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Assessment of Barriers to the Implementation of Intelligent (Smart) Logistics on the Example of Selected Systems Among Manufacturing Companies in Poland

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Robert Stanisławski[1], Andrzej Szymonik[2]

Abstract:

Purpose: *The development of intelligent logistics is the result of implementations made under the idea known as Industry 4.0. Intelligent logistics includes many systems whose task is to improve the efficiency of logistics processes. Despite many advantages, Polish enterprises are not willing to apply these solutions in practice. This is due to the existence of barriers that effectively limit the implementation of these systems. The article aims to identify barriers and assess their negative significance in the process of ISL implementation in the context of intelligent logistics.*

Design/methodology/approach: *The research was conducted in 2020 on a sample of 2,500 enterprises operating in Poland. An original questionnaire prepared for this study was used. The researchers used statistical summaries of structure indices to answer the researchers' questions. The Kruskal-Wallis test and the t-Student test were used to verify the hypotheses.*

Findings: *The results show that the barriers have a important negative impact on the decisions of enterprises regarding the implementation of intelligent systems in logistics. To a large extent, the level of impact depends on many factors (the size and age of the enterprise, the type of barrier or the number of implemented systems). Internal barriers are more negative than external ones. The conclusions clearly indicate that the greatest obstacles exist inside the entities - the importance of external barriers, i.e., those coming from the environment, are less important.*

Practical Implications: *The posted results are important for scientists and practitioners dealing with logistics or directly related to the use of cyber-physical systems in production and logistics processes.*

Originality/value: *Recognition of the negative importance of barriers in the implementation of intelligent systems in logistics among Polish manufacturing companies.*

Keywords: *Intelligent logistics, intelligent systems in logistics (ISL), ISL barriers, Polish production companies, e-logistics.*

JEL Codes: *M11, M15.*
Paper type: *Research paper.*

[1]*Lodz University of Technology, Faculty of Management and Production Engineering, Department of European Integration and International Marketing, Lodz, Poland, ORCID: 0000-0002-0845-8425, e-mail: robert.stanislawski@p.lodz.pl*
[2]*Lodz University of Technology, Faculty of Management and Production Engineering, Department of Production Management and Logistics, Lodz, Poland, ORCID: 0000-0002-7846-3959, e-mail: andrzej.szymonik@p.lodz.pl*

1. Introduction

The concept of intelligence logistics (IL) was first implemented into practice by IBM. The basis for its development is the use of intelligent systems in logistics (or also in production) such as, Big Data, Blockchain, Internet of Things (IoT), or artificial intelligence (Liu, 2021). The result of implementation of these systems is to be complete automation of production and logistic processes in the enterprises, enabling remote intervention to improve the operating parameters of devices. In addition, the goal of automation is to be greater customization, manifested by the possibility of quick conversion of production, machine conversion and production of products in short series while maintaining a high level of profitability (Nowicka and Szymczak, 2020). The introduction of this type of solutions is specific to systems defined as "cyber-physical", where physical and digital processes overlap and permeate (Baheti and Gill, 2011). Their feature is the parallel character manifested in the functioning of the real and virtual worlds side by side (Verdouw *et al.,* 2013)

In addition to a greater level of customization, other advantages resulting from the implementation of the "smart logistics" assumptions (automation) included, merging all elements of the logistics chain (supply, production and sales) into one whole (Wronka, 2017), quick response to changes and market restrictions (Ferdinand-James *et al.,* 2018), or the improvement and efficiency improvement of logistics processes (Wood, 2010). In turn, Dell identifies seven key benefits resulting from the use of intelligent systems in production and logistics (including the basic system such as IoT), reduction of energy consumption, increased security, faster data interpretation, easier movement of people and things, more effective inventory management, and identification of new revenue generation streams (Direct2Dell, 2017).

Despite the visible benefits directly or indirectly resulting from the implementation of intelligent systems in logistics (ISL), they are not very "popular" in Poland. This is evidenced by the research carried out last year (Stanisławski and Szymonik, 2021), where "only" about 50 respondents "admitted" to implementing at least one ISL. At this point, then, the question arises as to the reasons for this situation. Why, despite the existing advantages, manufacturing companies are not willing to acquire such systems? This question becomes the basis for formulating the main purpose of this article. It is the identification of barriers and the assessment of their negative significance in the process of ISL implementation in the context of intelligent logistics. For this purpose, an analysis of selected factors influencing the level of negative impact was considered, such as: the type and number of implemented systems, or the size and age of the enterprise.

