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Contents
Spis treści

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The logistics performance analysis in European Union – EU-15 vs. EU-13

Analiza wydajności logistycznej w Unii Europejskiej – UE-15 vs. UE-13

Abstract. Logistics accounts for 14% of total GDP in the European Union countries, which shows the importance of the logistics service and performance of the European Union countries. Logistics market of EU-15 countries is well developed while most of EU-13 countries need to address poor railway infrastructure and other political issues related to corruption and lack of competitiveness. However, EU-13 economies are growing fast and can benefit even more from the improvements in logistics market. Therefor this paper aims to analyze logistics performance in the European Union, distinguishing between EU-15 and EU-13 countries. For our analysis we use Worlds Bank Logistics Performance Index (LPI) which is a tool that measures the quality, velocity, accuracy and simplicity of the logistics processes. The analysis covers the period from 2010 to 2018. The results of our analysis show that some EU-13 countries are lagging behind EU-15 countries in terms of logistics performance, while countries like Poland, Czech Republic and Hungary are the best logistics performers among all EU-13 countries. Results also shows us correlation between logistics performance and economic growth which imply that EU-13 countries must take step forward in their logistics performance in order to integrate in regional and global supply chain and thus enhance their economic position and competitiveness.

Key words: logistics, logistics performance index – LPI, European Union, EU-15, EU-13

Synopsis. Logistyka stanowi 14% całkowitego PKB krajów Unii Europejskiej, co wskazuje na duże znaczenie tego sektora dla wyników ekonomicznych krajów członkowskich Unii Europejskiej. Rynek logistyczny krajów UE-15 jest dobrze rozwinięty, podczas gdy większość krajów UE-13 powinno podjąć działania dla rozwoju słabej infrastruktury kolejowej oraz pochylić się nad kwestiami politycznymi związanymi z korupcją, czy brakiem konkurencyjności. Szybko rozwijające się gospodarki UE-13 mogą jednak skorzystać na poprawie rynku usług sektora logistycznego. Celem artykułu było określenie wydajności sektora logistyki w Unii Europejskiej z podziałem na kraje UE-15 i UE-13. W pracy wykorzystano wskaźnik wydajności logistyki według Banku Światowego (Logistics Performance Index

– LPI), który jest narzędziem określającym jakość, szybkość, dokładność i prostotę procesów logistycznych. Analiza objęła okres od 2010 do 2018 roku. Wyniki wskazują, że niektóre kraje UE-13 pozostają w tyle za członkami UE-15 pod względem wyników logistycznych, podczas gdy kraje takie jak Polska, Czechy i Węgry osiągają najlepsze wyniki logistyczne wśród krajów UE-13. Wyniki wskazują również na korelację między wynikami logistyki a wzrostem gospodarczym. To oznacza, że kraje UE-13 muszą zrobić krok naprzód w swoich wynikach logistycznych, aby zintegrować się z regionalnym i globalnym łańcuchem dostaw, a tym samym poprawić swoją pozycję gospodarczą i konkurencyjność.

Słowa kluczowe: logistyka, wskaźnik wydajności logistyki – LPI, Unia Europejska, EU-15, EU-13

Introduction

As trade expands across the border, and the world becomes one market, logistics gains greater importance and logistics industry faces with the number of demanding and complex processes. Logistics is also perceived as a source of competitive advantage. Good foundations for performing logistics at the highest level possible are opening great opportunities for economic growth. The foundations cover quality, coverage and development of infrastructure, and export and import related processes and its velocity. Therefor World Bank has created index which helps countries to identify their logistics position. Logistics performance index helps countries to see where they stand and what should be improved in order to make the most of the logistics potential. "Logistics performance is about how efficiently supply chains connect firms to domestic and international opportunities. The logistics performance tries to capture how logistically accessible and how well connected to the physical internet of global logistics a country is." [Arvis et al. 2018, p.7].

The aim of this research is to analyse the performance of European Union countries and compare the performances of EU-15 and EU-13, respectively old and new European Union member states. Since the current body of knowledge relates logistics performance with the economic growth, it is important for countries to be aware of their strength and weaknesses in regard to logistics. Our analysis is based on the Worlds Bank Logistics Performance Index (hereinafter LPI) methodology and covers the biennial period from 2010 to 2018.

This paper consists of five parts. After the Introduction, the second part reviews the previous literature related to logistics performance. In the third part, data and methodology are explained. The fourth part presents and discusses the results of the analysis and the paper ends with conclusions and policy implications.

Literature review

As logistics is getting bigger attention, different measurement tools have been developed. This measurement tools evaluate the quality and efficiency of logistics by analysing trade infrastructure, trade regulations, IT development and availability of skilled workers. Logistics performance is measured with different tools, some of which is LPI. Since its

first publication in 2007, LPI became one of the most usable tools in logistics performance and trade facilitation analysis. Puertas, Marti and Garcia [2014] use LPI as a proxy variable for logistics performance in order to estimate the effects of logistics performance on trade in 26 European Union member states. Marti, Puertas and Garcia [2014a, b] followed the same methodology to detect the effects of logistics performance on trade in developing groups of countries, among which are Eastern European countries. Saslavsky and Shepherd [2014] also analyse the effects of logistics performance. The authors investigates the LPI effects on trade within international production networks which are more sensitive to logistics performance. Pupavac and Drašković [2017] analyse the logistics capability in Southeast Europe based on the LPI methodology.

Zekić, Samardžija and Pupavac [2017] use LPI as one of the measures of countries competitiveness. Host, Pavlić Skender and Zaninović [2019] in their gravity framework use LPI as a proxy variable for trade facilitation in order to detect its effects on trade for a group of 150 countries. Bugarčić, Skvarciany and Stanišić [2020] investigate the effect of logistics performance on trade volume in Central and Eastern European and Western Balkan countries. Their results suggest that logistics performance have important effects on trade volume, especially the variables international shipments, logistic quality and competence and tracking and tracing. Zaninović, Zaninović and Pavlić Skender [2020] estimate the mpact of logistics performance on the international bilateral trade distinguishing between trade of EU-15 and EU-13 countries with the rest of the world in the period 2010–2018. The authors use differences in LPI values as a main variable of interest and their results show that LPI differences affect bilateral trade differently, namely it depends of the type of goods that partner countries trade. According to Arvis et al. [2018, p. 5] „LPI results have been embraced by the academic community, as evidenced by the widespread use of LPI data in research reports, journal articles, and textbooks".

In general, scientific and professional literature agree that LPI is a good indicator of logistics performance and therefor we use LPI in our analysis.

Data and methodology

Worlds Bank Logistics Performance Index is a main variable of our interest and we use it in order to analyse the logistics performance in European Union countries. As previously mentioned, LPI is an indicator provided by the World Bank. It measures the logistics performance and the quality of logistics climate in evaluated countries through six indicators. "This index was developed through a joint survey of logistics providers, the World Bank and the scientific community. It covers a broad set of elements that indicate the perceived effectiveness of trade logistics in practice. The index was created as a result of freight forwarders' ranking of countries according to key logistical issues such as efficiency of customs procedures, quality of infrastructure and ability to track freight" [Pavlić Skender and Grčić Fabić, 2014, p. 102–103].

Worlds Bank Logistics Performance Index measures logistics performance through six indicators. These indicators are as follows [Arvis et al. 2018, p. 8]:

1. The efficiency of customs and border management clearance.
2. The quality of trade – and transport-related infrastructure.
3. The ease of arranging competitively priced international shipments.

4. The competence and quality of logistics services.

5. The ability to track and trace consignments.

6. The frequency with which shipments reach consignees within the scheduled or expected delivery time.

In order to facilitate trade, customs procedures must be simplified, and its number must be minimized. Usually, customs agencies are better evaluated. Other border agencies include standards, sanitary, phytosanitary, transport, and veterinary agencies. The number of agencies and the number of their physical inspections are in the process of reducing. Countries with higher customs score have faster customs process with less or none delays.

Comprehensive and productive infrastructure is essential for successful running of the economy, as it is a significant factor in deciding the area of economic action and the sorts of exercises or sectors that can evolve in a specific example [Pupavac and Golubović 2015, p. 245]. Comprehensive infrastructure which covers the country (including remote and underdeveloped parts) assists in the development of whole country at a specific pace, not just the centralized and most developed parts. Infrastructure includes both transportation infrastructure and ICT infrastructure. Both are important for the development of logistics. However, ICT infrastructure needs continuous adjustment as communication technology and communication speed changes. Better quality of trade and transport related infrastructure ensures goods to be moved faster, more accurately and more predictable.

"In the top performers, the ease of arranging shipments tends to lower overall LPI scores, possibly because macroeconomic factors generally make services more expensive there, which may make it hard to arrange shipments perceived as competitively priced elsewhere" [Arvis et al. 2014, p. 11]. However, the prices remain at certain, tolerable price since competition is also bigger. On the other hand, prices are higher in smaller land-locked and island countries since the connectivity and competition in those countries is smaller.

The competence and quality of logistics services can be the main reason for choosing a specific country to trade with or to trade in. There are many critical components of this indicator, such as the transparency of processes and the quality, predictability (especially of the clearance process), and reliability of services. However, we also must take into consideration that other factors like border policy and business environment affect logistics performance [Arvis et al. 2007].

Tracking and tracing are contemporary benefit that can increase the value of logistics service as they enable to track and trace the goods and to estimate the delivery time more precisely, thus facilitating planning and increasing predictability. The ability to track and trace consignments is often better graded than the very quality of logistics services.

Timeliness strongly depends on the quality of logistics services and infrastructure. According to Arvis et al. [2018, p. 28], the interruptions in delivery may be caused by following factors: "unpredictability in clearance, inland transit delays, and low service reliability". Taken into consideration that the recurrence of postpones usually increases as the logistics performance decreases, it is obvious that the timeliness of clearance and delivery is usually disrupted as country descends the LPI quintiles. Delays and errors in delivering are much less tolerated in high performing countries (such as European Union countries) than in lower and low performing countries.

Furthermore, when LPI data is used in the comparison, one should never use rank only. The rank does not say much about the country, and a big difference in rank does not mean a big difference in score. Furthermore, there should be used longer period for comparison, not just the latest with the previous one. Also, the reliability of respondents must be taken into consideration, since this index is questionnaire-based.

The LPI is based on an international survey of freight forwarders and express carriers. It is a measurement tool introduced by the World Bank that evaluates logistics performance through the whole supply chain within specific country. The observation of the results across 167 countries can help countries to recognize the difficulties and chances and improve their logistics performance. The survey is conducted every two years, with exception between 2007th and 2010th edition [Arvis et al. 2018, p. 70].

As mentioned above, there were 167 observed countries by logistics performance index in 2018th edition. The countries involvement depends on the respondents and where are they coming from. The respondents' rate eight markets they cooperate with based on six indicators listed earlier. Additionally, respondents also rate the market in which they work. Furthermore, the domestic LPI is also made based on data about their own market. In our analysis we distinguish between EU-15 and EU-13 countries. EU-15 is the grouping of the first 15 member states, also called old members. The EU-15 consists of the following countries: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden and the United Kingdom. All the EU-15 countries are high-income level countries. "Germany runs a trade surplus of U.S. $ 279 billion and imports only 79 percent of what it exports. The Netherlands and Belgium also show a trade surplus with imports representing only 89 and 78 percent of their exports, respectively" [David 2018, p. 13]. EU-13 or the new member states are the following: Bulgaria, Croatia, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia and Slovenia. Since LPI is being published every two years, we use biennial data from 2010 to 2018.

The results

The LPI scores of EU-15 vary from 3.2 to 4.2, and the average is 3.854. When comparing average scores of EU-15 and high-income countries, EU-15 has a higher mean of LPI score as well as all indicators. Nevertheless, some EU-15 countries have lower than average results. The only EU-15 country that has a LPI score lower than average in high-income countries (3.5) is Greece with a score of 3.2. Greece has scores of all of the indicators lower than the average of high-income countries. Tables 1 and 2 presents descriptive statistics of aggregate LPI and its six sub-indices in year 2018 separately for EU-15 and EU-13 countries.

All of the minimum values in the table above are scored by Greece. Portugal has also lower than average scores in customs and infrastructure indicators, and Ireland in timeliness indicator. All of the maximum values are scored by Germany, except for international shipment score of 3.99, which is achieved by Belgium. Germany is the best ranked European country holding first position. However, there are some other countries which have been constantly within top performers. Those are the Netherlands, Sweden and

Table 1. Descriptive statistics of EU-15 countries in 2018
Tabela 1. Statystyki opisowe krajów UE-15 w 2018 roku

Variable	**Obs**	**Mean**	***SD***	**Min**	**Max**
Overall LPI	15	3.845	0.261	3.200	4.200
Customs	15	3.635	0.334	2.840	4.090
Infrastructure	15	3.867	0.373	3.170	4.370
International	15	3.660	0.216	3.300	3.990
Logistics	15	3.865	0.297	3.060	4.310
Tracking	15	3.913	0.295	3.180	4.320
Timeliness	15	4.159	0.230	3.660	4.410

Source: own calculation.

Belgium. On the other hand, the worst EU-15 performers through the years were: Greece, Portugal, Spain and Ireland. Standard deviations are higher in case of EU-15 for all LPI sub-indices meaning that there is larger disproportion in logistics performance within EU-15 group of countries than within EU-13 group of countries.

Table 2. Descriptive statistics of EU-13 countries
Tabela 2. Statystyki opisowe krajów UE-13

Variable	**Obs**	**Mean**	***SD***	**Min**	**Max**
Overall LPI	13	3.179	0.262	2.810	3.680
Customs	13	3.025	0.277	2.580	3.420
Infrastructure	13	3.037	0.214	2.730	3.460
International	13	3.148	0.319	2.700	3.750
Logistics	13	3.104	0.284	2.690	3.720
Tracking	13	3.192	0.292	2.790	3.700
Timeliness	13	3.558	0.369	2.880	4.130

Source: own calculation.

The highest scores of EU-13 countries are achieved in timeliness indicator. This shows that the deliveries almost always arrive as planned. On the other hand, the lowest mean of EU-13 is achieved from customs and infrastructure scores. Compared to the EU-15, these scores are much lower, again showing that less developed countries have lower scores in logistics performance.

Following Figure 1 shows the difference in cumulative LPI score between EU-15 countries and EU-13 countries in observed period from 2010 to 2018. It is noticeable that not just there is a large score gap between two groups of countries, but also EU-15 countries are growing faster than EU-13, in terms of logistics performance.

When we analyse each sub-index separately, in Figure 2, the gap is even larger. For example, sub-indices Customs and Infrastructure, which are in "public domain" show lower scores, meaning there is a slow move forward in the better performance of infrastructure or customs regulations while sub-indices International, Logistics, Timeliness and Tracking which are in the "business domain" were performing better from 2010 to 2014 and then, in 2016 and 2018 decline their performance, particularly in case of EU-13 countries.

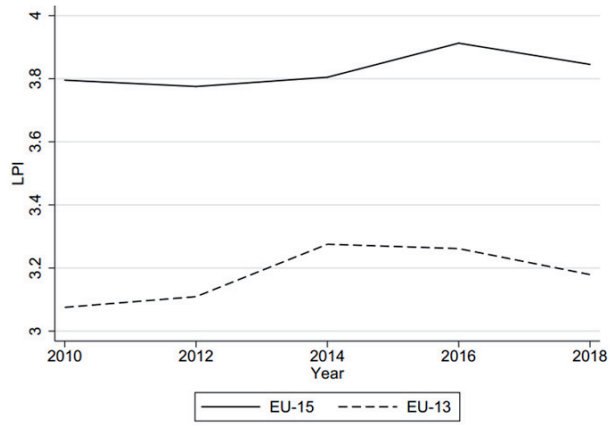

Figure 1. Cumulative distribution of EU-15 vs. EU-13 overall LPI scores in 2010–2018
Rysunek 1. Skumulowany rozkład ogólnych wyników LPI w UE-15 względem UE-13 w latach 2010-2018

Source: own calculation.

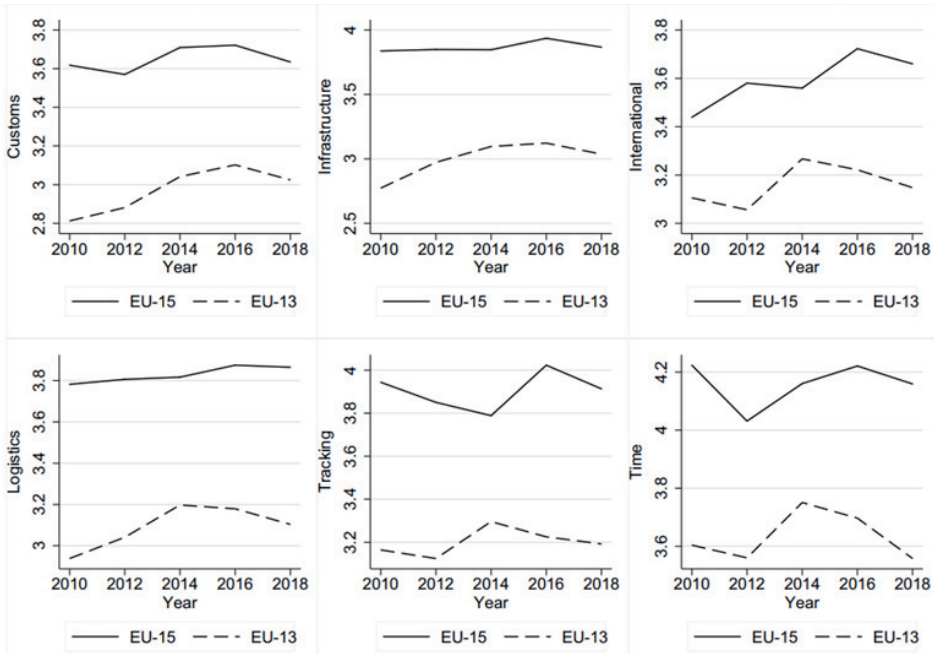

Figure 2. Cumulative distribution of EU-15 vs. EU-13 sub-LPI scores in 2010–2018
Rysunek 2. Skumulowany rozkład wyników UE-15 w porównaniu z wynikami sub-LPI w UE-13 w latach 2010–2018

Source: own calculation.

The highest scores of EU-15 countries are achieved in timeliness indicator. This shows that the deliveries almost always arrive as planned. The highest timeliness score of 4.4, achieved by Germany and Belgium, is the highest score in timeliness score overall, not just within scores of European Union countries. On the other end, the lowest mean of EU-15 countries is from international shipments indicator. Based on the results of EU-15 countries, there can be concluded that more developed countries, high-income level countries have higher results in logistics. The quality of logistics services, reliability and predictability is higher. Greece, on the other hand, as a country with unstable economic and political situation, has also worse logistics performance.

All of the EU-13 indicators scores are higher than the overall average of 167 countries, except for Bulgaria's infrastructure score, which is just below the average, 2.71 (overall average is 2.73). However, the results of EU-13 are lower than the average of high-income countries. More specifically, only Poland and the Czech Republic have higher than the average LPI score, international shipments, logistics competence and timeliness score. Further, the Czech Republic is the only country that has customs and tracking and tracing score higher than the average of high-income countries, while infrastructure is the only indicator in which all of the EU-13 countries have lower than the average score. The Czech Republic is by far the best EU-13 country, proved by the fact that all of the maximum values are achieved by Czechia. Four out of seven minimum values are achieved by Malta, two by Bulgaria and one by Romania. Countries that are top performers of EU-13 countries through the years are Hungary, Slovenia, the Czech Republic and Poland. On the other hand, countries with the lowest result through the years are Lithuania, Latvia, and Malta.

In order to analyse the relationship between economic development and LPI score, we run simple linear regression. Our model has the following form:

$$LPI_i = \beta_0 + \beta_1 GDPpc_{i+} \varepsilon_i,$$

where: LPI_i – the logistics performance index,
$GDPpc_i$ – the gross domestic product per capita,
ε_i – error term.

Our data consist of EU member states grouped in two groups (EU-15 and EU-13) in year 2018. The results of the regression are presented on the scatter plot (Figure 3).

Figure . shows us a noticeable gap between high- and lower-income countries, hence between EU-15 and EU13. However, it also shows that in the case of EU-15. Greece, Ireland and Luxemburg are underperforming countries when we look at the LPI score and economic development, while the rest of EU-15 countries are above regression line. In the case of EU-13, Czech Republic, Poland and Hungary are the best performing countries, while the rest of the countries are lagging behind them. If Croatia is compared with the Czech Republic, which was together with Croatia and Slovenia one of the most developed Central European transition economies, there can be seen large difference in their logistics performance (and economy in general) today. Today, according to LPI, Croatia is lagging behind the Czech Republic substantially. Actually, all EU-13 economies which

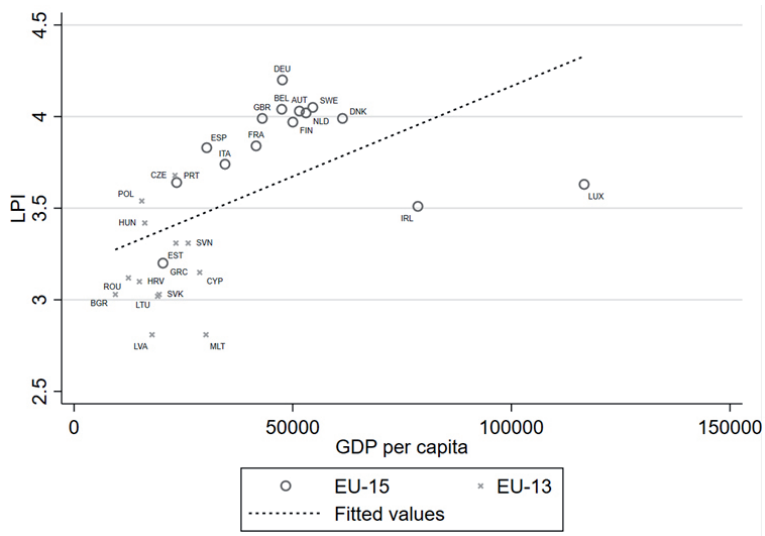

Figure 3. Regression LPI 2018 and GDP per capita (current USD, 2018)
Rysunek 3. Regresja LPI 2018 i PKB per capita (bieżące USD, 2018)
Source: own calculation.

are the best performers in logistics are among the fastest growing economies in European Union [Mordor Intelligence, 2018]. Better logistics performance enables to integrate in regional and global supply chains, and Czech and Poland are well integrated in European supply chains.

Conclusion

The aim of our research was to analyse logistics performance in the European Union, distinguishing between EU-15 and EU-13 countries. For our analysis we used LPI as it is a benchmark tool in logistics performance analysis and provide us better insights into the logistics performance and its position within increasingly complex regional and global supply chains. The logistics performance in European Union countries, measured by LPI, differs in size and scores. The difference occurs for reasons such as economic size, geographical size and position, and development of the country in general. However, European Union members compared to the rest of the world are well ranked. According to aggregated international logistics performance index results across five editions (2010, 2012, 2014, 2016, and 2018), 15 out of 28 European Union countries are in top 30, six of which are in the top 10. The worst-ranked European Union country is Malta, holding 61st position out of 167 countries evaluated, showing the development of European Union countries. The results show us a significant gap in their performance between EU-15 and EU-13 countries, however there is also present a large gap within each group of

countries. European Union countries like Germany, Netherlands and Belgium that traditionally dominate the supply chain industry are among best performing on the world scale. Czech Republic, Poland and Hungary are converging to the EU-15 logistics performance, while the rest of EU-13 countries must take step forward in order to perform better. Those "outperforming" countries must work on the developed of national logistics strategies in order to improve the functioning domestic and international logistics which is a precondition of national and European Union competitiveness.

Moreover, LPI covers six areas and it allow us to analyse each of them separately and detect strength and weaknesses in the logistics performance. The highest scores of EU-13 countries are achieved in timeliness indicator meaning that the deliveries almost always arrive as planned. On the other hand, the lowest mean of EU-13 is achieved from customs and infrastructure scores. This show us that businesses in EU-13 are working better and faster on enhancement of their logistics performance while the government must take step forward to enable better business climate, easier and faster customs procedures and better infrastructure.

The results shows us that EU-13 countries are better performing in logistics parts which are in the domain of the private sectors, in order to achieve better overall logistics performance, governments and institutions must take step forward and improve the parts which represents logistics performance bottlenecks, such as transport infrastructure. Improvements in infrastructure will help private sector to enhance their part of logistics performance since logistics performance overall is a multiway relationship and each part of logistics depends on others part parts of logistics. For example, improvements in infrastructure will lead to improvements in timeliness etc.

Logistics is a priority for many European Union member countries because trade and transport facilitation stimulate economic development. Logistics performance is significant for economic growth and competitiveness. EU-13 countries must constantly work on improvement of logistics-related policies, ICT, clearance processes, usage of multimodality, and encouragement of specialized logistics. The results of this research can help countries to frame their logistics policies and stategies and to work on the interventions and reforms at the national and European Union level. This research might be broadened to incorporate logistics performance index in macroeconomic growth model to estimate the contribution of logistics performance to an economy.

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Transport sector energy use and carbon emissions: a study on sectoral fiscal policies

Zużycie energii i emisja dwutlenku węgla w sektorze transportu: badanie sektorowych polityki fiskalnej

Abstract. As the energy sector worldwide is largely based on fossil fuel consumption, the amount of global-scale carbon emissions continues to increase over the years. One of the most important reasons for the increase in emissions, the transportation sector, continues to develop with globalization. The development of land, sea, and air transport together with international trade brings environmental problems in parallel with the increase in energy consumption. Accordingly, it is estimated that one fourth of total carbon emissions today originate from the transportation sector. In this context, in order to combat environmental problems such as global warming and climate change on an international scale, initiatives such as the Paris Climate Agreement are being implemented and environmental policies to reduce the amount of emissions are being recommended. The aim of this study is to examine environmental policies, which have been discussed extensively in the literature, in terms of fiscal policy. In this context, fiscal policy tools such as taxes, subsidies, incentives, and regulations specific to the transport sector were discussed. This study, in which the descriptive method is used, argues that fiscal policy practices can be an effective method in reducing the amount of carbon emissions.

