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ORIGINAL PAPER

BARRIERS TO ELECTRONIC DATA EXCHANGE IN THE SUPPLY CHAIN - RESULTS FROM EMPIRICAL STUDY

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ABSTRACT. Background: The purpose of this article is to present the results of a study on barriers to data exchange in supply chains between logistics service providers (3PL and 4PL) and their customers in Poland. The study investigates two research hypotheses regarding the relationships between the size of a company and the role of a logistics service provider in the electronic data exchange between their business partners.
Methodology: Bayesian ordinal regression was used to assess the reliability of the research hypotheses. The study used survey data from a population of 78 logistics service providers operating in Poland. Feedback was received from 51 respondents. Originality of the presented research results from the applied research method, Bayesian ordinal regression, rarely used in economic sciences to assess the reliability of research hypotheses concerning the determination of determinants of the studied phenomenon. The defined research hypotheses represent an important contribution to the research on communication in supply chains.
Results: The results indicate that the level of the employment and the role of logistics service provider in a supply chain do not determine the extent of problems in electronic communication between the logistics operator and customers.

Keywords: EDI, logistics provider, supply chain

INTRODUCTION

Today, the amount of data generated by companies is increasing dramatically every year [Krajk et al., 2022]. More and more processes are being digitized, forcing the use of ever newer techniques [Golinska-Dawson et al., 2023]. With the increasing amount of data, companies face the problem of ensuring easy access and security of the data [Krajk et al., 2022].

The interchange of all data and information with as little human involvement as possible is the main assumption of the digital economy [Godziewska-Nowicka and Janicki, 2019]. This allows the time of information and data interchange to be reduced and reducing its cost [Combe, 2006]. The most important characteristic of digital technologies is their ability to react dynamically (fast) to sudden changes in the market and customer preferences [Szopa and Cyplik, 2020]. They also provide the opportunity to keep interactive contact with the main business partners [Wang et al., 2007].

Supply chain integration, which requires organizational and informational cooperation between business partners, aims at optimizing logistics processes by, among other things, eliminating paper circulation of documents, and thus minimizing errors associated with it. The role of the logistics provider is not only to rationally organize the implementation of logistics processes, but also to integrate the information of the business partners it serves. Logistics providers are generally classified into five groups depending on their role in a supply chain [Werner-Lewandowska and Kosacka-Olejnik, 2020]. For the purpose of this research, the characteristics of 2 of them were made: 3PL and 4PL, as shown in Table 1. Table 1 also indicates the range of services provided by

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logistics operators according to the NACE classification. NACE is the 'statistical classification of economic activities in the European Community' and is the subject of legislation in the European Union, which imposes the use of the classification uniformly within all Member States. It is a basic element of the international integrated system of economic classifications, which is based on classifications of the UN Statistical Commission (UNSTAT), Eurostat, as well as national classifications; all of them are strongly related each to the others, allowing the comparability of economic statistics produced worldwide by different institutions.

Table 1.Characteristics of a 3PL and 4PL

Role	Characteristics	Basic services sections according to NACE Rev. 2 classification
3PL	- integrated storage and distribution - integration and support of IT infrastructure - data tracking - own assets	Section H — Transportation And Storage Section J — Information And Communication Section K — Financial And Insurance Activities
4PL	- supply chain design - planning and optimizing supply chain logistics processes - re-engineering of supply chain processes - integration of services, systems, information - continuous innovation - technology as the basic resource - lack of own assets (technical logistics resources)	Section H — Transportation And Storage Section J — Information And Communication Section K — Financial And Insurance Activities Section L — Real Estate Activities Section M — Professional Scientific And Technical Activities Section N — Administrative And Support Service Activities Section O — Public Administration And Defence; Compulsory Social Security

Source: Own study based on [Chrąchol-Barczy et. al., 2017; Werner-Lewandowska and Kosacka-Olejnik, 2020, NACE Rev. 2, 2008].

Effective supply chain management requires information integration, which means that each piece of information should be entered into the enterprise information system only once [Kolinski and Werner-Lewandowska, 2021]. Such a solution ensures that data acquisition costs are minimized, that the collected and exchanged data are more consistent, and that the risk of errors is reduced. Furthermore, there should be no delays in data transfer within the supply chain, so the information entered in the system should be made available in real time to all users for whom it is relevant [Speier, Mollenkopf and Stank, 2008; Sassi, Arrivabene, and Romero, 2011; Kawa and Zdrenka, 2016].