This goal was achieved in two stages. First, by formulating three research questions: what barriers are most often indicated as the greatest obstacle in the implementation of ISL; what is their negative significance for the discussed process of implementing these systems, and in which of the analyzed systems the level of the analyzed barriers is the highest? Second, by verifying four specific hypotheses (H_1 to H_4) and one main hypothesis - the H_0 hypothesis.

This article consists of two parts, i.e., theoretical, and empirical. The first one conceptualizes the concepts used in this article. First, the concept of "intelligent logistics" has been described, focusing on elements such as the term or its scope. In the second part of this article (empirical), the analyzed phenomenon (identification and assessment of barriers) was analyzed in two stages. First, the main barriers that significantly limit the implementation of ISL in the surveyed enterprises were identified by means of research questions. Then, by verifying the hypotheses, factors were identified (type and number of systems as well as size and age) negatively affecting the propensity to make decisions regarding the discussed implementation.

Apart from significant conclusions resulting from the conducted research, the authors' deliberations on the meaning scope of the discussed concept and its conceptualization based on studies related to the discussed issues available in the world literature are undoubtedly the added value of this article.

2. Theoretical Basis - Intelligent Logistics

The issues discussed in this article imply the need to clarify several important issues. The first is related to the concept of intelligent logistics. As it turns out, in the literature on this subject is not very precisely defined, what is more, there is no broader discussion on this subject. This concept often is associated with such expressions as, intelligent factory, or intelligent products or services that are evolving towards newer technologies (Fleisch *et al.*, 2005). The common element - connecting "intelligent" things, systems and processes is the development of technology and the implementation of newer (innovative) solutions (Dembińska *et al.*, 2018). The purpose of these implementations is to automate tasks and reduce human interference in (general and broadly understood) production processes (Sah, 2016).

Therefore, intelligence in this sense refers to the automation of these processes using more and more innovative technological solutions. Currently, "intelligence" is most often referred to and compared to the concept of Logistics 4.0, which is derived from the assumptions of Industry 4.0 (Dembińska *et al.*, 2018).

The term "smart logistics" also has a related meaning. It is often associated with "e-logistics, not necessarily correctly. While, as mentioned above, intelligent logistics is related to the development of automation of production processes, e-logistics means the use of the latest information technologies to support logistics management in an enterprise using electronic systems (Valkova, 2013). In addition, a strong emphasis in "intelligent logistics" is placed on the use of artificial intelligence, while in e-logistics generally refers to the implementation of electronic support systems. Therefore, it can be concluded that these two concepts are similar in meaning, but in practice they do not have to be synonyms. On the other hand, the terms "intelligent logistics" or "smart logistics" are used interchangeably in the literature on the subject.

So, what is intelligent logistics basically? As previously mentioned, this concept is not (at least yet) interpreted too often. Nevertheless, several shots characterizing its scope can be found. It is presented below in the Table 1.

Table 1. *Selected definitions of "intelligent logistics"*

Author(s).	Definitions	Keywords
Lin, C.C., Yang,J.W. (Lin and Yang, 2018)	It is related to the logistics distribution system. It combines computerization, intelligence using the Internet of Things (IoT) and information technology. It uses technologically advanced management methods to achieve high performance (...).	Computerization, artificial intelligence, new technologies, IoT
Zhang, C.X., Peng, D.H. (Zhang, and Peng, 2013)	Intelligent logistics emphasizes technological changes. It focuses on the use of systems such as: Bid Data, IoT, sensors and other technologies to improve logistics and distribution services and reduce their costs (...)	Technological changes, Big Data, Internet of Things
Y. Zhang and S. Liu (Zhang *et al.*, 2018)	Intelligent logistics covers the entire process of goods transfer, including transport, storage, distribution, packing, loading and unloading, and information processing. Thanks to real-time monitoring (…), it improves the efficiency of logistics resource management (…).	The entire process of goods transfer, management efficiency
L.Q Zhao (Zhao, 2005)	Intelligent logistics is characterized by: intelligence, integration, flexibility and socialization	Process integration, artificial intelligence
Y. Lin (Lin, 2019)	Intelligent logistics has three basic tasks: to ensure the proper flow of information to reduce costs and improve efficiency, to implement intelligent systems to automate processes, and to deepen cooperation and integration in various dimensions. This is to improve customer satisfaction (higher quality of services and lower costs)	IL tasks, process automation, customer satisfaction
D. McFarlane *et al.*, (McFarlane *et al.*, 2016)	Smart logistics is all about planning and controlling processes with intelligent tools and methods. The degree of intelligence depends on the applications used and the traceability of products and the environment, to the detection of the problem and its solution through automation	Process control and planning using intelligent methods, Automation