Key words: transportation, fiscal policy, carbon tax

Synopsis. Sektor energetyczny na całym świecie w dużej mierze opiera się na paliwach kopalnych, co skutkuje ciągłym wzrostem emisji dwutlenku węgla na skalę światową. Jedną z najważniejszych przyczyn wzrostu emisji jest sektor transportu, którego rozwój jest powiązany z procesami globalizacji. Rozwój transportu lądowego, morskiego i lotniczego wraz z handlem międzynarodowym i zwiększonym zużyciem energii powoduje problemy środowiskowe. W związku z tym szacuje się, że jedna czwarta całkowitej emisji dwutlenku węgla pochodzi obecnie z sektora transportu. W tym kontekście, w celu zwalczania problemów środowiskowych, takich jak globalne ocieplenie i zmiany klimatyczne w skali między-

narodowej, wdrażane są takie inicjatywy, jak porozumienie klimatyczne z Paryża, a także zalecana jest polityka środowiskowa mająca na celu zmniejszenie ilości emisji. Celem niniejszego opracowania jest analiza polityki środowiskowej, która była szeroko omawiana w literaturze, pod kątem polityki fiskalnej. W tym kontekście omówiono narzędzia polityki fiskalnej, takie jak podatki, dotacje, zachęty i przepisy specyficzne dla sektora transportu. Niniejsze badanie, w którym zastosowano metodę opisową, dowodzi, że praktyki polityki fiskalnej mogą być skuteczną metodą zmniejszania ilości emisji dwutlenku węgla.

Słowa kluczowe: transport, polityka podatkowa, podatek węglowy

Introduction

The transportation sector is one of the important components of an economy, and it is possible to see its impact on the economy both on a microeconomic level and in a macroeconomic context. In the macroeconomic context, transportation accounts for 6 to 12% of the gross domestic product in many developed countries, while logistics accounts for 6 to 25%; on the microeconomic level, transportation accounts for an average of 10% of household expenditures, and each unit of production accounts for approximately 4% of the cost of output [Rodrigue and Notteboom 2020]. However, population growth and economic dynamism both expand the transport sector and increase its effects. It is possible to see these effects as either positive or negative in many areas such as development, health, environment, energy usage and well-being.

One of the major impacts is on the transport sector and its systems, which also constitute this main theme, on energy use and the environment at both the global and local levels. In the transportation sector, fossil fuels are significantly consumed, especially by airplanes and vehicles, and they also emit many environmentally harmful substances such as carbon dioxide and noise while contributing to global climate change, which is one of the biggest problems today. Accordingly, when the United Nations Framework Convention on Climate Change (UNFCCC) Conference of Parties was held in Paris in December 2015 at COP21, the parties officially announced their climate commitments to limit global warming below 2°C compared to pre-industrial temperatures. Although it is clear that transportation policies that respect the environment will contribute to sustainable economic growth on a national basis, the transportation sector is important and should be focused on when defining global emissions reduction goals, as it is a primary source of carbon emissions.

For more than five years after the Paris Climate Agreement, the entire world, particularly the European Union, has focused on how to reduce carbon emissions. At this point, the transportation sector, an energy-intensive sector due to the use of fossil fuels, draws special attention. It has become increasingly important that countries implement policies to reduce greenhouse gas emissions in the transportation sector in order to achieve the objectives of the agreement. In this regard, the energy use of the transportation sector and its impacts on the environment accordingly were analysed with the purpose of revealing the current situation, and preventive or mitigating policy tools were discussed in the study. Although various policy tools can be suggested for adaptation and mitigation, the impor-

tance of fiscal policies for the transportation sector is at the core of the study. Data from international organizations were also used for comparison in this study, which indicates the reason why such certain fiscal policy implementations as tax and market regulations are important with the help of descriptive analysis, one of the qualitative analysis tools.

The current energy use of the transport sector and its environmental impacts: drivers and trends

More than 20 years after the transport sector was recognized as one of the foundations of sustainable development for the first time at the United Nation's Earth Summit in Rio in 1992, 193 countries were present in New York in 2015 to adopt safe, affordable, accessible, and sustainable transport systems by 2030 under the goal of providing access. This indicates that global interest in transportation continues and highlights the desire to provide more sustainable and green transportation to future generations on a global level.

Increasing urbanization, population, mobility, industrialization, and economic growth, have increased energy consumption in every sector. While the industrial sector has been a leader for many years in the trend of global energy consumption and thus greenhouse gas emissions, it is seen that the global energy consumption of the transportation sector has caught and even surpassed the industrial sector, especially since 2017 (Table 1).

Table 1. Total final consumption [ktoe] by sector, world in 1990–2018
Tabela 1. Całkowite zużycie końcowe [w ktoe] według sektorów, świat w latach 1990–2018

Years	Industry	Transport	Residential	Commercial and Public Services	Agriculture/ /Forestry	Fishing	Non- -specified	Non- -energy Use
1990	1 803 105	1 575 288	1 530 461	450 350	164 032	6 048	260 520	477 373
1995	1 791 088	1 716 062	1 726 692	502 760	174 387	6 048	88 345	530 906
2000	1 871 304	1 962 766	1 804 114	555 003	149 194	6 169	77 382	606 101
2005	2 236 928	2 218 273	1 897 469	642 824	174 375	8 054	99 106	702 822
2010	2 638 047	2 429 780	1 987 340	717 378	182 748	8 031	109 118	765 290
2015	2 784 319	2 691 655	1 995 755	761 226	197 573	7 173	135 777	834 508
2016	2 782 538	2 751 468	2 018 412	776 961	200 186	6 656	144 239	849 307
2017	2 805 617	2 821 408	2 052 914	788 970	207 737	6 955	148 846	884 054
2018	2 839 313	2 890 900	2 109 205	808 619	214 719	7 005	151 179	916 762

Source: [IEA 2020b].

It is possible to see a similar reflection of the global transportation sector taking leadership in total energy consumption from the industrial sector in the European Union as well. According to data from the European Energy Agency, 31% of the total final energy use of member countries was realized by the transportation sector, followed by households with 27% and the industrial sector with 25% as of 2017. It is evident that the transportation sector's portion of energy use will be significant in the future as well. Although renewable energy is the fastest growing source of energy in the world, according to estimates for 2050, fossil fuels will continue to meet most of the world's energy demands, although their use in primary energy consumption will decline from 32% in 2018 to 27%

in 2050. This decline will stem from the residential and electrical energy sectors, while the consumption of oil and other liquid fuels in the industrial, commercial and transport sectors will increase [EIA 2019].

The transport sector is energy intensive and highly dependent on petroleum and petroleum products, such as gasoline and diesel fuel. As can be seen in Figure 1, all the energy consumed by the transportation sector originates from fossil fuels. However, in recent years, it is possible to observe that the gap between the transportation sector's total energy consumption and total fossil fuel use has begun to expand, although slightly. The difference is the result of increasing use of biomass and electricity in the transport sector. Nevertheless, the share of these two sources is still quite small.

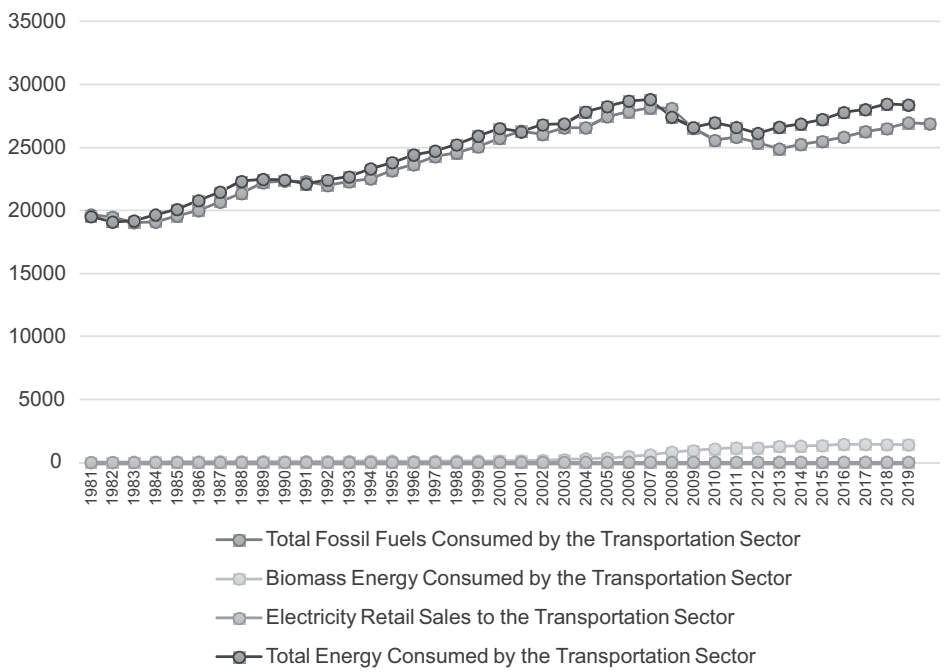

Figure 1. Transportation sector energy consumption
Rysunek 1. Zużycie energii w sektorze transportu
Source: own study based on [EIA 2020].

More than 60% of the petroleum products used in OECD countries and nearly half of those used in non-OECD countries are used as transportation fuel. Regarding passenger cars, even in the European Union with its important environmental and greenhouse gas emissions goals, in 13 of 24 EU Member States for which 2017 data are available, more than 50% of passenger cars (the most important for passenger transport in all European Union member states) used gasoline, while road transport continues to constitute the largest portion in European Union freight transport [European Commission 2019]. However, energy consumption is expected to increase in the transport sector particularly

in non-OECD countries in the coming years. The U.S. Energy Information Administration predicts this increase will be 77% in the period from 2018 to 2050 and expects that non-OECD countries will realize approximately 65% of the energy consumption related to transportation in the world in 2050. As for OECD countries, as the increases in vehicle fuel efficiency are expected to exceed travel demand, the total transport energy use for OECD countries is projected to decrease by 1% from 2018 to 2050 [EIA 2019].

Increasing mobility around the world is one of the main reasons for the increase in energy use in the transport sector. It is an established fact that increased income increases the demand for travel [Goodwin et al. 2004, Dargay 2007]. Fuel consumption related to passenger or personal mobility accounted for 61% of total world transport energy consumption in 2012 [EIA 2016]. However, due to the global pandemic and mobility affected by the pandemic in 2020, the energy demand of the transportation sector has decreased. According to International Transport Forums 2020 data, pandemic-struck sea freight and air freight volumes were the at lowest level since the global financial crisis of 2008 in the EU-27 [ITF 2020]. Conversely, it is expected that there will be a rebound effect and that the sector will recover once the pandemic is brought under control [IEA 2020a]. Therefore, it becomes important to create a sustainable transportation policy without reducing the quality of life of individuals. At this point, electric vehicles have a remarkable opportunity to change the rules of the game in favour of energy efficiency and the environment, and policy practitioners need to implement measures to encourage electric and hybrid electric vehicles.

Energy use in the transport sector is increasing in both developed and developing countries. The emission of carbon dioxide and other greenhouse gases into the atmosphere from the burning of fossil fuels such as gasoline and diesel also triggers problems such as climate change. The rate of increase in direct global carbon emissions resulting from fuel combustion in the transport sector has been 1.9% annually since 2000. Moreover, although ship and aircraft-based carbon emissions have increased more than other modes of transport in recent years, the amount of emissions from cars, trucks, buses, and other types of road transport account for three quarters of total emissions. Most of these emissions originate from road freight transportation [IEA 2020c].

Presently, although the share of parties defining certain transport reduction goals as per the Paris Agreement is low at 10%, 60% of them go beyond simply mentioning the transport sector in their nationally determined contributions (NDCs) and mention at least one transport reduction "measure" [ITF 2018]. In order to achieve the "far below two degrees" target defined at COP21 in Paris in 2015, upper- and high-income countries should intensify their transport carbon reduction targets as they are more responsible for the main share of transport carbon emissions. Measures to reduce carbon emissions and the relationship between the transport sector and the Paris agreement can be read in more detail in the next section.

Air and noise pollution are other environmental factors caused by the transportation sector. This sector is the largest contributor to NOX emissions, accounting for 46% of total EU-28 emissions (and 47% of EEA-33 emissions) in 2014. It also contributed 13 and 15% of total PM10 and PM2.5 primary emissions in the EU-28 in 2014, respectively. The external costs of noise in the European Union are at least 0.35% of GDP and mostly stem from road traffic [European Commision 2017].

Policies regarding carbon emission reduction in the transport sector

The fact that the transportation sector is heavily dependent on fossil fuels causes adverse effects on the environment and human health, primarily global warming. Although the rate of increase in emissions from transportation relatively decreased on a global scale in 2019, today, 24% of carbon emissions are a result of fuel consumed due to transportation. Considering the necessity of reducing carbon emissions in the transport sector [Trevisan and Bordignon 2020] to keep the world at an average temperature increase, more international initiatives are needed to reduce the emissions in question [IEA 2020c].

Governments in different parts of the world set standards for fuel and carbon emissions, especially for new vehicles, to combat climate change and tackle problems based on energy supply. The implementation of performance-based standards is often supported by fiscal policy tools such as taxes and incentives. Thus, it is argued that fiscal policy choices of policy implementers may reduce carbon emissions on one hand and have positive effects on fuel demand on the other [German and Meszler 2010]. Therefore, the relatively high cost of clean energy sources will increase the chances of success in policies to be implemented with the help of tools such as environmental taxes and subsidies [Santos 2017]. It is recognized that fiscal policies regarding energy have long-term effects on environmental quality [Ike et al. 2020]. Considering that the number of electric vehicles on the roads exceeded seven million at the end of 2019, high-speed train projects have been implemented, and solar-powered aircraft are being studied, it can be argued that these are a result of these policies.

For global warming to be kept at a scientist-advocated level of 2°C or less, the world, especially countries with high emission levels, should act collectively. The future of the 2015 Paris Climate Agreement, which was established with this in mind, is uncertain because of the USA's withdrawal from the agreement and the delay of some countries in approving it. However, it has been argued that if the goals defined in the Paris Climate Agreement are not achieved, natural disasters based on climate change may be experienced more frequently and that this will be very costly [Pigato and Black 2019].

According to the IMF, the global average emission amount, which is currently USD 2, should increase to USD 75 by 2030. On the other hand, other negative effects of said carbon tax implementation, such as increasing energy prices and increasing energy poverty, worry governments. Accordingly, electricity prices with a USD 75 carbon tax applied are estimated to increase 40% in Turkey, 64% in China, 89% in South Africa, 83% in India and 18% in Germany. Regardless, the belief that more than fifty countries around the world have some form of carbon tax planning and that this can be achieved is supported by examples of successful implementations. Notably, Sweden has reduced its emissions by 25% and expanded its economy by 75% by increasing its carbon tax per ton to USD 127 since 1995. Thus, it is argued that through an increase in carbon tax, there will be positive changes in the lives of households, businesses and societies, and that death rates due to air pollution will decrease [Devarajan et al. 2011, IMF 2019]. In this context, it is stated that carbon taxes are the most effective method that enables households and companies to switch to clean and low-cost energy sources by reducing the amount of carbon emissions. Accordingly, there are many studies in the literature on the effects of fiscal policy implementations on carbon emissions [Speck 1999, Timilsina and Shrestha 2009,

Brand et al. 2013, Mraïhi and Harizi 2014, Tscharaktschiew 2015, Ajanovic et al. 2016, Fridstrřm et al. 2016, Aggarwal 2017, Fridstrøm and Østli 2017, Liu et al. 2017, Østli et al. 2017, Cassen et al. 2018, Gloriant 2018, Yang et al. 2018, Zhou et al. 2018, Santarromana et al. 2020, Tsakalidis et al. 2020, Zhang et al. 2020]. In this sense, it is evident that policies enacted through instruments such as taxes, regulations and incentives reduce carbon emissions and have positive effects on the environment. These policies will be discussed in more detail in the next section.

Implementation of tax policies

It is clear that the transportation sector has also developed over the years as a result of the development of international relations through globalization, the increase in trade volume and the ease of transportation opportunities. This situation further expands the energy requirement of the sector as well. In particular, the increase in maritime and air transport has increased fossil fuel consumption substantially [OECD 2010]. Consequently, the increase in energy consumption negatively affects the amount of carbon emissions. These emissions nearly doubled from 4.6 million Mt in 1990 to 8.2 million Mt in 2018 [IEA 2020c]. The table shows the level of change in greenhouse gas emissions in the transport sector between 1990–2017 in the selected countries. Accordingly, Turkey, Poland and Luxembourg are ranked in the top three places in terms of greenhouse gas emissions in the transport industry (Table 2).

The transport sector's share of global carbon emissions is approximately one fourth. However, it is estimated that approximately 77% of the total carbon emissions in the transportation sector today are caused by road transportation. More than half of this is

Table 2. Change in total greenhouse gas emissions from transport
Tabela 2. Zmiana emisji gazów cieplarnianych w sektorze transportu

Countries	Change (1990–2017)	Countries	Change (1990–2017)
Austria	78.4	Latvia	15.1
Belgium	27.5	Liechtenstein	–20.7
Bulgaria	39	Lithuania	–2.7
Croatia	62	Luxembourg	144.1
Cyprus	57.7	Malta	101.8
Czechia	64.3	Netherlands	32.6
Denmark	28.7	Norway	32.4
EU-28 (convention)	28	Poland	206
Estonia	1.5	Portugal	78.6
Finland	3.7	Romania	43.5
France	15.8	Slovakia	13.6
Germany	11.8	Slovenia	102.2
Greece	21.8	Spain	66.9
Hungary	47.7	Sweden	–5
Ireland	141.9	Switzerland	14.1
Italy	3.9	Turkey	247.9

Source: [EEA 2020].

due to light-duty vehicles. Maritime transport accounts for 11% of total emissions, while the aviation industry accounts for 10%. Thus, carbon emissions from road transport have a significant portion of the total. Considering the development of the world's car market, the United States, China, European Union and India account for 46% of global carbon emissions within the scope of new vehicle sales [ICCT 2020, IEA 2020c]. Therefore, future projections of current policies show that they will fail to prevent the increase in emissions caused by the increase in demand in the transport sector. Estimates that the level of emissions in the sector will increase by 60% by 2050 require governments to take tougher measures [ITF 2019].

Carbon emissions, which are a type of negative externality, are on the agenda of politicians because of their negative effects on the environment and human health. For example, Hill et al. [2009], while considering all the impacts of one gallon of gasoline consumption, calculated that USD 0.37 is the cost of climate change resulting from carbon emissions and USD 0.34 is the cost of health-related pollution. Accordingly, as air pollution and global warming are among the most important risk factors threatening world health in the future [Gupta 2016], they are subject to public intervention to protect public health. It is not possible to reduce the amount of externality in the production or consumption process because the party that spreads the externality does not bear its cost. This situation, which is referred to as market failure in the literature, is one of the main factors that require public intervention in the economy [Ng 1980]. The main reason why externalities fail the market, from an efficiency perspective, is that an economic activity (consumption or production) creates an impulse to do too little or too much. And in this case, because the benefits or costs arising from the activity do not include external effects that cannot be priced, efficiency deteriorates [Rosen 2008, Case et al. 2012, Pindyck and Rubinfeld 2014].

According to the solution suggestion against externalities proposed by British economist Pigou (1877–1959), a tax to be imposed on each unit of production (subsidy on positive externalities) equivalent to the external cost arising in the presence of negative externalities will equalize the costs of the firm to the social cost and reduce external damage [Nath 1973]. For this reason, it is known that the implementation of a Pigouvian Tax will reduce the spreading negative externality because it internalizes the spread external costs.

Governments tax fossil fuels, automobiles, highways, and emissions caused by automobiles to reduce fossil fuel consumption and prevent other negative impacts, especially carbon emissions, in the transport sector. Carbon tax, which is applied to the carbon content of fuels for this purpose, stands out as one of the most effective tools used in reducing carbon emissions [Perloff 2012]. Accordingly, to reduce carbon and other harmful gases generated from the burning of fossil fuels, legislators aim to increase the price of the products subject to externality by taxing one point in the consumption chain and consequently to reduce the spreading externality. There is a lot of evidence in the literature to support this idea [Timilsina and Dulal 2008, Fridstrřm et al. 2016, Gloriant 2018, Zhou et al. 2018, Ike et al. 2020, Santarromana et al. 2020].

By 2050, seventy-seven countries, ten regions and more than a hundred cities aim to reduce carbon emissions to zero. For this purpose, currently forty-six countries in the world apply carbon taxes. While Finland and Poland started applying carbon tax in 1990,

Norway and Sweden began in 1991 and Denmark in 1992. The level of tax applied varies from country to country. Consequently, while the tax applied per ton in Ukraine and Poland is below USD 1, it is USD 50 in France, USD 70 in Finland, USD 96 in Switzerland and USD 139 in Sweden. Although the tax amount foreseen to reach the temperature goal envisioned in the Paris Climate Agreement should be between USD 40 and 80, the amount of carbon taxes in effect worldwide is far below this. On the other hand, revenues from carbon taxes in 2018 totalled approximately USD 44 billion [WB 2019].

Carbon taxes in the transport sector have been applied by adding them to other taxes on fuel. This situation could further increase the price of fuels such as gasoline and diesel that are already taxed at high levels for various reasons, thereby reducing consumption levels. However, these taxes are often supported by different tools so that they do not negatively affect a society's low-income earners. For example, Portugal reduced its gasoline tax in 2019, despite the increase in its carbon tax [WB 2019]. Similarly, although the carbon tax applied in Finland has had a significant and negative effect, it is argued that the carbon tax has had a limited effect due to intensive tax exemptions and deductions applied in Denmark, Sweden, the Netherlands, and Norway [Lin and Li 2011]. Thus, the implementation of carbon tax is debatable in countries such as Turkey, where the taxes on fuel are quite high.

Another way of reducing carbon emissions is to create a tax structure (motor vehicle tax) that will ensure a preference for motor vehicles with low carbon emissions. Accordingly, a tax structure that references the carbon emission levels of vehicles will reduce carbon emissions by directly affecting both producer and consumer behaviour [Timilsina and Shrestha 2009]. Thus, low taxes on low-emission vehicles will encourage consumers to buy these vehicles, and vehicle manufacturers will compete to reduce emission levels. For example, the four-year tax advantage of a zero-emission vehicle compared to a vehicle with emissions of 200 g/km CO_2 is approximately EUR 6,000 in Germany, while it is approximately EUR 40,000 in Norway [Wappelhorst et al. 2018].

In conclusion, environmental taxes such as the carbon tax help to generate income while simultaneously reducing harmful emissions such as greenhouse gases. The fact that these taxes are included in the price mechanism and communicate the necessary signals to producers and consumers will lead to changes in production and consumption behaviour, and positively affect social welfare [Elgouacem et al. 2020]. In this context, countries' fiscal policies are gradually becoming more sensitive to carbon emissions [Gerlagh et al. 2018]. For example, there is evidence that annual road taxes implemented in Ireland and Norway reduce carbon emission as consumers tend to use diesel vehicles.

Regulations

Reagan expressed the state's role in the economy as follows: "Government's view of the economy could be summed up in a few short phrases: If it moves, tax it. If it keeps moving, regulate it. And if it stops moving, subsidize it". In this context, regulation can simply be defined as state intervention by legal means. States implement regulations in social, legal and economic fields in order to increase the welfare of societies. Thus, although the scope of regulation is very wide, it also has many types. According to the

OECD [1997, p. 6], regulation can generally be implemented in three areas: economic, social, and administrative. Economic regulation is directed at areas that do not function due to market failures. From this point of view, regulation can also be defined as the state's direct intervention in the market and the activities of economic agents to establish rules or impose prohibitions in such a way as to protect public interests [Chang 1997, p. 704]. Thus, the state can directly intervene in the market through methods such as pricing, competition, and market entry/exit via economic regulation.

Today, regulation is considered another important tool for the public sector's interventions in economic and social life. Accordingly, public regulations are encountered in many different areas of daily life, from smoking in closed areas to speed limits on highways. In this context, to reduce carbon emissions in the transport sector, governments can regulate the sector with the help of prohibitions and rules and thus direct them to the desired goals. For example, Japan has prepared various policies to reduce its carbon emissions by 90% before 2050 [Utagawa and Horio 2020].

The regulatory activities implemented by the European Union for the transportation sector can be used as an example of this idea. The European Union set average carbon emission standards in 2009, as previous commitments by automobile manufacturers to reduce carbon emissions did not yield the desired results. Accordingly, the targeted emission level for 2015 was 130 g/km CO_2. A similar regulation was introduced in 2011 for light commercial vehicles known as minibuses, and the target for 2017 was set at 175 g/km CO_2. With a new regulation introduced in 2014, the aim was to reduce the carbon emissions of new vehicles to 95 g/km CO_2 by 2021. In minibuses, a new target of 147 g/km CO_2 by 2020 has been announced. A third regulation proposed in 2017 was accepted on December 17, 2018. Accordingly, a gradual phase-down in the carbon emission levels of new passenger vehicles and light commercial vehicles is targeted by 2050. For example, the target for 2030 is 59 g/km CO_2. It has also been emphasized that significant penalties will be applied in the event of non-compliance with the determined standards [Dornoff et al. 2018, Gerlagh et al. 2018, Mock 2019].

Another practice conducted to reduce carbon emissions in the transportation sector is the regulation of urban transportation. In particular, traffic congestion caused by excessive numbers of vehicles increases carbon emission levels and causes air pollution. For this reason, increasing parking fees in cities both decreases the number of vehicles in traffic and provides positive effects through the increased use of public transportation [Liu 2020]. Similarly, measures such as reconsidering entry and exit times into the city, charging vehicles for city access, and facilitating shared bicycle systems and public transportation opportunities also yield successful results.

Conclusion

It is clear that in the coming years the transportation sector will be discussed regularly, and that accordingly, rapid change will occur. Environmental concerns arising from new technologies on the one hand and fossil fuel dependence on the other point to the future of a new transportation sector and a transformation. Because this sector is the world's most energy consuming and since demand in developing countries will increase in the future, many concerns about the sector's energy consumption arise from this change. This con-

cern highlights the need to increase sectoral energy efficiency, as well as focus on greener solutions. In terms of increasing energy efficiency, electric and hybrid vehicles constitute an important alternative for road transport.

The transport sector, by its very nature, has a great impact on carbon emissions. Therefore, a correction in the energy consumption of the sector directly affects the emissions from it. In a sector where petrol and other liquid fuels are used extensively, the higher cost of clean energy resources compared to fossil fuels also highlights policies to be implemented with the help of tools such as market regulations, environmental and carbon taxes, and subsidies.