Integration of information is achieved through communication channels and technologies that support the flow of information between business partners in the supply chain [Leuschner, Rogers, and Charvet, 2013]. Integration of chain participants is based on the application of modern information technology and broad partnerships [Hadas et al., 2015; Trojanowska, Varela and Machado, 2017]. Information technology capabilities and information sharing have a significant impact on logistics integration [Prajogo and Olhager, 2012; Horzela et al., 2018]. Information integration reduces the time required to generate data and information necessary for operational-level decision-making in logistics processes [Kolinski and Werner-Lewandowska, 2021; Golinska and Hajdul, 2011]. Acquisition of real-time data increases the readiness of companies for possible changes in the implementation plan of logistics processes.

The global supply chain relies on reliable communication, identification of transported cargo, and coordination of logistics processes. This is due to the need to maintain and coordinate the supply chain [Kawa, 2012]. Moreover, through electronic data interchange, paper documents and their associated costs are reduced in favor of EDI (Electronic Data Interchange) messages and information flow times between business partners are minimized. Furthermore, EDI should be considered as a solution to

integrate information systems in the supply chain [Debicki and Kolinski, 2018]. Electronic data interchange is a response to the requirements of modern supply chains, which due to their complexity require a fast and reliable system of information exchange. EDI is treated as a technological solution as well as a solution with economic impacts [McLaren, Head and Yuan 2002; Nurmilaakso and Kotinurmi 2004; Moberg et al. 2002]. Research on the implementation of EDI has been conducted for many years [Collins, 1993; Riggins and Mukhopadhyay, 1999; Lee and Lim, 2005] and shows a diverse range of sectors and industries where EDI can be implemented [Klein, 1995; Laage-Hellman and Gadde, 1996; Angeles et al. 2001; Kim and Lee 2008; Bernardes &Miyake 2016; Bahija, Malika, and Mostapha 2016; Okano et al., 2017]. Evidence can also be found of the effectiveness of EDI implementation in business practice [Lee and Han, 2000; Lee, Lee and Kang, 2005; Zhou et al., 2018].

Companies began experimenting with EDI in 1970 and the first standards were developed and issued for the transport industry in 1975.

EDI provides a standard format that allows different business systems to communicate with each other. Business partners send and receive documents containing transactions such as invoices, purchase orders, waybills, etc. directly to their internal system or through an EDI network service provider. The process of sending a document requires three steps, Fig.1.

When identifying the data to be included in an EDI document, a company can use software programs to extract data from various systems when creating the document or having an employee manually enter the data. Using an extraction program makes the process more efficient but requires time to map the data sources of the existing system to the EDI application. Once created, the EDI document is transmitted directly to the trading partner's internal system or EDI network service provider.

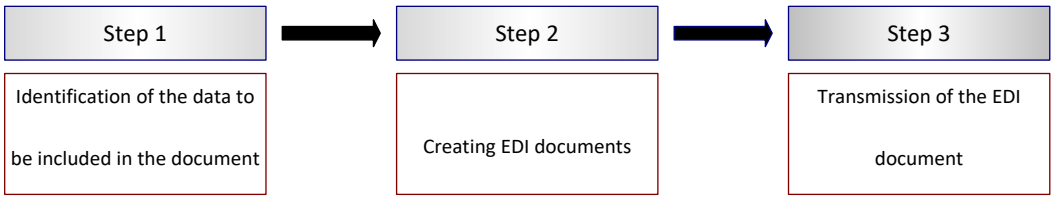

Fig. 1. The process of sending an EDI document, Source: own study.

The receiving of EDI documents mirrors the sending process. First, the trading partner receives the EDI document directly into its internal system or through an EDI network service provider. The EDI data is converted to be compatible with the internal system and then entered into that system. The information system sends the receipt confirmation to the sending partner.

Recently, EDI integration has moved to a cloud environment, called an integration platform. The cloud version of EDI allows companies to integrate through any type of protocol, format, and system, whether the company has IT systems that are maintained internally, managed by a third party, or are cloud-based. Cloud-based EDI solutions provide seamless updates without disruption to business operations.