Source: *Own elaboration.*

The above definitions strongly emphasize the use of new technologies and systems as part of intelligent logistics. It is indicated here, inter alia, on the importance of wireless networks, radio frequency identification (RFID) technology, sensor technology, and others such as laser technology, coding, or satellite positioning (Liu *et al.,* 2019). In addition to this type of solutions, attention is paid to individual systems such as: Internet of Things, Big Data, or artificial intelligence. It should also be noted that in these definitions the scope to which smart logistics relates appears. It turns out that it is related to the entire production process, including transport, storage, distribution, loading and unloading of goods, and the flow of information accompanying such activities.

Thanks to consolidation and integration, that all is planned and controlled automatically by intelligent systems. By combining knowledge in the field of intelligent logistics in this way, its three basic functions can be specified (Miao *et al.,* 2018). The first is the identification function that allows you to collect information at various stages of the logistics process (production, packaging, storage, distribution, transport, etc.), to create databases on occurring phenomena. The second is the decision-making function that uses technology to process and analyze data in terms of customer needs, inventory status, and other data informing about the occurring phenomena to make calculations and make optimal decisions. The third function of "feedback" consists in transmitting the right decisions for implementation within the systems (in real time) to ensure maximum customer satisfaction (Petrolo *et al.,* 2017). It is a simplified mechanism for the functioning of intelligent logistics, in which there are relationships based on the principle: collect information - processing information - making optimal decisions - implementing the decisions.

Therefore, in this study a definition has been adopted according to which smart logistics includes the use of various intelligent systems for the automation of logistics processes at their various stages - production, supply, distribution, warehousing, etc. Among these systems are: Internet of Things, Big Data, Cloud computing, Blockchain, or especially used in the production of SCADA or SMAC and many others. The inherent feature of these systems is the implementation of solutions with artificial intelligence properties, which allows to significantly reduce human participation in logistics processes (including production), thus contributing to a better efficiency of these processes. In addition, the result should be greater customization, and thus, increasing customer satisfaction (recipients of logistics services).

However, the implementation of intelligent systems in manufacturing enterprises faces many obstacles (barriers). Due to the "innovative" nature of the presented issues and the relatively short period of their "use" in practice, little is said about it in the literature on the subject. Studies on barriers usually focus on selected systems (e.g. blockchain), ignoring the issues of a holistic approach to this issue. Nevertheless, some preliminary analysis in this regard can be seen. The most frequently discussed barriers include their division according to the subject (scope) of these restrictions. Hence, the following barriers are listed: technical, technological and security, resource (human and financial), organizational and social, and environmental or cultural (Ozturk and Yildizbasi, 2020). The first (technological) ones includes lack of technological maturity, which is manifested by a low level of skills in the society in the field of computer science and the use of modern systems, including security rules; the lack of complete security of the stored data, despite the use of cryptographic methods of securing - which is the result of the development of quantum mathematics (Vasek *et al.,* 2014), low level of accessibility to the average user, which means that the operation of these systems requires specialists with extensive knowledge (Swan, 2015), lack of complexity and integration between systems, which is the result of a short implementation period and the lack of their proper standardization; magnitude within one system - results from the lack of permanent updating by system users, which causes the phenomenon of "multipolarity" of individual systems and their incompatibility (Zheng *et al.,* 2017).

On the other hand, among the latter (resource), the following are mainly indicated: lack of trained personnel (Britchenko *et al.*, 2018), lack of financial resources and too high investment costs, which means that the richest can afford to implement these systems, lack of appropriate technical infrastructure - it is a "guarantor" that enables the implementation of systems in enterprises (Bohme *et al.,* 2015), lack of commitment on the part of the government - in terms of economic and political support for the development of new technologies.

