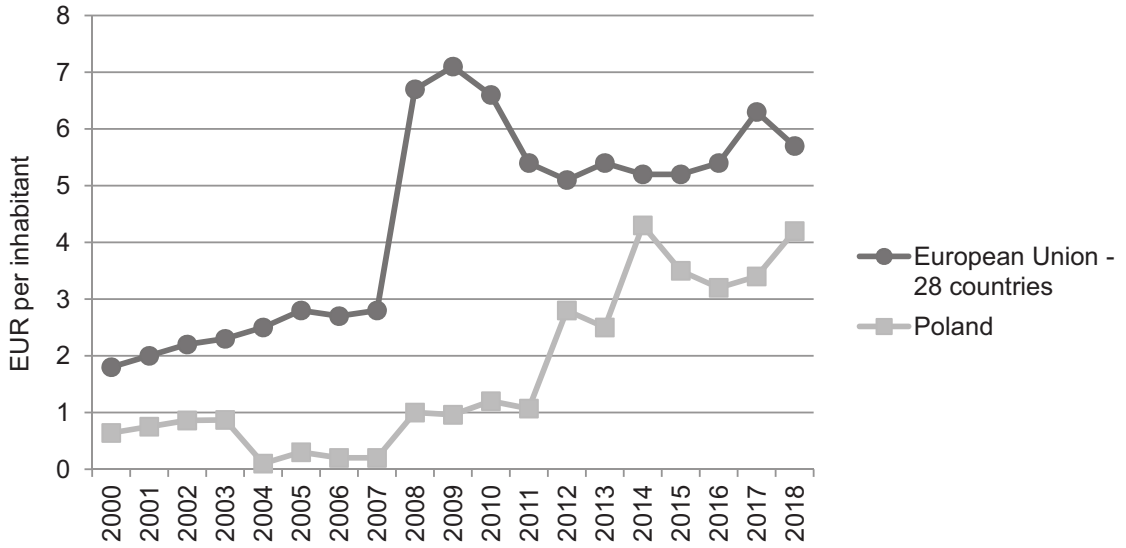

Figure 1. Budget expenditure on R&D in the field of transport, telecommunications and other infrastructure in Poland against the background of 28 EU countries

Rysunek 1. Wydatki budżetowe na badania i rozwój w dziedzinie transportu, telekomunikacji i innej infrastruktury w Polsce na tle 28 krajów UE

Source: own study based on Eurostat webpage https://ec.europa.eu/eurostat/web/science-technology-innovation/data/database [access: 05.11.2019].

In the last two decades, the level of budget expenditure on R&D in the transport, telecommunications and other infrastructure sector in EU countries has been at the level of 1.3–3.8% of total R&D expenditure (Fig. 2). There are two characteristic levels of these expenses. In 2000–2007, the level of expenditure was around 1.5% of all expenditure. In 2008, there was a visible increase in expenses to the level of 3.8%, followed by a gradual slight decrease in expenses to the level of 2.9% in 2018.

In Poland, it can be seen that in the years 2000–2003 and 2011–2018, the level of R&D expenditure in the transport, telecommunications and other infrastructure sectors in general research and development expenditure was higher than the average expenditure in the entire EU. In addition, since 2011, the level of these expenses has been growing steadily and quite dynamically and in 2018 reached 11.2% of all expenditure on R&D. Therefore, a high emphasis is placed on developing innovations in transport in Poland.

Analysing the situation in the scope of budget expenditure on R&D in the field of transport, telecommunications and other infrastructure in individual EU countries, it can be stated that the most budget is allowed in Sweden (Fig. 3). Respectively, GBP 18.9 per inhabitant in 2010 and GBP 16.5 per inhabitant in 2018. Malta and Lithuania spend the least on R&D in transport – around GBP 0.1 per inhabitant.

In 2010, Poland belonged to the group of countries least spending on research in the discussed area, but in 2018 the level of these expenses significantly raised Poland in this ranking. Unfortunately, but it can be seen that in most countries, spending on transport research has fallen in the years analysed. Only in eight countries there has been an increase.

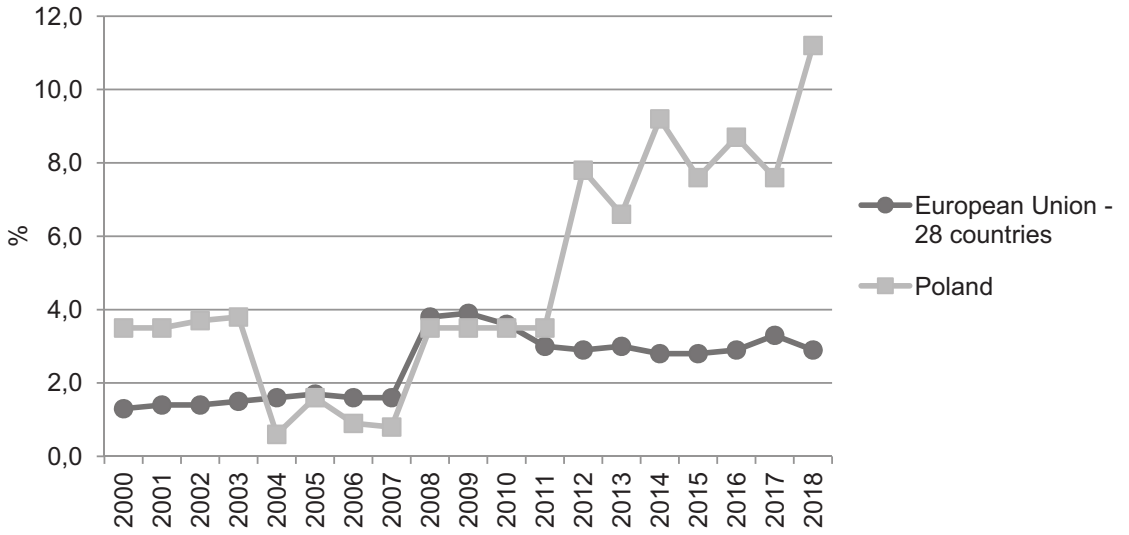

Figure 2. Share of budget expenditure on R&D in the transport, telecommunications and other infrastructure sector in total R&D expenditure in Poland against the background of 28 EU countries

Rysunek 2. Udział wydatków budżetowych na badania i rozwój w sektorze transportu, telekomunikacji i pozostałej infrastruktury w całkowitych wydatkach na badania i rozwój w Polsce na tle 28 krajów UE

Source: own study based on Eurostat webpage https://ec.europa.eu/eurostat/web/science-technology-innovation/data/database [access: 05.11.2019].

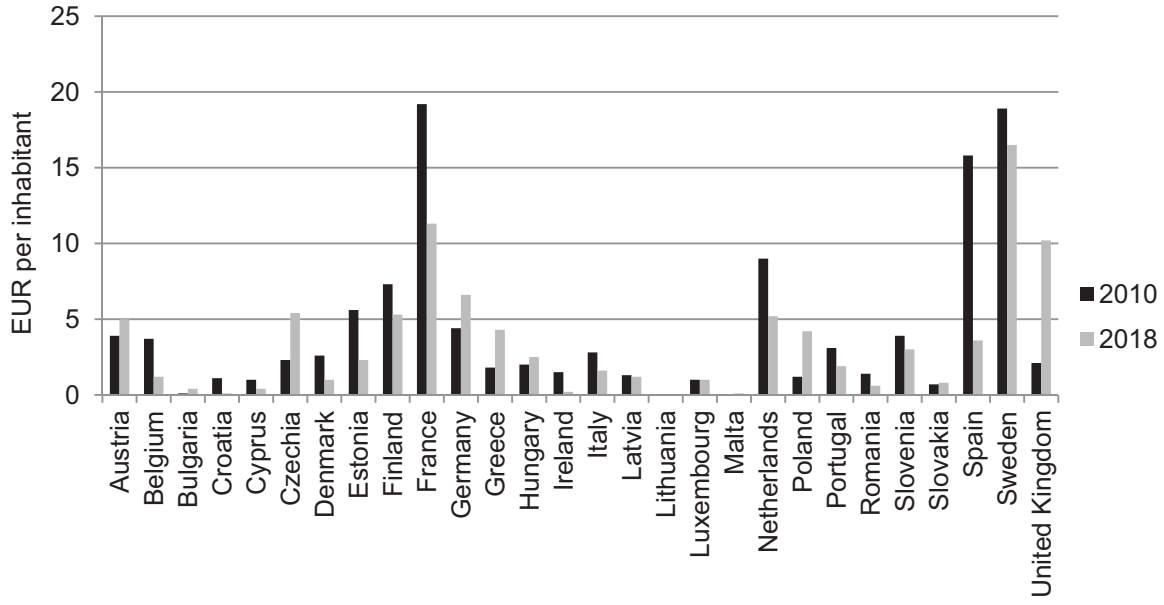

Figure 3. Budget expenditure on R&D in the field of transport, telecommunications and other infrastructure in individual EU countries

Rysunek 3. Wydatki budżetowe na badania i rozwój w dziedzinie transportu, telekomunikacji i innej infrastruktury w poszczególnych krajach UE

Source: own study of the authors based on Eurostat webpage https://ec.europa.eu/eurostat/web/science-technology-innovation/data/database [access: 05.11.2019].

Selected examples of innovative activities in the field of passenger transport in Poland and the EU

The expansion of transport networks contributes to the density of infrastructure, making travel more complicated. That is why more and more technologies supporting intermodality are being developed. An excellent example here is the Intermodal Journey Planning software using internet or mobile applications, which is a good way to plan travel and track disturbances. These applications use big data management technology and provide helpful information to drivers, making travel easier. The Great Britain was a pioneer in the application of this technology. Smart Motorway technology that allows a more even distribution of traffic due to road monitoring, or the use of mobile technology to track traffic data and communication with drivers, as well as smartphone applications informing drivers about the availability of parking spaces to improve parking in cities [PwC 2015]. In Poland, drivers can use similar applications, e.g. Yanosik. Due to interactivity and user involvement, current traffic incidents are always displayed. The application is a great alternative to CB Radio.

For several years, Carpooling has become fashionable, i.e. commuting to work, school and even on vacation. This fashion reached Europe from the USA, where ways to reduce car traffic in polluted and congested cities were sought. Carpooling consists in the fact that in a special application, e.g. BlaBlaCar, the driver reports the route of his journey, along with the number of available seats and the proposed cost of the trip. In turn, the potential passenger chooses from the offers presented the most favourable for him and reserves the journey. Such joint commutes contribute to the limitation of cars on the roads[1].

In recent years, many local governments have invested in Intelligent Road Traffic Management Systems. A good example is the Area Traffic Control System (SOSRD – System Obszarowego Sterowania Ruchem Drogowym) built in 2013 in Rzeszów. SOSRD affects the improvement of getting around the city. It consists of the following elements [Gmina Miasto Rzeszów n.d.]:

- traffic light control system that allows to maintain traffic flow and reduce waiting times at crossroads to a minimum;
- priority system for public transport vehicles, allocating first the right of transit to public transport;
- driver information system using variable content signs will allow for quick informing about difficulties, changes in traffic organization or recommended detours.

In the 21st century, innovations in fuel and propulsion technologies are dynamically implemented. The term electromobility has become the most popular concept in the last five years. The leaders in Europe are the Scandinavian countries, which are the most advanced in the implementation of electric drives in cars and buses. In such vehicles (BEV – Battery Electric Vehicle), electric drive is the only power source. This solution reduces exhaust emissions to zero only at the place of use of the vehicle, because the analysis of the "drawn bill: should take into account the emissions generated in the process of electricity production. And in many countries, electricity is produced mostly in coal-fired power plants. In passenger transport, the energy source for electric motors is energy accu-

[1] www.blablacar.pl [access: 06.11.2019].

mulated in high-power lithium-ion batteries. Charging batteries in electric buses: through a pantograph, induction loop and plug-in, i.e. a battery charger. This system is constantly improved, and the main barrier to the implementation of this drive is the cost of purchasing vehicles, as well as the construction of the necessary charging infrastructure. It is estimated that the cost of vehicles is almost twice as high as those powered by internal combustion engines [Sojka et al. 2016].

The innovative technology in transport is hydrogen drive. Fuel Cell Vehicles (FCVs) contribute to reducing emissions to the atmosphere. The product that results from the "combustion" is steam. It is a zero-emission transport. Hydrogen can be burned in a traditional internal combustion engine or used in fuel cells to generate energy that drives the engine [Burnewicz 2010]. The barrier to the popularization of this fuel is the negligible number of hydrogen distribution points.

In recent years, more and more self-governments of various European cities are analysing the possibility of implementing autonomous technologies in passenger transport. One of the first cities that has been testing small autonomous buses since 2019 is Vienna. Currently, small, 10-passenger vehicles are used, which use GPS to determine their position with an accuracy of 3 cm. Although the intention to build autonomous vehicles was to travel without a driver, every ride is supervised by a person. Another negative feature is the low speed of travel, because autonomous buses currently run at a maximum speed of up to 20 km/h [Urbanowicz 2019].

Another solution is monorail, which is a special kind of system similar to the metro – with a separate infrastructure, moving on a single rail. It is an underground class system, its unique feature is that it is mounted on elevated supports about 5–6 m high. Therefore, it provides high performance, maximum safety, and at the same time does not take up space that is lacking in cities. Monorail has similar parameters, traffic rules and level of safety as the underground, but the costs associated with the construction of these elevated structures are several times less than tunnelling [forsal.pl 2019]. The most advanced city in Poland, that has already developed the concept of locating a monorail train system, is Rzeszów. Subsequently, this system intends to be built by the Górnośląsko-Zagłębiowska Metropolis. The main barrier in the implementation of such an investment is the lack of legal regulations in Poland, allowing this type of transport for use, as well as high investment costs.

When discussing innovations in passenger transport, ambitious plans to build high-speed rail in Poland, an investment accompanying the creation of the Central Communication Port, cannot be missed. The plans assume the creation of so-called spokes, where from the central airport, completely new communication routes will be built in every direction of the country. It is assumed that by 2027, 1,100 km of double-track railway lines and 500 km of single-track railway lines will be built. The trains are to travel at speeds up to 250 km/h, and the journey time from the most distant provincial cities to the centre of Poland is to be two hours. The exception is to be Szczecin, where the trip is to last over three hours. Despite the fact that high-speed railways have been operating in Europe and the world for many years, this will be a long-awaited innovation on a national scale, as trains currently run on average at 120–160 km/h, and only on small sections from Warsaw to Gdańsk with maximum speed up to 200 km/h [Karnaszewski 2019].

Summary and conclusions

In the last two decades, innovations in passenger transport have been successively implemented in Poland and Europe, the aim of which is to effectively meet the existing needs in the field of passenger transport, and above all to effectively encourage passenger car drivers to use public transport. The introduction of new solutions in transport is possible thanks to the growing level of budget expenditure on research and development in the field of transport, telecommunications and other infrastructure. Only thanks to the close cooperation between science and business practice it is a condition for increasing innovation and implementing inventions. Thanks to this, the quality of passenger transport services is improved, new passengers are acquired, the satisfaction of current users is increased, and as a consequence the share of the passenger transport market is increased. In addition, congestion is reduced as well as a negative impact on the environment. People's quality of life is improving.

Despite favourable trends, it becomes necessary to further intensively develop completely new, breakthrough technologies that will enable further social and economic development. We should move away from oil and go into electromobility technologies. Thanks to material engineering, large energy resources can ultimately be stored in batteries, and fuel cells based on different forms of hydrogen should be widely used in high-capacity vehicles. In turn, the governments of individual countries must respond quickly to emerging technological solutions and change legislation so that the resulting innovations can be quickly implemented into practice. The European Union should continue its policy on sustainable transport, which makes it possible to financially support many institutions responsible for passenger transport. Due to such activities, the perspective of ecologically clean, safe and energetically sustainable transport is becoming more and more close and realistic.

References

Bąk M., 2015: Potencjał innowacyjny transportu w Unii Europejskiej [Innovative potential of transport in the European Union], Logistyka 3, 5502–5512.

Bąk M., 2016: Wydatki na badania i rozwój w transporcie europejskim w świetle polityki innowacyjności UE [Expenditure on research and development in European transport in the light of EU innovation policy], Problemy Transportu i Logistyki 2, 73–88.

Bukowski M., Szpor A., Śniegocki A., 2012: Potencjał i bariery polskiej innowacyjności [Potential and barriers to Polish innovation], Instytut Badań Strukturalnych, Warszawa, [electronic source] https://ibs.org.pl/app/uploads/2016/03/IBS_Report_02_2012_pl.pdf [access: 06.11.2019].

Burniewicz J., 2010: Perspektywa innowacyjna transportu i logistyki [Innovative perspective of transport and logistics], [in:] E. Załoga, B. Liberadzki (Eds.), Innowacje w transporcie, korzyści dla użytkownika [Innovations in transport, benefits for the user], Wydawnictwo Naukowe Uniwersytetu Szczecińskiego, Szczecin, 51–64.

Christensen C.M., 2010: Przełomowe innowacje [Breaking innovations], Wydawnictwo Naukowe PWN, Warszawa.

Directorate-General for Mobility and Transport – DG MOVE, 2011: White Paper on transport, [electronic source] https://ec.europa.eu/transport/sites/transport/files/themes/strategies/doc/2011_white_paper/white-paper-illustrated-brochure_en.pdf [access: 06.11.2019].

European Commission, 2019: Transport Research and Innovation in Horizon 2020, [electronic source] https://ec.europa.eu/transport/themes/research/horizon2020_en [access: 06.11.2019].

Eurostat, 2019: Transport statistics introduced, [electronic source] https://ec.europa.eu/eurostat/statistics-explained/index.php/Transport_statistics_introduced [access: 05.11.2019].

forsal.pl, 2019: Olszówka: Monorail jest kilkakrotnie tańszy niż metro w tunelu (wywiad z 10.10.2019) [Monorail is several times cheaper than the subway in the tunnel (interview of 10.10.2019), [electronic source] https://forsal.pl/artykuly/1434365,olszowka-monorail-jest-kilkakrotnie-tanszy-niz-metro-w-tunelu-wywiad.html [access: 07.11.2019].

Fundacja Centrum Analiz Transportowych i Infrastrukturalnych – CATI, 2012: Innowacyjność w transporcie do 2020 roku – podstawowe pojęcia i tezy [Innovation in transport until 2020 – basic concepts and theses], Warszawa.

Geerlings H., 1999: Meeting the Challenge Sustainable Mobility. The Role of Technological Innovation, Springer, Berlin–Heidelberg.

Główny Urząd Statystyczny – GUS, n.d.: Pojęcia stosowane w statystyce publicznej. Hasło: działalność innowacyjna [Terms used in public statistics. Definition: Innovation activities], [electronic source] http://stat.gov.pl/metainformacje/slownikpojec/pojecia-stosowane-w-statystyce-publicznej/759,pojecie.html [access: 05.11.2019].

Gmina Miasto Rzeszów, n.d.: Rzeszowski Inteligentny System Transportowy [Rzeszów Intelligent Transport System], [electronic source] http://www.transport.erzeszow.pl/zakres-rzeczowy/rzeszowski-inteligentny-system-transportowy [access: 06.11.2019].

Godecki T., 2008: Pomiar innowacyjności gospodarki przy użyciu pośrednich i bezpośrednich wskaźników innowacji Measuring the innovativeness of economy using direct and indirect innovation indicators], Zarządzanie Publiczne 3, 27–50.

Karnaszewski P., 2019: Centralny Port Komunikacyjny to także 1,6 tys. km nowych linii kolejowych [The Central Communication Port is also 1.6 thousand km of new railway lines], Forbes on-line of 25.03.2019, [electronic source] https://www.forbes.pl/transport-i-logistyka/centralny-port-komunikacyjny-to-takze-16-tys-km-nowych-linii-kolejowych/53xs82s [access: 06.11.2019].

Lakshmanam T.R., Anderson W.P., 2009: Transportation in the 21st Century Technological Innovation, [in:] T.J. Kim (Ed.), Transportation Engineering and Planning. Vol. 2, Eolss Publishers, Oxford, 132–163.

Mazur-Wierzbicka E., 2015: Działalność innowacyjna przedsiębiorstw w Polsce [Innovative activity of enterprises in Poland], Zeszyty Naukowe Małopolskiej Wyższej Szkoły Ekonomicznej w Tarnowie 26 (1), 97–109.