Carbon taxes, which can be applied to the carbon content of fossil fuels, automobiles, and transport vehicles, are extremely effective tools for reducing carbon emissions. For this reason, many countries apply carbon taxes; however, most of these are OECD members, and the increase in costs associated with these types of taxes is a topic of much thought and discussion in many developing countries. Since it is expected that energy usage in the transportation sector in countries outside the OECD will increase in the future, it is important to develop market regulations that increase energy efficiency and reduce greenhouse gas emissions by taking these countries into account. At the same time, taking advantage of emerging technologies and shifting to low-emission transport systems through smart pricing should be encouraged by governments the world over.

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Macro-logistics as tools for shaping today's economy

Makrologistyka narzędziem kształtowania współczesnej gospodarki

Abstract. The aim of the article is to determine the essence of micro- and macro-logistics and to present the elements of the macro-logistics system as factors in the development of the Polish economy. Secondary data was used to present the current state and perspectives for the development of four elements of the macro-logistics sub-system in Poland, i.e.: transport networks, systems of product distribution, infrastructure connected with the flow of information and systems for the management and treatment of waste. Also, the growing role of Polish logistics in Europe was noted.

Key words: micro-logistic, macro-logistic, economy, Poland

Synopsis. Celem artykułu jest określenie istoty mikro- i makrologistyki oraz przedstawienie elementów systemu makrologistyki jako czynników rozwoju polskiej gospodarki. Wykorzystując dane wtórne, zaprezentowano stan i perspektywy rozwoju czterech elementów podsystemu makrologistycznego w Polsce tj.: sieci transportowych, systemów dystrybucji produktów, infrastruktury związanej z przepływem informacji oraz systemów zagospodarowywania i utylizacji odpadów. Wskazano również rosnącą rolę polskiej logistyki w Europie.

Słowa kluczowe: mikrologistyka, makrologistyka, gospodarka, Polska

Introduction

In the era of globalisation, logistics is beginning to play not only a significant role in the functioning of individual enterprises but its importance on a macro-economic scale is increasing, too. Its effect on the entire economic system of a given country, continent or even world is being recognised. More and more often, the logistics sector, due to its growing significance, can be referred to as one of the sectors contributing to the generation of national income. Logistics makes up 13.8% of global GDP (the first decade of the 21st century – EUR 5.4 billion). Annual expenses on logistics in Europe and North America amount to about EUR 1 billion in each of these regions. In the European Union, logistics

accounts for 13% of the GDP (taking into account the entirety of logistical activities). At the same time, average logistics costs – including transport and storage – make up 10–15% of final costs of finished products. Considering the expected increase of the rate of growth of logistics on a macro-economic scale by about 50% until 2020, there is a clear upward trend[1].

According to Kempa [2010], macro-logistics is the entirety of the flow of tangible goods in an economy. Rydzkowski [1999] claims that macro-logistics includes global economic processes. In turn, Krzyżaniak perceives macro-logistics as the entirety of the flow of tangible goods in an economy, from their sources, through consecutive phases of processing, up to the ultimate links of final (consumption and investment) demand [Krzyżaniak 1997, p. 14]. On the other end, each economic entity creates an individual system of micro-logistics. The micro- and macro-economic approach to logistics differ in terms of the scale of analysed processes and flows. Both approaches condition each other and use a common philosophy of integration of physical flows and the accompanying information flows.

Aim and methods

The article aims to present the essence of micro- and macro-logistics, with special reference to the elements of the macro-logistics system as factors in the development of the Polish economy.

The article uses secondary data, such as Reports of Statistics Poland, EUROSTAT, World Bank, Reports of PKP Polskie Linie Kolejowe S.A., Reports of Polish Seaports, Reports of the Institute of Logistics and Warehousing in Poznań and the Civil Aviation Authority. The work makes use of the comparison method, deduction method, descriptive method as well as tabulation and graphic methods.

Links between micro- and macro-logistics, and the economy

Macro-logistics includes global economic processes studied on the level of e.g. country, industry, region, or international organisation. Therefore, within macro-logistics, we can differentiate [Matwiejczuk 2006, p. 24–25, Nowicka-Skowron 2000, p. 28–52]:

- meta-logistics – connected with the processes of enterprise cooperation;
- meso-logistics – occurs as a result of vertical integration of meta-logistical systems, includes trades and sections of the national economy;
- Euro-logistics – deals with logistical processes on the European level;
- global logistics – deals with logistical processes on the global level.

[1] The results were based on a model of econometric calculations taking into account 29 variables which included information concerning the geographic region, income level, country size, level of economy and transport (road, rail, and air transport of goods as well as the movement of containers in harbours). The results of the studies were quoted from: [Ojala et al. 2008].

The effect of the functioning of the macro-logistics system is the entire logistics infrastructure of a country, including e.g. transport routes, public means of transport, communication systems, the infrastructure of ports (land, sea, and airports), warehousing facilities, and customs warehouses, etc. (Table 1). An important area of macro-logistics is the making of economic laws and providing legal services to economic entities [Ficoń 2005]. Thus, macro-logistics systems include some components whose quantity and, most of all, quality has a significant effect on the efficiency and effectiveness of the functioning of enterprises. The importance of macro-logistics on today's market results not only from its specific role in the increase of the exchange of goods and globalisation of the economy but also from trends appearing in modern action strategies oriented at the management of entire supply chains and the growing role of time in today's management.

Table 1. Elements of macro-logistics systems
Tabela 1. Elementy systemu makrologistyki

Elements of macro-logistics systems	Specification
transport and freight networks	road network, rail network, auxiliary infrastructure, etc.
product distribution systems	logistics centres, container terminals, handling ports, etc.
infrastructure connected with the flow of information accompanying physical flows in supply chains	IT networks and databases concerning all areas connected with logistics in various sectors and trades
systems for the management and treatment of waste	installations for storage, recovery and neutralisation and/or incineration of waste; solutions allowing technological mergers of enterprises, etc.

Source: [Abt 1993, p. 192, Skowrońska 2013a, p. 10].

In turn, micro-logistics is most of all the logistics of a managing entity, i.e. the logistics of an enterprise. An enterprise – notwithstanding its scale – has similar goals in the market economy: generating income surpluses over costs, or making a profit while fully satisfying customer service standards. Micro-logistics can be divided into supply logistics, production logistics, sales logistics, and reverse logistics. The knowledge and development of micro-logistics is the basis for building global micro-logistics systems [Ficoń 2005].

There is a feedback loop between micro-logistics and macro-logistics systems. Full development of enterprise systems depends, most of all, on building macro-logistics systems, also including logistics chains, which are created as natural links between suppliers. Their form, however, is dependent on multiple conditions. They include legal and organisational circumstances and even cultural differences and differences in the development of various countries.

The growing role of macro-logistics results from the dependencies between logistics and the economy, such as [Skowrońska 2012, 2013b]:

- location of public logistics centres, affecting the level of availability of products made in distant parts of a country and the world;
- transport and warehousing infrastructure shaped by the state, affecting the behaviours of prospective industrial and commercial investors;

- basic economic importance of logistics for effective integration of peripheral areas and regions (logistics integrates enterprises located in the most distant parts of a country, continent, the world, resulting in the integration of markets, reducing the importance of geographic location, and, consequently, contributing to the support of the regional economic growth and competitiveness);
- acceleration of the harmonisation of organisational and legal procedures and standards thanks to the need of the functioning of enterprises creating the links of the supply chains based on identical technologies connected with the execution of logistics processes and document work-flow.

Current state and perspectives for the development of the elements of the macro-logistics system in Poland

Since 2007, the World Bank, in cooperation with scientists and logistics operators, has been publishing cyclical reports entitled "Connecting to Compete. Trade Logistics in the Global Economy", concerning an analysis of logistics efficiency of over 160 countries using the Logistics Performance Index (LPI). In the 2018 ranking, the German logistics trade emerged the best, with a result at the level of 4.2 LPI score. Poland's score of 3.54 (LPI score) gave it the 28th place out of the 167 qualified countries. In the first edition of the ranking in 2007, Poland came 40th (with 3.04 LPI score – Table 2). The LPI score is calculated as a weighted average of six key indicators:

- effectiveness of the process of border control, including customs control (Poland ranked 33rd);
- quality of infrastructure (e.g. of ports, railways, roads, IT technologies) (35th position);
- assessment of the organisation of international deliveries (12th position);
- competences and quality of logistics services (e.g. forwarders, customs agents) (29th position);
- possibility of identifying and tracing parcels (31st position);
- timeliness of the delivery of parcels concerning the scheduled delivery time (23rd position).

In turn, in the report published by the Fraunhofer Institute in 2017 entitled "Top 100 in transport and logistics services," Poland came 7th among European countries in terms of the value of the market of logistics services (EUR 4.22 billion, which makes up about 4% of all European expenses). The evaluation of the market of logistics services in individual countries of the European Union is presented in Figure 1. The first three places are taken by Germany, the United Kingdom and France. The expenses on logistics services in the European Union are mainly made up of transport (45%), warehousing (33%), and reserves (15%), while administration costs make up 7% of expenses (Figure 2).

Table 2. Selected items from the report entitled "Connecting to Compete. Trade Logistics in the Global Economy"
Tabela 2. Wybrane pozycje z raportu "Connecting to Compete. Trade Logistics in the Global Economy"

Country	Ranking position and LPI value	Customs clearance and LPI Score	Infrastructure and LPI Score	Organisation of international deliveries and LPI Score	Quality of services and LPI Score	Monitoring of parcels and LPI Score	Timeliness of deliveries and LPI Score
Germany	1, LPI – 4.20	1, LPI – 4.09	1, LPI – 4.37	4, LPI – 3.86	1, LPI – 4.31	2, LPI – 4.24	3, LPI – 4.39
France	16, LPI – 3.84	19, LPI - 3.59	12, LPI – 4.0	17, LPI – 3.55	17, LPI – 3.84	12, LPI – 4.00	14, LPI – 4.15
Spain	17, LPI – 3.83	17, LPI – 3.62	19, LPI – 3.84	6, LPI – 3.83	18, LPI – 3.80	19, LPI – 3.83	20, LPI – 4.06
Poland	28, LPI – 3.54	33, LPI – 3.25	35, LPI – 3.21	12, LPI – 3.68	29, LPI – 3.58	31, LPI – 3.51	23, LPI – 3.95
Lithuania	54, LPI – 3.02	46, LPI – 2.85	66, LPI – 2.73	74, LPI – 2.79	54, LPI – 2.96	50, LPI – 3.12	43, LPI – 3.65

Source: [Kulikowska-Wielgus 2018].

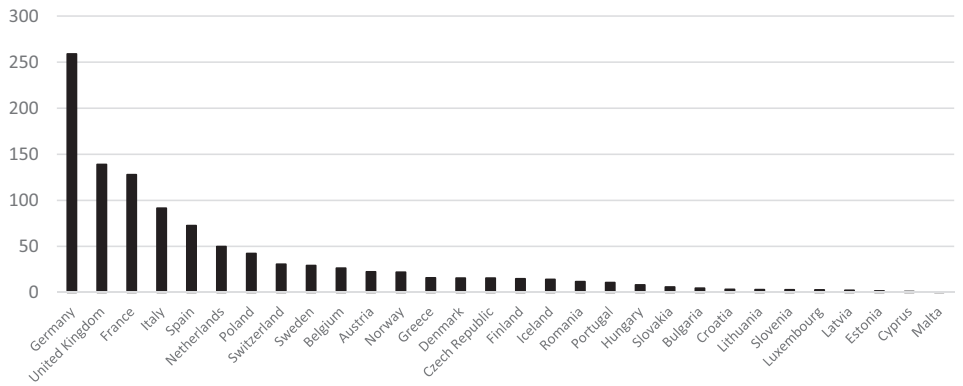

Figure 1. Logistics expenses in the European Union broken down by individual countries in 2016 [EUR billion]

Rysunek 1. Podział wydatków logistycznych w Unii Europejskiej między poszczególne kraje w 2016 roku [miliard EUR]

Source: [Fraunhofer Institute 2018].

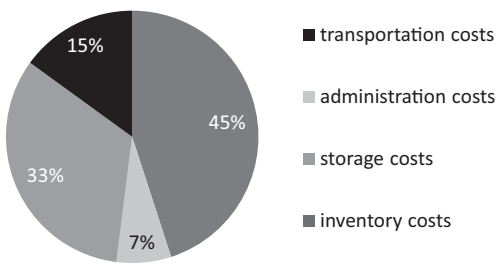

Figure 2. Expenses on logistics services in 30 European Union countries according to individual categories [%]

Rysunek 2. Wydatki na usługi logistyczne w 30 krajach Unii Europejskiej według poszczególnych kategorii [%]

Source: [Fraunhofer Institute 2018].

Taking into account the first element of macro-logistics – transport and shipping networks – it needs to be noted that recently the rate of modernisation of road infrastructure in Poland has weakened [Fechner and Szyszka 2018], resulting in a decrease in the increment of providing new and repaired national roads in relation to previous years. With increasing traffic of heavy goods vehicles, this has led to a deterioration of the technical condition of roads.

According to Statistics Poland, the total length of public roads in 2019 was 424,563.9 km, 72% of which were paved roads, and 28% were dirt roads. The total density of paved roads in 2019 was 135.9 km per 100 km^2. By comparing the number of kilometres of individual categories of roads, one can notice that almost 60% of them are municipal roads. They are the worst roads in terms of quality and have the least impor-

tance to the transport of people and goods. Another group are county roads, which make up slightly over 30% of all roads. This category is also used mainly for local purposes. The most important roads in the entire system are national and regional roads, which, unfortunately, constitute 4.6% and almost 7%, respectively, of all roads [Fechner and Szyszka 2018]. In the years 2000–2019, the length of motorways and express roads increased 7.5 times. However, it needs to be pointed out that the dynamics of the increment of the length of motorways and express roads in the years 2017–2019 is much lower than in the period 2010–2012 or 2012–2015 (Table 3). The presented statistic demonstrates the weakness of the Polish road infrastructure.

The length of all motorways in the countries belonging to the European Union and the Schengen area in 2017 was over 82,000 km. The longest motorways are found in Spain (17,100 km), Germany (15,306 km) and France (11,612 km). In this respect, Poland comes 12th, after countries such as Italy, the United Kingdom, the Netherlands, Portugal, or Greece (Table 4).

In turn, by taking into account the rail infrastructure, it can be concluded that the length of railways in Poland has been gradually decreasing since 2009. In 2009, this value was 19,336 km; whereas in 2018, it dropped to 18,536 km (800 km less) – see Figure 3. In Poland, the basic rail network is managed by PKP Polskie Linie Kolejowe S.A. The rail network is divided into railway lines of national significance[2] (about 12,300 km) and local lines. Some railway lines which are important for international rail transport pass through Poland. These lines are covered by international railway lines agreements AGC[3] and AGTC[4] and visualised in TENT base network or the Regulations of the European Union setting forth transport corridors.

Table 3. Hard surface public roads in 2000–2019 [in km]
Tabela 3. Drogi publiczne o twardej nawierzchni w latach 2000–2019 [w km]

Description	2000	2002	2004	2006	2008	2010	2012	2015	2017	2019
Hard surface public road of which:	249 828	250 291	252 273	255 543	261 233	273 760	280 719	287 649.9	288 000	303 956.9
– motorways	358	405	552	663	765	857	1 365	1 559.2	1 637	1 675.8
– expressways	193	226	233	297	452	675	1 053	1 492.2	1 536	2 432

Source: [GUS 2002–2019].

[2] National lines are defined by the Regulation of the Council of Ministers of December 7th 2004 (Dz.U. 2004 nr. 273, poz. 2704) [in Polish] concerning the list of railway lines which, due to economic, social, defensive or ecological reasons, have a national importance.
[3] AGC – Agreement on Main International Railway Lines.
[4] AGTC – Agreement on Important International Combined Transport Lines and Related Installations.

Table 4. Motorway lengths in individual European Union countries in 2017 [in km]
Tabela 4. Długość autostrad w krajach Unii Europejskiej w 2017 roku [w km]

No.	Country	Motorway lengths	No.	Country	Motorway lengths
1	Spain	17 100	15	Croatia	1 313,8
2	Germany	15 306	16	Denmark	1 246
3	France	11 612	17	Hungary	1 155.2
4	Italy	6 943	18	Ireland	916
5	United Kingdom	3 649	19	Finland	900
6	Netherlands	3 070	20	Bulgaria	750
7	Portugal	2 948.8	21	Romania	746
8	Greece	2 133.2	22	Slovenia	617
9	Sweden	2 130	23	Norway	466.5
10	Austria	2 105	24	Slovakia	463.5
11	Belgium	1 763	25	Lithuania	324
12	Poland	**1 639**	26	Cyprus	257
13	Czech Republic	1 243	27	Luxembourg	167
14	Switzerland	1 447.4			

Source: [Rynek Infrastruktury 2018].

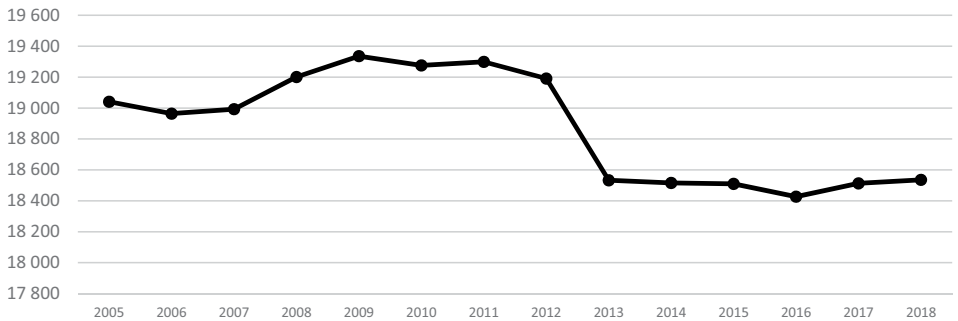

Figure 3. Długość linii kolejowych w latach 2005–2018 [in km]
Rysunek 3. Length of railway lines in 2005–2018 [w km]
Source: [PKP Polskie Linie Kolejowe S.A.].

In turn, the transport function of inland waterways in Poland is very limited. The requirements imposed on waterways of an international significance, i.e. class IV and higher were met in 2016 by only 5.9% of waterways, that is 214 km out of 3,654.6 km of inland waterways which are considered navigable [Fechner and Szyszka 2018, p. 78). This hasn't changed in Poland since 2007. The basic cause of this situation is the previously applied policy for the development of the transport infrastructure, which prioritised the investment needs of road and railway transport. The very low level of financing of inland waterways has led to their serious deterioration.

The second element of macro-logistics are distribution systems, including logistics centres, container terminals, handling ports, etc. The modern, commercial warehouse space in Poland in 2019 amounted to almost 17 million m^2. It is worth noting that over the period of 20 years, the supply of modern warehouse space increased over 16-fold (Figure 4). This rise in recent years has been caused by the increased activity of industrial developers on regional markets as well as the development of e-commerce, which has brought about several spectacularly big BTS-like investments (Amazon, Zalando). Most of the owners of modern warehouse space are industrial developers (76%), followed by private investors (about 11%) and investment funds (about 12%). The largest quantity of modern warehouse space is in the Masovian Voivodeship, because Warsaw and its surroundings, referred to by analysts as zones II and III, together constitute the largest internal consumption market in Poland, and this factor plays a key role in the demand for new warehouse space. Masovian Voivodeship is followed by Silesia, Greater Poland, Łódź, and Lower Silesia [Fechner and Szyszka 2018]. The determinants of the development of regional markets of warehouse space remain unchanged: quality, availability, and plans for the development of the infrastructure of road transport, the attractiveness of labour markets, and the size of internal consumption. These factors, however, have a varied effect on investors, decisions. With high gross demand for warehouse space, reaching up to 4 million m^2 in 2017, the vacancy rate dropped to an average level of 5.4%. According to data from the Institute of Logistics and Warehousing in Poznań, logistics operators (32%) and trading companies (28%) remain the main tenants of warehouses.

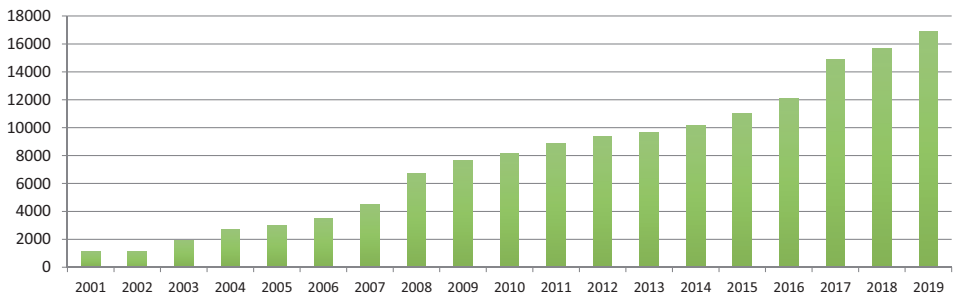

Figure 4. Modern warehouse space in Poland [in thousands m^2]
Rysunek 4. Nowoczesna powierzchnia magazynowa w Polsce [w tysiącach m^2]

Source: data from the Institute of Logistics and Warehousing in Poznań.

In 2017, Poland had 33 container terminals allowing inter-modal handling of transport units. Five of them handled freight in sea-railway and sea-road configurations (sea terminals), and the rest dealt with freight in railway-road configuration (land terminals) [Domagała 2019].

In Poland, one can distinguish three key seaports: Gdańsk, Gdynia, and Szczecin – Świnoujście group of ports. There are also other ports operating at the Polish coast, such as Elbląg, Police, Kołobrzeg, Darłowo, and some smaller ones, mainly fishing and tourist ports. The volume of goods handled in the Polish seaports exceeded 87 million t in 2017 (Table 5).

Table 5. Turnover in the biggest Polish seaports in years 2012–2018 [in thousands t]
Tabela 5. Obrót towarowy w największych polskich portach morskich w latach 2012–2018 [w tysiącach t].

Seaport	2010	2011	2012	2013	2014	2015	2016	2017	2018
Gdynia	14 735	15 911	15 809	17 659	19 405	18 198	19 536	21 225	23 492
Szczecin – – Świnoujście	20 843	21 354	21 267	22 750	23 401	23 174	24 113	25 424	28 614
Gdańsk	27 182	25 306	26 897	30 259	32 278	35 914	37 289	40 614	49 032
Total	62 760	62 571	63 973	70 668	75 084	77 286	80 938	87 263	101 138

Source: [Actia Forum 2019, p. 2].

In turn, the effect of airports on the economy in Poland is smaller than in many other countries. Despite that, the network of airports each year contributes to the generation of 4% of the GDP, mainly thanks to its stimulating effect on other areas of the economy. Airports also create 440,000 jobs in the country. In a globalised economy, air transport is particularly significant in inter-continental freight. In Poland, apart from the Warsaw Chopin Airport, which handles about 72,000 t, only three other airports exceed the volume of 1,000 t of goods. They are Katowice (about 16,000 t), Gdańsk (about 4,000 t) and Wrocław (about 2,000 t) – see Table 6.

Table 6. The number of parcels handled in airports in the years 2015–2016 [kg]
Tabela 6. Liczba obsłużonych przesyłek w portach lotniczych w latach 2015–2016 [kg]

Airport	2015	2016
Chopina in Warsaw	58 284 042	72 186 365
Katowice – Pyrzowice	14 523 862	15 586 274
Gdańsk	4 452 205	4 186 389
Rzeszów – Jasionka	3 863 349	731 770
Poznań Ławica	260 623	212 291
Wrocław – Starachowice	89 272	2 318 334
Szczecin – Goleniów	53 566	278 775
Bydgoszcz – Szwederowo	7 583	0
Port Lotniczy Lublin	14 968	1 007
Radom – Sadków	0	0
Warszawa – Modlin	0	0
Łódź – Lublinek	0	0
Kraków – Balice	0	3 487
Olsztyn – Mazury	0	0
Zielona Góra – Babimost	0	0

Source: [Urząd Lotnictwa Cywilnego].

The third element of macro-logistics is the infrastructure connected with the flow of information accompanying physical flows in supply chains. The dynamically growing needs concerning exchanging and processing bulk data (e.g. concerning the traffic, load, operations, container, shipping conditions — temperature, humidity) and its shar-

ing have led to development of digital cloud computing services. The needs for planning and monitoring transport have led to the development of multiple models of provision of digital services, e.g. SaaS (Software as a Service), PaaS (Platform as a Service), IaaS (Infrastructure as a Service) or CaaS (Communication as a Service). The repeatability of demand for similar types of services (truck and trace, delivery notification, electronic data exchange, etc. – e.g. in seaports, logistics centres) in many transport companies has resulted in a dynamic development of platforms offering digital services in SOA (Service Oriented Architecture). Comprehensive digital service of the flow of goods and transport, handling operations or border checks takes into account the connection between digital services of administration systems and business in Poland and on a global scale. The digitisation of the settlement of digital services and transactions in transport chains (including the e-toll, fuel, handling of goods, secondment of drivers, etc.) is integrated with platforms for e-invoicing, e-payments and e-banking.

Over the past year, all European Union countries improved their digital performance. Finland, Sweden, Denmark and the Netherlands scored the highest ratings in DESI[5] 2020 and are among the global leaders in digitalization. According to The Digital Agenda Scoreboard, Poland is among the six lowest-scored countries in the European Union in terms of digitization (Figure 5). Although Poland boasts a high level of penetration by mobile broadband services – making it stand out against other European Union countries – it still has a low level of penetration by broadband land-line Internet.

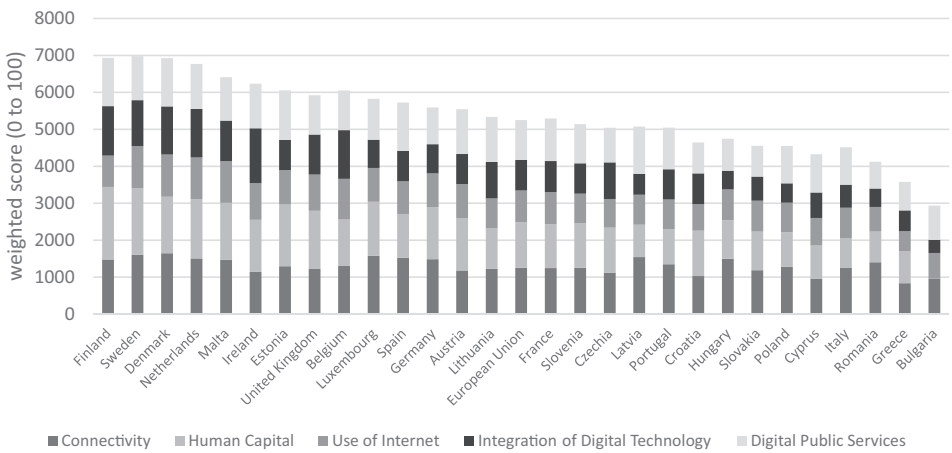

Figure 5. The Digital Economy and Society Index in European Union countries
Rysunek 5. Indeks digitalizacji gospodarki i społeczeństwa w krajach Unii Europejskiej
Source: [European Commission 2020].