The third group of barriers mentioned by these two authors (Ozturk and Yildizbasi, 2020) are organizational barriers, among which they mention the following: too strong bureaucracy and centralization in enterprises, too strong control system, which manifests itself in closure to cooperation with the environment, reluctance to share information about new solutions in the environment due mainly to the need to "extend" its competitiveness in the market against other entities, reluctance to make changes within the organization (enterprise), which requires a lot of effort and commitment of specific resources. The last group concerns environmental (social) barriers, which undoubtedly include reluctance to implementations caused by personal benefits (of people, organizations) (Baud-Lavigne *et al.*, 2014), or greater consumption of resources in the environment, including energy (Ozturk and Yildizbasi, 2020). In this article, many of the indicated barriers will be considered in the conducted analysis, divided into internal and external barriers.

3. Method (Scope of Research) and Characteristics of the Sample

3.1 Methodology of the Research

The research was conducted in 2020 on a sample of 2,500 enterprises operating in Poland. They were based on a multi-stage selection of the research sample. This means that the entities for this study were selected based on both deliberate selection (made using the Polish Classification of Activities - Polish Classification of Activities), taking into account only production enterprises (service and commercial enterprises were omitted) and random selection. In the case of the latter, a group of 10,000 production entities was defined, of which the population of 2,500 enterprises was tested as a result of a random selection. Feedback results were obtained from 103 entities, broken down into their different sizes and different voivodships (description above), and 88 of them conducted (the above-mentioned logistics activity). Among them, only 58 have implemented ISL, which constitutes approx. 50% of all surveyed entities. Responses were provided by the owners of enterprises or (competent) employees indicated by them (in the case of smaller entities) or by senior managers (in the case of larger entities).

The research was quantitative. They were carried out using the CAWI (Computer-Assisted Web Interview) technique, with the use of a proprietary questionnaire prepared especially for this study. The questions contained in it were closed. When creating this tool, only one's own knowledge of the discussed issues and own experience in conducting this type of research were used.

3.2 Characteristics of the Research Sample

The characteristics of the research sample were based on the presentation of several important elements. The first is the spatial division. In reference to this element, it should be emphasized that the research covered the territory of Poland, considering all voivodeships (administrative division of Poland). However, the research sample in spatial terms was diversified, which means that not all voivodships have the same number of enterprises surveyed. This differentiation resulted from two basic factors: one objective (resulting from the difference in the number of active entities operating in individual regions of Poland) and a subjective one, resulting from the different propensity of entrepreneurs to answer the research questions contained in the questionnaire. Hence, the participation of these enterprises in surveys in individual voivodships was the result of these two factors, and not their deliberate selection. The most enterprises were surveyed in such voivodeships as: Lodz (41.4% - 46.6%) and Masovian (17.5% - 14.1%), and the least in the Podkarpackie Province (1.0% - 1.8%), Podlasie (0.0% - 1.0%) or Warmia - Masuria (0.0 - 2.9%).

Another element that characterizes the research sample is the division according to the size of the entities participating in this research. The inference was based on 103 manufacturing companies, which were the result of the received responses. Out of this number, 88 (85.4%) entities conducted logistics activities, of which only 58 (65.9%) of the total number of enterprises used ISL in practice. The structure considering the size of enterprises from the point of view of individual sets (items) is presented in Table 2.

Table 2. *The size of enterprises participating in the study, broken down into sets*

The size of enterprises	Enterprises divided into sets					
	All enterprises in the study N=103 (100%)		Enterprises use logistics N=88 (100%)		Enterprises use ISL N=58 (100%)	
	N	%	N	%	N	%
Mikro	13	12.6	6	6.8	4	6.9
Small	17	16.5	16	18,2	12	20.7
Medium	20	19.4	17	19.3	10	17.2
Big	53	51.5	49	55.7	32	55.2
Together	103	100	88	100	58	100

Source: *Own study based on research results.*

The above data indicate that the largest number of entities covered by the study concerned the groups of medium and large enterprises (19.4% and 51.5%, respectively). The shares of entities that use logistics and implement ISL in their business activities are similar (large ones are: 55.7% and 55.2%, respectively, and medium ones: 19.3% and 17.2%, respectively). Small entities also constitute a large group (on average from 18.2% to 20.7%). The marginal shares both in the case of logistics activities and "ISL application" were recorded among micro-enterprises (approx. 6.8%). Therefore, it is reasonable to put forward the thesis that logistics and ISL relate to larger entities - the larger the enterprise, the more likely it is to use new solutions in the ISL area. This is undoubtedly the effect of "equipping" with much better resources, incl. financial. On the other hand, when assessing the general level of propensity to implement new logistics systems, it should be noted that it is moderate, as only half of the respondents "admitted" to this type of investment (56.3% - 58/103).