Ministerstwo Infrastruktury, 2019: Strategia Zrównoważonego Rozwoju Transportu do 2030 roku [Strategy for Sustainable Transport Development until 2030], [electronic source] https://www.gov.pl/web/infrastruktura/projekt-strategii-zrownowazonego-rozwoju-transportu-do-2030-roku2 [access: 06.11.2019].

OECD, 2005: Oslo Manual: Guidelines for Collecting, Reporting and Using Data on Innovation, 3rd ed., The Measurement of Scientific, Technological and Innovation Activities, OECD Publishing, Paris.

PriceWaterhouseCoopers – PWC, 2015: Ocena światowego rynku infrastruktury transportowej: Perspektywa do 2025 r. [Assessment of the global transport infrastructure market: Per-

spective until 2025], November report, [electronic source] https://www.pwc.pl/pl/pdf/ocena-swiatowego-rynku-infrastruktury-transportowej-raport-pwc.pdf [access: 07.11.2019].
Sojka K., Burdzik R., Łazarz B., Domin J., 2016: Research on economy of transport using fleet management systems, Prace Naukowe Politechniki Warszawskiej. Transport 111, 511–519.
Urbanowicz W., 2019: Wiedeń uruchamia linię autonomicznego autobusu. Na „ostatnią milę [Vienna launches an autonomous bus line. For the "last mile"], [electronic source] https://www.transport-publiczny.pl/mobile/wieden-uruchamia-linie-autonomicznego-autobusu-na-34ostatnia-mile34-61809.html [access: 07.11.2019].
Wiszniewski W., 1999: Innowacyjność polskich przedsiębiorstw przemysłowych [Innovativeness of Polish industrial enterprises]. Instytut Organizacji i Zarządzania w Przemyśle „Orgmasz", Warszawa.

Correspondence address:

Sławomir Stec, PhD, Eng
(https://orcid.org/0000-0002-5645-7507)
Ignacy Łukasiewicz Rzeszów of University of Technology
Department of Finances, Banking and Accounting
Powstańców Warszawy Ave. 12, 35-959 Rzeszów, Poland
e-mail: s.stec@prz.edu.pl

Ekonomika i Organizacja Logistyki
4 (3), 2019, 55–64

DOI: 10.22630/EIOL.2019.4.3.23

Teresa Gądek-Hawlena
University of Economics in Katowice

The efficiency of actions to improve road safety – assessing the implementation of the programme objectives

Skuteczność działań na rzecz poprawy bezpieczeństwa ruchu drogowego – ocena realizacji założeń programowych

Abstract. Road accidents and, above all, their negative consequences are a serious problem worldwide. Preventing them is a challenge that involves many actions taken by governments, international organisations, economic operators, and non-profit organisations. The actions that are to lead to a significant reduction in the number of casualties and fatalities are considered essential. In order to make a significant change in this field, it is necessary to take rational action. In Poland, the objectives for the improvement of road safety and the methods of achieving them were endorsed in the National Road Safety Programme 2013–2020. As the period of these seven years is to come to an end, this article will present the achieved results for years 2010–2018 in relation to the main causes of accidents induced by drivers.

Key words: road safety, National Road Safety Programme 2013–2020, road safety management

Synopsis. Wypadki drogowe, a przede wszystkim ich negatywne skutki są poważnym problemem na całym świecie. Zapobieganie im stanowi wyzwanie i wiąże się z podejmowaniem wielu działań przez rządy państw, organizacje międzynarodowe, podmioty gospodarcze czy organizacje non-profit. Jako zasadnicze uznaje się te, które mają doprowadzić do znacznej redukcji liczby zabitych i rannych. Aby wpłynąć w istotny sposób na zmianę w tym zakresie, niezbędne jest podjęcie racjonalnych działań. W Polsce cele w zakresie poprawy bezpieczeństwa ruchu drogowego oraz metody ich osiągnięcia przyjęte zostały w Narodowym Programie Bezpieczeństwa Ruchu Drogowego 2013–2020. Ponieważ okres ten dobiega końca, w artykule przedstawiono uzyskane efekty w latach 2010–2018 w odniesieniu do głównych przyczyn wypadków powodowanych przez kierowców.

Słowa kluczowe: bezpieczeństwo ruchu drogowego, Narodowy Program Bezpieczeństwa Ruchu Drogowego na lata 2013–2020, zarządzanie bezpieczeństwem ruchu drogowego

Introduction

In view of the high number of road accidents worldwide [WHO 2019], a global action has been taken to improve road safety. The main courses of action are reflected in documents of both international and national level [Communication COM(2010) 389, WHO 2011]. In Poland (pertaining to the national level of action) it was the National Road Safety Improvement Programme 2013–2020 to set out the objectives and directions of actions to improve road safety, and the implementation of those is expected to result in reduction in number of:

- fatalities (FATs) by at least 50% from 2020 onwards;
- serious casualties (CASs) by at least 40% by 2020 as compared to 2010.

The aim of this article is an attempt to examine the implementation of the general objectives set out in the National Road Safety Programme 2013–2020 and to analyse the changes related to the reduction of fatalities and casualties while taking into account the main causes of accidents resulting from drivers' actions in the years 2010–2018. The adapted research methods consist of a diagnosis of both the literature on the subject and program documents, and an analysis of quantitative data showing the discussed problem.

The systemic approach to road safety management

The matters of road safety and the initiatives to improve it appeared much earlier than the first motor vehicles and – in essence – were similar to those that are currently underway [Dąbczyński 2011, Serbeńska 2015]. The contemporary approach, which was the subject of scientific research [Shapiro and Mortimer 1969, Sabey 1991] and the activities of the road safety management authorities, began to take shape when the first motor vehicles were built[1] and has changed over time. The development stages of road safety research are set out within Figure 1.

As can be made out from Table 1, the approaches to road safety research have changed due to addressing different causes of road accidents and changes in the approach to road safety management. The first concepts for research related to road safety management emerged in the 1950s. As a result of constant changes in the area of motorisation, the significant number of road accidents, and their negative socio-economic impact, the current approach to achieving the goals of improving road safety has been changing. The current approach is systemic in nature. According to the basic assumption of system theories, an accident is the result of a mismatch between system components. Conforming to this theory, it is not possible for any part of the system to be more relevant than others [Elvik et al. 2009]. It is the relation between the elements of the system, and not the nature of the components themselves, that determines the system's properties and functioning [Skyttner 2005, Larssonet al. 2010]. This theory is considered the best one to be developed so

[1] The date of the beginning of automobilism is often assumed to be year 1885, when Karol Benz, the founder and co-owner of the factory Mannheimer Gasmotoren-Fabrik A.G. in Mannheim, and engineer Gottlieb Daimler, the technical director of the gas engine factory Deutz, independently of each other, completed the construction of the prototypes of the first motor vehicles with internal combustion engines [Grzywacz and Burnewicz 1968, Brzosko 1982, Gądek-Hawlena and Żabińska 2017].

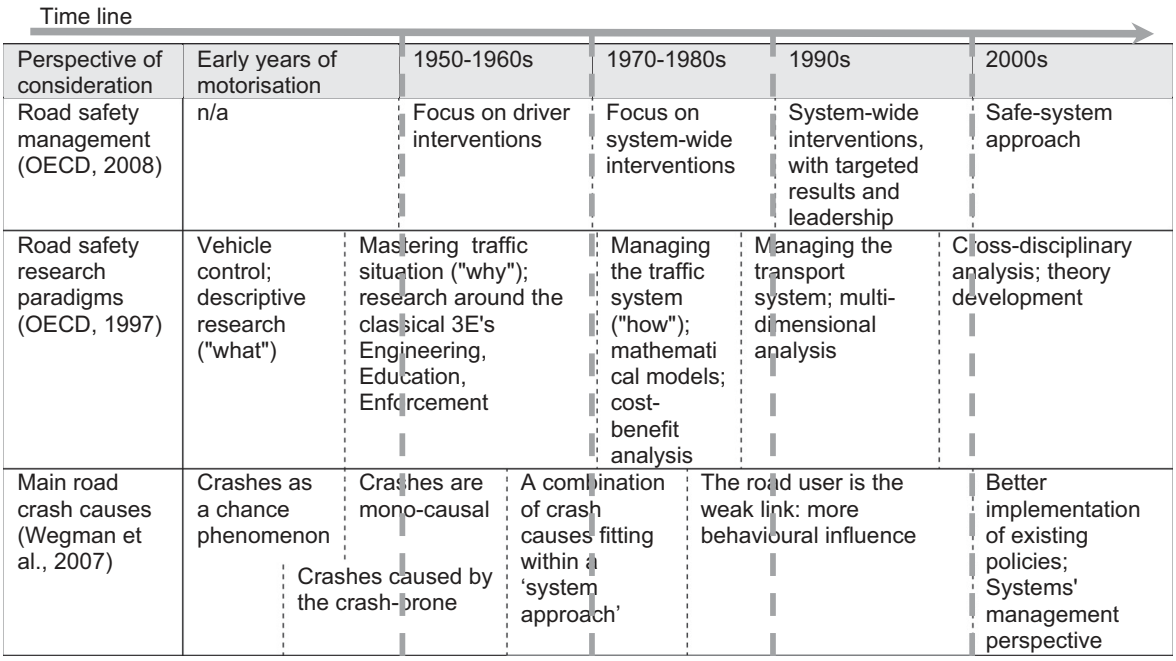

Figure 1. The development stages of road safety research
Rysunek 1. Etapy rozwoju badań dotyczących bezpieczeństwa ruchu drogowego
Source: [Hakkert and Gitelman 2014].

far. Using system theories and models, all the dependencies and relationships affecting the cause of the accident (the so-called time and space transfer factors), and the factors acting on site and at the time of the road accident are sought. This search for correlation makes it possible to build a system of preventive actions, and a system for monitoring and controlling the functioning of individual relationships and dependencies. According to the systemic approach to safety management – again, at national and regional levels – three interrelated elements should be taken into consideration: institutional management functions, specific actions (interventions), and results [KRBRD 2013]. An institutional approach means a complex institutional structure including some cooperating and collaborating bodies that support the necessary tasks and processes to prevent and reduce road traffic injuries [Muhlrod et al. 2011, Papaclimition and Yannis 2013]. The complexity of actions to improve road traffic safety causes the process of road traffic safety management to require modern tools that would help to identify threats to road users, to assess the safety of road infrastructure, and to select effective measures to improve road traffic safety [Jamroz et al. 2014]. At the same time, it is not simple to determine exactly how the implementation of (many) road safety interventions would affect its development, i.e. the obtained results. A special edition of "Science on Safety Science on Scientific Research on Road Safety Management" presents various approaches to the subject taken from different countries. Topics discussed included the ways to support decision making on the design of individual security interventions, questions on how to design strategies with multiple interventions in which those can interact and how to evaluate the implementation of individual interventions and implemented strategies. It was noted that the design and evaluation of road safety programs did not seem to be a very popular topic

among researchers, given the limited number of mutual interviews on this topic [Wegman et al. 2015]. Bax et al. [2009] stated that the designers of road safety programmes make little or no use of the research results but that there is some growing interest from both research and policy-making areas. One reason may be that more and more countries are setting quantitative road safety targets (e.g. 50% fewer road fatalities in 10 years). Data and knowledge are the necessary elements to establish realistic objectives. As those who set the targets are held accountable for achieving them, more and more attention is being paid to the monitoring progress over time as well as to using the results to further improve their achievements [Wegman and Hagenzieker 2010].

Improving road safety in the light of the programme objectives – actions in favour of drivers

The study titled "The critical values of driver response time and their influence on lowering the reliability and safety of road traffic" indicated that the main risk factors on roads are: human, as a participant of the traffic, the vehicle, and the road. These factors may impact the risk individually or several factors may combine [Kornacki et al. 2017]. Based on research and statistics, the main causes of human-induced road accidents include speeding, pedestrian and cyclist behaviour, young drivers' behaviour, alcohol, medicine and drugs, driver fatigue, and mobile phone use. Other causes, independent from human behaviour, include insufficient visibility, and road-related and vehicle-related factors [Jackisch et al. 2015].

Under the National Road Safety Programme 2013–2020, safe behaviour of road users, including drivers, is one of its pillars. The fundamental actions in favour consist of [KRBRD 2013]:

- shaping safe activities of road users – this refers to developing a conscious and cultural road user who respects the rights of others. This goal can be achieved mainly through activities related to proper education and traffic surveillance. Supervising road user behaviour is preventive through, i.e. discouraging dangerous behaviour;
- protection of road users – the aim is to carry out safety measures aimed at changing the behaviour of road users to ensure their safety through systems they do not control and sometimes are not even aware of. Mainly, these activities include: engineering activities (the construction of secure roads and surroundings), development of modern technology (safety systems in vehicles), control, or supervision and information activities.

A certain number of measures, particularly concerning drivers, have been taken since 2013. According to the reports of the National Road Safety Council (Krajowa Rada Bezpieczeństwa Ruchu Drogowego), in the years 2013–2019, among others, the following operations were carried out: the control of professional drivers' licences, the start of many social campaigns, including, for example, the Roads of Trust programme aimed at protecting the life and health of people on national roads, the "Armadillo Club Clicks in the Seats", a number of campaigns concerning the issue of driving under the influence of alcohol or the problem of using passive safety devices in cars, and a campaign related to shaping safe road etiquette for road users. Another means of concern for the safety of road users was the police intensifying their supervision in areas with a high level of pedestrian

risk [KRBRD 2014, 2015, 2018]. Apart from the National Road Safety Council, there are business entities that are also active in improving road safety in line with the programme assumptions: the company Solaris conducting so-called Safe Driver trainings, breweries actively indicating the negative effects of drink-driving, PKN Orlen among others trying to take care of road safety as part of CSR, as well as non-governmental organisations can be mentioned. The actions taken by stakeholders in this respect are based on their awareness of bearing costs in connection to road accidents.

The effects of actions to improve road safety in Poland in 2013–2018

As specified in the National Road Safety Programme, the fatalities' toll caused by accidents should be less than 50% by 2020, as compared to 2010, and is set to be no more than 2,000 fatalities in 2020. In 2018, the number of road accident fatalities was 662 victims higher than the assumed level (Fig. 2); however, the assumptive target is to be achieved in 2020 and seems quite realistic. The situation is decidedly worse for the casualties in road accidents. As shown in Figure 2, the number of road accident casualties in 2018 was 37,359, 30% less than in 2010. It can therefore be concluded that a systemic approach to road safety management is only effective in that one field. No less than one in the case of accidents caused by drivers, no visible improvement was observed.

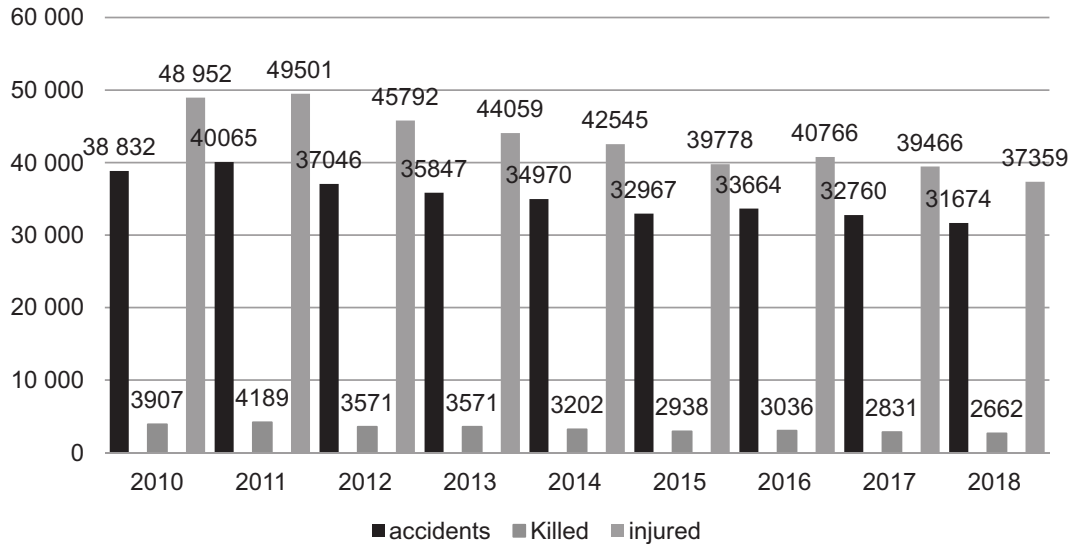

Figure 2. The structure of road accidents in Poland in years 2010–2018
Rysunek 2. Struktura wypadków drogowych w Polsce w latach 2010–2018
Source: own elaboration based on [Komenda Główna Policji 2017, 2019].

In Poland, since 2015, the main cause of road accidents is the failure to respect the right of way (Fig. 3). As shown in Figure 3, there are no significant changes in the structure of endured fatalities and casualties in road accidents which would be the result of not respecting the right of way, despite a substantial amount of training courses and social campaigns or police control and the implementation of modern ITS solutions. In both cases, i.e. the number of FATs and CASs, the fall in the number of victims is less than 50%.

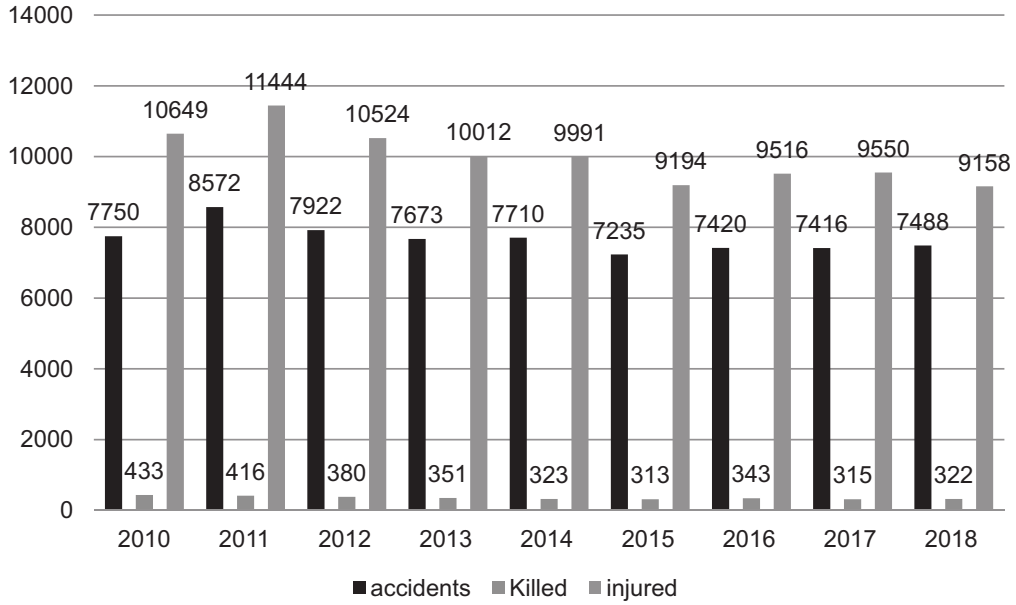

Figure 3. The structure of road accidents – failure to respect the right of way
Rysunek 3. Struktura wypadków drogowych – nieprzestrzeganie pierwszeństwa przejazdu
Source: own elaboration based on [Komenda Główna Policji 2016, 2017, 2018, 2019].

Another cause of road accidents in Poland is speeding. The structure of accidents resulting from driving a car at excessive speed is shown in Figure 4. The number of fatalities and casualties, even if the cause of the accident was indeed speeding, has not changed radically and is at an appropriate decrease of 339 FAT and 4,850 CAS.