Some general benefits of using EDI include the following:

- reduction of costs for personnel, consumables, and office/storage space,
- improved data quality by reducing data entry errors,
- reduced business cycle time from order to payment,
- improved business efficiency, by allowing staff to focus on critical issues rather than correcting errors,
- increased data security, through the use of passwords and program encryption,
- reduced disruption during the audit process,
- improved decision making as a result of having access to real-time information,
- increased corporate social responsibility and sustainability, due to reduced paper consumption.

EDI also has some disadvantages. Because trading partners must establish a connection between their information system and the EDI application, with new trading partners in the initial phase, these processes may take longer. Additionally, companies may have to redirect some IT resources in the initial implementation phase to data mapping and then to maintaining the EDI application. The process of implementing EDI into business reality can be:

- time-consuming and difficult,
- some trading partners may require additional information that needs to be modified,
- costly cause poorer visibility of information, using third-party EDI software, so companies may have difficulty tracking any errors that occur during data transmission.

In addition to technical problems, there are also problems resulting from the low number of EDI implementations at individual links in supply chains. The research aims to show the barriers related to EDI implementations in the opinion of 3PL and 4PL logistics providers.

RESEARCH METHODOLOGY

Scope of the study and conceptual model

The purpose of this research is to investigate the relationships between the size of a company and the role of logistics service providers in the electronic data exchange between 3PLs and 4PLs and their business partners. The conceptual model of the study is shown in Fig. 2.

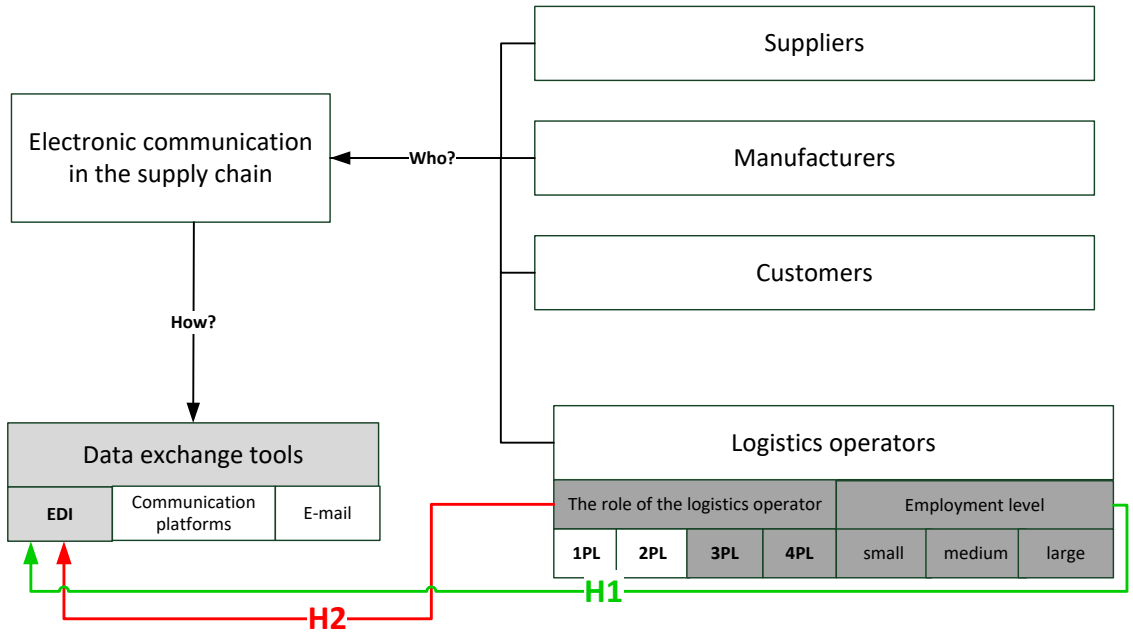

Fig. 2. Conceptual model
Source: own study

The research hypotheses have been stated as follows:

H1: Employment level determines the extent of problems in electronic communication between logistics service provider and customer.

H2: The role of logistics service provider determines the extent of problems in electronic communication between logistics provider and customer.

The hypotheses are justified by our previous work [Werner-Lewandowska and Golinska-Dawson 2021], in which it was identified that the size of the company (measured by the level of employment) influences the application of modern solutions in a supply chain. Second, we based on the previous studies on the role of logistics service providers in a supply chain with regard of the offered scope of services offered [Tang et al. 2019; Cichosz, 2018].