The next two elements constituting the description of the research sample are the location and market reach of the surveyed enterprises. The first one presents the place (seat) where enterprises conduct business activities, broken down into: agglomerations (provincial cities), larger cities (over 100,000 inhabitants), medium-sized cities (100,000 - 20,000 inhabitants), small towns (under 20,000 inhabitants) and provinces. On the other hand, the market reach presents the main purpose of the surveyed enterprises in spatial terms. Five main scopes of such activity are distinguished here: global (world), international (the closest countries in the region), national, regional (within the voivodeship) and local (the closest neighborhood). The characteristics of these two elements are presented in the table below (Table 3).

Table 3. *Location and market reach of the surveyed enterprises broken down into sets*

Location / market coverage	Enterprises divided into sets					
	All enterprises in the study N=103 (100%)		Enterprises use logistics N=88 (100%)		Enterprises use ISL N=58 (100%)	
	N	%	N	%	N	%
Location						
Agglomeration	41	39.8	37	4.,0	25	43.1
Bigger cities	16	15.5	14	15.9	11	19.0
Medium cities	27	26.2	24	27.3	15	25.9
Small towns	11	10.7	8	9.1	2	3.4
Provinces	8	7.8	5	5.7	5	8.6
Together	103	100	88	100	58	100
Market coverage						
Global	39	37.9	36	40.9	25	43,1
International	37	35.9	35	39.8	20	34.5
National	12	11.7	12	13.6	10	17.2
Regional	5	4.8	2	2.3	1	1.7
Local	10	9.7	3	3.4	2	3.5
Together	103	100	88	100	58	100

Source: *Own study based on research results.*

The above data clearly shows that the surveyed enterprises have their headquarters in agglomerations (39.8% - 43.1%), larger cities (15.5% - 19.0%) and medium-sized cities (25.9% - 27, 3%). The smallest number of entities included in this study operate in the provinces (5.7 - 8.6%). This structure is particularly important from the point of view of the analysis of companies using ISL. Most of them operate in urbanized regions, which has a specific meaning. It is easier to obtain the necessary resources related to the implementation of new (even more innovative) solutions. In addition, such a location allows them to enter new markets, and thus access to customers requiring the highest quality logistics service, who emphasize efficiency, comprehensiveness, or speed of services (Stanisławski and Szymonik, 2021).

This thesis is confirmed by the list presenting the market coverage of the surveyed companies. Most of them conduct activities of a global nature (37.9% - 43.1%) and international (34.5% - 39.8%). Only larger entities (with a greater level of resources) and better access to them can develop their activities based on modern solutions in logistics. This is ensured by their location in regions with a significant impact potential (external influence - e.g., agglomerations) and access to a wider market spectrum (more international clients). In this way, conditions are created for acquiring the necessary knowledge and competences in the field of ISL implementation.

4. Results and Discussion

4.1 Identification of the Main Barriers to ISL Implementation

In this section, the identification of barriers that most hinder the implementation of ISL among Polish manufacturing companies will be carried out. The analysis of these threats will be carried out based on structure indicators. It will cover the three most frequently used systems in production (and logistics). These include: Internet of Things (IoT), Big Data, or cloud computing. Identification will be made by obtaining answers to three key research questions: what barriers are most often indicated as the greatest obstacle in the implementation of ISL and what is their negative significance for the discussed process of implementing these systems, and in which of the analyzed systems the level of the analyzed barriers is the highest?

While the answers to the first two questions will be given when analyzing individual systems separately, the third question will be a summary of this analysis and the answer will be obtained at the very end of the considerations in this area. In addition, the above barriers will be considered in terms of internal and external.

The first of the systems assessed in the context of barriers that hinder its implementation among the analyzed enterprises is the Internet of Things (IoT). The obtained results are presented in the table below (Table 4).