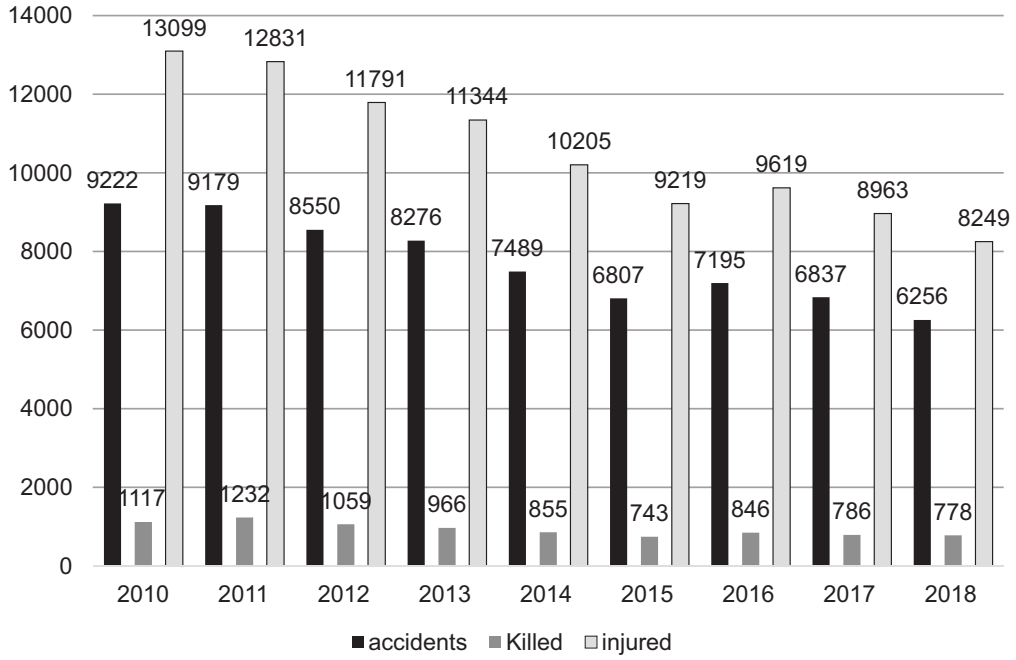

Figure 4. The structure of road accidents – excessive speeding
Rysunek 4. Struktura wypadków drogowych – nadmierna prędkość
Source: own elaboration based on [Komenda Główna Policji 2016, 2017, 2018, 2019].

Despite the police surveillance, the distribution of speed cameras or preventive measures, the results are unsatisfactory. Perhaps one of the reasons for these results is the increase in the number of fast cars and their safety systems that put the driver alertness to sleep.

The last factor discussed is the issue of not yielding the right of way to pedestrians (Fig. 5). From the presented list of tolls, the current one is much worse than the others. There are no positive changes in the number of fatalities, and even in 2018 the number of FATs was higher than in 2010. Concerning the toll of casualties, the decrease was 1,254 CAS. This situation is undoubtedly quite unfavourable and requires a change in the approach to the problem.

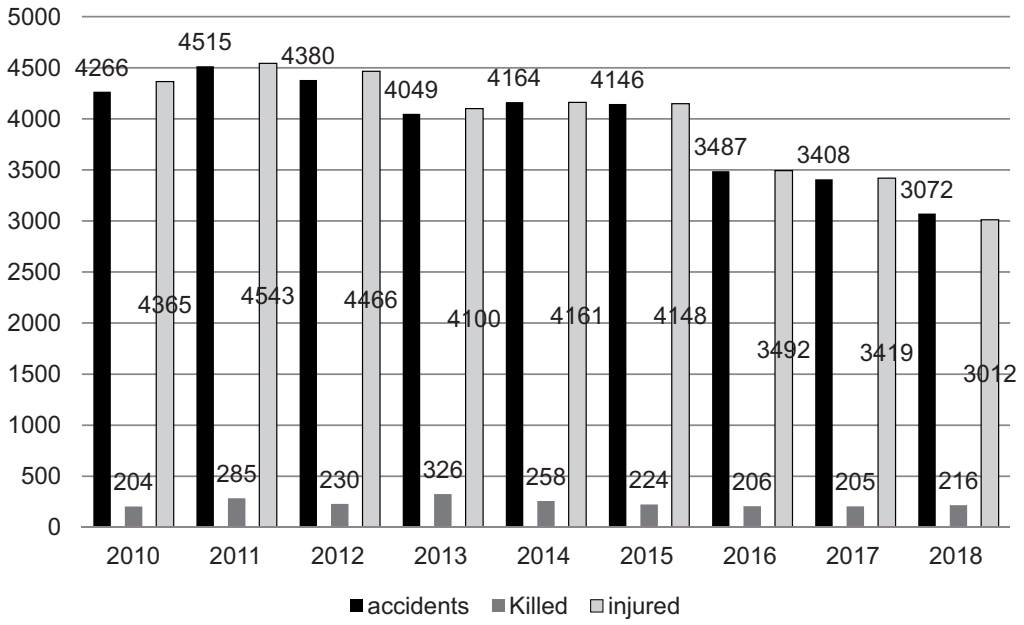

Figure 5. The structure of road accidents – not yielding the right of way to pedestrians
Rysunek 5. Struktura wypadków drogowych – nieustąpienie pierwszeństwa pieszemu

Source: own elaboration based on [Komenda Główna Policji 2016, 2017, 2018, 2019].

Conclusions

To sum up the presented observations, several conclusions can be drawn:

1. The steps to improve road safety are taken on the basis of objectives and directions of action set out in the programme documents and are based on a systemic approach.
2. When considering the overall number of fatalities and casualties in road accidents, it is to be expected that the objectives set out in the National Road Safety Programme 2013–2020 will be achieved, or that we will be significantly closer to achieving them.
3. The main factor of causing road accidents is man, including, above all, motor vehicle drivers, and, despite the important targets set for improving the safety of road users and the many actions taken, these initiatives are still not working. The number of fatalities and casualties during the considered period, either due to lack of right of way, speeding, or not yielding the right of way to pedestrians, is still above 50% compared to 2010.

4. However, some new action taken in this field should include autonomous vehicles. If in autonomous vehicles at Level 5 – Full Automation the driver will not participate in the driving process and the car will operate without him, then the issue of man causing accidents should be expected to resolve itself.
5. A significant problem that may be causing an increase in the number of accidents can be the transition period, i.e. the operation of traditional and autonomous vehicles but, at this stage, it is quite difficult to take action in this field, due to the lack of such occurrences.

Therefore, it can be concluded that the implementation of the programme objectives did not bring the intended effects in all fields.

References

Bax C.A., Elvik R., Veisten K., 2009: Knowledge utilisation in road safety policy: barriers in the use of knowledge from economic analysis, Knowledge. Technology. Policy 22 (4), 275––285.

Brzosko E., 1982: Rozwój transportu w Polsce w latach 1918–1939 [The development of transport in Poland in 1918–1939], Rozprawy i Studia 46. Wyższa Szkoła Pedagogiczna w Szczecinie, Szczecin.

Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions towards a European road safety area: policy orientations on road safety 2011–2020. COM(2010) 389.

Dąbczyński Z., 2011: Zarys historii rozwoju zasad zarządzania ruchem drogowym [Outline of road traffic management development], Drogownictwo 7–8, 264–266.

Elvik R., Høye A., Vaa T., Sørensen M., 2009: The Handbook of Road Safety Measures, Emerald Publishing, Bingley.

Gądek-Hawlena T., Żabińska T., 2017: Transport w turystyce [Transportation in tourism], Wydawnictwo Uniwersytetu Ekonomicznego w Katowicach, Katowice.

Grzywacz W., Burnewicz J. (Eds.), 1968: Ekonomika transportu [Transport economics], Wydawnictwa Komunikacji i Łączności, Warszawa.

Hakkert A.S., Gitelman V., 2014: Thinking about the history of road safety research: Past achievements and future challenges, Transport Research. Part F. Traffic Psychology and Behaviour 25, 137–149.

International Transport Forum – ITF, 2008: Ambitious Road Safety Targets and the Safe System Approach, Towards Zero, https://doi.org/10.1787/9789282101964-en

Jackisch J., Sethi D., Mitis F., Szymański T., Arra I., 2015: European Facts and the Global Status Report on Road Safety 2015, World Health Organization, Copenhagen.

Jamroz K., Budzyński M., Kustra W., Michalski L., Gaca S., 2014: Tools for road infrastructure safety management – Polish experiences, [in:] F.G. Benitez, R. Rossi (Eds.) 17th Meeting of the EURO Working Group on Transportation, EWGT2014, 02–04.07.2014 Sevilla, Transportation Research Procedia, Vol. 3, 730–739.

Komenda Główna Policji, 2016: Wypadki drogowe w Polsce w 2015 r. [Road accidents in Poland in 2015], Warszawa.

Komenda Główna Policji, 2017: Wypadki drogowe w Polsce w 2016 r. [Road accidents in Poland in 2016], Warszawa.

Komenda Główna Policji, 2018: Wypadki drogowe w Polsce w 2017 r. [Road accidents in Poland in 2017], Warszawa.

Komenda Główna Policji, 2019: Wypadki drogowe w Polsce w 2018 r. [Road accidents in Poland in 2018], Warszawa.

Kornacki A., Wawrzosek J., Bochniak A., Szymanek A., Pawlak H., 2017: Krytyczne wartości czasu reakcji kierowcy i ich wpływ na obniżenie niezawodności i bezpieczeństwa ruchu drogowego, Eksploatacja i Niezawodność – Maintenance and Reliability 19 (1), 142––148.

Krajowa Rada Bezpieczeństwa Ruchu Drogowego – KRBRD, 2013: Narodowy Program Bezpieczeństwa Ruchu Drogowego 2013–2020 [National Road Safety Program 2013––2020], [electronic source] https://www.krbrd.gov.pl/files/file/NP-BRD-2020_przyjety_przez_KRBRD.pdf [access: 20.01.2019].

Krajowa Rada Bezpieczeństwa Ruchu Drogowego – KRBRD, 2014: Program Realizacyjny na lata 2014–2015 do Narodowego Programu Bezpieczeństwa Ruchu Drogowego 2013–2020 [Implementation Program 2014–2015 to the National Road Safety Programme 2013––2020].

Krajowa Rada Bezpieczeństwa Ruchu Drogowego – KRBRD, 2015: Program Realizacyjny na lata 2015–2016 do Narodowego Programu Bezpieczeństwa Ruchu Drogowego 2013–2020 [Implementation Program for 2015–2016 to the National Road Safety Programme 2013––2020].

Krajowa Rada Bezpieczeństwa Ruchu Drogowego – KRBRD, 2018: Program realizacyjny na lata 2018–2019 do Narodowego Programu Bezpieczeństwa Ruchu Drogowego 2013–2020 [Implementation program for 2018–2019 to the National Road Safety Programme 2013––2020].

Larsson P., Dekker S.W., Tingvall C., 2010: The Need for a Systems Theory Approach to Road Safety, Safety Science 48 (9), 1167–1174.

Muhlrad N., Gitelman V., Buttler I. (Eds.), 2011: Road Safety Management Investigation Model and Questionnaire, Deliverable 1.2 of the EC FP7 Project DaCoTA.

Organization for Economic Co-operation and Development – OECD, 1997: Continuing Policy and Research Challenge, [in:] Road Transport Research: Outlook 2000, OECD Publishing, Washington.

Papaclimition E., Yannis G., 2013: Is road safety management linked to road safety performance?, Accident Analysis and Prevention 59, 593–603.

Sabey B.E., 1991: Road Safety: Research and Reality, 6th Reuben Smeed Memorial Lecture, Transportation 18 (2), 111–130.

Serbeńska A., 2015: Śladem drogowej myśli inżynierskiej [On the trail of road engineering thought], [electronic source] https://edroga.pl/drogi-i-mosty/sladem-drogowej-mysli-inzynierskiej-020211381 [access: 21.01.2019].

Shapiro L., Mortimer R.G., 1969: A Literature Review and Bibliography of Research and Practice in Pedestrian Safety. Report HUF-3 Highway Safety Research Institute, Institute of Science and Technology, the University of Michigan, Ann Arbor.

Skyttner L., 2005: General Systems Theory: Problems – Perspectives – Practice, Hackensack.

Wegman F., Berg H-Y., Cameron I., Thompsonc C., Siegrist S., Weijermars W., 2015: Evidence--based and data-driven road safety management, IATSS Research 39 (1), 19–25.

Wegman F., Hagenzieker M., 2010: Scientific research on road safety management. Special issue, Safety Science 48 (9), 1081–1224.

Wegman F., Johnston I., Kroj G., Lotan S., Pain R., 2007: Road Traffic Safety Research and Education in Israel, Peer Review by an International Experts Advisory Committee.

World Health Organization – WHO, 2011: Global Plan for the Decade of Action for Road Safety 2011–2020, [electronic source] https://www.who.int/roadsafety/decade_of_action/plan/global_plan_decade.pdf [access: 27.02.2019].

World Health Organization – WHO, 2019: Global Status Report On Road Safety 2018, Geneva.

Correspondence address:

Teresa Gądek-Hawlena, PhD
(https://orcid.org/0000-0003-4350-1246)
University of Economics in Katowice
Department of Transport
1 Maja St. 50, 40-287 Katowice, Poland
e-mail: gadek@ue.katowice.pl

Ekonomika i Organizacja Logistyki
4 (3), 2019, 65–75

DOI: 10.22630/EIOL.2019.4.3.24

Michał Kruszyński[1], ***Nataliya Struk***[2]
[1] International University of Logistics and Transport in Wrocław
[2] Ivan Franko National University of Lviv

Position and conditions of development of intermodal transport in Poland

Pozycja i uwarunkowania rozwoju transportu intermodalnego w Polsce

Abstract. The purpose of this paper is to present the development of intermodal freight transport in Poland for years 2010–2018. The study presents determinants and prospects of intermodal freight transport development in upcoming years. Intermodal transport in Poland is developing dynamically. It is determined by the geographical location of the country, the dense network of railway lines, the growing number of intermodal terminals and the increasing number of intermodal railway carriers. In the years 2010–2018, the volume of intermodal transport carried out using rail transport increased to 12.6 million t. Transport performance in the area of cargo transportation in 2018 reached the level of 6.2 billion tkm.

Key words: transport, combined transport, intermodal transport

Synopsis. Celem artykułu jest zaprezentowanie rozwoju intermodalnego transportu towarowego w Polsce w latach 2010–2018. Przedstawiono uwarunkowania i perspektywy rozwoju intermodalnego transportu towarowego w nadchodzących latach. Transport intermodalny w Polsce rozwija się dynamicznie. Rozwój ten jest wspomagany przez położenie geograficzne kraju, gęstą sieć linii kolejowych, rosnącą liczbę terminali intermodalnych i intermodalnych przewoźników kolejowych. W latach 2010–2018 wielkość transportu intermodalnego realizowanego za pomocą transportu kolejowego wzrosła do 12,6 mln t. Wydajność transportu w obszarze transportu ładunków w 2018 roku osiągnęła poziom 6,2 mld tkm.

Słowa kluczowe: transport, transport kombinowany, transport intermodalny

Introduction

Transport is considered a branch of the national economy that significantly determines economic and social progress [Klimek 2010]. In the national economy it plays the role of an instrument for the exchange of goods and services and is a factor, determining the choice of production location as well as the settlement in a given area. It generates an increase in gross domestic product (GDP) and development of the economy as a whole. It

also acts as an instrument securing the achievement of socially useful goals. This function refers to the prevention of communication exclusion, and also facilitates access to various spheres of life, e.g. health care, cultural institutions, educational institutions at all levels, as well as workplaces [Grzywacz et al. 1989]. Transport is an important pillar of modern society and economy, it forms the basis of the European integration process and is closely integrated with the creation of the internal market [Walasek 2018].

There are three terms in the transport area that need to be defined; we are talking about combined transport, intermodal transport and multimodal transport. Combined transport is a highly complex transport process in which loads are moved using means of transport representing different modes of transport. In the area of terminology accompanying combined transport, the concepts of multimodal transport and intermodal transport are very often used. These terms were defined and interpreted in 1998 on the basis of combined transport terminology [ECMT 1993] developed by the United Nations Economic Commission for Europe (UN/ECE), the European Conference of Ministers of Transport (ECMT) and Eurostat. Based on the cited document, it is assumed that multimodal transport is treated as the transport of goods for which at least two different modes of transport are used, and the goods may change the loading unit after changing the means of transport. In the case of multimodal transport, there are no restrictions specifying the share of road transport in relation to other modes. Intermodal transport differs from multimodal transport in that the load on the entire transport route stays in the same loading unit. In turn, combined transport is included in intermodal transport, in which a load unit (without reloading goods) is transported between terminals mostly by rail, inland waterway or sea, and its delivery to transshipment terminals is carried out, to a minimum extent, by road [Mindur 2014]. In the case of combined transport, one of the means of transport is passive and the other active.

Intermodal transport, which includes combined transport, is an alternative to road transport. Undoubtedly, it contributes to an increase in the share of transport in the greener modes of transport, which includes rail, sea and inland waterway transport. The implementation of cargo transportation using intermodal transport forces to take into account many organizational, as well as technical and technological aspects.

In the process of implementing intermodal transport technology, it is necessary to undertake infrastructural as well as legislative projects that will be aimed at applying preferences for this type of transport from the state. The development of intermodal transport will not be possible without changes at the microeconomic level. If business entities do not make a logistic revolution, the core of which will be the introduction of modern transport technologies and containerization of cargo, then the development of intermodal transport will not be possible.

Intermodal transport falls within the area of unified transport technologies. The classification of unified technologies concerns the criterion of transshipment method, the criterion of an integrated loading unit, as well as the criterion for the location of the transshipment device. In the area of the first criterion, i.e. the method of transshipment, there are [Kwaśniowski et al. 2004]:

- horizontal transshipment (roll on – roll off);
- vertical transshipment (lo – lo);
- mixed transshipment (com – ro).

Considering the criterion of an integrated loading unit, unified technologies are divided into four groups: large containers (according to ISO, Eurocontainers), swap bodies, semi-trailers and self-propelled vehicles.

In the area of intermodal transport mainly containers are transported, but the transport of entire car sets including a tractor and a semi-trailer, which are transported using low-floor railway platforms – the RoLa system (Rollende Landstraße), is also gaining importance.

In addition, road-trailers moved with the use of pocket railway wagons (piggy-back system) and swap-bodies transported with the use of railway wagons – container platforms, are also subject to transport.

The main advantages of intermodal transport include [Brill and Łukasik 2014, Mindur 2014]:

- reducing the external costs of transport that are negative for the environment;
- improving the condition of the environment;
- providing transport services in the door to door relationship;
- greater access to transport services;
- participation in the process of reducing the global cost of the transport process;
- high level of transport and load safety;
- improving the quality of transport services;
- increasing road safety;
- reducing the rate of road pavement wear;
- the possibility of providing transport services in the just in time system;
- relieving border crossings by transferring customs clearance from the border to terminals (start and end);
- standardization of transport technology as well as transport equipment;
- possibility of carrying out transport in the countries, where the law restricts freight transport using road transport.

Discussing intermodal transport, it should be emphasized that it is particularly friendly to the natural environment, which manifests itself in energy saving, limited emissions, as well as reduced consumption of road infrastructure and not causing congestion [Engelhardt 2013]. However, we should not forget that intermodal transport involves an additional number of terminal operations, which generates additional costs that are reflected in the final price of the transport service. Intermodal transport logistics is characterized by a higher degree of complexity than traditional rail transport [Barcik and Bylinko 2018].

Study goal and methods

The purpose of the study is to illustrate the development of intermodal transport in Poland over the period of 2010–2018. The article contains statistical data on intermodal transport, and also characterizes the infrastructure necessary for their implementation. An important part of the study is to diagnose factors determining the development of intermodal transport, as well as to specify the perspectives of its development in the coming years.

The study is based on the available literature on the subject, data of general statistics, as well as legislation in the field of intermodal transport of national and European origin.

Intermodal transport in Poland in the years 2010–2018

One of the determinants of the development of intermodal transport is the number of intermodal terminals, in which the transshipment of loading units from one means of transport to another takes place. In 2018, there were 35 intermodal terminals in Poland, 29 of which were road terminals designed to handle shipments transported by rail and road. Others are sea terminals, responsible for handling transport carried out using sea and rail transport, as well as sea and road transport. The largest number of terminals have been located in Łódzkie and Wielkopolskie Voivodeships (5), as well as Dolnośląskie, Śląskie and Pomorskie Voivodeships (4). There are no access to intermodal terminals in the Kujawsko-Pomorskie, Opolskie and Podkarpackie Voivodeships (Fig. 1).

Figure 1. Intermodal terminals in Poland in 2018
Rysunek 1. Terminale intermodalne w Polsce w 2018 roku
Source: https://portaltsl.pl [access: 16.10.2019].

Intermodal terminals are characterized by a certain infrastructure, which is created by, among others parking and maneuvering space, total and separate storage area for containerized units, as well as the length of the railway line or the capacity of storage yards expressed in TEU units. Table 1 presents data on the infrastructure of sea and road terminals.