Data to verify research hypotheses

Verification of the set research hypotheses was carried out for the population of N=51 Polish companies providing transport and storage services. Companies were selected according to the volume handled annually in Poland, based on the TOP list of logistics providers [GS1, 2018]. The selection of the research sample can be considered representative and it allows one to draw conclusions on an EU scale. Poland is an interesting market for studies in the logistics sector. According to Eurostat data, the Polish logistics sector has a very high share in tonnes-kilometers of freight transport in the European Union [16.4% of the total of the EU] [EuroStat, 2019]. Poland has an advantage in cabotage activities. In 2018, Polish haulers were the main third country carriers in inter-country freight transport in the EU [Werner-Lewandowska and Golinska-Dawson, 2021]. According to CSO data, in 2018 transport and warehousing service providers represented 12% of enterprises in Poland [Werner-Lewandowska and Golinska-Dawson, 2021]. In addition, logistics service providers generate the largest impact on GDP among Polish service companies [Werner-Lewandowska and Golinska-Dawson, 2021].

The characteristics of the sample of 51 logistics service providers are shown in Tables 2 and Table 3. We take into account the size of company which is measured according to the EU classification by number of employees and is called in this study "employment level" (Table 2).

In Table 3 the structure of the research sample is presented with regard of the logistics provider role.

Table 2. Basic information about the researched companies – employment level

Characteristics	Responses [%]
fewer than 10 employees	3,92%
from 10 to 49 employees	17,65%
from 50 to 250 employees	21,57%
more than 250 employees	56,86%

Source: Own study

Table 3. Basic information about the researched companies – role

Characteristics	Responses [%]
3PL	64,71%
4PL	35,29%

The research was conducted in 2018 among the leading logistics providers doing business in Poland. More than 77% of them are medium- or large-sized companies. More than 60% offer third-party logistics [3PL] services. According to the theory of estimation in operational research, the minimum research sample that guarantees the representativeness of the results is n=30. The confidence level should not be less than 85% and the maximum error greater than 18% [Balakrishnan and Basu, 1996]. The analysis carried out by the authors allows us to conclude that, assuming a maximum error of 15% and a confidence level of 95%, the research sample of 43 companies should be considered representative [Domanski and Kolinski, 2020].

The statistical sample of 51 logistics providers is representative and allows to draw the obtained conclusions.

The respondents were asked to: *What are the most common problems in electronic communication between your company and customers?*

- The respondents were able to indicate the following responses (multiple choice):
- Insufficient knowledge about EDI,
- Inadequate IT systems of customers,
- Customers do not want to implement EDI,
- Lack of a single standard solution,
- Long time and high costs of EDI implementation.

The percentage structure of the respondents' responses is shown in Fig.3.