Table 4. *Barriers to the implementation of the Internet of Things (IoT)*

Barriers	Importance													
	None		Very low		Low		Moderat		High		Very		Total	
	L	%	L	%	L	%	L	%	L	%	L	%	L	%
Internal barriers														
Lack of adequate resources	16	48.8	1	3.0	2	6.0	5	15.1	5	15.1	4	12.1	33	100
No company development strategy	19	57.6	2	6.0	3	9.1	3	9.1	4	12.1	2	6.0	33	100
Low risk appetite	13	39.3	3	9.0	3	9.09	5	15,1	7	21.2	2	6.06	33	100
Staff not qualified	13	39.4	5	15.1	1	3.0	5	15.1	5	15.1	4	12.1	33	100
Too few employees	13	39.4	2	6.0	4	12.1	6	18.2	6	18.2	2	6.0	33	100
There are no departments implementing ISL	18	54.5	2	6.0	2	6.0	3	9.1	4	12.1	4	12.1	33	100
Total number of indications	92	46.4	15	7.5	15	7.5	27	13.6	31	15.6	18	9.1	198	100
External barriers														
No demand from customers	20	60,6	1	3.0	4	12,1	4	12,1	3	9,1	1	3,0	33	100
Lack of communication with the environment	12	36,4	3	9.1	1	3,0	10	30,3	3	9,1	4	12,1	33	100
Distrust of partners	16	48,5	3	9.1	1	3,0	7	21,2	3	9,1	3	9,1	33	100
Bad law	14	42,4	4	12.1	5	15,1	2	6,0	4	12,1	4	12,1	33	100
Poor macroeconomic conditions	18	54,5	3	9.1	2	6,0	1	3,0	5	15,1	4	12,1	33	100
No government support	19	57,6	6	18.2	0	0,0	2	6,0	4	12,1	2	6,0	33	100
High implementation costs	18	54,5	3	9.1	2	6,0	3	9,1	5	15,1	2	6,0	33	100
System incompatibility	18	54,5	2	6.0	2	6,0	2	6,0	5	15,1	4	12,1	33	100
Different goals between partners	20	60,6	1	3.0	2	6,0	3	9,1	4	12,1	3	9,1	33	100
Bureaucracy	20	60,6	1	3.0	1	3,0	5	15,1	2	6,0	4	12,1	33	100
Total number of indications	175	53,0	27	8,1	20	6,0	39	11,8	38	11,5	31	9,4	330	100

Source: *Own study based on research results.*

The data presented in Table 4 above indicate several important conclusions. Internal barriers have a greater negative impact on the implementation of IoT among the surveyed companies (only approx. 46% stated that these barriers do not exist). About 57% of them claim that "the lack of a company's development strategy" does not constitute any limitation, as well as about 54% have a similar opinion regarding the "lack of departments implementing ISL". The opposite is true for external barriers. Significantly fewer entities (approx. 47%) emphasize the "importance" of this type of conditions in the process of implementing IoT. As many as 53% of respondents stated that external barriers are not important (i.e., practically non-existent) during this process.

Considering the three levels of significance (medium, high and very high), it can be concluded that most entities in relation to internal barriers indicate the lack of appropriate resources (82%-14/17). The remaining barriers in this group are assessed in terms of "significance" at the level of 70%. Regarding external barriers, bureaucracy is the most "significant" (over 84% among entities indicating this condition). There is a kind of paradox here, because this barrier is indicated by most entities as "non-existent" in the process of IoT implementation, and at the same time in the group of those who notice it it has the highest assessment. The second place among the respondents was taken by barriers related to the lack of openness to the environment, ie the lack of proper communication with the environment (80.9% - 17/21), distrust on the part of partners having such solutions (76.4% - 13/17) or too much differentiation between partners who have already implemented ISL (76.9% - 10/13).

In general, it can be concluded that the environment (partners) does not create conditions that would enable the exchange of resources resulting in an increase in the propensity to implement IoT among Polish manufacturing companies. The reasons for this situation can probably be seen in the context of the competitive game, the measurable effect of which is to be the elimination of competition (Stanisławski and Szymonik, 2021). Therefore, when answering the first research question, it should be stated, firstly, that internal conditions are perceived as definitely greater barriers to the implementation of IoT than external ones.