[5] The Digital Economy and Society Index (DESI) is a composite index that summaries relevant indicators on Europe's digital performance and tracks the evolution of European Union member states, across five main dimensions: connectivity, human capital, use of Internet, integration of digital technology, digital public services.

The fourth element of the macro-logistics system are systems for the management and treatment of waste. Waste management in Poland is based on the European hierarchy of waste management, in which the most desirable scenarios include preventing the production of waste and preparing waste for re-use, followed by recycling (including composting) and other methods of recovery (e.g. incineration with energy recovery) [Baran and Karlewska 2016, Kwaśniewski et al. 2018]. The last element in the hierarchy is the disposal (neutralisation) through storage of waste which cannot be recovered and neutralised in a manner that is safe for human life and the environment [Klojzy-Karczmarczyk and Staszczak 2013]. Although this option is the most harmful for the environment and human health, it is also one of the least expensive methods of waste management [Toruński 2010]. Since July 1st 2013, tasks in the scope of the management of municipal waste are the responsibility of municipalities as the managers of waste produced within their areas [Primus and Rosik-Dulewska 2018]. The main obligation of municipalities in the scope of its tasks concerning the management of municipal waste is to provide conditions for the functioning of a system of separate collection and pick up of municipal waste from residents. Municipalities are also obligated to build, maintain and operate regional facilities intended for the processing of communal waste (Regional Municipal Waste Treatment Facilities).

Conclusions

Due to the growing role of logistics on the macro-economic scale, the logistics sector has started to play a decisive role in providing: efficacy, efficiency and effectiveness of national economies, and, consequently, of the global economy. Macro-logistics itself is becoming a *sine qua non*-condition for the development of domestic and international trade. Macro-logistics is also becoming a factor facilitating convergence, i.e. imitation or catching up with highly developed countries. Through its integrating, coordinating and synergic properties, which facilitate the management of the complexity of configurations caused by globalisation, macro-logistics is becoming a tool for achieving not only a competitive advantage but also supporting the increase of prosperity, understood as an improvement of all conditions which affect enterprises.

The position of Polish logistics in Europe is perceived mainly through the aspect of international transport, in which Poland has been a decisive leader for many years now, accounting for 25% of the total tonnage of shipped goods. Besides, Poland continues strengthening its position, as – despite protectionist moves of other countries – it is developing faster than the European Union average. Poland remains attractive for foreign investors in the logistics sector mainly due to the low costs of operating a business, attractive location, and qualified workers. To sum up, it can be argued that Polish logistics is on a path towards accelerated growth. The determinants are consumption and exports on one part, and e-commerce and digitisation on the other part. The projected economic growth of Poland, constantly modernised road, logistics, and digital infrastructures, as well as the growing e-commerce market support strong prospects for the development of logistics.

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Determinants of spatial concentration of short food supply chains on example of marginal, localized and restricted activities in Poland

Determinanty przestrzennej koncentracji krótkich łańcuchów dostaw na przykładzie podmiotów marginalnych, lokalnych i ograniczonych w Polsce

Abstract. The article analyses spatial concentration of marginal, localized and restricted activities creating local food systems in Poland regarded as short supply chains. Local food systems in Poland can take the forms of direct sale, direct deliveries, agricultural retail as well as marginal, localized and restricted activities. Short food supply chains play crucial role in case of local economy, environment and society. Thus, article rises issue connected with sustainability, alternatives for mass produced and distributed food, spatial diversity of local activities. Empirical part of the article focus on marginal, localized and restricted activities. The first part of the article contains a characteristic of the analyzed activities and their spatial distribution. The second part identifies factors that have the strongest influence on the formation of marginal, localized and restricted activities with the application of nonparametric models of regression trees. It is reported that spatial and environmental factors occur most frequently in the process of recurrent division of the data set and, thus, constitute the strongest determinant of marginal, localized and restricted activities.

Key words: local food systems, short food supply chains, spatial concentration, marginal localized and restricted activities, nonparametric regression trees

Synopsis. W artykule analizie poddano koncentrację przestrzenną podmiotów marginalnych, lokalnych i ograniczonych tworzących lokalne systemy żywnościowe w Polsce i utożsamianych z krótkimi łańcuchami dostaw. Lokalne systemy żywnościowe w Polsce mogą przybierać formy organizacyjno-prawne takie jak: sprzedaż bezpośrednia, dostawy bezpośrednie, rolniczy handel detaliczny oraz działalności marginalną, lokalną i ograniczoną. Krótkie łańcuchy dostaw żywności odgrywają kluczową rolę w lokalnej gospodarce, środowisku i społeczeństwie. W artykule poruszono zatem problematykę związaną ze zrównoważonym rozwojem, alternatywami dla masowo produkowanej i dystrybuowanej żywności, przestrzennym zróżnicowaniem lokalnych podmiotów. Część empiryczna artykułu oparta jest na analizie podmiotów marginalnych, lokalnych i ograniczonych. W pierwszej kolejności dokonano charakterystyki analizowanych podmiotów i ich rozmieszczenia

przestrzennego. Następnie, wykorzystując nieparametryczne modele drzew regresji, zidentyfikowano czynniki, które najsilniej wpływają na powstawanie podmiotów marginalnych, lokalnych i ograniczonych. Dostrzeżono, że czynniki przestrzenno-środowiskowe występują najczęściej w procesie rekurencyjnego podziału zbioru danych, a tym samym stanowią najsilniejszą determinantę działalności marginalnej, lokalnej i ograniczonej.

Słowa kluczowe: działalność marginalna, lokalna i ograniczona, nieparametryczne modele drzew regresji

Introduction

The approach to production, sale and consumption of agri-food products is undergoing dynamic changes. This is influenced by many factors such as the development of production techniques, interference with the transport vulnerability of agri-food products, social trends in consumption or random events such as cataclysms and pandemics. Observing the agri-food sector, it is possible to identify two main trends in its development. The first development trend takes on the character of agriculture and industrial processing. Industrialism changed the structure of production factors in agriculture and increased the scale of economic profitability of production [Woś and Zegar 2002]. The agrarian structure of farms has changed. There have been processes of consolidation, specialization and concentration of agricultural production. There has been a mass approach to the production of agri-food products with an impact on, e.g. their unification, high degree of processing and loss of nutritional values. Nevertheless, there are many indications that local food systems, which play a particularly important role in the times of pandemics, are a very strong, opposing trend in the development of the sector [Malak-Rawlikowska et al. 2019, Michel-Villarreal et al. 2019]. Local food systems are based on short food supply chains gaining on prominence in the debate regarding farm competitiveness in European Union [Cesaro et al. 2020]. In Poland, local food systems can take the form of:

- direct sales,
- direct deliveries,
- agricultural retail,
- marginal, localized and restricted activities.

The latter group is the activity of great local importance, both in economic, social and environmental terms. Therefore, in this article, the author takes up a research problem related to marginal, localized and restricted activities (MLR). The main aim of this article is to identify factors that affect the spatial concentration of MLR activities. A considerable diversity can be observed both in terms of the activity profile and spatial distribution of the above mentioned organizational and legal forms. It is pointed out in literature that the diversity of spatial distribution of business activities may attributed to many very different factors [Godlewska-Majkowska 2013]. The processes of concentration (localization) of business activities observed in the geographical space provide valuable information on the functioning of regional economies and the directions of their development. Moreover, nowadays, spatial analyses seem to be an integral part of economic analyses. Thinking in spatial terms is considered to be a more comprehensive and

modern approach to account for interdependent phenomena [Suchecki 2010]. Thus, the research conducted will enhance the concept of development of activities within local food systems in spatial systems and provide information on the factors determining local activity in a given region. The specific objectives of the undertaken research problem assume the characteristics of marginal, localized and restricted activities in Poland and their spatial structure. To solve the research problem, nonparametric models of regression trees constructed in the "R program" were used. The specific objectives were achieved through a literature study and statistical analysis of secondary data published by the General Veterinary Inspectorate as of January 1st 2018.

Theoretical background of marginal, localized and restricted activities in Poland as a part short food supply chains

Trends in the agribusiness sector, which indicate reorganization of conventional supply chains, a return to direct producer-consumer relations and regionalization of food production, are called local food systems. The growing popularity of local food systems is associated with a crisis of public trust in the mass agri-food industry. This is due to increased epidemics of diseases, such as swine and avian influenza, BSE, ASF, as well as concerns about the use of genetic modifications or food preservatives. In addition, public awareness of the environment and concern for its sustainability are increasing, which contradicts the industrial approach to the agribusiness sector [Blouin et al. 2009]. The role of local systems can also be seen during the COVID-19 pandemic. Operating within local food systems yields independence from global food chains and, thereby, increases the chances of survival in times of crisis. The main idea of local food systems is to eliminate intermediaries in the supply chain, which creates a sense of security and facilitates access to food.

As at January 1st 2018, there are 12,765 entities in Poland engaged in the production, processing and sale of animal products operating locally. A possible form of undertaking activity within the local food systems is running marginal, localized and restricted (MLR) enterprises. Registration of MLR enterprises in Poland has been available since 2007. The scope of activity of such enterprises is the production and sale of processed and unprocessed products of animal origin to the final consumer and the supply of produced food to retail establishments for the final consumer [Rozporządzenie Ministra Rolnictwa i Rozwoju Wsi z dnia 30 września 2015 r.]. Marginal, localized and restricted activities provide an opportunity for small businesses entities and family production establishments, offering products with specific, unique characteristics, to produce, process and sell. The MLR activity is identified with a strategy of supporting local production by enabling business activities with relaxed technical, organizational and fiscal requirements. The territorial range of MLR activity is limited to an area of one voivodeship or an area of adjacent poviats, located within the areas of other voivodeships. The processing and sale of products manufactured by marginal, localized and restricted activities may take place in a special building intended for production, in an adapted room (e.g. "summer kitchen") or in the rooms of residential houses where the food is prepared. The equipment of the premises should meet the requirements specified in Regulation (EC) No. 852/2004. In addition, the

plant should develop HACCP rules and apply good practice principles. Products offered as a part of MLR activities should comply with the requirements set for microbiological criteria, storage temperatures and the so-called cold chain. As with other entities processing animal products, MLR activities are registered and supervised by the General Veterinary Inspectorate. In January 2018, there were 2157 registered MLR entities in Poland. Figure 1 presents, in absolute terms, the distribution of MLR entities in Poland.

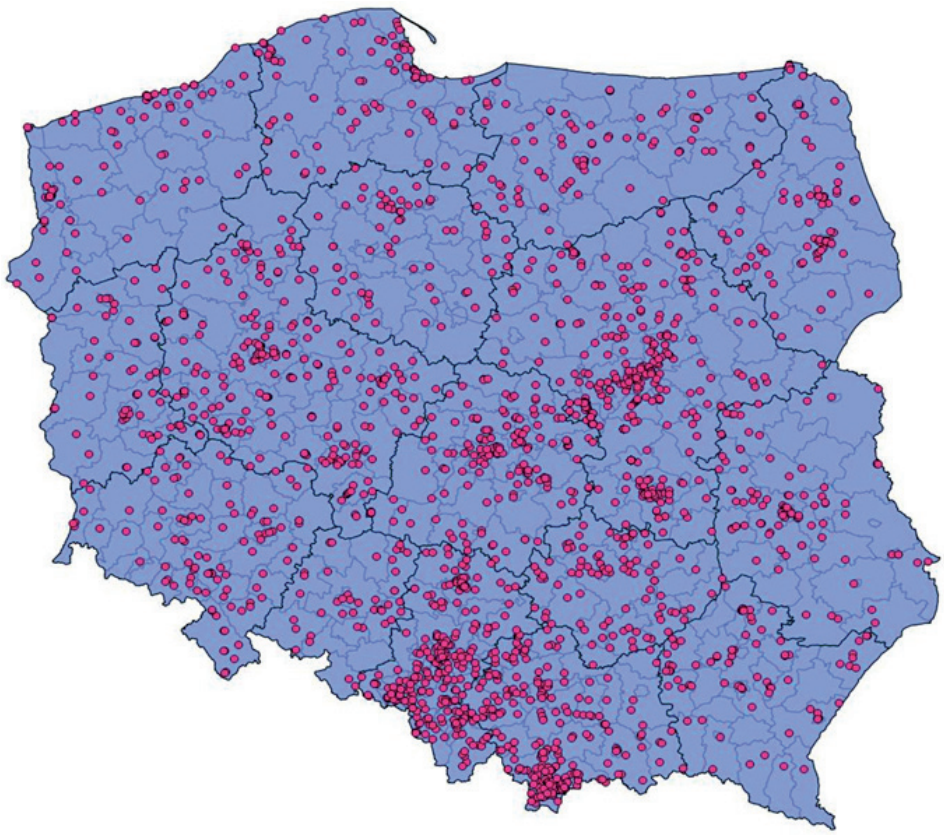

Figure 1. Entities involved in marginal, localized and restricted activity (as of January 2018)
Rysunek 1. Podmioty zaangażowane w działalność marginalną, zlokalizowaną i ograniczoną (stan na styczeń 2018 roku)

Source: [Główny Inspektorat Weterynarii 2018] own study in OGIS programme.

The largest number of MLR enterprises operate in the following voivodeships: Mazowieckie (Żyrardów and Radom poviats) i.e. central-east of Poland, Małopolskie (Nowy Targ and Tatra poviats),i.e. south of Poland and Śląskie (Cieszyn and Wodzisław poviats), i.e. south of Poland. 40% of all MLR activities in Poland are located within the area of these three voivodeships. Voivodeships with the smallest number of MLR activities include: Lubuskie (Żary, Sulęcin poviats), Kujawsko-Pomorskie (Bydgoszcz, Radziejów poviats) and Opolskie (Prudnik, Namysłów poviats).

Purpose and methodology

The main objective of the analysis was to identify the determinants of spatial concentration of marginal, localized and restricted activities. To this end, two nonparametric regression models were built. This method makes it possible to select, from among the variables characterizing a given region, those which significantly affect the analyzed local activities. Non-parametric regression models are a data mining tool that has recently been gaining in popularity. Literature contains a wide range of areas where analyses based on nonparametric regression models are used [Strojny 2010, Trzęsiok 2013, Chrzanowska and Drejerska 2015a, b, Pudełko 2015]. The undoubted popularity of the method stems from its properties (flexibility and good matching to data) [Gatnar 2008]. The model building process uses, among other things, a recurring division algorithm. As a consequence, the final model consists of local models built in each of the K-sectional segments into which the multidimensional space of variables is divided. Nonparametric models of regression trees may be of predictive nature, i.e. they are made to predict future values of explained variables, or verifying nature, i.e. describing an already existing data set. In the case of this study, the constructed models were used to verify which of the explained variables have a significant impact on the functioning of selected local activities in a given location. The analytical model was constructed at the poviat level to investigate, with the greatest possible precision, which factors determine this activity. Thus, a set of 380 observations resulting from the administrative division of the territory of Poland into poviats and cities with poviat rights was used to create nonparametric regression models. For the spatial units elected in this manner, the variables were adjusted in the form of a number of marginal, localized and restricted activities expressed in relative terms, i.e. per 1000 inhabitants. As predictors – explanatory variables – the indicators characterizing a given region were selected due to different characteristics assigned to groups of factors: spatial and environmental, economic, socio-cultural as well as technical and technological, listed in Table 1. The indicators were selected on the basis of the author's subjective evaluation of available local data. Each of the indicators included is justified by the theory of local food systems or refers to the results of pilot studies conducted by the author [Drejerska et al. 2019]. The explanatory variables used are also expressed in relative values so that they characterize individual poviats in the most relative manner that is practicable.

All calculations and visualizations were generated in the R CRAN statistical environment using dplyr, rpart, party, rattle packages. The trees were constructed with two different algorithms. Using the first of these, the CART (classification and regression trees) algorithm, further nodes of the tree were created on the basis of a certain measure of information in order to maximize the intergroup sum of squares for the resulting group divisions [Breiman et al. 1984]. The second, the recursive division algorithm, was based on statistical permutation tests of the independence of explained and explaining variables to determine whether another tree node would be created [Hothorn et al. 2006]. Two types of outlier observations were identified in the models. The first type of outlier observations was identified before the beginning of the process of recurrent division. Outlier observations in the whole set were defined as observations that exceed the value of three estimated (with the use of asymptotically normal estimator) standard deviations of the population above the mean or less than the difference between the mean and the above mentioned deviation value. The decision was made not to remove them from the set due to high resistance of regressive trees to a small number of outlier observations. The sec-

Table 1. Indicators used to build nonparametric regression models
Tabela 1. Wskaźniki użyte do budowy nieparametrycznych modeli regresji

Factors	Indicators	Abbreviated name
Spatial and environmental factors	municipal waste collected selectively in relation to all municipal waste collected during the year	waste
	population density	population
	markets or places in streets and squares for seasonal sale per 1000 people.	markets season
	permanent markets in total per 1000 people	markets permanent
Economic factors	capital expenditures in enterprises per 1 inhabitant [PLN]	expenditures
	support for local development under the LEADER initiative – support for the implementation of operations under the community-led local development strategy – RDP 2014–2020 commitments, December 31, 2017	leader
	registered unemployment rate (the registered unemployment rate was calculated as the ratio of the number of registered unemployed to the number of economically active population)	unemployment
	average monthly gross salary [PLN]	salary
	capital expenditure in enterprises (agriculture, forestry, hunting, fisheries) per 1000 people [PLN]	RLLR expenditures
Socio-cultural factors	feminization rate	feminization
	old age indicator (percentage of people aged 65 and over)	old age
Technical and technological factors	gross fixed assets in enterprises per 1 inhabitant [PLN]	fixed assets
	Tourist accommodation facilities per 1000 inhabitants	accommodation

Source: Local Data Bank 2017, the author's own study.

ond type of outlier observations were outlier observations in subsets, after division into nodes. They were defined as observations exceeding 1.5 IQR (interquartile range) above the third quartile.

Factors determining spatial concentration of marginal, localized and restricted activities

First, a regression tree model was built using the CART algorithm. The operation of this algorithm is based on calculating the "measure of information" for each variable – the higher it is, the more the algorithm will "want" to split the tree in accordance with this variable. The resulting tree is a coherent graph, consisting of a root and branches that form successive nodes (leaves). The entire test sample (i.e. 380 observations) is concentrated at the very top of the graph, i.e. in the root. Depending on the division, the sample elements are moved down the graph through the branches to the node (leaf). The branches are a certain result of a logical condition determining whether a given sample meets the division condition (if yes, you should head left, if not – right).

Figure 2 shows that for the nodes numbered 2 and 3, the predictor discriminating the subsets was the population variable. Sets of 65 observations (node 2) and 315 observations (node 3) were distinguished on this basis. Node 3 was further divided due to the feminization variable, creating node 7, with 7 observations, and node 6, with 308 observations. The feminization variable was also the basis for distinguishing nodes 24 and 25. For the nodes numbered 12 and 13, the predictor discriminating the subsets was the accommodation variable. On the other hand, node 48, with 239 observations, and node 49, with 44 observations were created as a result of a division relative to the unemployment variable. Node 49 was further divided due to the markets permanent variable into nodes 98 and 99.

When analyzing model 1 of the regression tree for MLR activities, the population, i.e. population density, was first indicated as a significant influence on this form of activity. This dependence provides the information that in the areas where the population density is lower, i.e. less than or equal to 553, there are more MLR activities (the value of MLR index, i.e. the number of MLR activities per 1000 inhabitants, is higher). Areas with higher population densities are generally metropolitan areas where service activities are the dominant form of activity. Thus, the resulting dependence seems to be the most appropriate, since marginal, localized and restricted activities involve the processing of animal products and are naturally linked to rural areas with a lower population density. Feminization (node 3), i.e. the coefficient informing about the number of women per 100 men, turned out to be another variable of importance for the functioning of MLR activities. The relationship between MLR and feminization indicators is positive, which means that there is a higher density of MLR activities in strongly feminized areas. On the other hand, only 2% of the examined activities are located (node 7) where there are fewer women per 100 men. The variable showing influence on the location of MLR activities also appeared to be the number of tourist accommodation facilities per 1000 inhabitants of a given poviat (node 6). This dependence is also positive, i.e. the majority of MLR activities are, in relative terms, located in the areas with a higher rate of accommodation facilities, provided that the previous conditions are met. The model also indicated the dependence between the unemployment rate and the MLR indicator. This dependence provides information that in areas with a higher unemployment rate (≥5) there is a higher

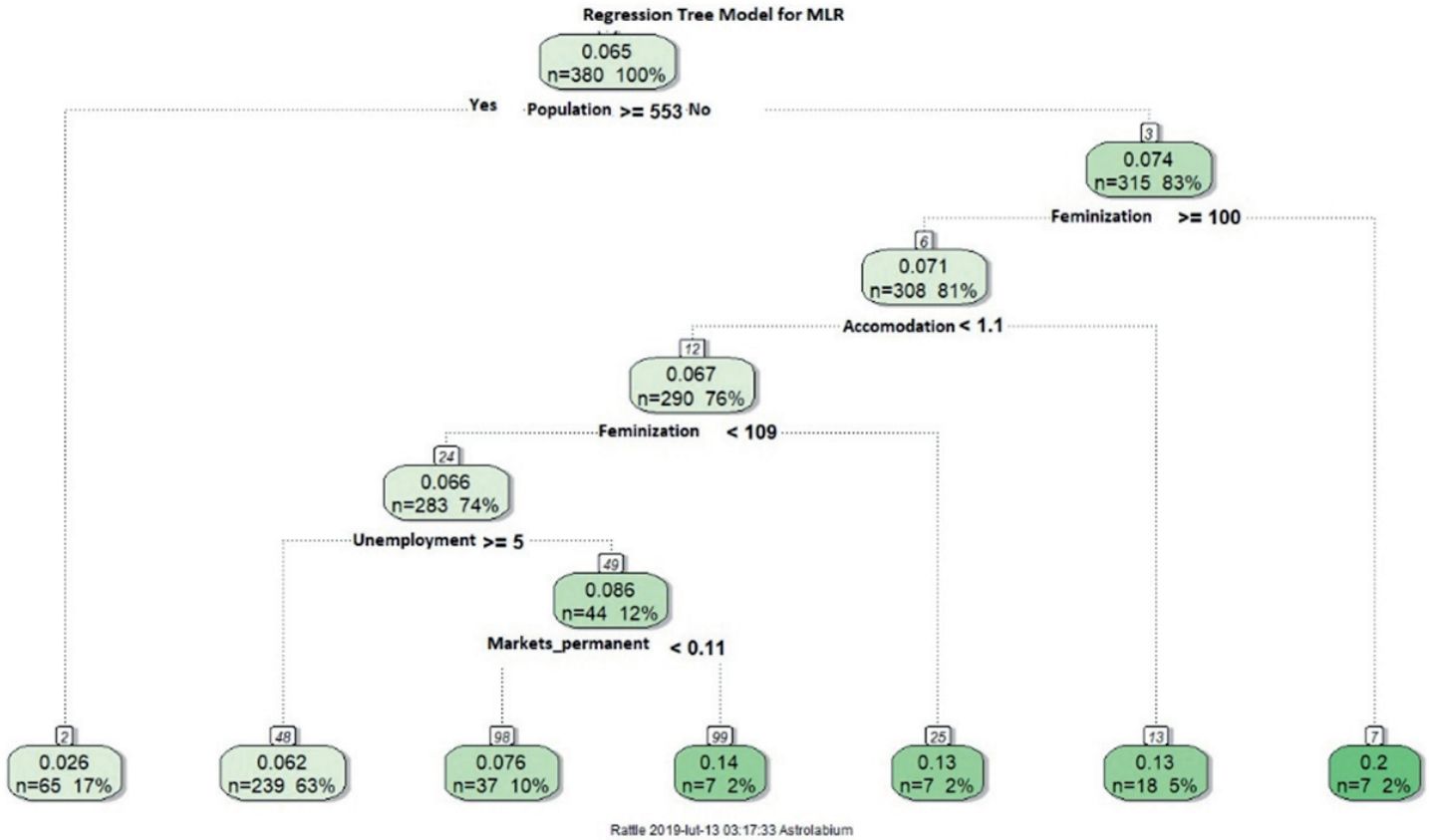

Figure 2. A regression tree model for MLR variable built with CART algorithm

Rysunek 2. Model drzewa regresji dla zmiennej MLR zbudowany przy użyciu algorytmu CART

Source: [Główny Inspektorat Weterynarii 2018] Local Data Bank 2017, the author's own study in R CRAN programme.