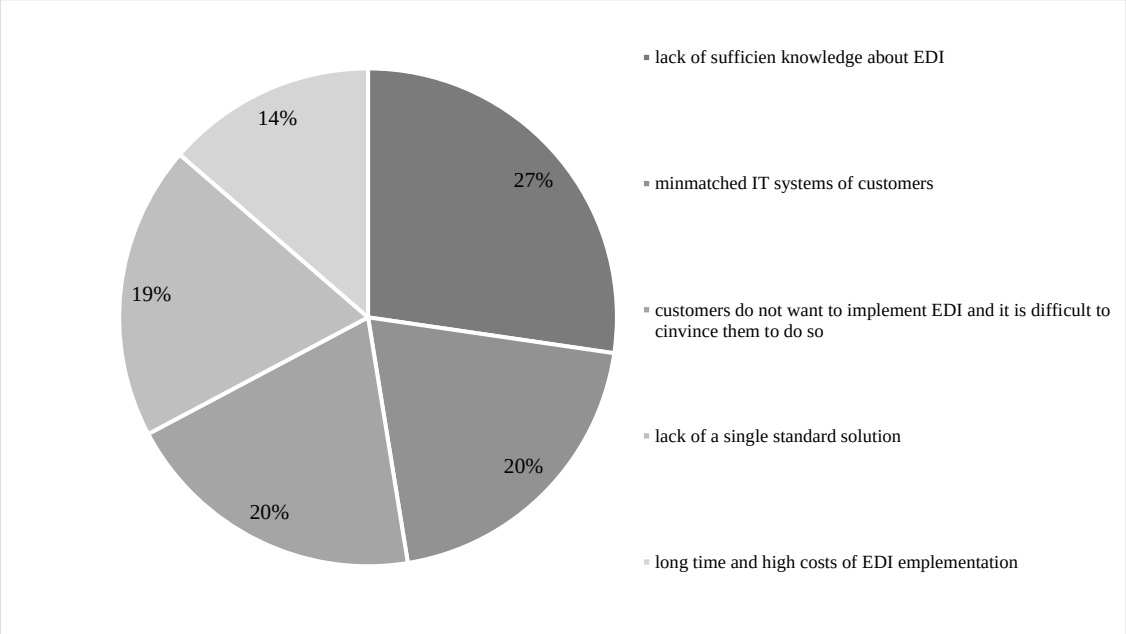

Fig.3. Structure of respondents' answers.
Source: own study

Analyzing the responses of the respondents (Figure 3), it can be concluded that the lack of sufficient knowledge about EDI is the most common problem in communication between logistics providers and their customers. This problem is also the most common barrier to implementing EDI with business partners. An in-depth analysis of respondents' indications has shown that this problem concerns all micro companies that are 4PLs, whereas in the case of larger companies, this problem was more often indicated by 3PLs (as shown in Fig. 4).

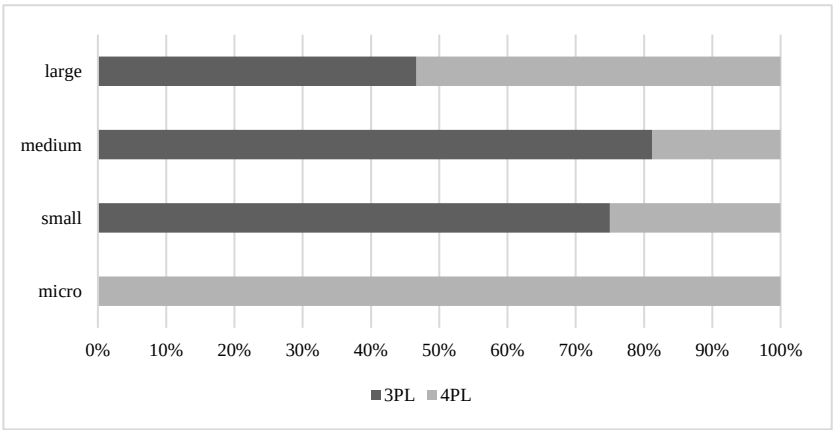

Fig. 4. Respondents' indications of insufficient knowledge about EDI as a communication problem.
Source: own study

Initial conclusions from the respondents' responses were further statistically analyzed to verify the research hypotheses. Data were analyzed using the statistical package R 4.0.2. For each dependent variable, a Bayesian regression with company size and logistics provider role was run as predictors to determine whether reliable differences between groups were present in the survey data. The size was coded 0.5 for large firms and -0.5 for other firms, while the role of 3PL was coded 0.5 and 4PL was coded -0.5. The regression weights of each predictor represent the estimated difference between the groups. Binary dependent variables (yes-no questions) were analyzed using regression.

In Bayesian statistics, inference is based on a posteriori distributions of the parameter (e.g., regression weights). Results are usually summarized by the mean and the 95% credible interval (95% CI). If the 95% CI excludes zero, the parameter value can be considered statistically reliable. The models were built using the brms package [Bürkner, 2017]. The prior logit scale regression weights were assumed to be normal (0, 1), ensuring uniform coverage of the probabilities. Four parallel chains with 2000 iterations (including 1000 for warm-up) were used for a posteriori approximation, and every second iteration was logged to reduce autocorrelation in the chains. The sampling procedure was efficient, as judged by analysis of the results, autocorrelation graphs, and the parameter $R < 1.01$.

VERIFICATION OF HYPOTHESES

Table 4 shows the results of Bayesian logistic regressions conducted with responses from respondents as the dependent variables, and Figure 2 shows the proportion of "YES" responses to the questions asked, depending on the size and role of the provider, where Me, SE and LI and UI are the median, standard deviation, and lower and upper bounds of the 95% credible interval of the a posteriori distribution of the regression weights.