Table 1. Infrastructure of intermodal terminals in Poland in 2018
Tabela 1. Infrastruktura terminali intermodalnych w Polsce w 2018 roku

Specification	Terminals	
	sea	land
Length of transshipment quays in terminals (km)	7.1	–
Parking and maneuvering area of terminals (ha)	7.1	22.4
Total storage area of terminals (ha) including area for containerized units (ha)	162.0 134.0	124.0 78.0
Capacity of terminal storage yards (thous. TEU)	93.2	90.7
Length of the standard gauge railway line in terminals (km)	13.5	78.2
Average length of train (number of wagons) operated at the sea terminal (pcs.)	53	33

Source: own study based on data from the Statistics Poland (Główny Urząd Statystyczny).

The parking and maneuvering area of the terminals in 2018 amounted to a total of 29.5 ha, with 75.9% of this area at the disposal of land terminals. The total storage area of the terminals is 286 ha, of which 56.6% is the technical potential of the sea terminals.

Intermodal terminals have a transshipment capacity of 9.1 million TEU. The transshipment capacity of sea terminals is 6.3 million TEU and is much higher than that of land terminals (2.8 million TEU). In 2018, 67.3 million t of cargo (7,301,094 TEU) were transshipped at Polish intermodal terminals, of which 27.6 million t were delivered by sea, 22.4 million t were transported by road and 17.3 million t by rail [GUS 2019a, b]. Compared to the volume of transshipped goods in 2017, this means an increase by 6.5 million t.

Particularly noteworthy is the increase in the volume of intermodal transport carried out using rail transport; over the past 10 years (2010–2018) there was an increase in the volume of transported loads by 12.6 million t – Figure 2.

The highest growth of transport dynamics expressed in millions of tonnes was recorded in 2016 in which there was an increase by 23% compared to the previous year (2015).

Transport performance in the area of cargo transportation in 2018 reached the level of 6.2 billion tkm and compared to 2010 increased by 4.3 billion tkm (Fig. 3).

The highest growth dynamics in the area of transport performance, expressed in billions of tonne-kilometers was recorded in 2017, in which there was an increase by 22.7% compared to the previous year (2016).

The group of railway carriers providing intermodal transport is dominated by PKP CARGO, which has the largest market share due to the criterion of transport performance (52.3%) and the weight of cargo (46.5%). Captrain Polska is right behind it (Table 2).

There are also other carriers on the intermodal transport market, including CTL Logistics Sp. z o.o., ECCO Rail Sp. z o.o., Eurotrans Sp. z o.o., Inter Cargo Sp. z o.o., Karpiel Sp. z o.o., Lotos Kolej Sp. z o.o., LTE Polska Sp. z o.o., Metrans Polonia Sp. z o.o., Olavion Sp. z o.o., PKP LHS PKP Linia Hutnicza Wideotorowa Sp. z o.o., STK SA Transchem Sp. z o.o. and Zakład Inżynierii Kolejowej Sp. z o.o. It seems important to note, that the position and significance of entities characterized by a smaller market share (e.g. Metrans Polonia Sp. z o.o.), which combined the carrier's functions with the function of a logistics operator, keeps growing. A favourable phenomenon in the area of intermodal transport is

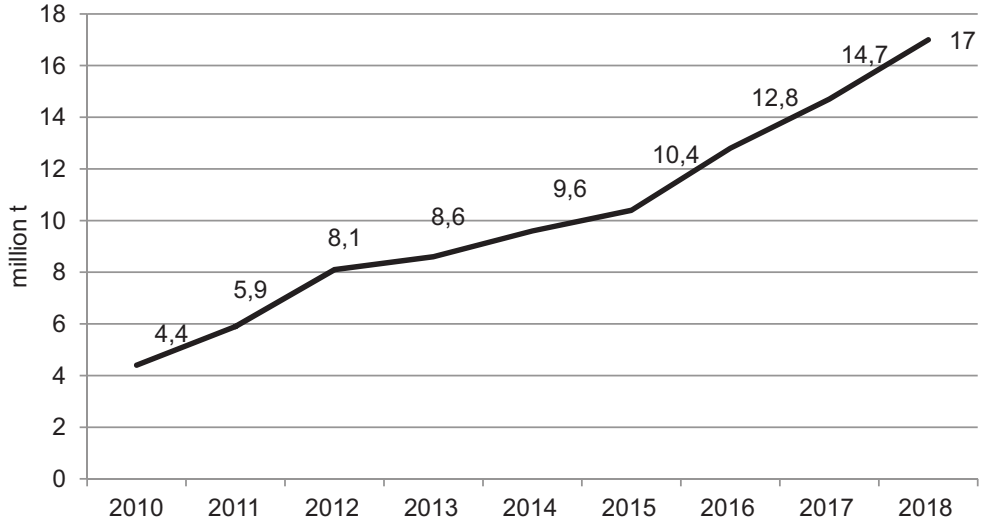

Figure 2. Intermodal rail transport in 2010–2018
Rysunek 2. Transport kolejowy intermodalny w latach 2010–2018
Source: own study based on data from the Office of Rail Transport (Urząd Transportu Kolejowego).

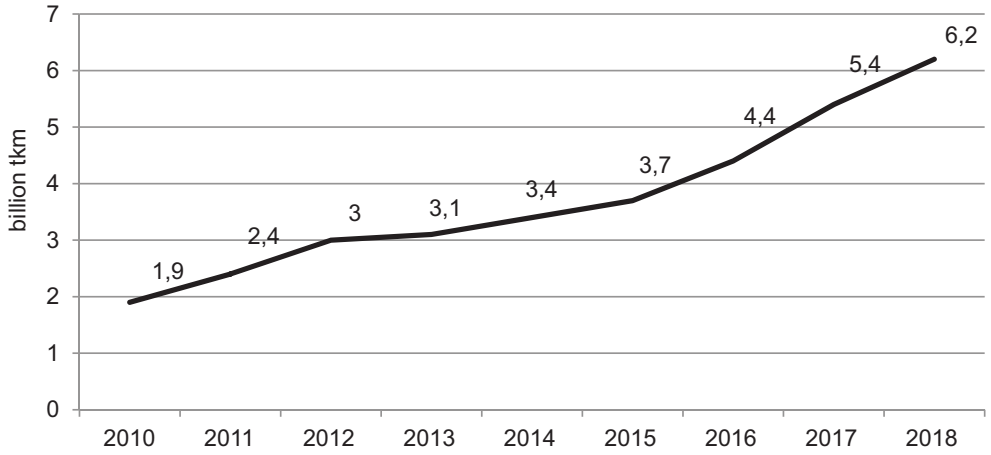

Figure 3. Transport performance in intermodal rail transport in the years 2010–2018
Rysunek 3. Wykonanie przewozów w intermodalnym transporcie kolejowym w latach 2010–2018
Source: own study based on data from the Office of Rail Transport (Urząd Transportu Kolejowego).

Table 2. Market share of rail carriers providing intermodal transport
Tabela 2. Udział w rynku przewoźników kolejowych zapewniających transport intermodalny

Carrier	Market share due to the criterion (%)	
	transport performance	the weight of transported cargo
PKP CARGO	52.3	46.5
Captrain Polska	12.5	13.7
PCC Intermodal	8.0	10.0
DB Cargo Polska	10.2	7.5

Source: own study based on data from the Office of Rail Transport (Urząd Transportu Kolejowego).

the increasing number of intermodal rail carriers; in 2016 there were 13, a year later 18, and in 2018 there were 20 railway companies providing this type of services.

Mainly containers are transported by means of intermodal transport, whose share in the total number of transported units in 2018 amounted to as much as 96.3%. Twenty-foot (47.8%) and forty-foot (43.8%) containers dominated here. The cited year 2018 was a record year in terms of transported load units: 1,894 thousand TEU.

Determinants of the development of intermodal transport in Poland

There are many different factors that influence the development of intermodal transport. Undoubtedly, the size of the country in which it is implemented is an important element determining the development of intermodal transport. Short connection relations translate into low efficiency of intermodal transport. The small area of the country eliminates intermodal domestic transport. The development of intermodal transport is also affected by the existing traffic restrictions. They may result from the terrain; in mountainous areas, cargo transport is transferred from road to rail. In the group of factors responsible for the development of intermodal transport, legal regulations which may stimulate the development of this type of transport through appropriate solutions, play an important role. In this area, the state of transport infrastructure as well as the number of transshipment terminals and their equipment also should be mentioned.

In the literature on the subject, the factors determining the development of intermodal transport include [Przybylska and Kruczek 2017]:

- situation on global financial markets;
- the possibility of obtaining financing sources;
- presence of well-qualified staff on the market;
- increase in the volume of bulk transport;
- international trade;
- development of international transport corridors;
- increased competition;
- development of road infrastructure;
- containerization development;
- the possibility of introducing innovations in intermodal transport;
- number and infrastructure capabilities of intermodal terminals;
- development of infrastructure of other transport branches;
- growing public environmental awareness;
- congestion and accident rate;
- promotion of intermodal transport;
- state policy in the area of intermodal transport support;
- concession for intermodal transport;
- road toll system.

Prospects for the development of intermodal transport in Poland are largely determined by the state of infrastructure, including rail infrastructure, which determines the competitiveness of this type of transport. It is also important to extend the existing terminals and construction of new reloading terminals, equipped with appropriate reloading devices.

Among the threats limiting the development of intermodal transport is the lack of sufficient cooperation between entities creating the intermodal transport market. This situation encourages actions aimed at taking over part of the domestic intermodal market by operators from European Union countries, who are stronger in terms of organization and capital [Mindur and Mindur 2018]. We should not forget about the insufficient number of specialized intermodal transport equipment, which is technically prepared for transporting trailers, swap chassis or trucks. Another problem is the lack of systems responsible for the overall monitoring of the passage of goods. Such systems should provide customers with information on the real time of transport as well as the status of shipments on the way. Finally, we should be aware of the limited price competitiveness of intermodal transport in relation to road transport. This situation is caused by the high level of rail freight, as well as the prices of reloading and handling operations in the area of road transport [Mindur 2010].

When considering the area of intermodal transport in Poland, it should be noted that it has many beneficial features that encourage the development of these transport technologies. This is the geographical location of a country whose territory is a bridge between Europe and Asia, since long distances are favourable for the development of intermodal transport. Successful forecasts in the area of the development of ports and their terminal infrastructure will increase transshipment capacity, and thus enable the development of intermodal transport. Improvement of the linear infrastructure and its satisfactory density as well as the level of electrification are also important in the area discussed. We should be aware that the volume of our foreign trade is conducive to the development of intermodal transport, and the area of the country's territory makes it possible to reach the distance threshold of profitability of intermodal transport [Antonowicz 2018].

Among the development opportunities in the area of intermodal transport, the following will be of significant importance [Engelhardt 2013]:

- An efficient network of night, fast container trains that will connect leading seaports with the largest and most important logistics centers in the country and abroad. This transport will be carried out by shuttle trains; their distinguishing feature will be the speed of implementation, reliability and comprehensiveness of provided services.
- An efficient network of night fast container trains that will connect logistics centers located in the immediate vicinity of major urban agglomerations.
- Reliable network of container trains in international relations (West–East, North––South).
- A reliable network of container trains serving large concerns operating on global markets.

Despite the existence of certain restrictions, it should be noted that intermodal transport in Poland has a very large potential, which results primarily from the density of railway lines, the degree of their electrification, as well as the intensive development of seaports in Gdańsk and Gdynia, which are infrastructurally prepared to provide highly complex transshipment services.

Intermodal transport is effective with at least a minimum degree of saturation with technical means in the form of transport equipment and the existence of a sufficient number of transshipment terminals, as well as relatively constant and balanced cargo flows, which are carried out by reliable organization of transportation [Brill and Łukasik 2014].

The ecological aspect of intermodal transport

The European Union's assumption in the area of transport is to balance existing transport modes, and also to raise the range of rail transport, so that in 2030 one can speak of a fully functioning intermodal transport network [GUS 2017]. The promotion of intermodal transport by the institutions of the European Union results from its pro-environmental nature. The use of various means of transport in this area means that the roads are less crowded, which in turn contributes to reducing congestion, but also slows down the wear rate of road infrastructure. Undoubtedly, combining and replacing with each other various means of transport, with particular preference of rail, brings tangible benefits to the environment. This is due to the fact that rail transport accounts for only 3% of external costs, while road transport accounts for over 50%. In addition, transport is responsible for 30% of total carbon dioxide emissions in the European Union, of which 80% produces road transport and only 1% rail transport. The small scale of territorial expansion of rail transport, as well as the fact that the amount of pollution emitted by diesel locomotives, when transporting 1 t of cargo is 10 times lower than in the case of road transport, argue for increasing the importance of rail transport, taking into account the popular concept of trucks on tracks.

Intermodal transport means less loads on the road, and this translates into the safety of all road users. Prioritizing rail transport eliminates emissions and reduces the noise level that accompanies road transport. Rail transport is responsible for 1.3% of all environmental pollution, with 98.7% of pollution generated by road transport. The use of intermodal transport technology contributes to a 17% reduction in fuel consumption and a 15% reduction in carbon dioxide emissions [Łukasik et al. 2017].

Conclusions

Intermodal transport in Poland is developing dynamically. It has increased almost four times within 10 years, from 2010 to 2018. The main routes on which intermodal transport is carried out, run from the East to the West, from the border with Belarus to the border with Germany, as well as in the South with the Czech Republic. The lines connecting ports located in Pomerania (Gdańsk and Gdynia) with terminals located in the interior of the country are also important. Intermodal transport mainly takes place using 20-foot (47.8%) and 40-foot (43.8%) containers. The geographical location of Poland is associated with the currently implemented concept of the New Silk Road, which predestines our country to be a European transit and distribution hub that will connect east and west, and the Baltic countries with the southern Europe. Intermodal transport in Poland is promising; this is determined by the density of railway lines and the increase in the number of intermodal operators.

References

Antonowicz M., 2018: Czynniki rozwoju przewozów intermodalnych w Polsce [Development factors for intermodal transport in Poland], Studia i Prace. Kolegium Zarządzania i Finansów SGH 170, 105–120.

Barcik R., Bylinko L., 2018: Perspektywy transportu intermodalnego w Polsce [Prospects for intermodal transport in Poland], Prace Naukowe Politechniki Warszawskiej, Transport 120, 9–17.

Brill J., Łukasik Z., 2014: Aspekty ekonomiczne, techniczne i strategiczne transportu intermodalnego [Economic, technical and strategic aspects of transport intermodal], Technika Transportu Szynowego 21 (3), 12–24.

Engelhardt J., 2013: Polityka państwa w zakresie transportu intermodalnego w Polsce [State policy in the field of intermodal transport in Poland], Zeszyty Naukowe Uniwersytetu Szczecińskiego. Problemy Transportu i Logistyki 22, 57–80.

European Conference of Transport Ministers – ECMT, 1993: Terminology on combined transport, OECD Publishing, Paris.

Główny Urząd Statystyczny – GUS, 2017: Transport – wyniki działalności w 2016 roku [Transport – activity results in 2016], Warszawa.

Główny Urząd Statystyczny – GUS, 2019a: Transport intermodalny w Polsce w 2018 r. [Intermodal transport in Poland in 2018], Warszawa.

Główny Urząd Statystyczny – GUS, 2019b: Transport – wyniki działalności w 2018 roku [Transport – activity results in 2018], Warszawa.

Grzywacz W., Burnewicz J., 1989: Ekonomika transportu [Economics of transport], Wydawnictwa Komunikacji i Łączności, Warszawa.

Klimek H., 2010: Funkcjonowanie rynków usług portowych [Operating of port services markets], Wydawnictwo Uniwersytetu Gdańskiego, Gdańsk.

Kwaśniowski S., Nowakowski P., Zając P., 2004: Uwarunkowania funkcjonalne i techniczne rozwoju transportu intermodalnego [Functional and technical conditions of intermodal transport development], Logistyka 2, 18–20.

Łukasik Z., Kuśmińska-Fijałkowska A., Kołodziejczyk P., 2017: Transport intermodalny alternatywnym rozwiązaniem dla zachowania równowagi ekologicznej [Intermodal transport as an alternative solution for maintaining ecological balance], Autobusy: Technika, Eksploatacja, Systemy Transportowe 18 (3), 45–50.

Mindur L., 2010: Uwarunkowania dla rozwoju runku transport kombinowanego (intermodalnego) w Polsce w latach 1993–2009 [Conditions for the development of combined (intermodal) transport market in Poland in 1993–2009], multimedial presentation, Politechnika Łódzka, Łódź.

Mindur L. (Ed.), 2014: Technologie transportowe [Transport technologies], Instytutu Technologii Eksploatacji, Radom.

Mindur M., Mindur L., 2018: Transport intermodalny w Polsce w latach 2001–2017 oraz czynniki kształtujące jego rozwój w perspektywie [Intermodal transport in Poland in 2001–2017 and factors affecting its prospective development], Prace Naukowe Politechniki Warszawskiej. Transport 120, 297–308.

Ministerstwo Infrastructury, 2018: Master Plan dla transportu kolejowego w Polsce do 2030 r. [Master Plan for rail transport in Poland until 2030], Warszawa.

Przybylska E., Zebrucki Z., Kruczek M., 2017: Identyfikacja czynników rozwoju transportu intermodalnego w Polsce [Identification of development factors for intermodal transport in Poland], Zeszyty Naukowe Politechniki Śląskiej. Organizacja i Zarządzanie 103, 195–206.

Walasek R., 2018: Interoperacyjność transport intermodalnego jako element jego konkurencyjności w Unii Europejskiej [Interoperability of Intermodal Transport as an Element of Competitiveness in the European Union], Studia i Prace. Kolegium Zarządania i Finansów SGH 166, 153–164.

Correspondence address:

Michał Kruszyński, PhD, Eng
(https://orcid.org/0000-0002-7905-1403)
International University of Logistics and Transport in Wrocław
Department of Management
Soltysowicka St. 19b, 51-168 Wroclaw, Poland
e-mail: mkruszynski@mail.mwsl.eu

Nataliya Struk, PhD habil.
(https://orcid.org/0000-0002-1933-265X)
Ivan Franko National University of Lviv
Faculty of Economics
Hetman Mazepy St. 10/13, 79068 Lviv, Ikraine
e-mail: natalistruk@hotmail.com

Ekonomika i Organizacja Logistyki
4 (3), 2019, 77–85

DOI: 10.22630/EIOL.2019.4.3.25

Joanna Domagała
Warsaw University of Life Sciences – SGGW

Efficiency of Polish seaports against the background of the largest ports in Europe

Efektywność polskich portów morskich na tle największych portów Europy

Abstract. Seaport efficiency are the critical factors for handling of goods in the international supply chains and plays an important role in trade exchange with other countries. It is important to evaluate efficiency of seaports to reflect their status and reveal their position in competitive environment. The main purpose of this article is to use Data Envelopment Analysis to measure the technical efficiency of main seaports in Poland and main seaports in Europe. Data Envelopment Analysis enables one to assess how efficiently a Polish seaports uses the available inputs to generate a set of outputs relative to other units in the data set. The analysis gives a possibility to create an efficiency ranking of seaports.

Key words: seaports, efficiency, Data Envelopment Analysis

Synopsis. Efektywność portów morskich jest kluczowym czynnikiem w obsłudze towarów w międzynarodowych łańcuchach dostaw, a tym samym odgrywa ważną rolę w wymianie handlowej z innymi krajami. Ocena efektywności portów morskich umożliwia zidentyfikowanie ich pozycji w konkurencyjnym środowisku. Głównym celem tego artykułu jest wykorzystanie metody Data Envelopment Analysis do pomiaru efektywności technicznej głównych portów morskich w Polsce i głównych portów morskich w Europie. Analiza DEA pozwala ocenić, jak skutecznie polskie porty morskie wykorzystują dostępne nakłady do generowania wyników (efektów) względem głównych portów morskich w Europie. Przeprowadzenie analizy umożliwi stworzenie rankingu efektywności badanych portów morskich.