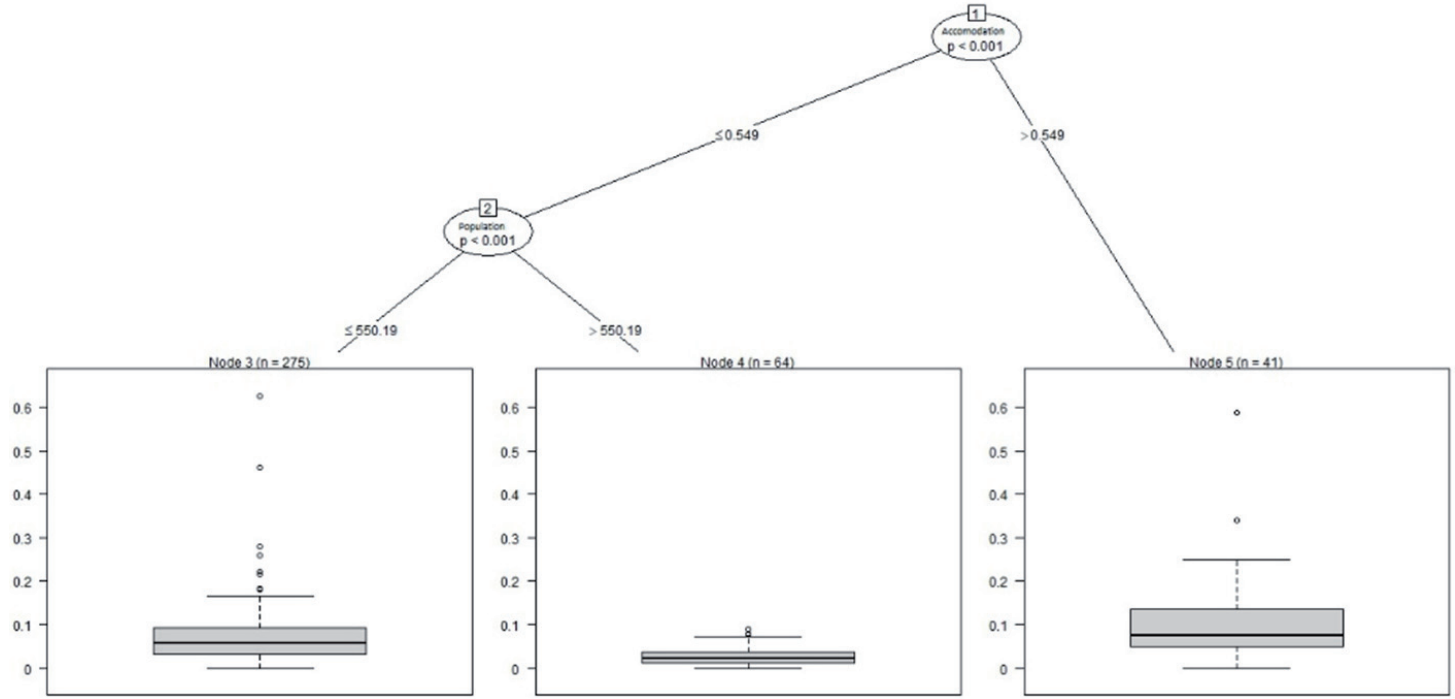

Figure 3. A regression tree model for MLR activities built with ctree algorithm

Rysunek 3. Model drzewa regresji dla działań MLR zbudowany przy użyciu algorytmu ctree

Source: [Główny Inspektorat Weterynarii 2018] Local Data Bank 2017, the author's own study in R CRAN programme

density of MLR activities (node 24), also provided that the previous criteria are met. The reason for such correlation may be the fact that it is an alternative form of activity, giving the opportunity to do business in areas with less industrial potential. The lowest impact strength among the selected indicators was found in the markets permanent index, which informs about the number of permanent marketplaces per 1000 inhabitants of a given poviat. In this case, the dependence proved to be negative, i.e. the relative value of MLR activities (node 49) increases with lower density of permanent markets.

Taking into account Figure 3 obtained with the use of ctree algorithm, only two variables, i.e. accommodation (value of $p = 0.001$) and population, i.e. population density (value of $p = 0.001$) turned out to be statistically significant (assuming the value of $p = 0.10$). In model 2, it can be seen that, for the nodes numbered 2 and 5, the predictor discriminating the subsets was the accommodation variable. Node 2 was further divided due to the population variable, creating node 3, with 275 observations, and node 4, with 64 observations.

As mentioned above, the initial division was made on the basis of the accommodation variable, i.e. the number of tourist accommodation facilities per 1000 inhabitants. In the case when higher density of accommodation facilities is observed the MLR indicator is also higher. It can be concluded that tourists are a potential customer group of MLR activities. In addition, MLR activities are allied with traditions and specific characteristics of various regions. Regions with distinctive traditions are attractive to tourists, hence the positive dependence between these variables seems to be right.

Conclusions

Summing up, as a result of modelling using the rpart algorithm, dependencies were indicated between the explained variable, i.e. the number of MLR activities per 1000 inhabitants of a given poviat, and the variables: population, feminization, accommodation, unemployment, permanent markets. In the case of the ctree algorithm, the accommodation and population variables proved to be statistically significant. The indicator that is most often involved in the process of recurring division is the feminization coefficient. The feminization coefficient was used 32 times during the modelling. The second indicator in terms of the frequency of use in the process of dividing the set was an indicator from the spatial and environmental category, i.e. population density. This indicator was involved 25 times in the process of recurring division of the set. The index with the lowest prediction value was the index of markets or places in streets and squares for seasonal sale per 1000 people, gross value of fixed assets in enterprises per 1 inhabitant and capital investments in enterprises per 1 inhabitant. Summarizing the ranking of prediction importance at a higher level of indicator aggregation, it can be seen that spatial and environmental as well as socio-cultural factors were the most important ones (see Table 2).

The spatial and environmental factors were involved 40 times in the process of recurring division of the set. The socio-cultural factors were used slightly less, i.e. 36 times. On the other hand, the factors that had the smallest share in the division process were technical and technological factors. The specificity of local food systems presupposes a close dependence between the products manufactured and the area where production takes place. This dependence results, among other things, from the legally limited territorial range within

Table 2. The sum of the importance of predictions for individual groups of factors in the model of marginal, localized and restricted activities

Tabela 2. Suma ważności prognoz dla poszczególnych grup czynników w modelu działalności marginalnej, zlokalizowanej i ograniczonej

Factors	Sum of the importance of predictions
Spatial and environmental	40
Socio-cultural	36
Economic	13
Technical and technological	11

Source: the author's own study.

which production and sale may be carried out, but also from the raw materials available in a given area (e.g. Małopolska, production of sheep and goat cheese), traditional and site-specific production methods or, for example, the non-use of preservatives, which makes transport over long distances impossible. Without a doubt, these conditions are of spatial and environmental nature and are key for the concentration of local food system activities. The research carried out as part of this paper allowed for a multi-aspect analysis of the concentration of marginal, localized and restricted activities comprising local food systems. All information obtained may be used to explain the mechanisms of locating activities and may provide developmental guidance to individual regions.

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Assessment of the place of purchase of vegetables and fruits as expressed by consumers

Ocena miejsca zakupu warzyw i owoców w opinii konsumentów

Synopsis. According to studies, Poland is the leader in the production of certain fruits and vegetables as well as certain food products. The development of discount chains is where the changes are visibly heading. The article presents the results of the most common places to buy fruits and vegetables. The research was carried out on a sample of 812 people. Research shows that consumers most often buy fruits and vegetables in super and hypermarkets, with supermarkets being chosen most often when purchasing all food products. The smallest percentage of respondents declared making food purchases in bazaars and markets. The place of purchase is an important factor for choosing food.

Key words: place of purchase, fruits and vegetables, consumers

Synopsis. Jak wynika z badań, Polska jest liderem w produkcji niektórych owoców i warzyw, a także producentem wybranej żywności. Najbardziej widoczny kierunek zmian stanowi rozwój sieci dyskontowych. W artykule zaprezentowano wyniki dotyczące najczęstszego miejsca zakupu żywności owoców i warzyw, które uzyskano na próbie 812 osób. Jak wynika z badań, konsumenci najczęściej kupują owoce i warzywa w super- i hipermarketach, markety natomiast są wybierane najczęściej w przypadku zakupu całej żywności. Najmniejszy odsetek respondentów dokonuje zakupu żywności na bazarach i targowiskach. Dla 70% respondentów miejsce zakupu jest istotnym czynnikiem decydującym o wyborze żywności.

Słowa kluczowe: miejsce zakupu, warzywa i owoce, konsumenci

Introduction

Poland is the European leader in the production of certain fruits and vegetables, it is one of the largest producers of apples, blackcurrants, blueberries, strawberries, chokeberries, white cabbage, mushrooms, carrots, onions, and tomatoes in the European Union. The production largely exceeds the domestic needs and consequently, we sell nearly

3.5 million t of fruit and vegetables for foreign markets. Despite such high production of vegetables and fruits, Poles still consume a relatively small amount of them [Strojewska 2020]. According to the recommendations of the World Health Organization and the Food and Nutrition Institute, one should eat at least 400 g of vegetables and fruits daily, divided into five or more servings. This is however not followed by Poles who consume only about 280 g of the recommended amount. The research carried out in 2020 at the request of the National Association of Fruit and Vegetable Producers as part of the "National Fruit and Vegetable Consumption Survey" shows that as many as 57% of Poles have a diet that is too poor in vegetables and fruit, and women eat them more often than men [Sikorska 2020]. The retail sector tries to respond to changes in consumer behavior and meet their expectations regarding the range of food products. The more the knowledge of food increases, the more its acceptance increases. Knowledge of food is conditioned by contact with it, which in the literature is also referred to as food exposure [Jeznach 2009]. "Human behavior, including food choice, is to a large extent conditioned by the impact of people with whom the person is in touch" [Jeżewska-Zychowicz et al. 2009]. The changes taking place in the organization of food trade in Poland are the result of, *inter alia*, the implementation of structural innovations by retail enterprises resulting in the emergence of new trade forms. The most notable changes are the dynamic development of the discount store network with the simultaneous "lifting" of their equipment, assortment, and market image. Previously, discount stores based their strategies on price-and-cost leadership, they offered basic versions of relatively low-quality products, but now they are introducing branded products, private labels while improving their image on the market [Lipowski and Agnowski 2004, Maciejewski 2017]. The assortment of fruits and vegetables available at discounters has also improved, market leaders have started to modernize their fruit and vegetable stands, both in terms of the breadth of the available assortment and product merchandising. As part of the fight for customers, it also forced changes in other trading formats. Nowadays, when purposefully shaped sales activation instruments play an extremely important role, enterprises are forced to apply an increasingly active promotion policy [Kowalczuk and Ratyńska-Bojar 2010]. The results of the survey carried out by the Polish Food Institute show that consumers very highly evaluate the quality of the assortment of vegetables and fruit offered in modern trade establishments (super, hypermarkets, and discounters) [Maciejewski 2018].

The article focuses on consumers' assessment of the place of purchase of vegetables and fruits as expressed by consumers.

Research methodology

The study was carried out in the form of an online survey (CAWI) in May 2019 on a sample of 820 people, of which 812 respondents were included in the analysis like the ones who in the filtering question "are you the person responsible for food purchases in your household" gave answers "yes" or "I do some shopping". Additionally, the characteristics of the respondents included: gender, place of residence, the size of their household. The article presents the results of the most common places to buy food, vegetables, and fruits. The results of questions measured on the 5-point Likert scale were also

presented. The obtained results were analyzed statistically in the Statistica 13 software. The level of statistical significance was assumed for α = 95% ($p \leq 0.05$) for the variables measured with the Likert scale when comparing the sex of the Mann-Whitney U test with continuity correction. The statements concerned the assessment of the availability of the fruit and vegetable assortment as well as factors related to the price, income, and quality for the purchase of vegetables and fruit.

Table 1. Characteristics of the research sample
Tabela 1. Charakterystyka grupy badawczej

Description	Quantity	[%]
Gender		
Woman	417	51.4
Man	395	48.6
Age [years]		
18–24	135	16.6
25–34	221	27.2
35–44	195	24.0
45–54	133	16.4
55 and more	128	15.8
Place of residence		
Village	300	36.9
City to 20 thousand of inhabitants	93	11.5
City to 20–99 thousand of inhabitants	159	19.6
City to 200–499 thousand of inhabitants	144	17.7
City to 500 thousand of inhabitants	116	14.3
Education		
primary or secondary school	47	5.8
trade school	78	9.6
high school	348	42.9
higher education	339	41.8
Monthly net income per 1 person in the household [PLN]		
below 700	59	7.26601
701–1500	276	33.99015
1501–2500	276	33.99015
over 2500	201	24.6
Number of people in the household		
1	55	6.77340
2	171	21.05911
3	220	27.09360
4	214	26.35468
5 and more	152	18.71921

Source: own research, $N = 812$.

Women accounted for 51.4% of the research population. In terms of age, the most numerous groups were people aged 25–34 and 35–44. In the case of the place of residence, over 1/3 of the respondents lived in the countryside and almost 20% were people living in cities with 20 to 99 thousand. As for the inhabitants, the smallest number lived

in cities of up to 20,000 inhabitants. More than 40% were people with secondary and higher education, and the smallest group was those with primary or lower secondary education. People with a monthly net income per 1 person in the household in the range of PLN 701–1500 and PLN 1501–2500 each accounted for 1/3 of the studied group, and only 7% of the respondents had an income below PLN 700 net per person in the household (Table 1).

Results and discussion

The respondents were asked to define the most commonplace of food shopping and in a separate question, the most frequent place of purchase of vegetables and fruits. Both general food and vegetables and fruits are most often bought in super and hypermarkets, however, supermarkets are chosen more often for overall food purchases. Discount stores are the second most common place to buy food. Marketplaces and bazaars are in third place – over 28% of respondents choose this place of sale to buy vegetables and fruits, and 11% of respondents buy food there in general. Specialty stores and online stores are the most commonplace to buy food for only about 2% of the respondents (Figure 1).

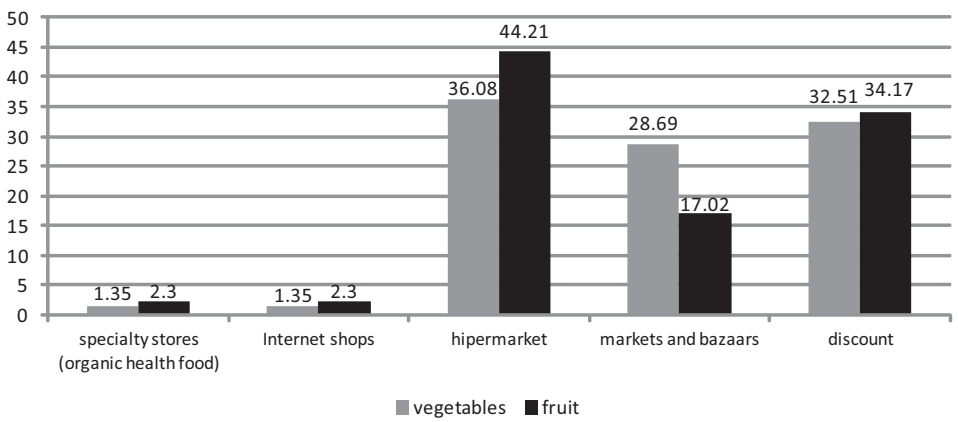

Figure 1. The most common places to buy food, vegetables and fruit [percentage of indications]
Rysunek 1. Najbardziej popularne miejsca zakupu żywności, warzyw i owoców [procent wskazań]
Source: own research, $N = 812$.

Over 70% of the respondents assessed that their place of purchase offers a wide range of fresh vegetables and fruits (Tables 2 and 3). Statistically significant differences in the responses of women and men were noticed in the context of the assortment of fresh fruit, women more often believed that their place of purchase had a wide assortment of fresh fruit. Respondents assessed the breadth of the range of frozen vegetables and fruits worse compared to the fresh ones. As regards the frozen fruits, similarly to the results of fresh fruits, women, statistically significantly more often assessed the breadth of the range of frozen fruits as favorable, while almost 1/3 of men had no opinion about the range of fro-

zen fruits. The respondents assessed the breadth of the assortment of canned vegetables and canned fruits to a similar extent to one of frozen fruits and vegetables. More than 2/3 of women were satisfied with the place where they buy fruits and vegetable men however were less satisfied with the place of purchase of fruits and vegetables. This difference was statistically significant in the Mann-Whitney U test (continuity corrected).

Table 2. Assessment of the vegetable and fruit assortment of the place of purchase by gender
Tabela 2. Ocena asortymentu warzyw i owoców w miejscu zakupu w podziale na płeć

	All	Woman	Man	With correction
S1 The place where I buy has a wide selection of fresh vegetables				
Strongly disagree + disagree (1 + 2)	7.64	7.43	7.85	–1.61
Neither disagree nor agree (3)	18.23	17.03	19.49	
Strongly agree + agree (4 + 5)	74.14	75.54	72.66	
Mean	3.83	3.87	3.78	
S2 The place where I buy has a wide selection of fresh fruit				
Strongly disagree + disagree (1 + 2)	7.51	6.47	8.61	–3.13*
Neither disagree nor agree (3)	19.95	16.31	23.80	
Strongly agree + agree (4 + 5)	72.54	77.22	67.59	
Mean	3.80	3.88	3.72	
S3 The place where I buy has a wide variety of frozen vegetables				
Strongly disagree + disagree (1 + 2)	10.59	11.27	9.87	–1.44
Neither disagree nor agree (3)	25.37	21.34	29.62	
Strongly agree + agree (4 + 5)	64.04	67.39	60.51	
Mean	3.63	3.65	3.59	
S4 The place where I buy has a wide selection of frozen fruit				
Strongly disagree + disagree (1 + 2)	14.53	14.15	14.94	–3.02*
Neither disagree nor agree (3)	26.23	20.38	32.41	
Strongly agree + agree (4 + 5)	59.24	65.47	52.66	
Mean	3.52	3.60	3.43	
S5 The place where I buy has a wide selection of canned vegetables				
Strongly disagree + disagree (1 + 2)	10.22	10.31	10.13	–1.70
Neither disagree nor agree (3)	28.57	24.94	32.41	
Strongly agree + agree (4 + 5)	61.21	64.75	57.47	
Mean	3.59	3.64	3.55	
S6 The place where I buy has a wide selection of canned fruit				
Strongly disagree + disagree (1+2)	11.82	11.75	11.90	–1.22
Neither disagree nor agree (3)	28.82	27.10	30.63	
Strongly agree + agree (4+5)	59.36	61.15	57.47	
Mean	3.57	3.60	3.53	
S7 I'm happy with the place where you buy vegetables and fruits				
Strongly disagree + disagree (1 + 2)	7.14	6.95	7.34	–3.30*
Neither disagree nor agree (3)	20.94	17.27	24.81	
Strongly agree + agree (4 + 5)	71.92	75.78	67.85	
Mean	3.81	3.89	3.72	

*Test U Manna-Whitney (corrected for continuity) p-value <0.05

Source: own research, $N = 812$.

Table 3. Opinions on purchases of fruits and vegetables
Tabela 3. Opinie o zakupach owoców i warzyw

	All	Women	Men	With correction
S8 I think vegetables are reasonably priced where most food is bought				
Strongly disagree + disagree (1 + 2)	10.34	8.63	12.15	–3.63*
Neither disagree nor agree (3)	21.55	16.79	26.58	
Strongly agree + agree (4 + 5)	68.10	74.58	61.27	
Mean	3.68	3.78	3.58	
S9 I think the fruit is affordable where most of the food is bought				
Strongly disagree + disagree (1 + 2)	10.34	9.59	11.14	–2.45*
Neither disagree nor agree (3)	22.41	18.71	26.33	
Strongly agree + agree (4 + 5)	67.24	71.70	62.53	
Mean	3.67	3.74	3.59	
S17 Income limit me the opportunity to purchase more vegetables				
Strongly disagree + disagree (1 + 2)	45.69	43.41	48.10	–0.98
Neither disagree nor agree (3)	26.23	27.82	24.56	
Strongly agree + agree (4 + 5)	28.08	28.78	27.34	
Mean	2.73	2.76	2.69	
S18 Income limit me the opportunity to buy more fruit				
Strongly disagree + disagree (1 + 2)	42.49	41.49	43.54	–0.32
Neither disagree nor agree (3)	26.11	27.34	24.81	
Strongly agree + agree (4 + 5)	31.40	31.18	31.65	
Mean	2.81	2.82	2.79	
23S16 I am happy to buy fruit and vegetables that are subject to a special price				
Strongly disagree + disagree (1 + 2)	6.53	6.71	6.33	–2.88*
Neither disagree nor agree (3)	21.18	17.99	24.56	
Strongly agree + agree (4+5)	72.29	75.30	69.11	
Mean	3.86	3.93	3.79	
I am able to go to another store to buy fruit and vegetables at promotional prices				
Strongly disagree + disagree (1 + 2)	17.61	17.51	17.72	–0.65
Neither disagree nor agree (3)	29.80	29.74	29.87	
Strongly agree + agree (4 + 5)	52.59	52.76	52.41	
Mean	3.44	3.46	3.42	
23S18 I am able to go to another store to buy higher quality fruit and vegetables				
Strongly disagree + disagree (1 + 2)	16.26	17.75	14.68	0.92
Neither disagree nor agree (3)	29.56	29.26	29.87	
Strongly agree + agree (4 + 5)	54.19	53.00	55.44	
Mean	3.48	3.44	3.52	

*Test U Manna-Whitneya (corrected for continuity) p-value <0.05

Source: own research, $N = 812$.

Conclusions

Vegetables and fruits should form the basis of the diet, so consumers must have high availability of them in their preferred places of purchase. As a society, we still eat insufficient amounts of this food group. The conducted research shows that the most common places to buy food in general, as well as vegetables and fruits specifically, are super and hypermarkets, discount stores, markets, and bazaars. However, in the case of fruits and vegetables, respondents make purchases at marketplaces and bazaars more often than in the case of food in general. According to the respondents, they are most satisfied with the assortment of fresh vegetables and fruits available in their place of purchase, and the least with fruits sold in the form of frozen food and canned food. At the same time, the respondents highly rate the places where they buy food. The obtained results allow us to conclude that women are more aware of the available assortment of vegetables and fruits, while men more often do not have an opinion about its range. Besides, it was found that the overwhelming majority of respondents believe that vegetables and fruits are attractive price-wise in the place where they buy most of their food and they are very eager to take advantage of the available price promotions for this food category. Despite the price sensitivity, the surveyed consumers are more likely to shop elsewhere if the quality of the fruits and vegetables offered there is higher.

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The factors influencing the growth in dropshipping orders during the COVID-19 pandemic

Czynniki wpływające na wzrost liczby zamówień w modelu *dropshipping* w czasie pandemii COVID-19

Abstract. The paper aimed to investigate the most significant factors influencing the growth in orders in the dropshipping model in Poland. The research was conducted during the pandemic time and was compared with the results in the levels in orders in 2019. The main factors that have impacts on the growth in the level of orders were introduced out of B2B and B2C variables. The results present that apart from the product type, the payment method, marketing by supplier entity, and the number of suppliers is crucial for a dropshipping business model.

Key words: dropshipping, Polish market, COVID-19

Synopsis. Celem artykułu było zbadanie najważniejszych czynników wpływających na wzrost zamówień w modelu *dropshipping* w Polsce. Badania przeprowadzono w okresie pandemii COVID-19 i porównano z wynikami w zakresie poziomów zamówień w 2019 roku. Czynniki mające wpływ na wzrost poziomu zamówień (zmienne) podzielono na dwie grupy: B2B i B2C. Wyniki wskazują, że poza rodzajem produktu kluczowe dla wzrostu zamówień w modelu biznesowym *dropshipping* były: dostępne sposoby płatności, rozwiązania marketingowe, dostawcy oraz liczba dostawców sklepu.

Słowa kluczowe: *dropshipping*, polski rynek, COVID-19

Introduction

The 2020 COVID-19 crisis has led people in many OECD countries to significantly reduced physical interactions. Strict restrictions literally stopped the operation of traditional brick-and-mortar stores [Donthu and Gustafsson 2020, OECD 2020a]. In the United States, retail and food services sales between February and April 2020 were down 7.7% compared to the same period in 2019. However, sales increased for grocery stores and e-commerce providers, by 16 and 14.8% respectively. In the

EU-27 retail sales via mail order houses or the Internet in April 2020 increased by 30% compared to April 2019, while total retail sales diminished by 17.9% [OECD 2020b]. And so, the COVID-19 impact caused the consumers are increasingly turning to online purchases. Thus, managers need to be innovative in seeking alternative forms of supplies which raise the interest in the facilitation between firms and consumers [Trong Thuy Tran 2020].

E-commerce is a phenomenon that has been developing for about three decades. During this time, its gas gained popularity and became a contributor for many sellers to a profitable business. It is defined as an enterprise in which electronic devices are used to carry out a sale transaction. Currently, the most popular tool of e-commerce is the Internet [Dobosz 2012, p. 1]. Because of the Internet connection, it is possible to conduct business in geographically limited places, and the sale of products is constantly improved supported by the existence of social networks, online payment systems, and new logistics sales models [Luo et al. 2011, Reuschke and Mason 2020]. E-commerce reduces the meaning of economies of scale and minimizes the operation costs, hence enabling profitability with a small turnover. Online stores (e.g. Magento, Shopify) and marketplaces (e.g. Amazon Marketplace, eBay, Etsy, Alibaba) have created new market opportunities with no geographical constraints, enabling businesses, and micro-enterprises in particular, to showcase their merchandise and direct customers to their e-commerce site [Church and Oakley 2018]. As a consequence, several new functions were added into the structure of the supply chain, such as e-procurement, e-ordering, e-sourcing, and e-fulfilment, as well as changes in management practices [Zair et al. 2018].

It is said the most critical activities in the business to consumer (B2C) is e-fulfilment [Park 2016]. This activity can be influenced by factors such as the accelerated pace of the Internet and the increasing expectations of timely service by customers, who are highly demanding [Robusté 2005]. Therefore, on the other hand, the high level of customer service and fluent B2C communication is the critical factor for successful e-commerce models. A model that stands out among e-commerce stores is dropshipping.

The paper is organised as follow: firstly, there is a literature review which explains the idea, characteristics, and assumption of dropshipping model. In the second section, the aim of the paper and the research methods including characteristics of the investigated online shops are presented. The next section includes the results of the research and in the last one the readers can find the conclusions and recommendations.

Dropshipping and supply chain – literature review

The logistic dropshipping model is an order fulfilment method that does not require keeping products in stock, as the store sells the product, and passes on the sales order to a third-party supplier, who then ships the order directly to the customer. It is said to be a very suitable business model for entrepreneurs intending to enter the field of e-commerce but does not have enough capital to purchase, store, and sell goods directly to customers online. As shown in Figure 1 dropshipping fulfilment model allows playing the role of intermediary between customers and merchants who have stock of goods by

receiving requests buying from customers online and transferring them to other electronic stores that have stock of products to be shipped directly to customers, in exchange for getting a commission for every sale made through it[1].

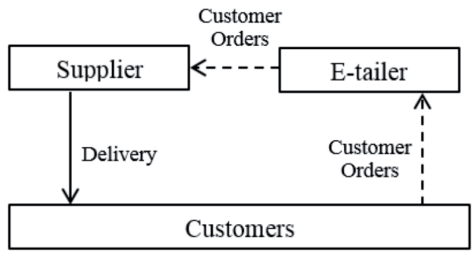


Figure 1. Dropshipping supply chain
Rysunek 1. Łańcuch dostaw w modelu *dropshipping*
Source [Kamalapur and Lyth 2020, p. 82].