Secondly, enterprises estimate that the greatest obstacle in implementing this system is the lack of appropriate resources (financial, human, knowledge, material resources) in the case of internal ones, and in the case of external ones: bureaucracy and the lack of proper relations (cooperation with the environment). In turn, answering the second research question, it can be stated without any doubts that the negative impact mainly concerns three internal conditions, low propensity to risk (from 9 to 21% of respondents according to the Likert scale), lack of proper qualifications of the staff (from 3 to 15% of respondents) according to the Likert scale) and very few employees (from 6 to 18% of respondents according to the Likert scale). In the case of external conditions, the highest level of negative impact concerns "lack of communication with the environment" (21 respondents).

This barrier is understood as the reluctance of the environment to cooperate, where enterprises gave a positive answer in the range from 3 to 30% according to the Likert scale and "improper law" (according to 19 respondents), where the answers ranged from 6 to 12% according to the scale Likert. To sum up, in the implementation of IoT, among the internal conditions, the greatest negative significance was observed in relation to three barriers, and in the case of external conditions - in the case of two barriers. However, the "common denominator" of both is the reluctance to exchange knowledge (resources) to and from the environment.

Another of the analyzed systems is Big Data. Both previously and here, internal barriers are more "significant" than external ones. This means that the level of irrelevance of these barriers (counted by the number of general indications) is on the one hand lower, and on the other hand, more enterprises indicate the importance (i.e., negative significance) of a given barrier. By comparing these values, it is possible to indicate which conditions (internal or external) are “negatively” more important for the surveyed companies. In the case of this system (Big Data), the irrelevance of internal barriers was determined at 41.9% (i.e., barriers are important for 58.1% of the surveyed entities), and regarding external barriers, this level is 51.9% (barriers are significant for 48.1%). Hence, the thesis put forward above is justified, that internal barriers are more important than external ones. This will be presented by the data in the table below (Table 5).

Table 5. *Barriers to the implementation of Big Data*

Barriers	Importance													
	None		Very low		Low		Moderate		High		Very		Total	
	L	%	L	%	L	%	L	%	L	%	L	%	L	%
Internal barriers														
Lack of adequate resources	17	45.9	1	2.7	4	10.8	5	135	6	16.2	4	10.8	37	100
No company development strategy	17	45.9	3	8.1	3	8.1	4	10.8	8	21.6	2	5.4	37	100
Low risk appetite	13	35.1	3	8.1	4	10.8	8	21.6	9	24.3	0	0.00	37	100
Staff not qualified	11	29.7	5	13.5	5	13.5	5	13.5	6	16.2	5	13.5	37	100
Too few employees	18	48.6	7	18.9	2	5.4	6	16.2	4	10.8	0	0.0	37	100
There are no departments implementing ISL	17	45.9	2	5.4	5	13.5	2	5.4	8	21.6	3	8.1	37	100
Total number of indications	93	41.9	21	9.4	23	10.3	30	13.5	41	18.4	14	6.6	222	100
External barriers														
No demand from customers	16	43,2	4	10,8	5	13,5	4	10,8	5	13,5	3	8,1	37	100
Lack of communication with the environment	15	40,5	3	8.1	6	16.2	4	10.8	6	16.2	3	8.1	37	100
Distrust of partners	13	35,1	5	13.5	4	10.8	6	16.2	4	10.8	5	13.5	37	100
Bad law	16	43,2	1	2.7	6	16.2	3	8.1	7	18.9	4	10.8	37	100
Poor macroeconomic conditions	16	43,2	2	5.4	4	10.8	6	16.2	4	10.8	5	13.5	37	100
No government support	23	62,1	3	8.1	1	2.7	1	2.7	5	13.5	4	10.8	37	100
High implementation costs	22	59,4	0	0.0	3	8.1	4	10.8	3	8.1	5	13.5	37	100
System incompatibility	24	64,8	0	0.0	2	5.4	3	8.1	3	8.1	5	13.5	37	100
Different goals between partners	23	62,1	2	5.4	4	10.8	3	8.1	1	2.7	4	10.8	37	100
Bureaucracy	24	64,8	1	2.7	1	2.7	6	16.2	3	8.1	2	5.4	37	100
Total number of indications	192	51,9	21	5.6	36	9.7	40	10.8	41	11.0	40	10.8	370	100