Słowa kluczowe: porty morskie, efektywność, Data Envelopment Analysis

Introduction

Recent trends in international trade in an era characterised by the globalisation of production and consumption patterns have led to the increasing importance of container transportation. This is largely because of the numerous technical and economic advantages it possesses over traditional methods of transportation. Standing at the interface of

sea and inland transportation, container ports play a pivotal role in the container transportation process. The above-mentioned two characteristics of the contemporary container port industry are particularly true for the container ports in Europe. The paramount importance of the container port industry as the basis for the economic development of the EU and the fierce competition between/among ports have been variously discussed [Notteboom 1997, Wang and Cullinane 2004, Winkelmans 2004].

There have been hardly papers interested comparing the biggest world container ports. The issue of seaports efficiency is usually considered in literature from a one-dimensional perspective, using conventional economic indicators, such as: labour productivity or asset productivity. One the other hand the use of non-parametric methods for the assessment of the efficiency of seaport is also a very popular direction of research.

The purpose of this article is to use the Data Envelopment Analysis to compare the technical efficiency of seaports in Poland, Germany, Belgium and the Netherlands.

Methods

Data Envelopment Analysis (DEA) is a non-parametric mathematical programming approach for measuring relative efficiencies of comparable decision making units (DMUs) with respect to multiple inputs and outputs [Charnes et al. 1978]. The efficiency score in the presence of multiple input and output factors is presented mathematically in the following manner [Charnes et al. 1978]:

$$\max \frac{\sum_{k=1}^{s} u_k y_{kp}}{\sum_{j=1}^{m} v_j x_{jp}}$$

$$\frac{\sum_{k=1}^{s} u_k y_{ki}}{\sum_{j=1}^{m} v_j x_{ji}} \leq 1$$

$$u_k, v_j \geq 0 \quad \forall k$$

s – quantity of outputs;
m – quantity of inputs;
u_k – weights denoting the significance of respective outputs;
v_j – weights denoting the significance of respective inputs;
y_{ki} – amount of output of k-th type in i-th object;
x_{ji} – amount of input of j-th type in i-th object.

Each DMU selects input and output weights that maximize its efficiency score. In general, a DMU is considered to be efficient if it obtains a score of 1 while a score of less than 1 implies that it is inefficient.

The DEA models may be categorised based on two criteria: model orientation and type of returns to scale. Depending on the model orientation a calculation is made of

technical efficiency focused on the input minimization or of technical efficiency focused on the output maximisation. But taking into account the type of returns to scale the following models are distinguished: the Charnes–Coopers–Rhodes (CCR) model providing for constant returns to scale [Charnes et al. 1978] and the BCC model providing for changing return to scale [Banker et al. 1984]. The CCR model is built on the assumption of constant returns to scale: this means that inputs and output are linked in a strictly proportional manner. The CCR efficiency scores measure the overall technical efficiency. The Banker–Charnes–Cooper (BCC) model is an extension of the CCR model and allows for the fact that the productivity at the most productive scale size may not be attainable for other scale sizes at which a given DMU is operating. Therefore, the BCC model estimates the pure technical efficiency of a DMU at a given scale of operation. The only difference between the CCR and BCC models is the convexity condition of the BCC model, which means that the frontiers of the BCC model have piecewise linear and concave characteristics, which lead to variable returns-to-scale.

Literature review

Meyrick and associates and Tasman Asia Pacific report, there are two partial productivity measures have been used in port productivity studies [ATC et al. 1998]. First is annually lifts per employee (labour productivity), and it is defined as the number of container movements (container lifts) per terminal employee. The other is net crane rate (capital productivity), and it is defined as the number of container movements (container lifts) per net crane hour. This is the key word of an efficient container terminal to show to the stakeholders for high productivity [Mokhtar and Shah 2013].

On the other hand full efficiency is attained by any port container if and only if none of its inputs or outputs can be improved without worsening some of its other inputs or outputs. Many researchers have used various approaches to evaluate seaport efficiency. There are numerous studies on port performance with Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA). For example, Roll and Hayuth [1993] apply a DEA model to measure the efficiency of twenty seaports. Tongzon [2001] investigates the efficiency of sixteen international seaports. Bonilla et al. [2002] employ DEA in order to measure the commodities traffic efficiency of the seaports in Spain. Barros [2003] utilizes DEA in Portuguese seaports and finds that the reform made by the authorities does not fulfil the targets. Similarly, Barros and Athanassiou [2004] compared the efficiency of seaports in Portugal and Greece and provided benchmarks. Cullinane et al. [2004] used a DEA window analysis in order to achieve more robust results. Estache et al. [2004] applied the Malmquist Productivity Index (MPI) to examine if seaport liberalisation was a success in Mexico. Park and De [2004] used a four-stage DEA to investigate the efficiency of the North American seaport infrastructure productivity from 1984 to 1997. Pang [2006] analysed and evaluated 50 major ports in China by using DEA and dynamically evaluated their efficiency based on three years of consecutive data. Min and Park [2008] proposed a hybrid DEA-simulation model to evaluate the relative efficiency of major container terminals in South Korea. Wu and Lin [2008] performed an international comparison of logistic port operations with a focus on India. Ablanedo Rosas and Ruiz-Torres [2009] used DEA to evaluate the

efficiency of cargo and cruise operations in major Mexican ports. Ablanedo-Rosas et al. [2010] used a financial ratio-based data envelopment analysis to examine the relative efficiency of 11 major Chinese ports.

Results

The port market in Poland records annual increase in transshipments. The cargo turnover of Polish ports in 2018 reached a record result of over 100 million t. The position of the leader is invariably the Port of Gdansk, where transhipments increased by over 8 million t. The Port of Gdynia and the Port of Szczecin-Świnoujście also recorded higher results (Table 1). The increase in trans-shipments at the Port of Gdansk by 20.7% is the highest dynamics of growth on the Polish coast.

Table 1. Turnover in the biggest Polish seaports in years 2012–2018
Tabela 1. Obrót towarowy w największych polskich portach morskich w latach 2012–2018

Seaport	2012	2013	2014	2015	2016	2017	2018	Change 2018/2017
	thous. t							%
Gdańsk	15 809	17 659	19 405	18 198	19 536	21 225	23 492	10.7
Gdynia	21 267	22 750	23 401	23 174	24 113	25 424	28 614	12.6
Szczecin--Świnoujście	26 897	30 259	32 278	35 914	37 289	40 614	49 032	20.7
Total	63 973	70 668	75 084	77 286	80 938	87 263	101 138	15.9

Source: [Polish ports in 2018. ActiaForum Port Monitor February/March 2019].

The results of Polish seaports are very favourable compared to the Baltic ports. In total, Baltic ports have transshipped over 482.8 million t of cargo. High dynamics and a significant increase in cargo turnover influenced the promotion of the Port of Gdansk to the 4th position in the ranking (Fig. 1). The biggest port in the Baltic Sea is Ust Luga with transhipments at the level of 98.7 million t. The port, which occupies the second position in the ranking is Port St. Petersburg. On the third position was located Port Primorsk (Fig. 1).

The dominant group in the transshipments in Polish seaports was general cargo, which share in total cargo turnover in Polish ports is 48%. The large share of general cargo is due to increased container handling in the Port of Gdansk. The Port of Gdańsk has the largest share in container handling in Polish ports. Through Port of Gdańsk passes 69% of all containers handled by Polish seaports. In 2018 Port of Gdańsk recorded increase in container turnover by over 23% (+368,466 TEU). Container handling in Port of Gdynia increased by 13.1% (+93 173 TEU). However, Port of Szczecin-Świnoujście recorded drop by 13% (–12,128 TEU) – Table 2.

The sample comprises the 6th container ports ranked in 2016. Based on data availability, the ports are listed below according to the country where they are located:

- Germany: Hamburg;
- Belgium: Antwerp;

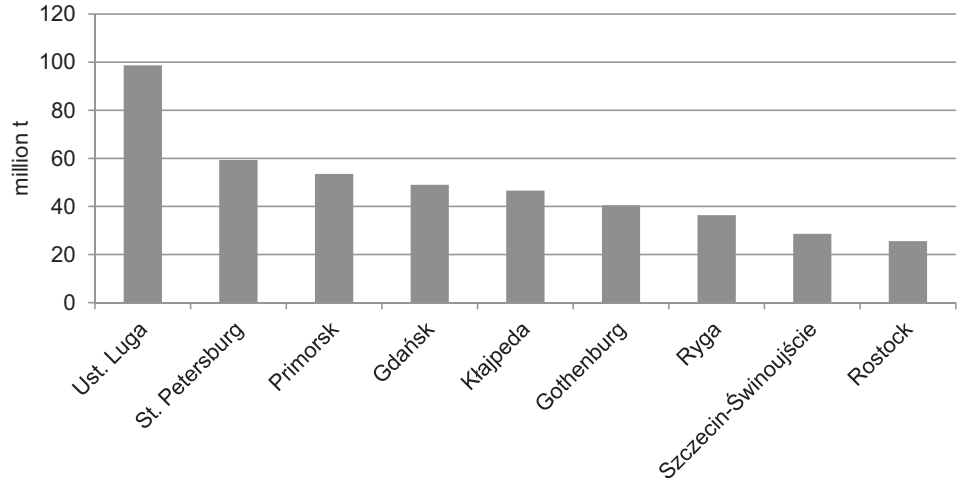

Figure 1. The busiest Baltic seaports in 2018
Rysunek 1. Najbardziej aktywne porty bałtyckie w 2018 roku
Source: [Polish ports in 2018. ActiaForum Port Monitor February/March 2019].

Table 2. Container handling in the biggest Polish seaports in years 2012–2018
Tabela 2. Obsługa kontenerów w największych polskich portach morskich w latach 2012–2018

Seaport	2012	2013	2014	2015	2016	2017	2018	Change 2018/2017
	TEU							%
Gdańsk	928 399	1 177 626	1 212 054	1 091 202	1 299 373	1 580 508	1 948 974	23.3
Gdynia	676 349	729 518	684 796	642 195	642 195	710 698	803 871	13.1
Szczecin--Świnoujście	52 179	62 307	87 784	90 869	90 869	93 579	81 451	–13.0
Total	1 656 927	1 969 451	1 863 782	2 032 437	2 032 437	2 384 785	2 834 296	18.85

Source: [Polish ports in 2018. ActiaForum Port Monitor February/March 2019].

- Netherlands: Rotterdam;
- Poland: Gdańsk, Gdynia, Szczecin-Świnoujście.

Since the main activity of container ports is handling containers only one output will be identified in this study and four variable input factors:

- input x_1 – number of berths (total number of berths of all terminals);
- input x_2 – terminal area (total terminal area in m^2);
- input x_3 – employees (total number of employees);
- input x_4 – quay length (total quay length in m);
- output y_1 – annual throughput (annual port throughput in TEU).

Data Envelopment Analysis models can be distinguished according to whether they are input- or output-oriented. The former is closely related to operational and managerial issues, whilst the latter is more related to planning and macroeconomic strategies. Both orientations have their usefulness in the container port industry context. With rapid expansion of global

business and international trade, many container ports must frequently review their capacity in order to ensure that they can provide satisfactory services to port users and maintain their competitive edge. Sometimes, the need to build a new terminal or increase capacity is inevitable. However, before a port implements such a plan, it is of great importance for the port to know whether it has fully used its existing facilities and that output has been maximised given the input. From this point of view, the output-oriented model provides a benchmark for the container industry. Finally, it has been decided that output-oriented models should be chosen as the basis for the analysis undertaken herein.

Table 3 indicates the BCC model which are used to evaluate container ports. In 2016, the average technical efficiency (BCC model) score is 0.772. Two out of the six container ports included in the analysis are identified as efficient. The highest average indices of technical efficiency were recorded in the Rotterdam and Antwerp. In turn, the lowest annual average indices of efficiency were observed in the Szczecin seaport (Table 1). The ports located in Rotterdam and Antwerp have high technical efficiency scores, which implies that they can well exploit their facilities and serve a large amount of containers (TEUs). The Szczecin-Świnoujście has relatively low technical efficiency. Those ports accommodate a large number of containers with limited performance, as they do not efficiently manage their resources.

With the information about the returns to scale properties of the individual terminal production yielded by DE–BCC model, in 2016, five out of the six samples exhibits decreasing returns to scale, only 1 seaport in Szczecin showed constant returns to scale (Table 3).

Table 3. The technical efficiency and returns to scale of seaports in 2016
Tabela 3. Efektywność techniczna i korzyści skali w portach morskich w 2016 roku

DMU	DEA, BCC model Technical efficiency	RTS Return to Scale
Rotterdam seaport	1	decreasing
Antwerp seaport	1	decreasing
Hamburg seaport	0.97	decreasing
Gdańsk seaport	0.95	decreasing
Gdynia seaport	0.63	decreasing
Szczecin-Świnoujście seaport	0.09	constant
Average	0.77	

Source: own calculations.

Table 4 contains the improvements required in order to make inefficient seaport efficient. Projections suggest that the total number of TEUs handled should increase as follows: Hamburg by about 10%, Gdańsk 17%, Gdynia 154%, Szczecin-Świnoujście 2,174%.

Table 4. Projections values of output
Tabela 4. Prognozowana poprawa wyników

DMU	Projections improvement (TEUs handled) (%)
Hamburg seaport	10
Gdańsk seaport	17
Gdynia seaport	154
Szczecin-Świnoujście seaport	2 174

Source: own calculations.

Conclusions

In this paper, DEA analysis has been applied to determine the relative efficiency of Polish main seaport and Europe's leading container terminals. From the practical point of view the results of this analysis can be summarized as follows:

- The average efficiency of container terminals under study amounts 0.77.
- Rotterdam and Antwerp were the leaders in technical efficiency. They have the highest position in the ranking.
- Parameters of transportation activity in efficient seaports may constitute a benchmark for other (inefficient) evaluated entities.
- It was found that, while one seaport (Szczecin-Świnoujście) container terminals are scale-efficient, in general, rest of the container ports under study exhibit decreasing returns to scale. However, most of the container terminals that are large in production scale are more likely already to be associated with higher efficiency scores. These findings are particularly informative for policy-makers and corporate decision-makers. For example, these findings provide some theoretical support for the increasing tendency towards the construction of large-scale container ports (mega-ports) that is progressing world-wide, These findings, however, also suggest that not every individual container terminal (even ones that are currently small) follows the law of increasing returns to scale. Decision-makers, both commercial and political, will need to study carefully, therefore, their own particular set of circumstances and general situation.

From the methodological point of view the proposed approach for ranking and benchmarking of transportation sectors has a universal character and can be applied in a variety of industries. It is composed of the following stages: 1 – recognition of the DMU; 2 – definition of the variables based on the literature review; 3 – definition of DEA model (model orientation and type of returns to scale); 4 – computational experiments leading to the final ranking.

References

Ablanedo-Rosas J.H., Gao H., Zheng X., Alidaee B., Wang H., 2010: A study of relative efficiency of Chinese ports: a ratio-based DEA approach, Expert Systems 27 (5), 349–362.

Ablanedo-Rosas J.H., Ruiz-Torres A.J., 2009: Benchmarking of Mexican ports with data envelopment analysis, International Journal of Shipping and Transport Logistics 1, 276–294.

Australian Transport Council – ATC, Meyrick and Associates – M&A, Tasman Asia Pacific – TAP, 1998: Measures to Promote Effective and Efficient Container Port Practices. Final report.

Banker R.D., Charnes A., Cooper W.W., 1984: Some Models for Estimating Technical and Scale Inefficiency in Data Envelopment Analysis, Management Science 30 (9), 1078–1092.

Barros C., 2003: Incentive Regulation and Efficiency of Portuguese Port Authorities, Maritime Economics & Logistics 5 (1), 55–69.

Barros C., Athanassiou M., 2004: Efficiency in European Seaports with DEA: Evidence from Greece and Portugal, Maritime Economics & Logistic 6, 122–140.

Bonilla M., Medal A., Casasus T., Sala R., 2002: The Traffic in Spanish Ports: an Efficiency Analysis, International Journal of Transport Economics 29 (2), 215–230.

Charnes A., Cooper W.W., Rhodes A., 1978: Measuring the Efficiency of Decision Making Units, European Journal of Operational Research 2 (6), 429–444.

Cullinane K., Song D.W., Ji P., Wang T-F., 2004: An Application of DEA Windows Analysis to Container Port Production Efficiency, Review of Network Economics 3 (2), 184–206.

Estache A., Tovar B., Trujillo L., 2004: Sources of efficiency gains in port reform: A DEA decomposition of a Malmquist index for México, Utilities Policy 30 (4), 221–230.

Min H., Park B., 2008: A hybrid data envelopment analysis and simulation methodology for measuring capacity utilisation and throughput efficiency of container terminals, International Journal of Logistics Systems and Management 4 (6), https://doi.org/10.1504/IJLSM.2008.019184

Mokhtar K., Shah M.Z., 2013: Malmquist Productivity Index for Container Terminal, European Journal of Business and Management 5 (2), 58–70.

Notteboom T., 1997: Concentration and load centre development in the European container port system, Journal of Transport Geography 5 (2), 99–115.

Pang R., 2006: Dynamic evaluation of main sea ports in mainland china based on DEA model, Economic Research Journal 41, 92–100.

Park R.K., De P., 2004: An alternative approach to efficiency measurement of seaports, Maritime Economics & Logistics 6, 53–69.

Polskie porty w 2018 roku [Polish ports in 2018], ActiaForum Port Monitor Luty/Marzec 2019.

Roll Y., Hayuth Y., 1993: Port performance comparison applying data envelopment analysis (DEA), Maritime Policy and Management 20 (2), 153–162.

Tongzon J.K., 2001: Efficiency Measurement of Selected Australian and Other International Ports Using Data Envelopment Analysis, Transportation Research. Part A 35, 113–128.

Wang T., Cullinane K., 2004: Industrial concentration in container ports, [in:] Proceedings of Annual Conference of International Association of Maritime Economists (IAME). 30.06––02.06.2004 Izmir, Eylul University, Izmir.

Winkelmans W., 2004: The socio-economic value of seaports in the European Union, The European Sea Ports Conference 2004: European Sea Ports in a Dynamic Market-Ports and the EU Agenda, Rotterdam.

Wu Y.J., Lin C., 2008: National port competitiveness: implications for India, Management Decision 46, 1482–1507.

Correspondence address:

Joanna Domagała, PhD
(https://orcid.org/0000-0001-9801-4344)
Warsaw University of Life Sciences – SGGW
Institute of Economics and Finance
Department of Logistics
Nowoursynowska St. 166, 02-787 Warsaw, Poland
e-mail: joanna_baran@sggw.pl

Ekonomika i Organizacja Logistyki
4 (3), 2019, 87–98

DOI: 10.22630/EIOL.2019.4.3.26

Andrzej Jezierski
University of Gdańsk

Competitiveness of the Polish system of road transport on the EU system of road transport – selected issues

Konkurencyjność polskiego systemu transportu drogowego w porównaniu z systemem transportu drogowego UE – wybrane zagadnienia

Abstract. Polish companies operating in the market of road transport services do not come only as some background for companies with foreign capital, but they are equal business partners and competitors in this market. Road cargo transport accounts for a major part of the system of transport in Poland and in the European Union. The paper is a comparative analysis of the structure of road transport sector, cost of carrier services in different countries and their economic performance. The paper is aimed at demonstrating that the structure of Polish road transport sector and its economic performance, compared to other EU countries, inhibit Polish entrepreneurs' adaptation efforts connected with the so-called Mobility Package. Studies have shown that the implementation of proposed changes will deteriorate the competitiveness of Polish carriers, who currently enjoy cost advantage over their competitors, but whose labour productivity is low, economic performance poorer and who suffer from unfavourable structure of road transport.

Key words: road transport, competitiveness, road transport sector structure, costs of transport services

Synopsis. Polskie przedsiębiorstwa rynku usług transportu drogowego nie stanowią już tła dla firm z kapitałem zagranicznym, lecz są równorzędnymi partnerami i konkurentami na tym rynku. Transport drogowy w Polsce stanowi podstawę polskiego systemu transportowego, a także jest istotnym elementem europejskiego systemu transportowego. Artykuł koncentruje się na wybranych aspektach określenia miejsca i roli transportu drogowego w strukturze polskiego systemu transportowego. Obecnie już z całą pewnością można mówić o dojrzałym, konkurencyjnym rynku usług transportu drogowego z rozwiniętymi procesami konkurencyjnymi stanowiącymi element nie tylko krajowego, ale też europejskiego, a nawet światowego systemu gospodarczego. Artykuł zawiera analizę porównawczą polskiego systemu transportu drogowego z systemami transportu drogowego wybranych krajów UE w aspektach kosztowych, a także innych czynników przewagi konkurencyjnej.