Israfilzade [2017] searched the literature and pointed out the advantages and disadvantages of dropshipping which are, as in Table 1.

Table 1 Advantages and disadvantages of dropshipping fulfilment model
Tabela 1. Zalety i wady realizacji wysyłek w modelu *dropshipping*

Advantages	Disadvantages
– less investment is needed – positive cash flow – flexibility in location – product variety – reduces risk – managing imbalance demand – private labelling – customization and personalization	– high prices – high competition – lack of quality control – low margins – shipping complexities

Source: own elaboration based on [Israfilzade 2017].

Dropshipping is said to be an excellent start in an e-commerce business without the need to worry about inventory or shipping, and primarily in the view of low investment needed. The activity is based on listing a product for sale on the website and sending an email to the supplier to ship the goods to the final customer. While starting a dropshipping business is a great way to start an e-commerce business, digging deep through the internet to find a reliable supplier can be tough.

The research conducted in 2019 based on the performance of 458 online stores on the Internet indicated that 16.4% of these stores depends on the method of selling via the retail chain dropshipping, i.e. they rather play the role of intermediary between customers and stores that have stock of products, as it turned out This method has achieved remarkable growth of 32.7% compared to last year and also achieved a conversion rate of 1.74% instead of 1.29% in 2018 [eCommerceFuel 2020].

[1] https://www.code-ship.com/en/Blog/dropshipping-explained/ [access: 28.09.2020].

Moreover, it was found that 45% of them had bought from an independent online store and that 78% of them had bought from Amazon and 34% had bought from e-Bay. Social media platforms had a role in completing purchases, with 11% of these shoppers reporting that they made purchases from Facebook merchants and 6% of them made purchases via Instagram, and 4% from Snapchat[2]. Therefore, it is important for those working in the field of e-commerce to ensure that it has an individual presence in the sites visited by potential customers interested in its products to facilitate access to them and purchase the products they desire.

Aim and methods

Undoubtedly, the dropshipping model has been developing and geographically covered the worldwide market; however, it is advisable to present the assumption of dropshipping market changes during the pandemic time in Poland. The aims of the chapter are:

– determining the significance of effective communication between the participants of the dropshipping model for achieving the increase in order,
– investigating the variables which influenced the changes in the dropshipping market in Poland during the pandemic times.

Online stores using the dropshipping logistics model were deliberately chosen from the ETSY and AliExpress websites due to their increasing popularity among Polish customers. Data was collected based on the on-line questionnaire – 51 stories were investigated. The shop owners offered the following 13 groups of goods to their customers: clothes, sports equipment, medical, IT, babies' goods, home and garden, beauty and cosmetics, gadgets, accessories, books, and others[3] (Figure 2). Out of 13 groups of goods, the results indicate, that over 23% of disposal is clothes / shoes / underwear group, home and garden group represents over 17% (Figure 2).

To study the most important factors which influenced the increase of interest in dropshipping stores classification tree model was used. It is a non-categorical and numerical target variable and aims to divide up the data into sub-setting rectangles that are homogeneous concerning the response. In efforts to attain this homogeneity regression tree algorithms will decide which predictors are important and are to be split, at which value of the predictor the split should occur, how deep the tree should be (i.e. how many layers of internal nodes are needed), how complex the tree should be (i.e. how many branches are needed), and provide a prediction equation for each terminal node [Whitley 2015]. The flexibility of classification trees make them a very attractive analysis option, but this is not to say that their use is recommended to the exclusion of more traditional methods. Indeed, when the typically more stringent theoretical

[2] https://www.code-ship.com/en/Blog/dropshipping-explained/ [access: 28.09.2020].

[3] Clothes: clothes, shoes, underwear. Medical: medical goods, masks. IT: electronics, photography equipment. Gadgets: mobile accessories, cups and T-shirts with personized logotypes, pens. Others: tobacco goods, automotive goods.

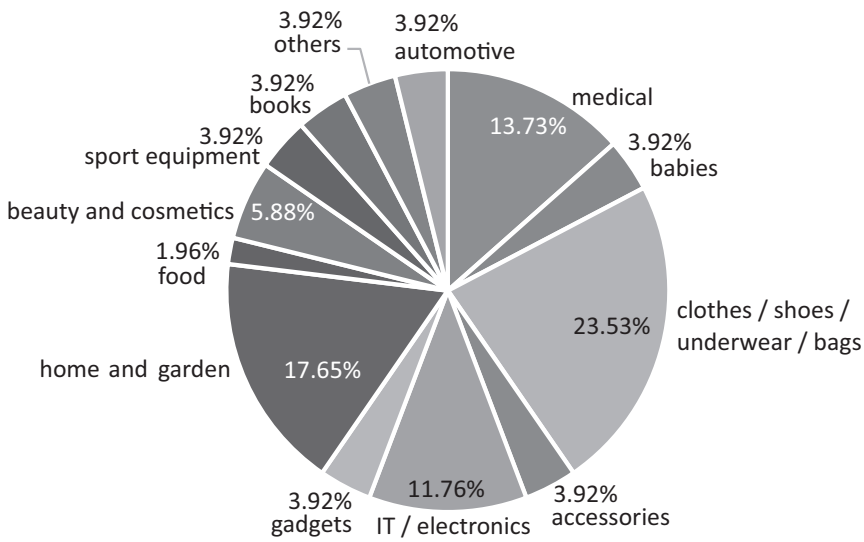


Figure 2. The share of groups of goods selling among the surveyed stores
Rysunek 2. Udział grup sprzedawanych towarów w badanych sklepach
Source: own calculation based on the questionnaire.

and distributional assumptions of more traditional methods are met, the traditional methods may be preferable. But as an exploratory technique, or as a technique of last resort when traditional methods fail, classification trees are, in the opinion of many researchers, unsurpassed [Breiman et al. 1993]. The tree is a graphic model resulting from the division of the set recursive A follow-on *n* disjoint subsets A1, A2, A3, ..., A*n*. The construction of the model is obtaining a maximum homogeneous subset from the variable point of view. This is a multi-step process. On each stage, it is analysed for all predictors and selects the one that provides the best node division [Gantar 2001, Łapczyński 2002].

To create the regression tree model B2B and B2C oriented groups of variables were taken into the research. These groups were selected on the basis of the answers of dropshipping stores managers / representatives. The next step was scaling, important for technical reasons. It changed the words into numerical signs in order to use the data in the regression tree calculation. Apart from *x*3, all the variables have a qualitative character. The percentage increase in ordering in April 2020 to April 2019 declared by the respondents was the dependent variable (*y*), and there were 13 independent variables including in the model (Table 2).

The variables relating to customer service together with those which demonstrate B2B cooperation is said to be crucial for a successful dropshipping business.

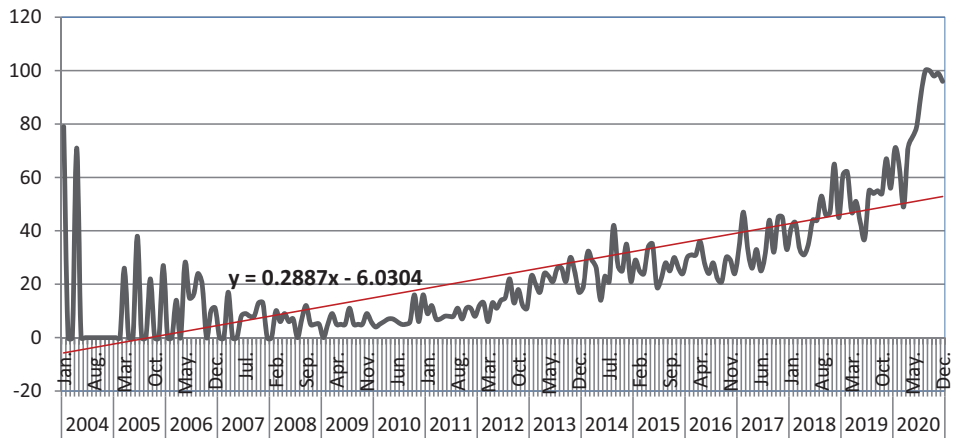
Table 2. Variables and their scaling for a regression tree model
Tabela 2. Zmienne i ich skalowanie dla modelu drzewa regresji

Variables	Scaling variables for the model
B2B oriented variables	
*x*1 seller's web page form	1 web platform 2 own website
*x*2 multiple websites/platforms for selling	1 yes 0 no
*x*3 number of suppliers*	number
*x*4 B2B communication tool	1 through the website on which the store is embedded 2 e-mail communication 3 face-to-face contact 4 telephone contact
*x*5 returns responsibility	1 store 2 supplier 3 both
*x*6 services provided by a wholesaler	0 none 1 personalized product packaging 2 attaching store cards 3 attaching promotional leaflets
*x*7 a wholesale / lower prices policy	1 yes 0 no
B2C oriented variables	
*x*8 B2C communication tool	1 post mail 2 e-mail 3 online contact form
*x*9 templates communication with the customer	1 yes 0 no
*x*10 the usage of social media	1 yes 0 no
*x*11 tracking possibility	1 yes 0 no
*x*12 payment methods	1 online bank transfer 2 credit/debit card payment 3 online payment wallets 4 mobile text messages payment
*x*13 the market coverage	1 Poland, 2 abroad, 3 Poland and abroad

* quantitative variable
Source: own elaboration.

Dropshipping interest in Poland in 2004–2020

The interest in the e-commerce business based on dropshipping in Poland has been rising since 2004 (Figure 3).



* 100 = the month with the highest level of searching

Figure 3. The scale of searching the dropshipping term in Google browser in 2004–2020 in Poland

Rysunek 3. Skala wyszukiwań terminu *dropshipping* w przeglądarce Google w latach 2004–2020 w Polsce

Source: own elaboration based on Google Trends data.

As shown in Figure 3, between 2004 and 2020 there were two periods of increased interest in forging the dropshipping term: May 2004 and August–September 2020. Those two moments seem not to be incidental. In May 2004 Poland becomes a member of the European Union, therefore it was the time when also European Union e-commerce common law was introduced. The e-tailers who had focused mostly on local market cooperation could have started following international European Union trends and business models. August–September 2020 was the time just after worldwide lockdown for SARS-CoV-2 reasons. The entrepreneurs noticed that the dropshipping business become to be leading one in e-commerce. Regardless of the periods of the most frequent searches, there has been stable growth in searching for the dropshipping theme in Google browser in Poland from January 2004 and August–September 2020 which is presented as a trend line in Figure 3.

Although dropshipping in Poland is becoming more and more popular, the result of its introduction has no scientific cover. There is still a small number of Polish publications in this field, and additionally, it is worth investigating the changes in the dropshipping market during the pandemic time.

Results

Based on the collected data, the average level of the increase in orders in dropshipping stores in April 2020 compared to the same month in 2019 was estimated at 119% [Shoper Blog eXperience 2020], however, this level was different for the various groups of products (Figure 4).

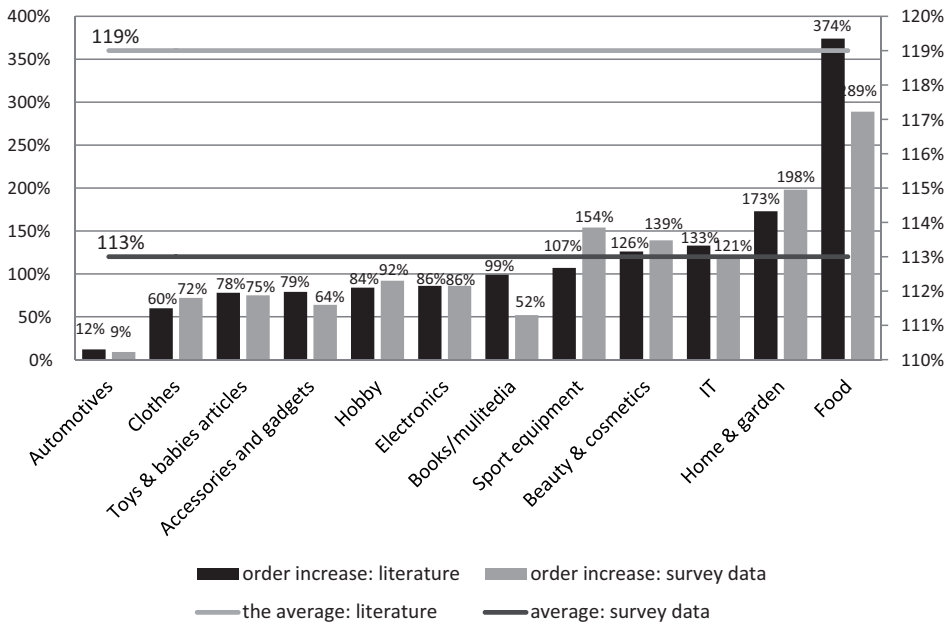


Figure 4. The percentage level of increase in orders in dropshipping stores by groups of products
Rysunek 4. Poziom wzrostu zamówień w sklepach dropshipping według grup produktów
Source: own elaboration based on survey data and [Shoper Blog eXperience 2020].

The highest growth in orders was recorded by food products (374%), which can be treated as an outlier. Next, the 173% increase in home and garden and 133% for IT products. The lowest level of the rise was for an automotive group (12%).

The rise in the orders in dropshipping stores was also pointed out by the respondents in the survey. Its level was different though (see Figure 4). The average level was 6 p.p. lower, and the biggest difference was in the case of food products (85 p.p.) and sports equipment (47 p.p.).

The next step is to investigate, which other factors, apart from the type of the products selling in the store, were the most crucial for increasing the number of orders at the beginning of the pandemic period.

Regression analysis, which is the part of regression tree model calculation, points that the most significant variable, which influences the level of increase of orders by dropshipping store webpages is the market coverage (x_{13}), while the usage of social media for selling in looks to be completely irrelevant.

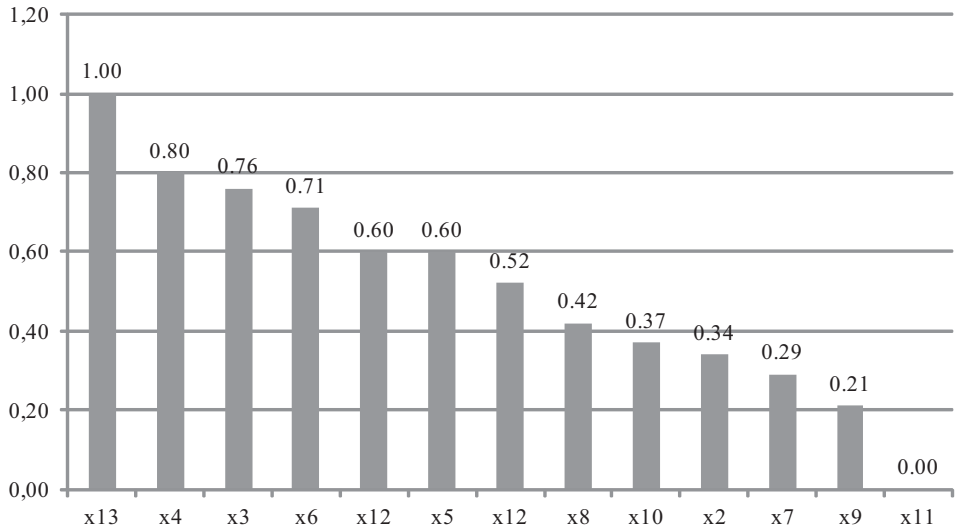


Figure 5. The significance of variables for *y*
Rysunek 5. Ważność zmiennych dla *y*
Source: own calculation.

The three model (see Figure 6) presents the groups of stores (nodes, IDs), with their specific features (x_i). The statistical collectiveness $N = 51$ was divided into the final 5 final nodes: IDs = 4, 5, 13, 14, and 15 by the variables as follow: x_{12}, x_5, x_6, x_3 (Figure 5, Table 2). Based on the model results it is noticeable that 51 stores were divided into two groups (ID = 2 and ID = 3). In the first one, the average *y* level is higher and is calculated as a 188.4% increase in orders. On the other side, in the second group, with a lower *y* average, it is 114.54%.

The variation in the final nodes is unlike. Apart from the nodes in which there is only one store ($N = 1$) i.e. ID = 4 and ID = 15, the ID = 13 demonstrates the low variance as well (Var = 0.271078). That means the low difference in the level of increase of orders within the stores belonging to this node. As for nodes ID = 4 and ID = 15, there is only one store in each, which can be explained by the fact that those stores are outlier variables. The reason for that could be again the specification of the products selling, and the store in 15th node offered food products however the one in node 4 – clothes.

The high average level of increase in order represents also node 5 (165%). The results indicate, that if the seller allowed online bank transfer, credit/debit card payment, and mobile text messages payment possibilities, and additionally, his returns responsibility policy was shared by the wholesaler and wholesaler together with the seller, the average orders level was relatively high. Respectively, the stores with the increase in the level of ordering over 100% were those classified in node 14 (147.5% of the increase). These dropshipping stores the whole combination of payment possibilities (apart from 1, 2, 4 together), at the same time the business contractor did not provide any service when selling the products to the final customer, however, the dropshipping store cooperated

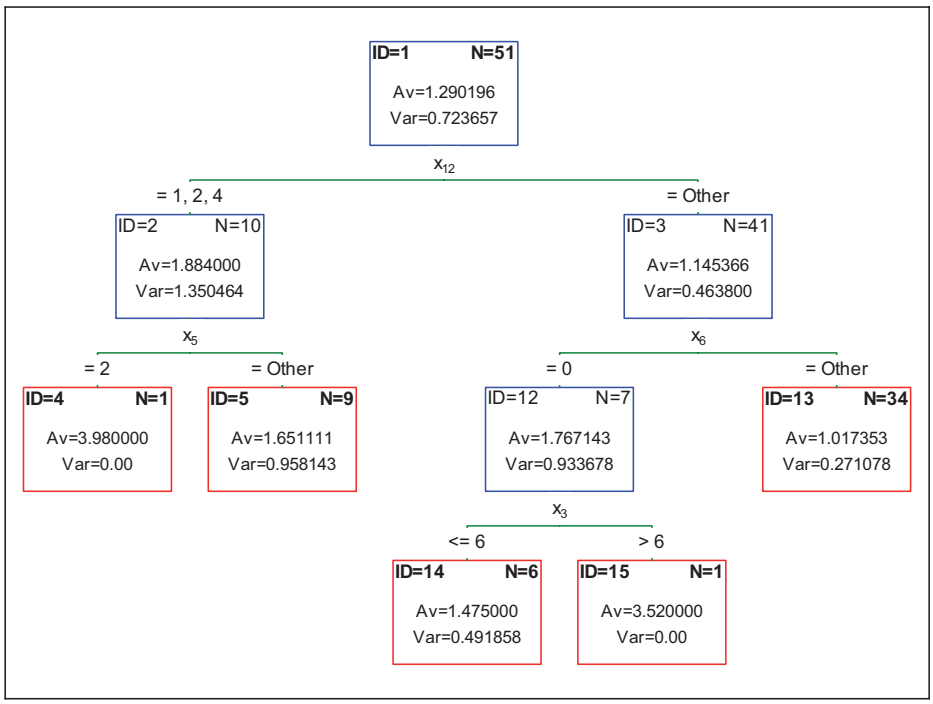


Figure 6. Regression tree model for the level of increase in ordering *y*
Rysunek 6. Drzewo regresji dla poziomy wzrostu zamówień *y*
Source: own calculation.

with not more than 6 contractors. That can indicate that the lower number of wholesalers to cooperate with, even if they are not involved in the additional marketing while they prepare the product for sending it to the final customer is more desirable to achieve the increase of ordering.

Conclusions

The beginning of the COVID-19 world pandemic was an equal unstable situation for the whole markets, due to the number of restrictions, uncertain decision for the future, however, it seems that the e-commerce business gained good results, being perceived as the safe way of shopping.

Dropshipping, where the entrepreneur does not have to store the product to sell as it is directly shipped from the producer to the customer [Singh et al. 2018] is a good opportunity for lowering the market entry barriers and overall facilitating entrepreneurship. In April 2020 there was a huge interest in business leading based on the dropshipping model, and this month represents the highest number of searches the conditions for dropshipping business in the commonly used internet browser since 2004.

The average increase in order via dropshipping stores achieved 129%. This increase differed within the group of 51 investigated stores. Different level of increase was noticed for different product kinds; however, the market coverage is the factors which supported this growth. Moreover, the payment method, number of suppliers and returns responsibility classifies dropshipping stores into the groups with the highest level of increase in April 2020.

To perform well design business in the crisis time, the recommendation for the managers of the stores in dropshipping model would be to pay the special attention for the decisions about the market coverage (national/international), number of supplying entities and payment methods offer for customers as these indicators determined the level of increase of orders in the critical pandemic condition.

To continue the research it would be advisable to conduct the same investigation in 2021 when the situation in the market because of the pandemic is going to be more stabilized.

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The impact of WMS implementation on work productivity. The case of three distribution warehouses

Wpływ wdrożenia systemu WMS na produktywność pracy. Przypadek trzech magazynów dystrybucyjnych

Abstract. Solutions of Industry 4.0 cover more and more areas of the economy. In logistics, digitization applies to each of the functional areas. Introducing IT solutions in logistics leads to an increase in the reliability of communication, faster stock rotation, and a higher level of service. It enables higher work efficiency and overall productivity. Changes in work productivity in three warehouses as a result of the implementation of a WMS class system and accompanying necessary changes in the equipment and organization of warehouse space was analysed in this work. The source of data for the analysis was the measurement of labour productivity for 12 months: three months before the implementation of the WMS and nine after its implementation. Work productivity after the implementation of the WMS increased by 40% compared to the level before it. The period of introducing WMS and obtaining an increase in personnel productivity was at least six months. Labour productivity in the analysed period increased in each month of the analysis. Only one of the three warehouses showed stabilization of workforce productivity at a level 50% higher than before the implementation. The research results confirm that the presence of WMS in the warehouse makes it possible to reach a significant increase in work productivity in warehouses.

Key words: WMS, warehouse, labour productivity

Synopsis. Cyfryzacja obejmuje coraz więcej obszarów gospodarki i życia społecznego. W logistyce obejmuje każdy z obszarów funkcjonalnych. Podstawowe cele, jakie są realizowane poprzez wdrożenia systemów informatycznych to wzrost szybkości i niezawodności obsługi, obniżenie strat, wzrost wydajności pracy, obniżka kosztów. W pracy analizowano zmiany produktywności pracy w trzech magazynach w wyniku wdrożenia systemu klasy WMS i koniecznych zmian w zakresie wyposażenia oraz organizacji przestrzeni magazynu. Podstawą analizy były wyniki pomiarów produktywności pracy w okresie 12 miesięcy: trzech przed wdrożeniem systemu i dziewięciu po wdrożeniu systemu. Stwierdzono, że produktywność pracy po pół roku od wdrożenia wzrosła o 40% w stosunku do poziomu przed wdrożeniem systemu WMS. Okres produkcyjnego uczenia się po zmianach wynosił co najmniej sześć miesięcy. Tylko w jednym z trzech magazynów zaobserwowano

stabilizację produktywności pracy na poziomie o 50% wyższym niż przed wdrożeniem. Wdrożenie systemu WMS w istotnym stopniu przyczynia się do wzrostu produktywności pracy.

Słowa kluczowe: WMS, magazyn, produktywność pracy

Introduction

The 20th century brought enormous progress in the field of Information Technology. Currently, one cannot efficiently manage an enterprise without vital IT systems, and the larger the company, the larger its needs within the scope of IT systems. The IT-supported processes in big companies are numerous and overly complex. The smaller the scale of operations, the easier it is to function without IT support. For the IT systems to correctly fulfill their purpose in the enterprise, they must reflect the company's operation, which is possible thanks to integrated IT systems (IITS). They are usually of modular structure, which allows their construction from previously designed "bricks" and inclusion in the IT support of various areas of the firm's operation, from single processes to comprehensive support.

The origins of IITS date back to the systems whose role was to manage the levels of stock, the Inventory Control (IC). The next stage of development is the emergence of MRP (Material Resources Planning), i.e. a system for planning the material needs, which answers the question of when and where the resources are needed. Further works over MRP resulted in the creation of MRP-II (Manufacturing Resources Planning) system for planning the production resources, which in turn was enriched concerning MRP with planning the auxiliary materials, fixed assets, human resources, funds, time, and others [Długosz 2009]. Usually, after the correct implementation of the IT system the increase in production efficiency and the sales results are achieved [Rut and Kulińska 2013].

The priority goals of implementing the IT systems are synchronizing the flow of products and services in the supply chain and the cooperation with the business partners. The choice of technology ought to be preceded by an in-depth analysis, as often many functionalities of the applied systems remain unused or are poorly suited for the company's specifics. Therefore, it is necessary to first define and optimize processes, and to them match the best solutions from the scope of IT, technology, and automation. Unfortunately, often the opposite happens, i.e. firstly, the companies put into operation expensive and complicated solutions and then consider how to use them effectively [Ozga 2011]. It is also observed that in the micro and small enterprises the IT implementations are rarer and include a smaller functional scope [Wicki and Franc-Dąbrowska 2013]. It results from the relationship of costs to the advantages resulting from their implementation. In small-scale operations, cost reduction and increase of productivity after implementation of IT do not always compensate for the costs of investment in IT, or the period of return on the investment is extensive [Wicki and Jałowiecki 2010]. The factor forcing the introduction of IT systems is, especially in logistics, efficient cooperation with other companies in the supply chain.

Goal and methodology

The aim of the paper is to assess the impact of WMS introduction and related to its organization of work in the distribution warehouse on work productivity.

As part of that goal, the following research tasks were carried out:

- characteristics of changes in the physical distribution of goods in warehouses,
- determination of changes in work efficiency in the researched warehouses.

The time of preparation of one order line (item) was adopted as an indicator of efficiency in the paper. This time is counted from the moment of receipt of the order to the moment of the shipment, i.e. issue to the carrier. This time consists of such elements as internal warehouse manipulation, picking, shipping, and administrative work. Thus, it is the sum of all warehouse workloads.

For the purposes of the study, data were collected on the following values every month:

- number of prepared (sent) lines of the order,
- total working time of all employees in the warehouse in minutes.

The data was obtained from the company's internal registry system for 12 months, including three months before the introduction of the new system and nine months after its introduction.