Table 4. Hypotheses testing

Hypotheses	**Predictor**	**Me**	**SE**	**LI**	**UI**
		lack of sufficient knowledge about EDI			
H1	Company size - Employment level	-0.73	0.54	-1.76	0.32
H2	The role of the logistics provider	-0.21	0.54	-1.25	0.77
		mismatched customer IT systems			
H1	Company size - Employment level	-0.83	0.53	-1.82	0.24
H2	The role of the logistics provider	0.47	0.52	-0.54	1.47
		customers do not want to implement EDI and it is hard to convince them to do so			
H1	Company size - Employment level	-0.78	0.53	-1.82	0.27
H2	The role of the logistics provider	-0.06	0.55	-1.12	1.05
		no one standard solution			
H1	Company size - Employment level	0.06	0.51	-0.94	1.02
H2	The role of the logistics provider	0.32	0.53	-0.7	1.39
		long time and high costs of EDI implementation			
H1	Company size - Employment level	0.47	0.56	-0.62	1.62
H2	The role of the logistics provider	0.41	0.57	-0.7	1.59

Source: own study

The distributions of the affirmative answers indicating the determinants of problems in electronic communication between logistics operators and customers (black dots and red figures) as a function of company size and operator role are presented in Figure 5.

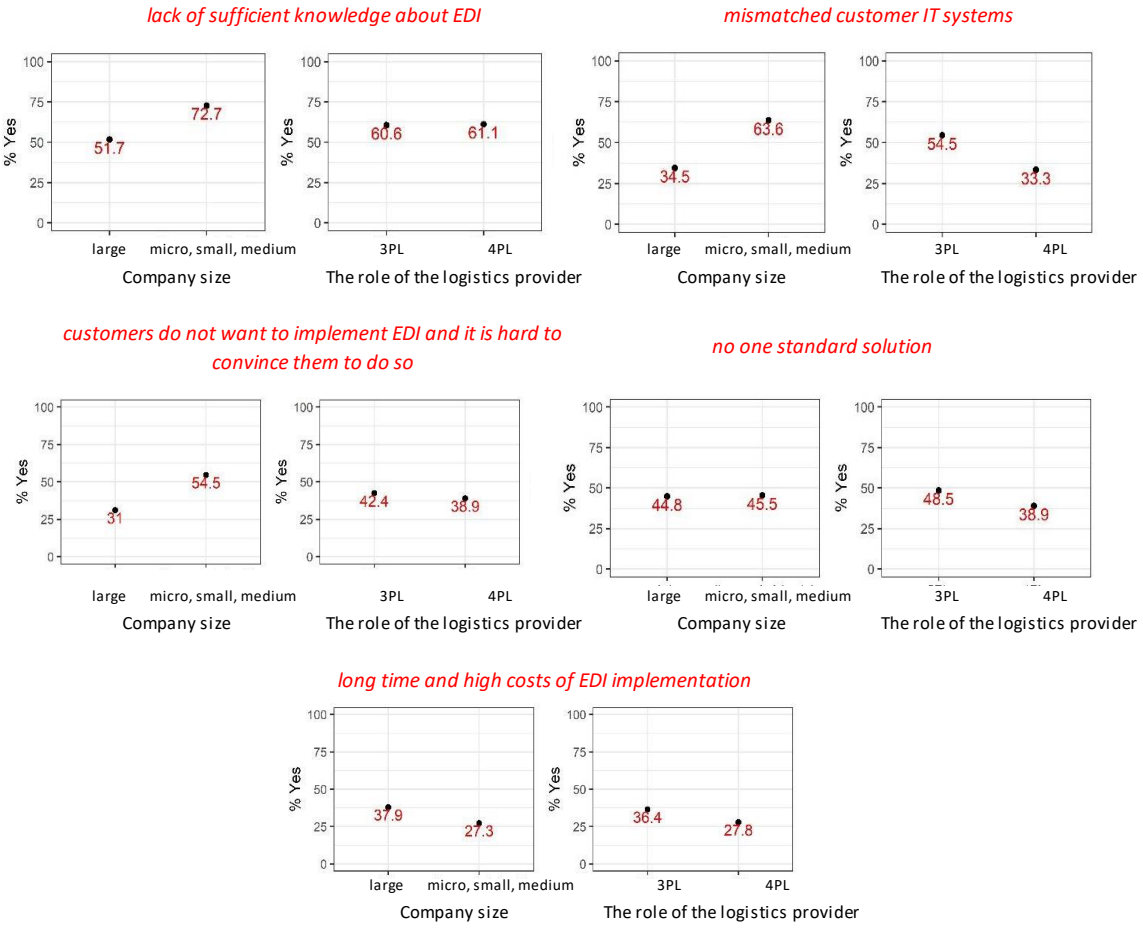

Fig.5 Percentage of respondents' affirmative answers
Source: Own study

DISCUSSION

According to the data presented in Table 4, in all analyzed cases the reliability intervals contain zero (LI and UI have opposite signs), which means that no statistically reliable relationship was observed between the predictors, employment level and role of the logistics provider and the dependent variable, the most common problem in electronic communication between the logistics provider and customers. On this basis, it should be concluded that the verified research hypotheses are not supported by the research data. Therefore, they may be rejected in favor of hypotheses 0 such as:

H1: The problems in the IT communication between the logistics service provider and the customer do not depend on the size of the company (measured by the variable level of employment);

H2: The role of the logistics provider does not influence the extent of problems in the electronic communication between the logistics service provider and its customers.

Based on this, the conclusion is that the size of the logistics provider (measured by the number of employees, called the "employment level here) and its role in the supply chain do not affect the extent of electronic communication problems within the supply chain.

Analyzing the values of individual statistics such as median, standard deviation, and lower and upper bounds of 95% credible interval of a posteriori distribution of regression weights, it can be concluded that, in the opinion of logistics service providers, regardless of their size and role in the supply chain:

lack of sufficient knowledge about EDI, mismatched customers' IT systems, and customers' reluctance to implement EDI are not problems in electronic communication between a company and customers,

lack of a single standard solution and the long time and high cost of EDI implementation are problems in electronic communication between a company and its customers.

CONCLUSION