Słowa kluczowe: transport drogowy, konkurencja, struktura branży transportu drogowego, koszty usług transportowych

Introduction

Since the beginning of the short history of Polish market economy which was initiated by an economic reform taking place at the turn of the 1990s, the market of transport services has been through a lot of evolution. The beginning of Polish market economy was a time when a traditional transport sector was developed along with other fields of national market economy. Today, it is definitely possible to discuss a mature and competitive market of road transport services on which competitive processes have been fully developed and which comes as an element of the national, European and even global economic system. Polish companies operating in the market of road transport services do not come only as some background for companies with foreign capital, but they are equal business partners and competitors in this market. The particular segments of the market have also undergone some transformation in the fields of cargo transport and passenger transport in terms of structural and quality aspects. The use of road transport for individual needs has been systematically decreased. Transformation of traditional transport companies into more specialised logistics operators has become more and more common. Contract logistics has been trying to take a stronger position on the market of road transport services and – in a broader perspective – on the market of logistics services.

Development of road transport in Poland, which can undoubtedly be defined as a specific economic phenomenon, depends on numerous factors. Transport services provided by Polish carriers account for 25% of cargo transported by road in the European Union [Mindur 2017]. Surely, this situation has been affected by demand factors related to all the processes of pro-market orientation of Polish economy since 1989. The development of Polish economy in a new market reality and establishment of its competitive position in the international scene has resulted from the adjustment of the road transport sector to new requirements on one hand, and, on the other hand, growing needs of competitive economy have required efficient services in the road transport sector, first of all. After 30 years, when considered from the perspective of road transport, the above-mentioned interdependency can be undeniably defined as favourable. The main goal of this paper is a comparative analysis of the structure of road transport sector, cost of carrier services in different countries EU and their economic performance. The paper is aimed at demonstrating that the structure of Polish road transport sector and its economic performance, compared to other EU countries, inhibit Polish entrepreneurs' adaptation efforts connected with the so-called Mobility Package.

The national transport system as an element of the national economic system

The current condition and development of the Polish transport system depend on the growth rate of national economy. The Polish transport system comes as an important element of the national economic system. Its proper operation allows all interested parties to achieve their developmental aims efficiently. Therefore, the research on both these

systems (the national economic system and the national transport system, including road transport) should be carried out simultaneously, with consideration of their mutual relations. Considering the above-mentioned conditions, some selected macro-economic indices which allow us to set the data on the current condition of the market of road transport services in Poland against some specific background are presented in Table 1.

Table 1. Selected economic indices in the years 2016–2018
Tabela 1. Wybrane wskaźniki ekonomiczne w latach 2016–2018

Specification	2016	2017	2018
Gross domestic product (% year of the year)	3.1	4.8	5.1
Domestic demand (% yoy)	2.8	4.7	5.3
Individual consumption (% yoy)	3.9	4.8	4.3
Gross fixed capital formation (% yoy)	–	–	8.7
Industrial production (% yoy)	6	6.2	6.8
Real retail sale (% yoy)	6.1	5.2	7.1
Unemployment rate (%)	8.3	6.6	5.7
Gross real wages (% yoy)	4.2	3.4	5.3
Budget deficit (% yoy)	2.8	11.4	8.5
Inflation (% yoy)	–0.6	2.0	1.6

Source: own study based on 2018 Statistical Yearbook of the Republic of Poland [GUS 2018].

Considering the data presented in Table 1, it is possible to assume that during the analysed period (2016–2018) the growth rate recorded for Polish economy was considerably high. The development of Polish economy was relatively evenly distributed in the particular quarters and years. Also, during the analysed period, the GDP growth rate index was maintained at the high and relatively constant levels of 3.1% (2016) and 5.1% (2018). While analysing the above-mentioned indices for the development of market economy in Poland retrospectively over the past 30 years, various conditions of Polish economy in the particular periods of time should be emphasized. Undoubtedly, it is possible to notice that there were years of fast and slow development or even stagnation. For example, in the years 2004–2007 economic conditions were favourable and the GDP growth rate reached the level of 5% approximately. The economic crisis of 2008 affected Polish economy and the situation was reflected in economic indices related to the operation of the transport system, including the road transport system. An important moment, which had a lot of impact on formation of the road transport system, was the accession of Poland to the EU structures and the acceptance of the Schengen Agreement.

While observing global production in the years 2016–2018, it is possible to notice its stable growing tendency. The years 2016–2018 were characterised by moderate capital expenditures. Hence, the growing level of Polish economy in the recent years has positively affected the development of the transport system, including the road transport system.

The value of the market of transport services, warehousing and mail (objects and passengers) in Poland has grown up to PLN 170 billion approximately, which is about 10.6% of the GDP (2018).

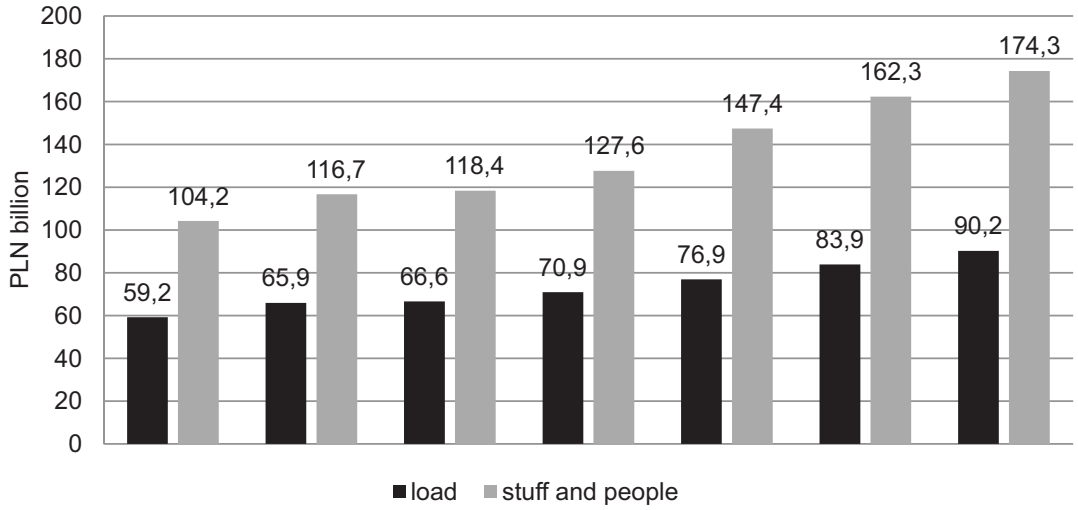

Figure 1. Revenues from the sale of transport services in the years 2012–2018
Rysunek 1. Przychody ze sprzedaży usług transportowych w latach 2012–2018
Source: own study based on 2018 Statistical Yearbook of the Republic of Poland [GUS 2018].

It should be emphasized that the shares of the particular profiles of business activities (services) on the logistics market are not even in its total revenues and the top position is taken by transport, forwarding and warehousing. In Table 2 the shares of the particular business activity profiles in the revenues of the market of logistics services in Poland are presented.

Table 2. The share of the particular business activity profiles (types of services) in the total revenues of the market of logistics services in Poland in the years 2011–2016
Tabela 2. Udział poszczególnych profili działalności (rodzajów usług) w całkowitych przychodach rynku usług logistycznych w Polsce w latach 2011–2016

Business activity profile	Share in the total revenues (%)					
	2011	2012	2013	2014	2015	2016
Transport	34.63	33.83	34.93	32.83	32.93	32.98
Forwarding	46.86	45.86	45.96	46.53	46.71	46.79
Warehousing	14.85	14.85	15.40	16.40	16.60	16.70
Customs services	0.84	0.84	0.80	0.80	0.80	0.80
Cross-docking	1.38	1.38	1.42	1.42	1.42	1.43
Logistics consulting	0.70	0.70	0.50	0.50	0.50	0.50
Others	0.74	0.50	0.99	1.52	1.04	0.80

Source: own study based on 2018 Statistical Yearbook of the Republic of Poland [GUS 2018].

Transport, forwarding and warehousing services have always been the centre of the market of logistics services. Despite the growing significance of other logistics services, it seems that this situation will not change in the years to come.

The position of road transport in the mode structure of the national transport system

At present, road transport is a mode of transport which prevails in cargo transport in Poland and in the European Union. Its share in transport performance (without air and sea transport) has been maintained at a stabile level of, approximately, 72% for many years. Economic significance of road transport as a service sector in the European Union is determined by the fact that it generates a turnover at the level of EUR 470 billion (including cargo transport – EUR 330 billion and passenger transport – EUR 140 billion) and provides employment to 5 million people approximately [European Commission 2017].

Considering the domestic market of transport services, it is estimated that in 2018, it concentrated about 132 thousand companies, which was approximately 3.6% of all enterprises in Poland [Enter Poland 2015]. It should be emphasized that the growing domination of road transport on the market of transport services has already reached the value of over 80% of total general transport. The volume of cargo transported by the particular modes of transport is presented in Table 3. The percentage share of the particular modes of transport in cargo transport is presented in Table 4.

Table 3. Cargo transported in the years 2014–2018
Tabela 3. Ładunek przewożony w latach 2014–2018

Transport mode	Amount of cargo transported (thous. t)				
	2014	2015	2016	2017	2018
Road transport	1 553 050	1 1505 719	1 546 572	1 747 266	1 873 022
Rail transport	227 890	224 320	222 523	239 501	249 260
Sea transport	6 781	6 963	7 248	8 254	9 149
Pipeline transport	49 810	54 850	54 058	52 393	55 287

Source: own study based on 2018 Statistical Yearbook of the Republic of Poland [GUS 2018].

The data presented above indicate the absolute domination of road transport. Over the past few years, however, this tendency has been slightly decreased. Based on the above-mentioned data and with the consideration of other sources, it is possible to formulate some fundamental conclusions as to the place and the role of road transport on the market of transport services in Poland, namely:

- prevailing significance of road transport in total cargo transport;
- specific phenomenon that can be observed in Polish economy and on the European market (every fourth driver in the EU is a Polish driver);
- high supply of transport services provided by private entrepreneurs;

Table 4. Share of the particular modes of transport in cargo transport in the years 2014 and 2018
Tabela 4. Udział poszczególnych rodzajów transportu w transporcie towarowym w latach 2014 i 2018

Transport mode	Share in cargo transport			
	thous. t	%	thous. t	%
	2014		2018	
Total	1 837 531	100.00	2 186 718	100.00
Road transport	1 553 050	84.51	1 747 266	79.90
Rail transport	227 890	12.40	239 501	10.50
Sea transport	6 781	0.004	8 254	0.004
Pipeline transport	49 810	0.03	52 393	0.023

Source: own study based on 2018 Statistical Yearbook of the Republic of Poland [GUS 2018].

- strong competition which results in falling prices and growing quality of services;
- constant increase in operation costs of road transport.

At this point, the field of regulations in the development and operation of the market of road transport services should be emphasized. In the 1990s, as a result of fast development of international road traffic, some serious problems with the throughput capacity at the borders were observed. The fast growth in the number of Polish carriers resulted in a situation in which foreign authorities permanently refused to grant permits for international road transport operation [IRU report]. Accepted in 1991, the Act on International Road Transport Operation introduced operating licenses which could be granted only to carriers who:

- had at least three years of practice in national transport or one year of practice in international transport, with relevant documents to prove it;
- had clean criminal records in the last three years and were not punished for any offences against road traffic safety or against the property.

The amendment to the legal regulations in 1997 facilitated development of transport companies through the implementation of a legal practice which allowed carriers to pass their operating licenses to each other, selling particular vehicles with operating licenses. They were signed over to their new owners – such operations were confirmed by relevant administrative decisions. The Polish Act of 17 November 2006 on road transport and traffic introduced some significant changes to the access to the occupations related to providing road transport services (including forwarding services, for example). An important aspect in the field of legal regulations referring to road transport was the Mobility Package. Published in 2017, it included a set of directives proposed by the European Commission. The new regulation initiatives refer to, among others, the access to the market of cargo road transport, social regulations in road transport, tolls for using transport infrastructure and interoperability of various toll collection systems.

In the future, the Mobility Package will significantly contribute to an increase in costs related to provision of transport services by Polish carriers; hence, it will affect their competitiveness on the EU market of road transport services, mainly because it will be necessary to comply with the regulations referring to salaries paid at the levels established in the countries where services are provided.

The share of Polish road transport companies in the European market

The competitiveness of the Polish system of road transport in comparison to the EU transport system can be analysed in various aspects and from different perspectives. The position taken by carriers coming from various countries can be evaluated based on the dynamics of changes in the volume and performance of transport and the shares of carriers from the particular countries in services related to cargo turnover on the European market. The dynamics in the volume and performance of transport is presented in Figure 2, assuming that the base year is 2000 = 100%.

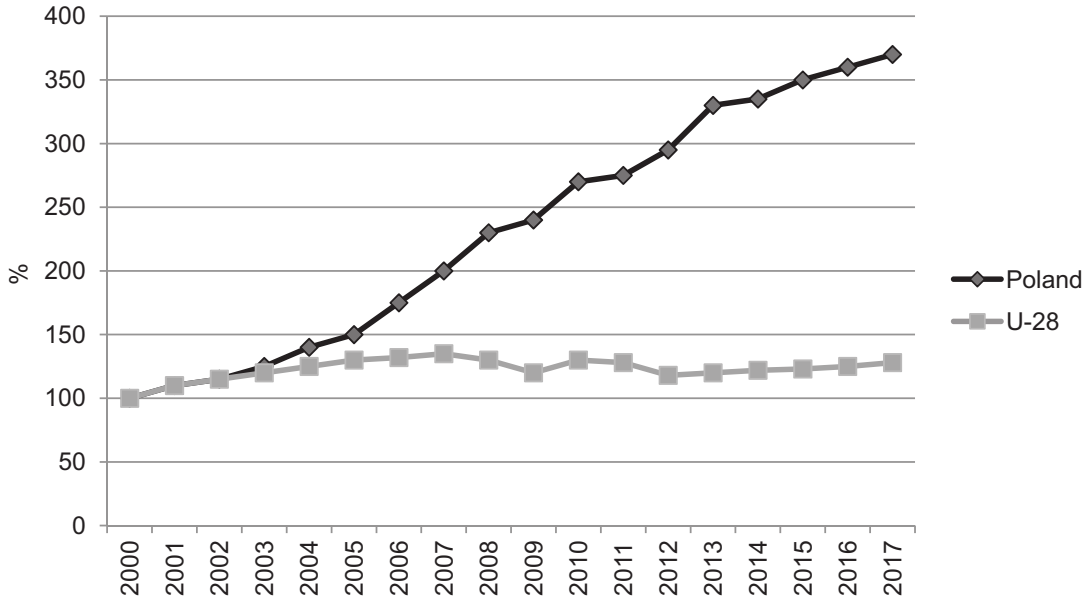

Figure 2. The dynamics of changes in the volume and performance of cargo road transport in the EU-28 and in Poland in the years 2000–2017 (year 2000 = 100%)

Rysunek 2. Dynamika zmian wielkości i wydajności drogowego transportu towarowego w UE-28 i Polsce w latach 2000–2017 (2000 r. = 100%)

Source: own study based on Statistical Yearbooks of the Republic of Poland of relevant years [GUS 2000–2017].

The data presented in Figure 2 indicate that the performance of cargo transport services provided by Polish road transport companies in the years 2000–2015 was characterised by growth dynamics which was much higher than the average in the EU-28 (growth by 247.6%). It proves their high competitiveness and constant development.

Considering the volume of transport, it is usually analysed in terms of shares taken in the international markets (export and import, cross-trade and cabotage) and national markets (where services are provided by domestic carriers). Domestic transport accounts for approximately 2/3 of the total transport operations in the EU, expressed in tonne-kilometres. In 2015, the total domestic transport provided by carriers from different countries accounted for 65.1% in the performance of transport in the EU. Intensified integration within the single market contributed to some faster growth in international road transport than in domestic road transport. In the years 2005–2015 the number of tonne-kilometres covered in international transport was increased by 46% and in domestic transport it was

higher only by 6%. Some dynamic growth in cabotage transport services (Table 1) should be also noticed. In the years 2005–2015 there was an increase in cabotage transport services by 115%, however their share in total transport is rather small and it is only 1.8% [Eurostat, 2018a].

Table 5. International and domestic cargo road transport in the EU-28 in the years 2000, 2005, 2010 and 2015

Tabela 5. Międzynarodowy i krajowy transport drogowy towarów w UE-28 w latach 2000, 2005, 2010 i 2015

Transport	Share in cargo road transport							
	billion tkm	%	billion tkm	%	billion tkm	%	billion tkm	%
	2000		2005		2010		2015	
Domestic	1 086.4	72.0	1 225.8	68.3	1 176.9	67	1 151.0	65.1
International	421.6	28.0	568.8	31.7	578.4	33	616.9	34.9
including cabotage	no data	no data	14.9*	0.8	20.5	1.2	32.1	1.8
Total	1 509.5	100	1 794.6	100	1 755.3	100	1 767.9	100

*For the EU-25.

Source: own study based on [Eurostat 2018a].

After the accession of Poland to the European Union, Polish carriers started to participate in international transport more intensively, which was reflected in the data provided by the Statistics Poland (Główny Urząd Statystyczny). In the years 2004–2015, an increase in transport operation was as follows [GUS 2005–2016]:

- in domestic transport – 37.8 billion tkm (growth by 64%);
- in international transport – 110.4 billion tkm (growth by 251%), including export – 33 billion tkm; import – 32.2 billion tkm, cross-trade – 37 billion tkm and cabotage – 8.1 billion tkm.

The analysis of the changes in the performance of transport indicates that Polish carriers achieved success and the growth in their performance of transport services considerably differs from the results achieved by their competitors from other countries. Polish carriers recorded the highest growth in transport performance (258.7 billion tkm) in the years 2000–2015, and it was four times the number of tonne-kilometers which was reported by Spanish carriers and six times the number of tonne-kilometers which was reported by German carriers, who occupied the subsequent positions on that list. The high dynamics in performance of transport was reported for Bulgarian, Lithuanian and Croatian carriers; however, the levels of growth reported for them did not exceed 26 billion tkm [DG MOVE 2017]. The expansion of Polish carriers on the European market resulted in fact that they took over a large share of cargo which had been so far transported by carriers from other countries. Carriers from Italy, France, the Great Britain and Belgium were affected by that situation in the most negative way. Polish carriers have held the greatest share in international transport for several years (in 2015 was as high as 25.2%). The next positions have been taken by Spain (11.7%) and Germany (7.6%). The domination of carriers from Central and Eastern Europe in cross-trade transport is even more conspicuous. They provide over 80% of such transport services and the largest share is taken by Polish

carriers (29.5%). Among the EU-15 countries, only Portugal (3.5%) and the Netherlands (3.1%) stand out in that sector [Koźlak 2018].

An important factor of competitiveness in cargo road transport is the price of the service, which largely depends on the prime costs related to providing services (and, obviously, the margin).

Based on some interviews with road carriers, the AECOM research team [2014] defined a typical structure of cargo transport costs in some EU member countries (Fig. 2). In the research, costs related to drivers included wages and remuneration surcharges and costs related to training. Fuel costs were calculated based on the purchase prices, including fuel taxes. The category of other costs included depreciation, maintenance costs, costs related to tyres, insurance, financial expenses, taxes and tolls.

In majority of the EU member countries, the level of labour costs exceeds 33%; according to the above-mentioned research survey, Poland is the only country where labour costs were at a lower level of 20%. This level corresponded to the data published by the Statistics Poland [GUS 2017]. The costs related to fuel ranged from the levels of 24% and 38% of the total costs. In comparison to other countries, Polish carriers report a considerably large share in the category of other costs. It results from high costs related to outsourced services, especially costs of fleet leasing and depreciation. The structure of costs related to cargo transport in the selected EU member countries is presented in Figure 3.