Based on monthly data, performance indicators were determined according to the following formula: number of items sent / staff working time. The indicator was calculated separately for the three examined warehouses and jointly for all warehouses. The dynamics indicator was used in the assessment of performance changes in time. As the comparative period, the results obtained for a given warehouse and in general for all warehouses within three months before the introduction of changes were adopted. The results were evaluated in two periods: the phase of changes introduction and the phase of full implementation.

The period of the first three months from the launch of the new system was classified as the phase of introducing changes. The period from the seventh to the ninth month after commencing the operation of the system was classified as the full implementation phase.

Warehouse Management System (WMS)

The Warehouse Management Systems are specialist software that improves all processes taking place inside the warehouses. They are of great significance in the enterprises that serve the daily large number of varied shipments, originating from many suppliers and directed at many recipients, where a high complexity of processes occur, as well as the necessity to monitor them. Concerning that, they are extraordinarily important to logistic operators, e.g. 3PL and collaborating enterprises.

The implementations of new tools are often perceived negatively by the employees, who are to use new solutions directly; hence, they display resistance to change [Selander and Henfridsson 2012]. The employees frequently identify new solutions

with an increase in their scope of work and its complications. Learning new solutions is also forced. Thus, it is extremely important to involve future users, e.g. warehouse workers, in the customization of software already at the stage of introduction. When the employees understand the assumptions and goals, they often get involved in the project, are positive towards it, thanks to which new work organization is quickly accepted [Majewski 2013].

Correctly designed and implemented WMS should take into consideration all processes and activities taking place inside the warehouse. The usefulness of warehouse management systems is very often brought down only to the role of recording inventories and flows of materials, and significant benefits result from optimization of all processes of storing and other warehousing activities [Dotoli et al. 2015]. Very often the employee decides where a given pallet should be allocated, which causes it to go to a random place. In such a case there is no question of optimizing storage. Moreover, lacking automatic system control, inactive positions often appear, which are not identified [Kunert 2020]. It is the system, in accordance with assumed algorithms (FIFO, FEFO, LIFO), that should decide about the distribution of materials and the order of their collection and release [Majewski 2006]. Therefore, the proper configuration of implemented system is particularly important, including the possibility of periodic optimization of product distribution or transport routes [Głodowska and Świderski 2019]. Introduction of the WMS usually minimizes the problems related to the unforeseen disturbances in the flow of information, the time of warehouse operations is shortened, and the efficiency of processes and effectiveness of the facility increase [Bartosiewicz 2017, Jankowska and Łukasiak 2017, Grzelak and Owczarek 2019].

The introduction of the WMS, but also other systems, allows to shorten the time of process implementation and reduce the risk [Ślaski 2018]. It contributes to the increase in the competitiveness of the supply chain in which the company participates, and indirectly to better results of entities participating in the chain. Usually, greater benefits are obtained in such chains, in which each of the partners has not only introduced solutions allowing the improvements of internal activities of the firm [Masłowski 2020], but also enhancements within the scope of information exchange and coordination between partners. Thus, one should agree with the statement that IT solutions are indicated among the most important areas for improving the functioning of supply chains [Rut and Wengel 2019]. Some researchers also imply that the increase in the efficiency of warehouse services in Poland was largely due to the application of modern IT systems [Sobczak 2020], although it is not always possible to determine the net impact of such implementation on the results [Jałowiecki 2018]. Nevertheless, both the use of emerging opportunities and meeting the challenges related to the digitization of the economy, including logistics, will be a key factor in the success of companies [Gajdzik 2019]. It should be emphasized that IT implementation is not a one-off activity. The systems are constantly enriched with new functions; hence the introduction of a given system, e.g. WMS, is the beginning of a continuous cycle of advancements and introductions [Jurczak 2019]. Additionally, in many small and medium-sized enterprises, the application and development of IT solutions may not be profitable due to the small scale of operations [Klepacki and Wicki 2014, Banaszyk 2020].

Process of WMS implementation

The general principles and methods of designing and implementing a WMS class warehouse management system provide for several basic steps that should be taken in order to avoid post-introductory problems [Bobiński 2009, Wiązowski 2018]. These are presented below.

1. Assessment of external conditions, i.e. the impact of the environment of the warehouse. During this process, many substantial questions about the predominant goals of logistics need to be answered:
   - Analysis of the structure and flow of goods in the supply chain,
   - Development of synthetic indicators and norms for those indicators, which aims to assess the warehouse operation.
2. Review and analysis of the warehousing processes. Thanks to that we can determine what functionalities of the necessary system are required. All logistics processes are analysed: from the receipt to the warehouse, through storage and completion of stock, co-packing, to shipment. What is important, they are examined both in terms of the flow of materials and accompanying them flows of information.
3. Design and commissioning of the system. This is the last stage of implementation which, like the concept phase, requires the creation of a detailed system specification. The very launch of the system in a given location should be carried out in the next steps:
   - system project,
   - parametrization of standards and programming of specific extensions,
   - configuration of IT system, i.e. mapping the physical structure of the warehouse, storage zones, definition of the logical warehouses, input of data relating to articles, contractors, etc.,
   - testing and training of personnel,
   - starting the system.

The enterprise must be prepared for the period of organizational learning of the new system causing a temporary decrease in productivity, which in this time can only be counteracted with extra employment or overtime, which is usually not calculated as a cost before implementation. Therefore, a plan is needed for gradual, as quick as possible, and at the same time efficient transition to the new management system.

The scope of activities that should be performed before the decision on purchasing and implementing an appropriate IT system is equally important as the choice of system and its price. It is also important to be aware that it is necessary to wait for obtaining the assumed implementation results for up to several months in the case of correct diagnosis of needs. Only after such time, the assumed performance is achieved, the presumed benefits can be accomplished, and the users of the system become independent.

Characteristics of logistics and warehouse processes in the enterprise

The surveyed company is a 3PL logistics operator and provides a number of standard services offered by this type of operators, such as:

- storage: in own warehouses or service in customer's warehouses,

- in-warehouse services:
  - unloading and receipt; many levels of control from visual to detailed,
  - storage; many types of storage places from small shelving of 0,072 m^3 to large pallet positions of 8,64 m^3,
  - picking; preparation and shipment in 24 hours from the date of placing an order, in special cases in four hours from the moment of order placement,
  - co-packing; additional services of creating sets, disassembling, assembling complex elements, e.g. stands, foiling,
  - labelling, attaching additional markings, labels to products,
  - loading;
- transport: organization and selecting appropriate transport taking into account the optimization of costs and maximum use of available cargo space;
- inventory management: inventory analysis, inventory management, triggering deliveries;
- administrative services: invoicing on behalf of the client, monitoring of client's receivables.

The possibility of improving the efficiency of processes and reducing both operational costs and costs connected to the low quality of processes resulted from the implementation of the WMS, the task of which is to better supervise the flow of goods and provide information that allows shortening the time of completion and control.

Characteristics of the analysed warehouses

The analysis covered three warehouses with an area of approximately 3,000 m^2 each, dedicated to the handling of fast-moving products. The Comarch ERP XL system was introduced in the warehouses. A WMS class module called High Storage Module (HSM) was put in operation.

The implementation of a WMS class warehouse system required changes both in the warehouse equipment and in the organization of warehouse processes. The most important changes concerned the method of handling warehouse processes (implementation using WMS), defining the picking path, and optimizing the address of goods in the warehouse depending on the number of pickings and frequency of occurrence of goods in orders. The changes also concerned the method of notification and procedure of goods acceptance, description, and location of warehousing units, as well as generating and circulation of documents. These areas were not subject to detailed analysis within the framework of this study; only the total workload was determined. It should be emphasized here that the change in labour productivity presented in this paper results from many changes introduced together with the implementation of the WMS. There is a lot of evidence that the increase in labour productivity in warehouses resulted from the reorganization of space and changes in storage equipment [Park et al. 2018, Pereira et al. 2020], may be related to the introduction of new reading devices [Nair et al. 2018] and a new picking method [Valchkov and Valchkova 2018], route planning [Mahalakshmi 2019] or even with the appropriate data architecture [van Geest et al. 2020].

After the implementation of the system, in the description of each unit, in addition to the standard information with the reference number and word description, also the following information is recorded: series and best before date (suggested consumption date), average number of items in a single order, and frequency of goods appearing in the orders. This allows automation of data analysis using the software's algorithms.

The implementation of the WMS was related to the changes in the warehouse space organization. One of the more important changes was the division of the warehouse into two zones: storage and completion, instead of dividing it into areas in accordance with the group of goods (Figure 1). Within the storage zone, the areas were distinguished for storing goods from various groups that must be separated. The goods in the storing area are placed on the homogenous pallets, on the racks, instead of positioning them on the floor level in the joint storage and picking area.

Based on the current inspection of inventory levels, the movement of goods is forced from the storage area to the completion zone. The units of the same goods with varied best before date are divided in terms of their location. The FEFO queue is in effect.

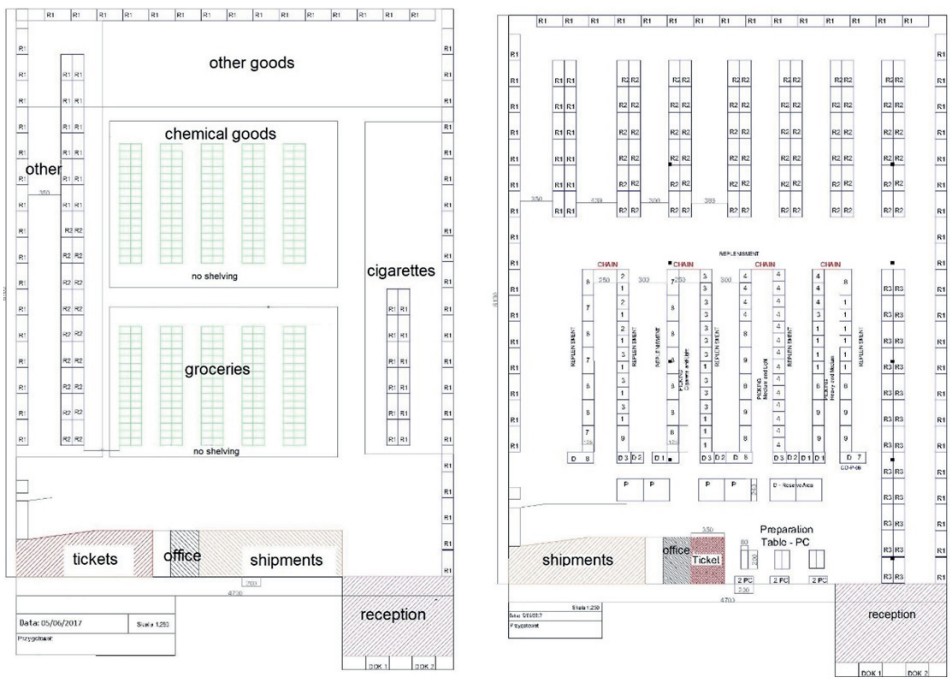

Figure 1. Warehouse scheme and goods location before (left diagram) and after implementation of the WMS (right diagram)

Rysunek 1. Schemat magazynu i lokalizacja towarów przed (lewy diagram) i po wdrożeniu WMS (prawy diagram)

Source: own research.

The WMS has a module for analysis of goods rotation. This module is based on the ABC method. Using the ABC analysis, twice a month the changes are made to the order in the completion zone to achieve the optimal, due to the length of the complete path, the arrangement of products in the warehouse, within the zones for individual products.

After the implementation of the WMS, the processes of completion of order and release of goods were amended. The orders are generated in an electronic form in the WMS. Based on the analysis of availability and location, the goods system generates transfer orders and a complete list taking into account the shelf life of goods for sale and location of goods' units. The order of products on the completion list results from the optimization of the path to be followed by a picker. Before the implementation of the WMS, the picker had to locate products independently, which required a perfect knowledge of their distribution within the warehouse. It was thus not possible to optimize the distribution without disrupting work. As a result of implementing the WMS solutions, the completion path was significantly shortened. Before the implementation, the distance covered by the employee during the completion of a single order was about 410 m. After the changes, the length of the picking path was shortened by an average of 59%, to 170 m per order (see Figure 2). In order to fulfill 100 orders, the employees had to travel 41 km before the reorganization of the warehouse and 17 km after the changes. The time needed for picking was shortened and productivity increased.

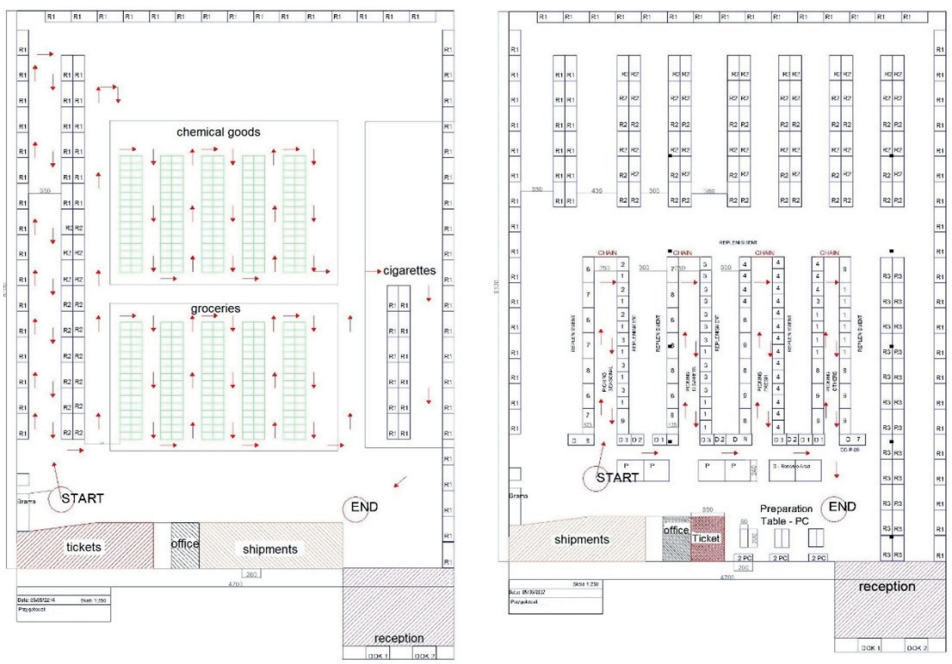

Figure 2. The picking path in the warehouse before (left diagram) and after the implementation of WMS (right diagram)

Rysunek 2. Ścieżka kompletacji w magazynie przed (lewy diagram) i po wdrożeniu WMS (prawy diagram)

Source: own research.

To optimize the quantity and availability of goods, an ABC cross-analysis was used according to the criterion of the number of pieces of goods issued daily and the frequency of appearing of a given item in orders. Data from three months before the implementation of the WMS system was used as the input information – 1950 products were examined. The ABC analysis (1) was performed, considering the criterion of the number of items issued daily, followed by the ABC analysis (2), taking into account the percentage of orders in which a given product appeared as the criterion. The results are summarized in Tables 1 and 2 About 14% of products accounted for as much as 86% of issued units.

Table 1. The results of the ABC (1) analysis
Tabela 1. Wyniki analizy ABC (1)

Groups of goods	The number of items in the assortment	Percentage share of goods		Total of shipped items	Percentage share of items	
A+	104	5.33	14.21	4 416 752	65.19	85.77
A	173	8.87		1 394 593	20.58	
B	692	35.49		854 500	12.61	
C	981	50.31		109 651	1.62	
Total	1950	100.00		6 775 496	100.00	

Source: own research.

Similar results were obtained in the ABC (2) analysis in accordance with the frequency of appearance of articles in the orders (see Table 2). (A+ – 10% orders, A – 4% orders, B – minimum 0.5% orders). Approximately 17% of goods appeared not less frequently than in every 25th order.

Table 2. The results of the ABC(2) analysis
Tabela 2. Wyniki analizy ABC(2)

Commodity group	Number of item's position	Percentage share of goods		Total of shipped lines	Percentage share of items	
A+	161	8.25	16.66	189 383	60.53	79.28
A	164	8.41		58 647	18.75	
B	578	29.64		59 849	19.13	
C	1047	53.70		4 983	1.59	
Total	1950	100.00		312 862	100.00	

Source: own research.

These analyses were combined, and the product categories were created, which were used to plan their distribution in the preparation zone. Most frequently outgoing goods, i.e. present in the highest number of orders, were located closest to the completion and shipment zones, whilst goods rarely present in orders were put at the end of the racks, furthest from the preparation and shipment zone.

Change in employee performance after the implementation of WMS

The introduction of WMS, the change of warehouse layout, and the new distribution of goods led to the alteration in work performance.

Table 3. Productivity changes in the examined warehouses
Tabela 3. Zmiany produktywności w badanych magazynach

Month	Number of product lines, working time and labour productivity											
	warehouse 1 (W1)			warehouse 2 (W2)			warehouse 3 (W3)			total		
	lines	working time [min]	productivity	lines	working time [min]	productivity	lines	working time [min]	productivity	lines	working time [min]	productivity
03b	152 796	235 026	0.65	183 132	282 650	0.65	41 531	64 320	0.65	377 459	581 996	0.65
02b	129 876	201 019	0.65	186 795	277 874	0.67	200 772	322 900	0.62	517 443	801 793	0.65
01b	150 734	218 970	0.69	156 908	237 675	0.66	204 845	320 095	0.64	512 487	776 740	0.66
01a	151 313	206 760	0.73	169 489	230 284	0.74	208 195	278 980	0.75	528 997	716 024	0.74
02a	175 369	229 177	0.77	182 917	231 450	0.79	194 553	268 920	0.72	552 839	729 547	0.76
03a	166 656	197 280	0.85	210 199	242 220	0.87	226 396	297 315	0.76	603 251	736 815	0.82
04a	145 996	174 660	0.84	193 205	227 190	0.85	221 446	292 701	0.76	560 647	694 551	0.81
05a	180 198	219 697	0.82	166 766	174 350	0.96	207 486	260 350	0.80	554 450	654 397	0.85
06a	171 165	213 320	0.80	201 023	189 300	1.06	212 251	270 540	0.79	584 439	673 160	0.87
07a	157 061	168 870	0.93	202 567	201 720	1.00	231 039	296 670	0.78	590 667	667 260	0.89
08a	154 339	174 570	0.88	188 277	187 500	1.00	166 763	197 220	0.85	509 379	559 290	0.91
09a	173 304	193 020	0.90	188 796	190 680	0.99	161 955	171 820	0.94	524 055	555 520	0.94
Before 03b–01b (3-month avg)			0.66			0.66			0.63			0.65
After, 07a–09a (3-month avg)			0.90			1.00			0.84			0.91
Change (before = 100)			137			151			133			140
Average percent change per month			2.34			4.03			2.49			2.92

Source: own research.

In Table 3 the results were presented of productivity achieved in individual warehouses in 12 months of measurements for each warehouse. The analysis period included in the table related to each of the analysed warehouses three months before (lines 01b–03b) and nine months after implementing the WMS (lines 01a–09a).

The changes made in the process allowed for the shortening of the complete path, and also the acceleration of the possibility to find the sought goods. Work efficiency in the studied facilities increased. On average, before the implementation 0.65 positions per working minute were completed. Directly after introducing the system and changes in the spatial organization in warehouses, as well as the alteration of processes, the slight increase in productivity to approx. 0.75 positions per minute took place. After half a year post-implementation, the productivity equaled on average 0.91 positions per working minute. Only in one warehouse (M2) the productivity stabilized on the level of 1 position per minute.

In each of the studied warehouses, the increase in work performance was noted as a result of implementing the WMS, as well as changes in the spatial organization of a warehouse and completion techniques. In nine months after applying modifications, the increase in work performance in warehouses took place, measured by the time of completion per line, on average by 40% compared to the period before the alterations. In individual warehouses, it was from 37 to 51%. In monthly terms, it was on average up to 44% in month nine (see Figure 3). Also, the differences were noted in the post-implementation time, after which the performance improvements were achieved. In warehouses W1 and W2 it took place after two months from the implementation of the system, and in W3 only after four months. The factors that led to these differences were not researched in detail, but they could result from the involvement and experience of working teams in individual

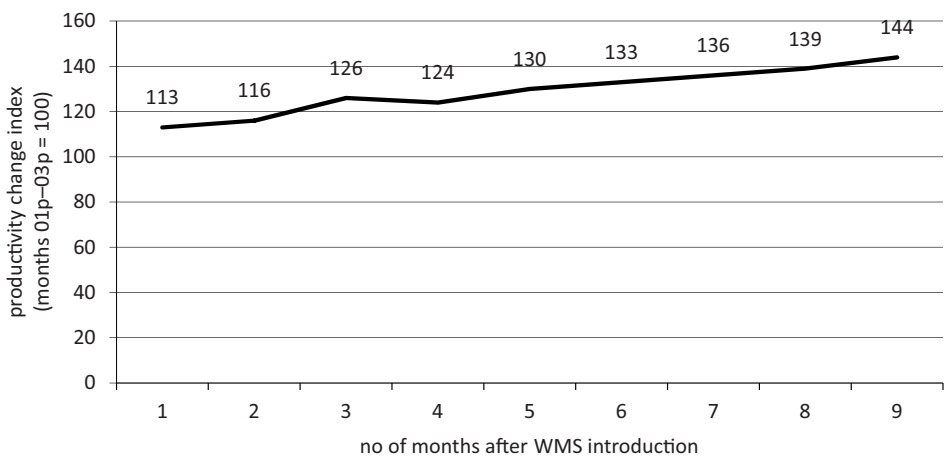

Figure 3. Average change in labour productivity in warehouses in the nine-month period after the implementation of the WMS

Rysunek 3. Średnia zmiana wydajności pracy w magazynach w okresie dziewięciu miesięcy po wdrożeniu WMS

Source: own research.

warehouses. On average, in the post-implementation period analysed in the study, there was an increase in labour productivity at a rate of about 3% per month, and in the last three months covered by the study (07w–09w), there was a stabilization of productivity, although it cannot be stated that no further increase will occur. Considering the stabilization of the productivity level in the W2 warehouse, it can be concluded that the further increase in labour productivity will be limited, and the implementation effects are fully achieved not earlier than after six months, with the commitment and high experience of the staff. Further growth may occur with additional improvements or gaining experience by employees, but this cannot be observed based on this study.

Costs after the implementation of WMS

The implementation of the WMS brought with it new costs. In addition to IT expenditure, such as software, network access, and hardware, expenses were incurred related to equipping the warehouse. The introduction of high storage racks created the need to purchase forklifts. The increase in fixed costs was estimated at 9%. Implementation costs were not, however, the subject of the study, but must be taken into account in the decision-making process. The increase in labour productivity and associated savings may be correlated with higher costs of technical equipment, as well as the consumption of materials and energy.

Summary

The introduction of IT solutions supporting the implementation of logistics processes is now a necessity. The progressive digitization of the economy enables the effective use of computer-controlled systems in almost every area of logistics. IT solutions currently concern not only the improvement of information processing and exchange but more and more often supporting the processes of physical movement of units. Often, as in the surveyed warehouses, the implementation of, for example, a WMS required not only the purchase of an IT solution but also warehouse technical equipment. Additionally, it is usually necessary to reorganize processes, including such aspects as the form of communication with the client, generating orders, reporting, and settlements. In the warehouses surveyed, the implementation of the WMS system was associated with a partial change in the organization of the warehouse space, the introduction of a new type of racks, but above all with a change in the technique for classifying goods and the rules for locating goods in space. A storage zone and a picking zone were separated. Goods were divided and arranged according to their rotation and share in turnover.

As a result of the implementation, an increase in labour productivity was achieved. After the first implementation period (six months), the productivity increased by 40%, and the number of completed items increased from 0.65 to 0.9 per minute. The study showed that the period of productive learning of employees after the implementation of the IT system in the warehouse is at least six months. After this period, the level of labour productivity was stabilized. It should be emphasized that the observed increase in labour productivity did not only result from the implementation of the WMS system, but also

from the accompanying changes in equipment, space layout, and work organization in warehouses.

The implementation of a WMS requires investments that lead to an increase in fixed costs. With rising labour costs, labour-saving investments seem to be a necessity. Cost reduction related to the increase in labour productivity, improvement of communication with internal and external partners, and avoidance of warehouse losses should compensate for the increase in infrastructure costs. Besides, there are benefits for partners in the supply chain, which increases its competitiveness. However, the issue of benefits obtained by partners in the supply chain resulting from the implementation of the WMS system for one or several partners was not the subject of this study. This should be the subject of further research.

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The volatility of price offers of passenger airlines on the example of the Warsaw – Brussels route

Zmienność ofert cenowych przewoźników pasażerskich na przykładzie trasy Warszawa – Bruksela

Abstract. In the study, the authors dealt with the price offer of four air carriers on the Warsaw – Brussels route. There were two traditional carriers (LOT Polish Airlines and Lufthansa) and two low-cost carriers (Ryanair and Wizz Air). The analysis considered changes in the ticket prices for a flight on a specific day over six months. A diversified pricing policy was found. Low-cost carriers and Lufthansa changed prices frequently but to a small extent. On the other hand, the cost of a ticket on Polish airlines was gradually increasing, the fastest in the last month before the flight. To minimize the ticket price at PLL LOT, a reservation had to be made at least three months before the flight. The lowest price of a Lufthansa and Ryanair ticket occurred a month before departure. On the other hand, at Wizz Air, the final price was lower than that offered at the beginning of the study.

Key words: air communication, ticket prices, pricing policy

Synopsis. W opracowaniu autorzy podjęli problematykę oferty cenowej czterech przewoźników lotniczych na trasie Warszawa – Bruksela. Było to dwóch przewoźników tradycyjnych (PLL LOT i Lufthansa) oraz dwóch niskokosztowych (Ryanair i Wizz Air). W analizie uwzględniono zmiany cen biletu na lot konkretnego dnia w półrocznym okresie. Stwierdzono zróżnicowaną politykę cenową. Przewoźnicy niskokosztowi oraz Lufthansa zmieniali cenę często, ale w niewielkim zakresie. Z kolei koszt biletu w polskich liniach stopniowo rósł, najszybciej w ostatnim miesiącu przed lotem. W minimalizacji ceny biletu w PLL LOT należało dokonać rezerwacji minimum trzy miesiące przed lotem. Najniższa cena biletu Lufthansy oraz Ryanair wystąpiła na miesiąc przed wyjazdem. Z kolei w Wizz Air cena ostateczna była niższa od zaoferowanej na początku badania.