The research allowed us to obtain primary data on the problems in electronic communication between logistics service providers and customers. Statistical analysis allows identification of the main barriers associated with EDI implementations at logistics partners. These barriers include the lack of a single standard solution and the long time and high cost of implementation.

The obtained research results have practical implications for 3PLs and 4PLs. They indicate barriers to the implementation of EDI at their business partners, which translates into cooperation in the supply chain. The results of the research can also help providers of EDI solutions, as they indicate what causes the lack of widespread implementation of this solution in companies. Therefore, they should strive to reduce implementation time and costs.

Further research will focus on empirically identifying the enablers for cooperation in a supply chain with EDI solutions.

Knowledge of barriers to the use of electronic data exchange in the supply chain is essential in order to assess and analyze the current level of digitalization. The so-called Digitalization Index [Szopa and Cyplik, 2020] is used to measure the overall effectiveness of the work in digitizing processes and transforming business models through the use of innovative digital technologies. This index consists of 21 subindices, among which is an indicator expressed as Annual sales volume realized through computer networks (websites, EDI and other methods of electronic data exchange, excluding email) [Szopa, and Cypli, 2020].

Modern technological solutions (such as the use of cloud technologies, EDI, or flow tracking standards) increase the positive effects of logistics coordination [Kmiecik, 2023]. This is because the use of EDI enables the centralization of demand and logistics coordination by the 3PL operator in the distribution network and can provide the manufacturer with better information about sales, plans, deliveries, and inventories. The 3PL will be able to support the manufacturer's demand plans. It will also be able to modify create contingencies using knowledge of flows in the distribution network [Kmiecik, 2023].

The barriers to electronic data exchange between business partners in the supply chain are worth noting in the context of the benefits of EDI. Existing EDI technologies combined with Blockchain and Big Data analytics solutions can offer a flexible and updated solution to transfer data across different platforms [Blakely et al., 2021]. Analytical techniques can process and build models for both structured and unstructured data. The execution of these techniques is often automated and can run continuously, accepting large portions of data for analysis. EDI transactional data can be transformed based on the application in question and the area of transactional data that the EDI service wishes to explore. On the basis of the parameters available in the data, a combination of models can be built for analysis. In addition, convolutional machine learning techniques and deep learning algorithms can be used to build AI models to perform complex tasks to obtain the required output of big data applications from EDI transactional data [Blakely et al., 2021].

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