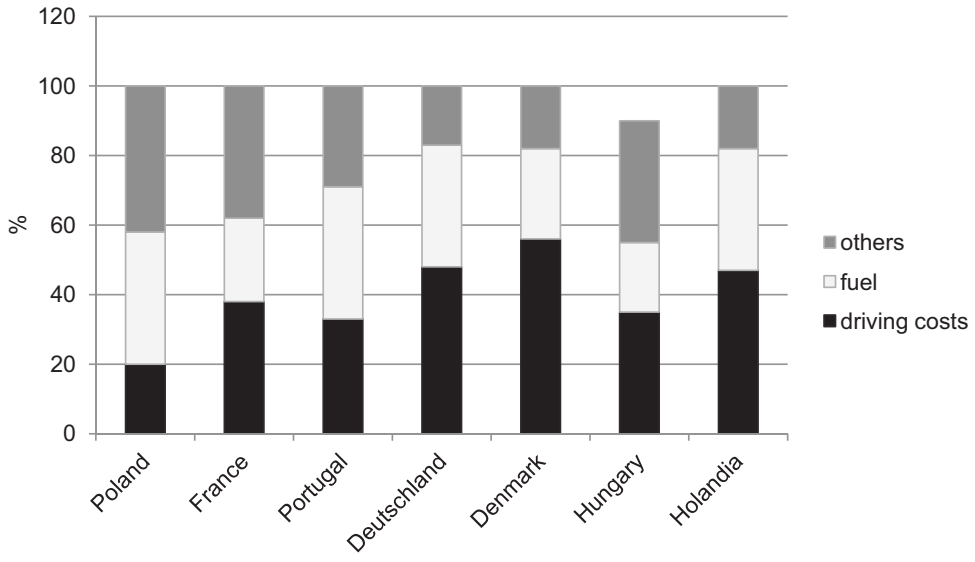

Figure 3. The structure of costs related to cargo transport in the selected EU member countries in 2012

Rysunek 3. Struktura kosztów związanych z transportem ładunków w wybranych krajach członkowskich UE w 2012 roku

Sources: [AECOM 2014].

The above-mentioned data indicate that the lowest labour costs in transport can be observed in Polish companies (the available data indicate that the lowest labour costs can be observed in Bulgarian companies). The highest labour costs are reported in Denmark and they are almost tenfold higher than in Bulgaria. It should be emphasized that given in the absolute values, labour costs in the EU member countries which joined the EU

in 2004 and in 2007 are much lower than in the EU-15 member countries, however, as a result of the convergence process, the discussed difference has been gradually decreased. The dynamics of remuneration growth in road transport is higher in the EU-13 countries than in the EU-15 countries. It results mainly from the obligation imposed in some countries on foreign carriers to pay the minimum wages (among others, in Germany, France and Italy).

In the EU, the costs of fuel change according to the situation on the global oil market, nevertheless the differences between the countries are quite considerable. In the EU taxation on energy products has been standardised and the minimal levels of taxes which are calculated into the price of fuel have been established. Apart from that limitation, the EU member countries can freely shape their domestic tax rates in a way which is in line with their current policies, which is usually reflected in the prices of fuel. The lowest prices of diesel oil are reported in Luxembourg and Bulgaria, the highest – in Italy and Sweden. In the most expensive country fuel costs over 40% more than in the cheapest country. Compared to the countries of Western Europe, relatively cheaper fuel in Poland reinforces the competitive position of Polish carriers. A weak point of Polish road transport companies is low work efficiency; it is reported to be several times lower for Polish carriers than for German, Danish, Dutch or British carriers. Companies of Western Europe have some technological and innovative advantages in terms of product, process and organisational innovations. It is also possible to discuss some capital advantage because Western European companies have higher equity levels and they have an easier access to external funding. Furthermore, Western European companies offer higher quality and broader ranges of services related to cargo transport. It results from their technological and capital advantage. Services of higher added value are offered mainly by medium-sized and large companies with their own cargo handling terminals and logistics centres. Polish transport companies which operate on the European market specialise in simpler services of transporting cargo from its sender to its recipient.

Conclusions

Some available forecasts provided by the government agencies and independent experts and scientists allow us to state that the competitive position and the role of road transport in Poland continue to strengthen, also in terms of the structure of the national transport system and in the perspective of competition in the field of international transport. All activities undertaken to limit the role of road transport in Poland are inefficient; hence, the pursuit of the properly balanced structure in the cargo transport can be achieved only by providing favourable conditions for cooperation between the particular transport modes and by achieving synergic results in that field. In accordance with the forecast published in the Transport Development Strategy (with a perspective until 2030) by the Ministry of Infrastructure and with consideration of the particular transport modes, the largest share of demand for cargo transport will belong to road transport; the demand for cargo transport performance (tkm) in terms of the spatial configuration will grow in the sector of international transport – by 2.8–3.2% on average annually. The aim of the Polish transport and economic policy is to achieve higher integration of road and rail modes of transport (with consideration of needs and

possibilities of other modes of transport in that respect) and, eventually to increase the throughput capabilities of the transit system in cargo transport. A necessary condition to achieve the above-mentioned aim is to provide infrastructural and organisational conditions for the operation of logistics chains. Some important signals in that field can be observed in the form of plans for, among others, the construction of the Central Communication Port or for the establishment of the national logistics operator, etc. The achievement of the above-mentioned aim will also depend on maintaining the high competitiveness level of Polish carriers in road transport. Although the present situation of Polish carriers in the European market is favourable, the implementation of the Mobility Package, as it is proposed by the European Commission, may considerably worsen their competitiveness. In the near future, Polish carriers will certainly face some problems generated by protective activities undertaken by the particular EU member countries in order to support their own transport companies. Therefore, it is very important for companies to become aware of the significance related to the development of their own competitiveness factors which refer not only to competitive prices of services resulting from low labour costs, but also to the increase in work efficiency, to the increase in innovation, higher corporate culture and synergic effects resulting from cooperation among particular elements of the national logistics system.

References

AECOM, 2014: Report on the State of the EU Road Haulage Market. Task A: Collection and Analysis of Data on the Structure of the Road Haulage Sector in the European Union, [electronic source] https://ec.europa.eu/transport/sites/transport/files/modes/road/studies/doc/2014–02-03-state-of-the-eu-road-haulage-market-task-a-report.pdf [access: 15.11.2019].

Burnewicz J., 2017: The competitiveness of Polish road transport on the European market, ResearchGate, [electronic source] https://www.researchgate.net/publication/315656322 [access: 15.11.2019].

Directorate-General for Mobility and Transport – DG MOVE, 2017: EU transport in figures. Statistical pocketbook 2017, Publication Office of the European Union, Luxembourg.

Enter Poland, 2015: Polski rynek transportu drogowego w pigułce [The Polish road transport market in a nutshell], [electronic source] https://enterpoland.com./polski-rynek-transportu-drogowego [access: 15.11.2019].

European Commission, 2017: An overview of the EU road transport market in 2015. DG for Mobility and Transport, [electronic source] https://ec.europa.eu/transport/sites/transport/files/mobility-package-overview-of-the-eu-road-transport-market-in-2015.pdf [access: 15.11.2019].

Eurostat, 2018a: Eurostat Statistics Explained, [electronic source] http://ec.europa.eu/eurostat/statistics-explained/index.php/Main_Page [access: 15.11.2019].

Eurostat, 2018b: Structural Business Statistics, [electronic source] http://ec.europa.eu/eurostat/web/structural-business-statistics/data/database [access: 15.11.2019].

Główny Urząd Statystyczny – GUS, 2005–2016: Transport – wyniki działalności [Transport – activity results], Warszawa.

Główny Urząd Statystyczny – GUS, 2014–2018: Rocznik Statystyczny Rzeczypospolitej Polskiej [Statistical Yearbook of the Republic of Poland], Warszawa.

Główny Urząd Statystyczny – GUS, 2017: Transport drogowy w Polsce w latach 2014 i 2015 [Road transport in Poland in the years 2014 nad 2015], Warszawa.

International Road Transport Union – IRU: Road Transport in Poland – selected data. Report, Geneva.

Koźlak A., 2018: Struktura sektora transportu drogowego w Polsce i ocena jego wyników ekonomicznych na tle państw Unii Europejskiej [Structure of the road transport sector in Poland and assessment of its economic results against the background of European Union countries], Studia i Prace. Kolegium Zarządzania i Finansów SGH 166, 62–63.

Mindur L., 2017: Znaczenie międzynarodowego transport drogowego dla wzrostu i konkurencyjności gospodarki Polski [The meaning of the international road transport for the growth and competitiveness for Polish economy], [in:] M. Chaberek, L. Reszka (Eds.), Modelowanie procesów i systemów logistycznych. Część XVI [Modeling of logistics processes and systems. Part 16], Zeszyty Naukowe Wydziału Ekonomicznego Uniwersytetu Gdańskiego. Ekonomika Transportu i Logistyka 65, 83–93.

Ustawa z dnia 17 listopada 2006 r. o zmianie ustawy o transporcie drogowym oraz o zmianie ustawy – Prawo o ruchu drogowym. Dz. 2006 nr 235, poz. 1701 [Act of 17 November 2006 amending the act on road transport and amending the act – road traffic law. Journal of Laws 2006 No 235, item 1701].

Correspondence address:

assoc. prof. Andrzej Jezierski, PhD habil.
(https://orcid.org/0000-0001-7360-2086)
University of Gdańsk
Department of Logistics
Armii Krajowej St. 119/221, 81-824 Sopot, Poland
e-mail: andrzej.jezierski@ug.edu.pl

Ekonomika i Organizacja Logistyki
4 (3), 2019, 99–109

DOI: 10.22630/EIOL.2019.4.3.27

Elżbieta J. Szymańska, Michał Wielechowski
Warsaw University of Life Sciences – SGGW

The New Silk Road importance for Polish-Chinese trade relations

Znaczenie Nowego Jedwabnego Szlaku dla wymiany handlowej między Polską i Chinami

Abstract. The aim of the research was to recognize the importance of the New Silk Road concept for trade relations between Poland and China. The study uses data from the Statistics Poland (Główny Urząd Statystyczny) on Poland's foreign trade turnover with China, as well as information from the source literature. The adopted research period covers the years 2010–2018. The analysis shows that the New Silk Road has a significant impact on global supply chains by reducing the time of transporting goods on the China-Europe route, and by expanding infrastructural, financial and IT links to improve international trade. The analysed route gives the ability for China to extend the influence zone, and strengthen its position in the international arena, and for European countries is a source of infrastructural development and increased trade. Poland, due to its geographical location, can act as a bridge connecting Western markets with Central Asia, and should seize the opportunity to become a logistics hub and distribution centre of goods transported on the New Silk Road. The challenge for Polish businesses, trade organizations and the government is to increase exports of goods and services to China via terminals in Gdańsk, Małaszewicze, Łódź and Sławków.

Key words: trade relations, the New Silk Road, terminal, Poland, China

Synopsis. Celem badań było rozpoznanie znaczenia koncepcji Nowego Jedwabnego Szlaku dla wymiany handlowej między Polską i Chinami. W opracowaniu wykorzystano dane Głównego Urzędu Statystycznego w zakresie obrotów handlu zagranicznego Polski z Chinami oraz informacje z literatury przedmiotu. Przyjęty okres badawczy obejmuje lata 2010–2018. Z analizy wynika, że Nowy Jedwabny Szlak istotnie wpływa na globalne łańcuchy dostaw poprzez skrócenie czasu przewozu towarów na trasie Chiny – Europa oraz ekspansję powiązań infrastrukturalnych, finansowych i IT służących poprawie prowadzenia wymiany handlowej. Chinom daje możliwość rozszerzania strefy wpływów oraz umacniania swojej pozycji na arenie międzynarodowej, a dla krajów europejskich stanowi źródło rozwoju infrastruktury i zwiększenia wymiany handlowej. Polska z racji swojego położenia geograficznego może stanowić swoisty pomost łączący rynki zachodnie z Azją Centralną. Powinna ona wykorzystać szansę stania się portem logistycz-

nym i centrum dystrybucyjnym towarów przewożonych na Nowym Jedwabnym Szlaku. Istotne wyzwanie dla polskich przedsiębiorstw, organizacji handlowych i rządu stanowi zwiększenie eksportu produktów i usług do Chin poprzez terminale w Gdańsku, Małaszewiczach, Łodzi i Sławkowie.

Słowa kluczowe: wymiana handlowa, Nowy Jedwabny Szlak, terminal, Polska, Chiny

Introduction

One of the most important factors determining the country's economic development is transport, which acts as the "bloodstream" of the national economy. Transport is a key component of production and distribution processes of material goods and services. Transport is complementary to all human economic activities. In the era of globalisation, international trade and international competition are growing fast. As a consequence, the increased role of logistics and transport in the organization and management of efficient flows of resources and ensuring their availability at the lowest costs and in the shortest possible time has been observed [Nerć-Pełka and Wysocka 2012].

In Poland, there is a need to improve and develop a coherent and well-functioning transport system, integrated with the European and global system. Without effective transport, it is not possible to accelerate the country's economic growth and develop international trade. As a result of changes taking place in the international arena, the following new challenges are facing the national transport system [Resolution No 105 of the Council of Ministers of 24 September 2019]:

- the increase of transport services availability (for both Polish and foreign users);
- the reduction of transport costs and time, combined with a gradual energy efficiency improvement and an unit emission costs decrease;
- development of multimodality.

Transport development is possible due to investments intended for the existing infrastructure modernization as well as investments responsible for modern infrastructure facilities creation. Developed and well-maintained infrastructure attracts investments, enables opening to new markets and access to its own markets, facilitates the rational use of the workforce potential and promotes regional development [Walasek 2018]. Transport infrastructure strengthens the social, economic and spatial cohesion of the country and contributes to strengthening the economy competitiveness. The infrastructure, or more detailed the access to it, is a one of the most important determinants of enterprises, regions, countries and continents development.

A good example of transport infrastructure is the New Silk Road, an extensive infrastructure network connecting China, Central Asia, the Middle East and Europe. It is worth noting that the original Silk Road was established over 2100 years ago during the Han Dynasty to tighten trade between China and European countries [Liu 2010]. However the "Silk Road" is not an ancient invention, and it dates back to 1877. Baron Ferdinand von Richthofen, a prominent geographer who worked in China from 1868 to 1872, used the phrase "Silk Road" for the first time in his five-volume atlas [Hansen 2012]. The historical role of the Silk Road is considered from the perspective of mutual benefit of states along the trade route [Silin et al. 2018].

The New Silk Road is also called the One Belt and One Road strategy. The initiative is based on six following pillars [Huang 2016]:

- Coordination of activities aimed at developing cooperation and communication mechanism.
- Promotion of undisturbed international trade by the economic integration at regional level and reduction of trade and investment barriers.
- Creation of interpersonal relationships by the organization of academic and cultural exchange.
- Improvement of connectivity by creating an appropriate technical infrastructure and developing a common system of standards.
- Financial integration based on joint financial institutions creation.
- Monetary policy coordination.

According to Cui and Song [2019], the New Silk Road will surely change the existing pattern of the international trade, which may substantially affect both global supply chain management and logistics development. The New Silk Road is based on two types of transport, i.e. maritime and railway. Currently, railway transport handles a small proportion of China-European Union goods turnover, in practice about 3–4%. Maritime transport of goods is much more developed. That branch of the New Silk Road is to increase China's economic ties not only with Europe, but also with Middle East countries. Both routes of the New Silk Road need not compete with each other, but should be rather complementary.

Research aim, material and methods

As the New Silk Road leads through Central Asian countries to Western Europe via Poland, the purpose of the research was to recognize its significance for trade between Poland and China. The study uses data from the Statistics Poland (Główny Urząd Statystyczny – GUS) foreign trade turnover with China, as well as information from the source literature. Comparative analysis and inductive reasoning were used in the studies. The paper presents changes in the value of Poland's trade with China in 2010–2018 and the structure of imports and exports of goods in 2018. Then, the development of cooperation between Poland and China was described, and the New Silk Road initiative was presented. In the area of that concept, the importance of Polish terminals was pointed out. A descriptive and graphic method was used to present the results of the research.

Foreign trade turnover between Poland and China in 2010–2018

China is Poland's largest trading partner in Asia and, on the other hand, Poland is the most important Chinese trading partner in Central and Eastern Europe. In 2010, Poland's trade in goods with China amounted to over USD 18.3 billion (Fig. 1). By 2018, it increased 84.3% to USD 33.8 billion. However, the trade structure was dominated by imports of goods from China to Poland. In 2010, its value was over USD 16.7 billion and by 2018 it increased to USD 31.3 billion.

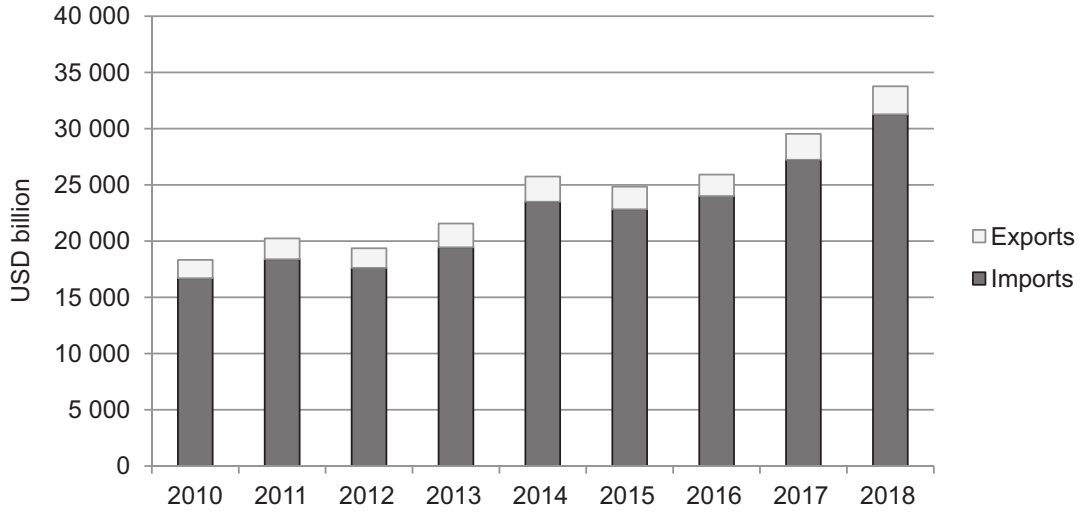

Figure 1. Foreign trade turnover between Poland and China in 2010–2018
Rysunek 1. Obroty handlu zagranicznego Polski z Chinami w latach 2010–2018
Source: own elaboration based on Statistical Yearbooks of Foreign Trade of 2011–2019 [GUS 2011–2019].

The value of Polish exports to China in 2010 was more than 10 times lower than imports and amounted to USD 1.63 billion, and by 2018 it increased 53.5% to USD 2.5 billion. As a consequence, the characteristic asymmetry in Polish foreign trade relations with China increased, i.e. in 2018 Poland imported goods from China with a value 12.5 times higher than the value of Polish exports to China. Trade deficit of Poland with China widened to a record level of USD 28.7 billion. Poles more and more willingly imported goods from China mainly due to the increasing quality of Chinese products, transport improvements, as well as constantly developing routes and tightening trade relations with Chinese enterprises.

Among the imported consumer goods from China to European countries including Poland, textiles, leather and leather-like products, clothing, electronics, chemicals, vehicles and automotive parts, agricultural products and food products dominate. Poland exports to China mainly copper, machinery, rubber, plastics and food products. In 2018, according to Statistics Poland data, the structure of Polish imports from China was dominated by machines, devices and transport equipment, which constituted 51.9% of the total value of imports (Fig. 2). A large part of imports also included various transport products (29.2%). Industrial goods classified mainly by raw material constituted a smaller share of imports (12.7%), and chemicals and related products constituted only 4.1%.

The structure of Polish exports to China was dominated by machines, devices and transport equipment, which constituted 33.2% of total export value (Fig. 3). A similar percentage concerned industrial goods classified mainly as raw materials. Transport products accounted for 16% of Polish exports to China, while chemicals and related products accounted for 5.5%.