Słowa kluczowe: komunikacja lotnicza, ceny biletów, polityka cenowa

Introduction

Passengers, air transport, in the period before the pandemic, became more and more popular every year. Carriers increased the number of flights and connections and competed with the attractiveness of offers. Therefore, travelers could choose the lines based on various reasons, both price and non-price (comfort, transfers, luggage weight, departure and destination airport, etc.).

Four airlines dominate the Polish market, namely traditional carriers, i.e., LOT Polish Airlines and Lufthansa, and low-cost carriers, Ryanair and Wizz Air. Many destinations can be reached via these lines. However, they differ in the offered price of the air ticket and the proposed range of additional services. In the years before the pandemic, all these lines showed a growing number of passengers (see Figure 1).

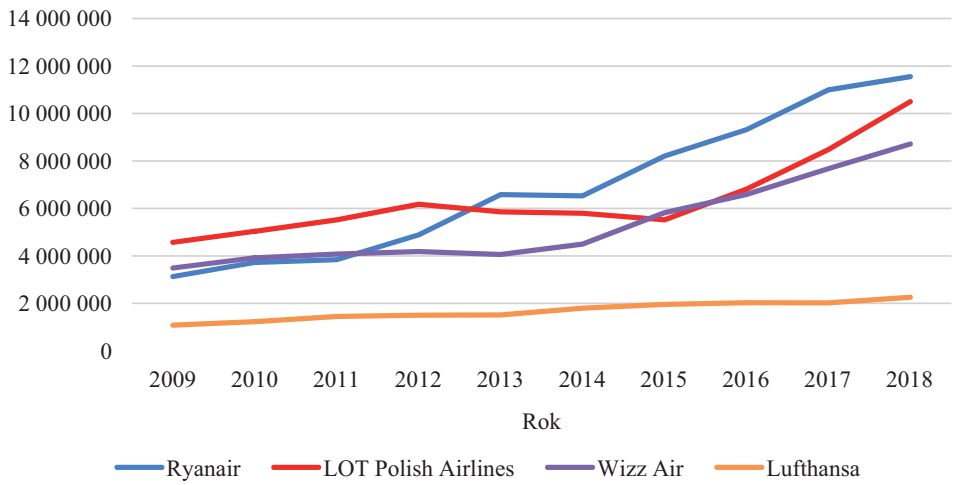

Figure 1. Number of passengers handled by major carriers at Polish airports in domestic and international regular traffic in 2009–2018

Rysunek 1. Liczba pasażerów obsłużonych przez głównych przewoźników na polskich lotniskach w ruchu regularnym krajowym i międzynarodowym w latach 2009–2018

Source: own study based on [Urząd Lotnictwa Cywilnego 2019a].

Ryanair showed the most significant dynamics in this respect, although LOT and Wizz Air were also very active. Only in the case of Lufthansa was the upward trend insignificant.

Research purpose and material

The research aims to identify trends in changes in ticket prices for six months and find the best time to book a flight. An additional goal was to compare the largest passenger carriers' price offers on the Polish market on the Warsaw – Brussels route.

While collecting empirical material, the Internet was used to monitor the price offer and the scope of services provided by the compared carriers. In order to identify trends

in changes in airline tickets prices, a survey was carried out, which lasted for six months (from July 15, 2019, to January 14, 2020) and consisted of daily checking the current values for a flight of one adult from Warsaw to Brussels, which was to take place in Wednesday, January 15, 2020 and was to be served by each of the four previously discussed airlines. The date and the cities were chosen deliberately so that visiting the place was not dependent on the weather, and it was a "working day" in both Poland and Brussels, thanks to which external factors did not overstate ticket prices. The earliest flight was selected when traditional airlines offered more than one flight on the route under study. Additionally, to standardize, the prices of tickets for the first offer in economy class are presented. To make the results as realistic as possible, the tickets were monitored at a fixed time around 20:00.

Research objects were selected on purpose. These were the four-passenger airlines with the highest share in the Polish market. To obtain answers to the formulated research problems, a comparative analysis (horizontal and vertical) was used.

Features of air transport

As part of air transport, mainly long-distance passenger transport is carried out, using aircraft of various sizes, from several to several hundred on-board seats [Kacperczyk 2016, pp. 172–173]. This segment accounts for approximately 70% of global air transport performance [Czownicki 1993].

Due to the high speed, this type is often chosen for the transport of mail, and the transport of goods is its smaller segment. Airplanes allow for a single transport of up to 250 t of goods, which is a small load compared to rail or sea transport, and the price for the transport of various types of products is high [Lewandowski et al. 2013].

Until the pandemic, air transport was the branch with the fastest pace of development, because it allows reaching destination very quickly, and is also the safest means of transporting goods. The advantage is an extensive spatial range, and air transport deliveries are characterized by high regularity and punctuality [Kacperczyk 2016]. Besides, the advantage for passengers is the convenience of travel and food during the flight. The airline offers a different standard of service, and the prices are different, which attracts both less and more demanding people.

Table 1. Advantages and disadvantages of air transport
Tabela 1. Zalety i wady transportu lotniczego

Advantages	Disadvantages
• short transport times • high security (goods protection) • large spatial range • greater frequency of transports • regularity and timeliness of deliveries • convenience of travel • food during the flight • diverse standard	• high transport costs (mainly freight) • aircraft load capacity is low • the least versatile branch of transport • unfavorable spatial distribution of transport points • the necessity to use other modes of transport • long clearance time

Source: own study.

The disadvantage of air transport is the high cost of transport, especially freight. It is also possible to distinguish the small payload of aircraft and the lowest versatility among the modes of transport. The location of airports makes it necessary to use an additional mode of transport, which significantly extends door-to-door delivery [Neider 2008]. Passenger transport is becoming cheaper, and the price depends on the date of the flight, carrier, and time of booking. The downside may be the long check-in time. The entire list of advantages and disadvantages of air transport is presented in Table 1.

Characteristics of airports in Warsaw and Brussels

The surveyed carriers fly from different airports (see Table 2). In the case of the Warsaw – Brussels route, two ports serve each city. Traditional airlines, i.e., LOT Polish Airlines and Lufthansa, depart from Chopin Airport and arrive in Brussels – Zaventem. Wizz Air also departs from Okęcie but arrives at Brussels – Charleroi Airport. Ryanair, operated by the Warsaw-Modlin Airport in Poland, lands similarly. This means that passengers using the offer of Irish airlines have to cover the most significant distance from the center of the metropolis to the terminal, as Charleroi is 43 km from Brussels, and Modlin – about 42 km from Warsaw.

Table 2. List of airports in Warsaw and Brussels serving the largest carriers on the Polish aviation market

Tabela 2. Lista portów lotniczych w Warszawie i Brukseli obsługujących największych przewoźników na polskim rynku lotniczym

<table>
<tr><td colspan="2">Place of departure</td><td rowspan="3"></td><td rowspan="3"></td><td rowspan="3"></td></tr>
<tr><td colspan="2">Poland (Warsaw)</td></tr>
<tr><td>Warsaw Chopin Airport (WAW)</td><td>Warsaw Modlin Airport (WMI)</td></tr>
<tr><td>PLL LOT Lufthansa</td><td></td><td>Brussels Airport (BRU)</td><td rowspan="2">Belgium (Brussels)</td><td rowspan="2">Place of arrival</td></tr>
<tr><td>Wizz Air</td><td>Ryanair</td><td>Brussels South Charleroi Airport (CRL)</td></tr>
</table>

Source: own study.

Warsaw airports are essential for air transport in Poland. Historically, the Okęcie airport was opened on April 29, 1934, to which passenger traffic was transferred from the airport in Mokotów. It was bombed during World War II, but traffic was quickly resumed. The reconstruction was provisional, and the new station was put into use after thirty years. In 1971, the port handled the first million passengers, and in 1979 this number exceeded two million – the modernization works, which resulted in the creation of Terminal 1. In 2006, Terminal 2 was put into operation, and nine years later, the reconstruction of the central and southern pier was completed. All these parts make up Terminal A. Besides. The port has a General Aviation Terminal for corporate and private aircraft. In 2001, the

airport was granted the patronage of Fryderyk Chopin, and since 2010 it has been officially called Chopin Airport, it is commonly called Okęcie [Sipiński et al. 2016]. The port serves cargo and charter carriers, but the largest group is scheduled. These include, among others, airlines such as Lufthansa, British Airways, Air France, Emirates, Qatar Airways, KLM, SAS, as well as LOT Polish Airlines, which have their main base there [Lotnisko Chopina Warszawa 2020a]. Chopin Airport is a significant transfer point, which is also indicated by the record result of 18.86 million passengers served in 2019. The main destinations include London, Paris, and Kyiv. The most popular carrier was Polish airlines, whose services were used by 10 million people [Lotnisko Chopina Warszawa 2020b].

The second airport located in Warsaw is Modlin. Information about its creation dates back to 1937, but the opening date is considered to be July 15, 2012, when a Wizz Air plane landed at the airport. It had a high development potential in the first period because, after less than two years of operation, it served a two-million passenger [Sipiński et al. 2016]. The main airport facility is a two-story terminal. The port cooperates with travel agencies and low-cost airlines, servicing short and medium-haul transports. Thanks to cooperation with Ryanair airlines, passengers can travel to over 30 cities in Europe [Warsaw Modlin Airport].

The origins of Brussels Airport date back to 1914 when German troops began building a hangar on Evere and Haren's territory. In April 1919, the first test flight to London was organized, which transported two people. Since then, regular passenger services have been introduced on this route and new destinations have been added. The port was divided into two parts – Evere – for military use and Haren – for civil, where the new terminal was used. During World War II, the German army invaded Belgium and began building an airport in Melsbroek, where civil aviation was later transferred. Due to the growing number of tourists visiting the country (after the war), the port became too small and in 1956 the construction of a new one was approved. After two years, the airport in Zaventem was handed over. Modernized continuously, it has become one of the fastest-growing and most modern international airports, connecting central Europe with many destinations worldwide [Brussels Airport 2020c]. Moreover, it is in the 23rd place of the most crowded airports in the old continent. It serves over 250 carriers and performs approximately 237,000 air operations annually. It is the home base for Brussels Airlines, Jetairfly, and Thomas Cook Airlines Belgium. The airport has a terminal divided into two halls – A, which serves all flights, and B, for flights only outside the Schengen area [Brussels Airport 2020b].

Another airport serving the Belgian capital is Brussels South Charleroi Airport, whose history began in 1919 when the first Belgian flying school was established here. During World War II, this place was a landing strip, and after its end, it became a public airport. However, the airport was used primarily for private and training flights, as passenger traffic was negligible. On July 9, 1991, the port was officially named until today. A few years later, Ryanair opened the first route from the airport, and more lines followed suit. The number of served passengers was growing, which forced the construction of new terminals [Brussels South Charleroi Airport 2020a]. The port offers customers flights to nearly two hundred destinations in 53 countries. It regularly cooperates with nine airlines, among which the most flights are provided by low-cost carriers [Brussels South Charleroi Airport S.A. 2020c].

The airports tested are not identical. In both cities, however, you can see dominant facilities (in Warsaw Chopin Airport, and Brussels Airport in Brussels) and with less passenger service at 17.4% in Warsaw and 29.1% in Brussels (see Figure 2).

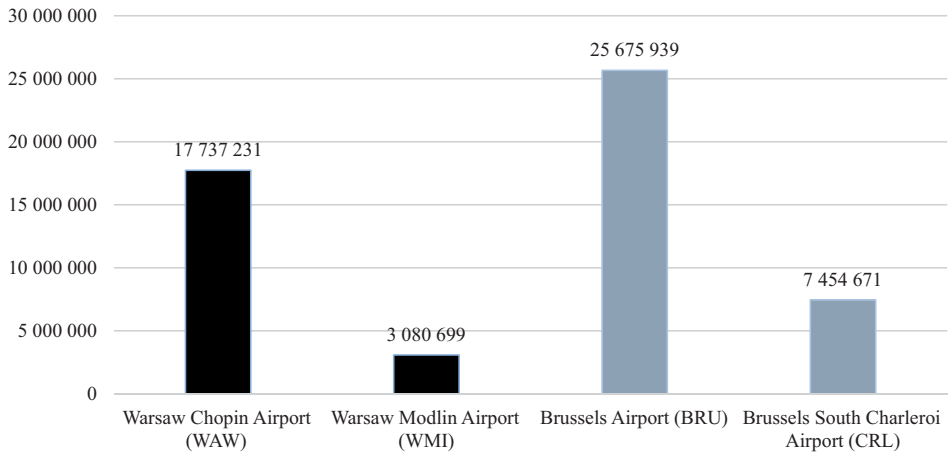

Figure 2. Number of passengers (people) served at the airports in Warsaw and Brussels in 2018
Rysunek 2. Liczba pasażerów (osób) obsłużonych na lotniskach w Warszawie i Brukseli w 2018 roku

Source: [Urząd Lotnictwa Cywilnego 2019b, Brussels Airport 2020c, Brussels South Charleroi Airport S.A. 2020b].

Trends in price changes offered to passengers during the period considered

To identify the trends in airline tickets prices changes, a survey was carried out, which is presented in the initial part of the study. It lasted six months and consisted of daily checking the current values for a flight of one person from Warsaw to Brussels on January 15, 2020.

The first analysis concerns the Hungarian carrier Wizz Air. The plane was supposed to take off from Warsaw Chopin Airport at 05:45, but as a result of the delay, it was moved to 06:10. The flight took two hours and 10 minutes, and at 08:20, the passengers landed at their final destination.

Starting the test six months before the departure date, it was found that the basic tariff "Basic" was charged at PLN 209 and lasted 51 days until September 4. As part of the promotion, the carrier offered a price lower by almost 16.5%, reaching PLN 174.6. It was then reset to the previous value and held for the next 13 days. From September 18 to October 7. the price was PLN 169 and PLN 149 on the following day. On October 9 and 10, the ticket value was reduced again, this time to PLN 129. For the next week, the flight fee was PLN 109, i.e., almost 52% of the initial price. On October 18, so nearly three months before the departure date, the ticket value was reduced to PLN 59 and was kept almost permanently for 53 days with three exceptions. One of them was on Octo-

ber 29, when the carrier announced promotions and offered PLN 54.60 for the ticket. On November 29 and December 2, as part of the "Black Friday" and "Pink Monday" campaigns, choosing a Wizz Air flight could save on purchasing a ticket, paying PLN 54.20. For the next month, from December 10 to January 10, the price was reduced to PLN 39, and besides, on December 12, 2019, and January 8, 2020, as part of the special offer, it was even lower by PLN 0.40. It was then PLN 38.60, reaching the lowest value in the analyzed period. In the last four days before departure, the value of the ticket has increased again. On Saturday, January 11, the price was PLN 69, on Sunday and Monday PLN 129, and Tuesday PLN 169.

Passengers who used the Wizz Go fare could purchase a ticket, the price of which in the analyzed period ranged between PLN 126.40 and PLN 334. On the other hand, by choosing Wizz Plus, the difference between the values was more significant, and the prices were in the range of PLN 176.40–401. Additionally, by being a Discount Club member, could save around EUR 10 on the ticket price, regardless of the package selected.

The second case concerns a flight operated by the German company Lufthansa. It connected with a transfer in Munich, so the time to get to Brussels turned out to be significantly longer than for other airlines. The plane took off at 6:00 from the airport in Warsaw, landed in Belgium at 10:05, and the flight itself took just over three hours.

Contrary to the previous carrier, the prices were not subject to large fluctuations. From July 15, 2019 to November 12, 2019, the difference between the lowest and the highest ticket value was PLN 12.13. During this period, however, passengers who purchased at the turn of August and September had to pay the most, while spending a maximum of PLN 1,121.61. On November 13, 2019, the price was reduced to PLN 1,098.41 and remained at a similar level until January 8, 2020, when it amounted to PLN 1,096.06. The ticket price increased significantly six days before the departure date. On January 9, the basic tariff was PLN 1,214.19, and a day later, PLN 1,214.52. For the next three days, the price did not change, amounting to PLN 1,332.35, and the day before the flight, it reached the highest value in the analyzed period, namely PLN 1,332.52.

Customers using the Lufthansa offer could choose two other packages from the economy class, which was similar to the discussed basic tariff in the analyzed period. On the other hand, a business class ticket's cost has increased significantly in the last fifteen days, reaching even over PLN 10,000. Additionally, the German carrier offered four more connections to the Belgian capital.

The third flight in the order of analysis was the LOT Polish Airlines connection. It was scheduled for 7:20 am, and after two hours and 15 minutes, the passengers arrived in Brussels.

As in the German carrier case, in the initial period of the study, ticket prices fluctuated only slightly. For the first 95 days, the primary tariff value difference was only PLN 0.09, and the average cost – PLN 229.44. On 18–21 and 25 October, the ticket price was around PLN 257.22. On the other hand, between October 22 and October 24 and again on October 26 –November 4, the price was the lowest and amounted to approximately PLN 227.15. Since then, the flight charges have gradually increased. First, they amounted to PLN 242.05 for three days, and then they increased to PLN 257.13 and remained at a similar level for the next nine days. On November 17, the price was raised again, this time to PLN 467.24, and on December 12, the value was already PLN 599.23. Nearly

a month before the departure date, the "price jump" was the biggest. Namely, the ticket had to be paid almost three times more than the previous dish, i.e., PLN 1,532.14, and a similar price was maintained until January 11. The next increase in costs occurred three days before the trip, and the most for the flight was on January 14, 2020, and exactly PLN 1,859.02.

In addition to the economy class, passengers could also choose a premium or business package. The cost of such a ticket was similar throughout the study and only increased a few days before departure. On January 15, 2020, customers could choose other Polish carriers' flights to Brussels, which included both direct and indirect ones.

The fourth airline is Ryanair, which offered the first and only connection on the surveyed day from Warsaw to Brussels at 18:45. The flight duration was identical to that of the Hungarian carrier and was 130 minutes.

The introductory fare price was continually fluctuating throughout the research period, and the difference in value up to five days before departure was PLN 54. At that time, the highest price ticket could be purchased at the beginning of the observation for PLN 97.74. On December 2, as part of the "Cyber Monday" campaign, the carrier offered a promotional price of PLN 19. On the other hand, passengers planning a trip on the day in question could most often come across a ticket for PLN 73. A steady increase in the price can be seen from 08/12/2019 when the tariff was reduced to PLN 39 and kept constant for a month. Then the ticket cost increased to PLN 73, and on January 10, it was already PLN 231. When purchasing at the weekend, PLN 379 had to be spent on the trip, PLN 456, on Monday, and PLN 673 on Tuesday. A few hours before the flight, the price was reduced to PLN 562.

Passengers could also use the "Plus" and "Flexi Plus" packages for the selected flight. Their prices fluctuated similarly to the basic tariff, reaching a maximum of PLN 773.11 and PLN 840, respectively.

Differences in price formation by the surveyed airlines

When comparing the level of prices of airline tickets offered by selected carriers, one can notice many differences in their formation over the analyzed period (Figure 3). The first thing that should pay attention to is price fluctuations. With low-cost airlines, they were frequent, with one value only for a short time. However, the situation was different from traditional carriers. The Lufthansa ticket price changed almost every few days, but the differences were slight, even imperceptible at such a high cost.

On the other hand, fluctuations in PLL LOT were the smallest, and for the first three months, the price was at a similar level. Moreover, the value of tickets of the German, Hungarian and Irish carriers increased and decreased in the analyzed period. However, the price offered by Polish airlines, except for five days in October, was increasing. Moreover, this value started to rise more than two months before the departure date – this also distinguished LOT from its competitors, whose steady growth was only visible in January.

Significant differences can also be noticed in the price of tickets. A significant disproportion occurs in the case of the value of the trip with German lines. However, it is

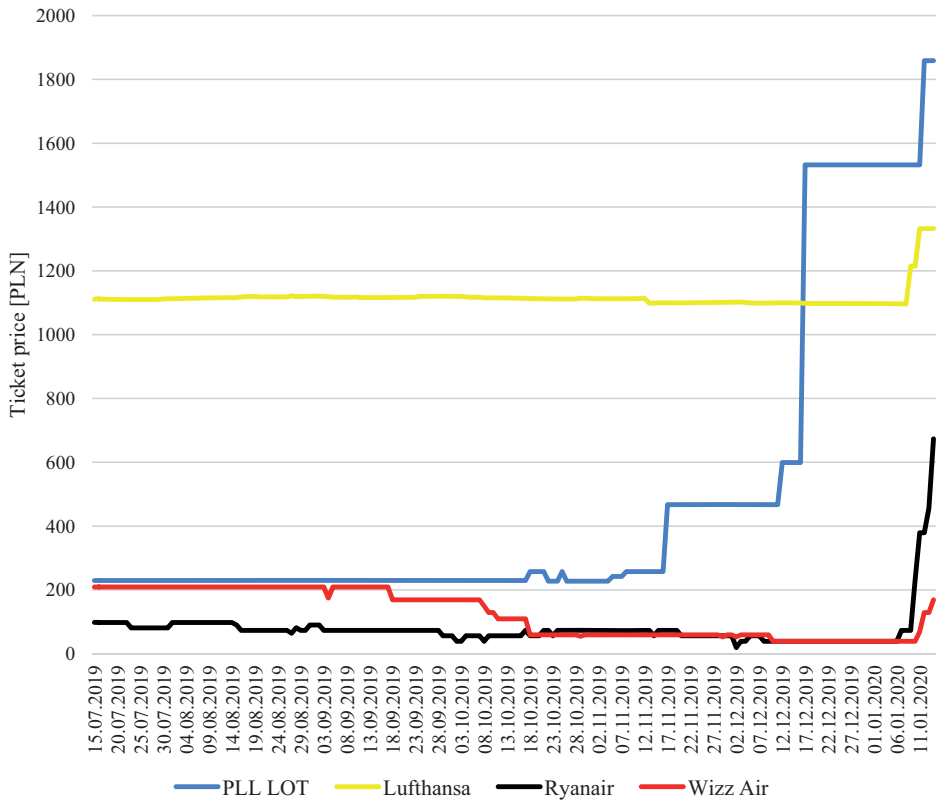

Figure 3. List of ticket prices of the largest carriers on the Polish aviation market from July 15, 2019 to January 14, 2020

Rysunek 3. Cennik biletów największych przewoźników na polskim rynku lotniczym od 15 lipca 2019 roku do 14 stycznia 2020 roku

Source: own study based on the obtained research results.

a connecting flight, which partly explains the discrepancy. Other carriers' prices in the first part of the study were much lower and similar, and more significant differentiation can be noticed only in the second half. It is also worth analyzing the differences between the starting price and the final price. The Lufthansa ticket value increased by almost 20%, Ryanair almost seven times, and LOT Polish Airlines eight times. Wizz Air was the only carrier whose price the day before departure was lower than the starting price by PLN 40. LCC, unlike traditional ones, also offered passengers promotions. Ryanair lowered the ticket price as part of "Cyber Monday", and on the Wizz Air website, it was possible to purchase at a bargain price six times.

Carriers need to balance two strategies when pricing their tickets. The first is to fill airplanes as much as possible, i.e., to offer a relatively low price to passengers whose purpose is leisure. Such action is aimed at persuading them to buy a ticket well in advance. Revenue maximization is also essential, and this strategy is implemented

shortly before the planned flight date. It is addressed to business customers who make reservations shortly in advance, and the key aspects are frequency of connections, convenient location of the port, or amenities at the airport. The ticket price for these people becomes less important; therefore they are willing to pay more [Walków 2017].

The surveyed airlines also follow these strategies, which can be seen in Figure 3. Customers buying tickets in advance will pay much less than in recent days. In the case of Ryanair, Wizz Air, and Lufthansa, by booking several months before the departure date, the trip's cost turned out to be higher than that up to one week in advance. Passengers visiting their families abroad plan long-distance flights much earlier. They must have a specific seat on the plane, which means accepting the current flight price without waiting for a possible discount.

However, the pricing strategy of the airlines depends on the applied business model, on which the tariff policy depends. Each carrier has internal IT systems and profit managers who modify its thresholds. Prices are set individually for each route and are the result of many variables. These activities are top secret and constitute the company's secret [Cybulak 2012].

Summary and conclusions

The conducted research allowed us to formulate several conclusions.

1. One of the criteria differentiating the compared lines is the ticket price. Taking the Warsaw – Brussels route as an example shows many differences in their shaping. For LCCs and Lufthansa, there were frequent but minor fluctuations in prices. On the other hand, LOT Polish Airlines remained at a similar level for the first months. Moreover, the prices of the German, Irish and Hungarian carriers both increased and decreased. On the other hand, the cost of a ticket on Polish airlines was gradually increasing, the fastest in the last month before the flight.
2. Although all airlines have analyzed the introductory offer in economy class, there were also differences in the flight itself's value. Initially, LOT Polish Airlines' prices, Ryanair and Wizz Air were at a similar level, and only in the second half of the study, more significant disproportions appeared. By contrast, the cost of a Lufthansa ticket was significantly higher already six months before the date of travel. However, this discrepancy is explained by the fact that it was the only connecting flight. It is also worth noting that only LLC in the analyzed period lowered ticket prices as part of various promotions. Traditional carriers did not even participate in such popular campaigns as "Black Friday" and "Cyber Monday".
3. If anyone wanted to take advantage of the cheapest LOT Polish Airlines offer, they need to make a reservation at the earliest, i.e., at least three months before the planned date of departure. On the other hand, the lowest price of a Lufthansa and low-cost ticket occurred a month before the trip and lasted about 30 days, after which there was a sharp increase. The most significant difference between the fee proposed half a year before and the final one occurred at the Polish carrier, where an eightfold increase was recorded. What is more, the final value even exceeded the price of the German carrier's ticket by over PLN 500. On the other hand, Wizz Air

turned out to be the only one whose final price was lower than that offered at the beginning of the study.

4. The higher the amount that has been allocated to the ticket, the more excellent the choice of potential carriers. However, in the times before the pandemic, the budget was not a problem because anyone could fly to many places for a few dozen PLN. Moreover, tickets purchased in advance are often cheaper. Therefore, people who already have a trip planned should think about making a reservation in advance. In contrast, there are many promotions at LLC, and the ticket's value a few weeks before the flight can turn out to be very low. Therefore, consumers who do not have specific plans as to the place and date are advised to observe the connections, as it is possible to find a desirable offer.

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