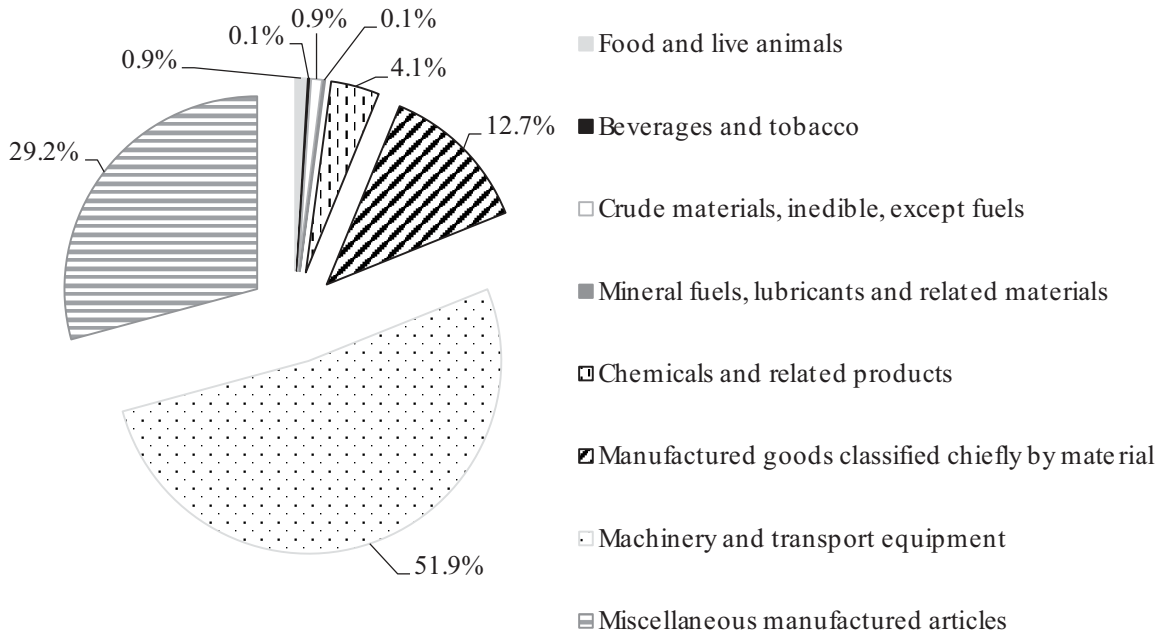

Figure 2. Import structure of goods from China to Poland in 2018
Rysunek 2. Struktura importu towarów z Chin do Polski w 2018 roku
Source: own elaboration based on Statistical Yearbook of Foreign Trade of 2019 [GUS 2019].

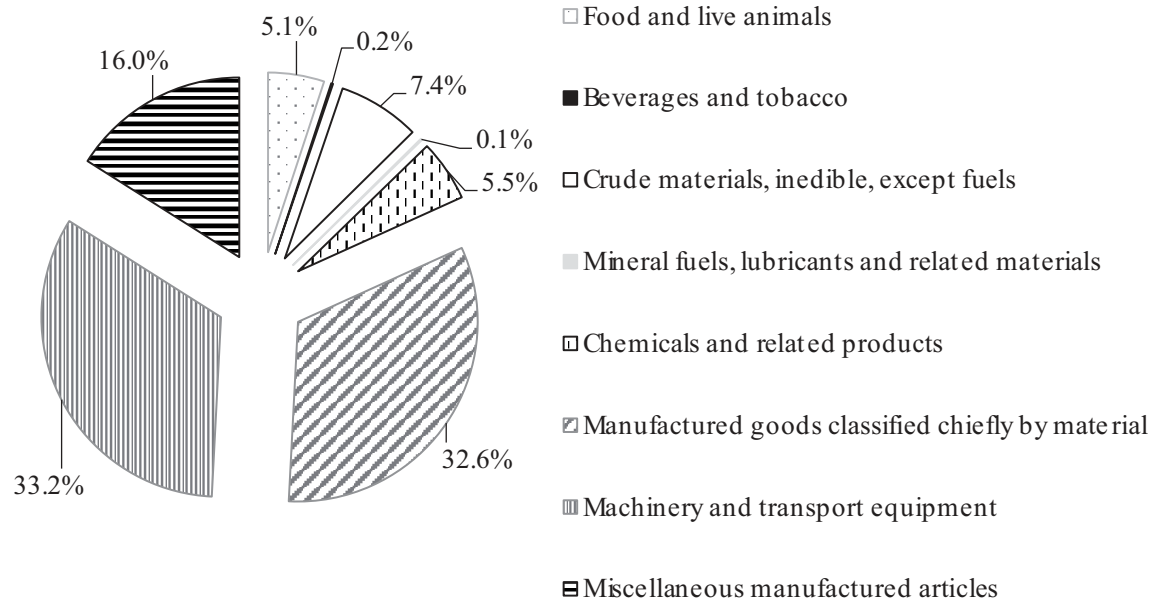

Figure 3. Export structure of goods from Poland to China in 2018
Rysunek 3. Struktura eksportu towarów z Polski do Chin w 2018 roku
Source: own elaboration based on Statistical Yearbook of Foreign Trade of 2019 [GUS 2019].

Development of Poland and China cooperation

Lively cooperation between Poland and China was initiated in 2011, when the presidents of those countries signed an agreement on strategic cooperation. Since then, the period of ever closer mutual economic relations began [Szczudlik-Tatar 2015]. In 2012, Chinese government submitted a plan of 16+1 initiative based on 12 steps of mutual cooperation between China and 11 European Union Member States: Bulgaria, Croatia, the Czech Republic, Estonia, Lithuania, Latvia, Poland, Romania, Slovakia, Slovenia and Hungary, and with five Balkan countries: Albania, Bosnia and Herzegovina, Montenegro, Macedonia and Serbia. The aim of that cooperation was develop investment in infrastructure, transport, finance, tourism, and culture and science [China-CEEC 2015].

The New Silk Road has significantly developed and improved the quality of Polish-Chinese cooperation, and gave the chance for increased imports from China to Poland. The route gave the opportunity for fast and economical transport of imported goods. The New Silk Road concept was firstly presented by Chinese president, Xi Jinping, during his visit to Kazakhstan in 2013 [Pepermans 2018]. For China, the New Silk Road (also known as One Belt and One Road initiative) is the continuing and deepening of the Chinese "Going Global Strategy", i.e. an opportunity for further development by expanding its sphere of influence and strengthening its position on the international arena [Chen 2016]. The New Silk Road may also bring substantial economic benefits to other Eurasian countries [Li et al. 2015]. For European countries, the route contributes building or modernizing transport, transmission and telecommunications infrastructure, increasing trade and strengthening multicultural human relations.

The New Silk Road is a long-term and relatively new project, therefore it is constantly developing and evolving and its scale is increasing. The concept of the land and sea New Silk Road assumes the creation of transport corridor network connecting China with European Union countries, i.e. the main trade partners for China. The official route indicates one land section and one sea section, which connect in northern Italy. However, this is a simplification, because the concept of the New Silk Road is a conglomerate of routes and provides several variants of China transport connection with Europe. Some of connections already existed, such as railway connections from Chongqing to Duisburg or from Wuhan to Prague. Some have been launched after the announcement of New Silk Road initiative, such as the route from Chengdu to Łódź or from Yiwu to Madrid, while others are in plan [Majszyk and Niedziński 2015]. The New Silk Road is a flexible initiative and can even be expanded to include past projects as there are no deadlines or detailed parameters [Fallon 2015].

In 2014, in order to provide funding for the New Silk Road, the Silk Road Fund was established, estimated at USD 40 billion. The aim of the fund is to finance economic corridors and infrastructure elements. Moreover, in 2014 the Asian Infrastructure Investment Bank (AIIB) was established, currently associating 70 countries, including Poland, with capital of USD 100 billion. Additional financing for the New Silk Road is provided by the New Development Bank (NDB) created in 2015, with a capital of USD 50 billion, which consociates BRICS countries, i.e. Brazil, Russia, India, China and South Africa [pc 2017].

The role of Poland on the New Silk Road

Poland has the chance to play the role of an important logistics hub and distribution centre for goods transported on the New Silk Road to European Union countries. Geographical location is a strength of Poland, and allows a convenient transport of Chinese goods to the European Union. Transported goods have to cross only two customs borders due to existence of the Eurasian Economic Union, i.e. custom union between Kazakhstan, Russia and Belarus. Moreover, Poland is the largest member of 16+1 group, which can be a key issue. It is worth mentioning that Germany, the Netherlands and the United Kingdom are China most important trading partners in Europe.

There are several major plans determining the route of the New Silk Road connecting China with the European Union. Selected planned routes are presented on Figure 4:

- The northern corridor assumes the use of the Russian Trans-Siberian Railway and runs from Kazakhstan, through the territory of Russia, to Belarus, and then to Poland. The corridor is currently in operation. Its advantages include the small number transitional countries and the lowest number of border crossings. However, the disadvantages are connected with difficult climate conditions and potential impediments on Russian part of the route, as Russia is a strong and demanding partner for China.
- The southern corridor begins near Kazakhstan, then passes through territory Turkmenistan or Kyrgyzstan, Tajikistan, and reaches Iran. Through Iran, the southern corridor leads to Turkey and then connects to Europe. Its main disadvantages include a large number of border crossings and growing political instability in the region.
- The central corridor crosses the Kazakhstan territory and uses the sea connection, reaching the Azerbaijani port of Alat, then passes through the southern Caucasus and reaches Europe in Turkey. The middle corridor is a good alternative because of the relatively "friendly" countries along its route. Its main disadvantage is the diversity of transport forms and political uncertainty in the Caucasus.

Polish container terminals may play an important role on the above presented the New Silk Road routes, in particular:

- Małaszewicze border terminal and connection to the Łódź-Olechów terminal;
- Hrubieszów-Sławków Południowy LHS railway and Sławków terminal;
- DCT Gdańsk – Deepwater Container Terminal Gdańsk, BTDG – Baltic General Cargo Terminal Gdynia, and GCT – Gdynia Container Terminal.

Key important for railway transport from China through Poland is Małaszewicze terminal, located 5 km from Polish-Belarusian border. In recent years there has been a sharp increase in the number of trains serviced by that terminal. In 2018 there were 2,200 trains, while in 2011 only 17. In 2018 over 98% of serviced containers in Małaszewicze terminal were from or to China. Currently (in 2019) Małaszewicze terminal is able to receive 2,825 trains a year. In order to further Małaszewicze terminal development the managing company PKP Cargo CL Małaszewicze, belonging to the PKP Cargo Group, obtained European Union funding for terminal expansion. After the works are completed – by the end of 2020 – the terminal will be able to service 3,285 trains yearly [Świderski 2019].

Sławków Terminal is located on the final section of the broad-gauge railway line (1,520 mm) and has been improved its transshipment, storage, forwarding, logistics and

Figure 4. The New Silk Road routes
Rysunek 4. Nowy Jedwabny Szlak
Source: Straits Times.

customs offer for many years. It can be used for handling: containers, semitrailers, swap bodies, loose goods (coal, coke, anthracite), Pelle salt, cereals, metallurgical products, iron, glass, wood, palletized goods, goods in big bags and chemical products. Sławków terminal has the following annual capacity: about 285 thousand TEU of container handling, 380 thousand t of metallurgical products, 200 thousand of palletized goods, 2 million t of bulk goods, 365 thousand other bulk goods. Principals of transshipment services have the option of weighing loads on rail and road scales. It is also possible to use three large warehouses on Sławków terminal, i.e. with an area of 8,500 m^2, 4,860 m^2 and the area for 1,760 Euro-pallets [Perenc 2018]. At Sławków terminal conditions for direct and indirect transshipment in the following three routes have been created:

- broad gauge wagons – standard gauge wagons;
- standard gauge wagons/standard gauge wagons – cars;
- cars – cars.

Łódź-Olechów terminal is served by Spedcont company. It has very good conditions to increase the scale of its operations, thus the number of connections is constantly increasing. His role has long gone beyond the container handling area, in favour of an important link in the intermodal supply chain. Regarding the New Silk Road initiative, Łódź Olechów terminal may become an important logistics hub enabling the movement of loads from China and other Far East countries to European countries, while minimizing the costs of transshipment and transport between terminals. Spedcont reloading terminal in Łódź has 2,800 running meters of tracks, 42,000 m^2 of storage area for 5,000 TEU, both for containers and exchangeable bodies[1].

[1] https://www.spedcont.pl/oferta.html [access: 05.11.2019].

The New Silk Road maritime route will enter Europe in the southern part of the continent and due to geographical location will favour the Balcans and Hungary. In Poland, a significant element for the functioning of the New Silk Road maritime route will be ports in Tri-City (Gdańsk, Gdynia, Sopot). They can act as a transshipment hub for smaller ships with delivery to Finnish and Russian ports. The Tri-City port complex has a very large transshipment and storage potential. The total reloading capacity of DCT Gdańsk – Deepwater Container Terminal Gdańsk, BTDG – Baltic General Cargo Terminal Gdynia, and GCT – Gdynia Container Terminal is around 5 million TEU [Perenc 2018].

Due to the functioning of the New Silk Road land and sea routes, international trade of goods between Asian and European countries can be present by various transport modes that are suitable for long-distance transport. The advantages of maritime transport include the mass character, relatively low operating costs and environmentally friendliness. The current size of ships, their modern technological solutions, and relatively small crews make maritime transport is getting more and more popular. As a consequence, most of loads from China, Korea, Singapore, India to Western and Central Europe are transported by sea. The only disadvantage of the New Silk Road maritime transport is the relatively long transport time of 30–40 days. However, an important advantage is the relatively favourable price for the sea freight which amounts USD 1,380–1,630 per twenty-foot container [Perenc 2018]. It should be noted that effective liner shipping vessel sharing is essential for maritime Silk Road initiative in terms of building efficient maritime transport networks [Qiu et al. 2018].

Railway transport may be another important channel of international transport on China-Europe route. The railway in these transports can use a broad-gauge railway line (1,520 mm) along the LHS line to Sławków or through the customs border in Małaszewicze (on tracks with a gauge of 1,435 mm). It should be noted that reloading at border stations causes additional costs and extends the transport time. The advantage of the New Silk Road railway routes is a shorter delivery time of 14–20 days. However, a significant disadvantage of it are high transport costs (in comparison to maritime transport), as the price of railway freight is about USD 9,000 per twenty-foot container.

Conclusions

1. Efficient transport plays a crucial role in foreign trade and globalization and integration processes. Without efficient transport, it is not possible to accelerate the country economic growth and develop foreign trade. Transport development is possible due to infrastructural investments. The New Silk Road, the extensive infrastructure network connecting China, Central Asian, Middle East and European countries, is an important initiative tightening international trade relations.
2. The new Silk Road has a significant impact on global supply chains by reducing the time of transporting goods on the China-Europe route, and improves trade by expanding infrastructure, financial and IT links. The analysed route gives the ability for China to extend the zone of influence, and strengthen its position in the international arena, and for European countries is a source of infrastructure development and increased trade.

3. Poland, due to its geographical location, can act as a bridge connecting Western markets with Central Asia, and become a logistics hub and a distribution centre for goods transported on the New Silk Road. Therefore, it is important from Polish perspective to handle cargo at every stage, starting from storage, further transport management, documentation and optimization of logistics processes.
4. In the analysed period imports of Chinese goods dominated in Polish-Chinese trade relations. Increasing quality of Chinese products, transport improvements and tightening trade relations with Chinese companies were the source of worsening Polish trade balance. A challenge for Polish government, enterprises, and trade organizations is to increase exports of goods and services to China using the New Silk Road through terminals in Gdańsk, Małaszewicze, Łódź and Sławków in subsequent years.

References

Chen H.P., 2016: China's 'One Belt, One Road' Initiative and its Implications for Sino-African Investment Relations, Transnational Corporations Review 8 (3), 178–182.

Cooperation between China and Central and Eastern European Countries – China-CEEC, 2015: China's Twelve Measures for Promoting Friendly Cooperation with Central and Eastern European Countries, [electronic source] http://www.china-ceec.org/eng/zdogjhz_1/t1410595.htm [access: 05.12.2019].

Cui L., Song M., 2019: Ec**o**nomic evaluation of the Belt and Road Initiative from an unimpeded trade perspective, International Journal of Logistics Research and Applications 22 (1), 25–46.

Fallon T., 2015: The New Silk Road: Xi Jinping's Grand Strategy for Eurasia, The American Foreign Policy Interests 37 (3), 140–147.

Główny Urząd Statystyczny – GUS, 2011–2019: Rocznik Statystyczny Handlu Zagranicznego [Statistical Yearbook of Foreign Trade], Warszawa.

Hansen V., 2012: The Silk Road. A New History, Oxford University Press, New York.

Huang Y., 2016: Understanding China's Belt & Road Initiative: Motivation, Framework and Assessment, China Economy Review 40, 314–321.

Li P., Qian H., Howard K.W.F., Wu J., 2015: Building a new and sustainable "Silk Road economic belt", Environmental Earth Sciences 74, 7267–7270.

Liu X., 2010: The Silk Road in World History, Oxford University Press, New York.

Majszyk K., Niedziński B., 2015: Nowy jedwabny szlak przyniesie korzyści. Nie tylko Chinom [The new Silk Road will benefit. Not only for China], [electronic source] https://biznes.gazetaprawna.pl/artykuly/885634,nowy-jedwabny-szlak-przyniesie-korzysci-nie-tylko-chinom.html [access: 04.11.2019].

Nerć-Pełka A., Wysocka A., 2012: Logistyka i transport a wyzwania współczesnej gospodarki [Logistics and transport versus challenges of the modern economy], Problemy Zarządzania, Finansów i Marketingu 27, 69–82.

pc, 2017: Czym jest chińska inicjatywa „Pasa i Szlaku"? [What is the Chinese Belt and Road initiative?], [electronic source] https://www.gospodarkamorska.pl/Porty,Transport/czym-jest-chinska-inicjatywa-pasa-i-szlaku.html [access: 04.12.2019].

Pepermans A., 2018: China's 16+1 and Belt and Road Initiative in Central and Eastern Europe: economic and political influence at a cheap price, Journal of Contemporary Central and Eastern Europe 26, 181–203.

Perenc J., 2018: Koncepcja włączenia Polski i polskich terminali do obsługi ładunków w relacjach Chiny-Europa-Chiny [The concept of including Poland and Polish terminals to handle cargo in China-Europe-China relations], Ekonomiczne Problemy Usług 1 (130), 109–120.

Qiu X., Wong E.Y.C., Lam J.S.L., 2018: Evaluating economic and environmental value of liner vessel sharing along the maritime silk road, Maritime Policy & Management 45 (3), 336–350.

Silin Y., Kapustina L., Trevisan I., Drevalev A., 2018: The Silk road economic belt: balance of interests, Economic and Political Studies 6 (3), 293–318.

Świderski P., 2019: Polskie porty i Małaszewicze są kluczowe dla przewozów intermodalnych Nowym Jedwabnym Szlakiem [Polish ports and Małaszewicze are key for intermodal transport on the New Silk Road], [electronic source] https://strefabiznesu.pl/polskie-porty-i-malaszewicze-sa-kluczowe-dla-przewozow-intermodalnych-nowym-jedwabnym-szlakiem/ar/c3-14042379 [access: 05.11.2019].

Szczudlik-Tatar J., 2015: Poland-China Strategic Partnership: Waiting for More Results, PISM Bulletin 106(838), [electronic source] https://www.pism.pl/files/?id_plik=20936 [access: 04.11.2019].

Uchwała nr 105 Rady Ministrów z dnia 24 września 2019 r. w sprawie przyjęcia Strategii Zrównoważonego Rozwoju Transportu do 2030 roku. M.P. 2019, poz. 1054 [Resolution No 105 of the Council of Ministers of 24 September 2019 regarding the adoption of the Strategy for Sustainable Development of Transport until 2030. Official Gazette of the Republic of Poland 2019, item 1054].

Walasek R., 2018: Interoperacyjność transportu intermodalnego jako element jego konkurencyjności w Unii Europejskiej [Interoperability of intermodal transport as an element of its competitiveness in the European Union], Studia i Prace Kolegium Zarządzania i Finansów, SGH w Warszawie 166, 153–164.

Correspondence address:

assoc. prof. Elżbieta J. Szymańska, PhD, Eng
(https://orcid.org/0000-0001-7686-1243)
Warsaw University of Life Sciences – SGGW
Institute of Economics and Finance
Department of Logistics
Nowoursynowska St. 166, 02-787 Warsaw, Poland
e-mail: elzbieta_szymanska@sggw.pl

Michał Wielechowski, PhD
(https://orcid.org/0000-0002-1335-8971)
Warsaw University of Life Sciences – SGGW
Institute of Economics and Finance
Department of Economics and Economic Policy
Nowoursynowska St. 166, 02-787 Warsaw, Poland
e-mail: michal_wielechowski@sggw.pl

ISSN 2450-8055