Source: *Own study based on research results.*

When answering the first research question (which barriers are the greatest obstacle in implementing Big Data), among the internal conditions, "lack of adequate resources" was indicated first (75%-15/20), and "low propensity to risk" (70, 8%-17/24) and in third place "no development strategy (70%-14/20). On the other hand, in the group of barriers, i.e. external barriers in the key places, there are two indications: incompatibility of systems and bureaucracy (84.6%-11/13). Another barrier is the high implementation costs (80%-12/15). So also, in the case of this system (similarly to IoT), most determinants directly concern the lack of resources (material and non-material). Therefore, it can be concluded that enterprises show interest in the implementation of this system (Big Data), but encounter obstacles in obtaining funds, e.g. financial. This is confirmed by the indications concerning external barriers, among which one of the main indications is the "high cost" of implementation. The "incompatibility" barrier is also disturbing, which suggests that systems of this type are so new solutions that they are not so consistent that they can cooperate with each other without any restrictions.

As far as "bureaucracy" is concerned, this indication also occurred with the previous of the discussed systems (IoT), which confirms that the implementation process from the point of view of the formal handling of the necessary documents and carrying out the necessary procedures is extremely laborious and time-consuming. In practice, this may undoubtedly discourage entrepreneurs from undertaking projects aimed at acquiring and implementing this system. In turn, answering the second of the research questions (among internal barriers), it should be stated that the negative impact mainly concerns the lack of "qualified personnel" (26 entities), where the level of indications of the "significance" of this barrier was in the range of 13.5 - 16.2% of the surveyed and too low "propensity to risk" of enterprises (this was stated by 24 respondents), which ranges from 8.1 to 24.6%.

On the other hand, among the external barriers, the highest level of negative impact is characterized by the barrier "distrust from other partners" (24 entities), which in percentage terms ranges from 10.8 to 16.2%, and "lack of communication with the environment" (22 entities), which in relative terms, it ranges from 8.1 to 16.2% of the respondents. These two conditions above indicate difficulties in the exchange of resources with the environment, including mainly the broadly understood knowledge.

The next system among the most "known" in Polish manufacturing companies is cloud computing. In the case of this system, the advantage of internal barriers is much greater than that of external barriers. This is evidenced by the data included in the Table 6.

Table 6. *Barriers to the implementation of cloud computing*

Barriers	Importance													
	None		Very low		Low		Moderate		High		Very high		Total	
	L	%	L	%	L	%	L	%	L	%	L	%	L	%
Interial barriers														
Lack of adequate resources	10	32.2	2	6.4	6	19.3	3	9.7	7	22.5	3	9.7	31	100
No company development strategy	13	41.9	3	9.7	10	32.2	2	6.4	3	9.7	0	0.0	31	100
Low risk appetite	8	25.8	3	9.7	5	16.1	9	29.0	4	12.9	2	6.4	31	100
Staff not qualified	16	51.6	3	9.7	1	3.2	2	6.4	7	22.5	2	6.4	31	100
Too few employees	18	58.0	1	3.2	4	12.9	2	6.4	5	16.1	1	3.2	31	100
There are no departments implementing ISL	15	48.3	2	6.4	4	12.9	2	6.4	4	12.9	4	12.9	31	100
Total number of indications	80	43.0	14	7.5	30	16.1	20	10.7	30	16.1	12	6.4	186	100
External barriers														

No demand from customers	12	38,7	0	0.0	5	16.1	5	16.1	6	19.3	3	9.7	31	100
Lack of communication with the environment	10	32,2	4	12.9	4	12.9	6	19.3	2	6.4	5	16.1	31	100
Distrust of partners	18	58,0	2	6.4	2	6.4	6	19.3	0	0.0	3	9.7	31	100
Bad law	15	48,4	2	6.4	6	19.3	1	3.2	4	12.9	3	9.7	31	100
Poor macroeconomic conditions	18	58,0	1	3.2	2	6.4	2	6.4	3	9.7	5	16.1	31	100
No government support	21	67,7	2	6.4	1	3.2	1	3.2	3	9.7	3	9.7	31	100
High implementation costs	19	61,3	1	3.2	2	6.4	3	9.7	2	6.4	4	12.9	31	100
System incompatibility	20	64,5	1	3.2	2	6.4	1	3.2	3	9.7	4	12.9	31	100
Different goals between partners	20	64,5	2	6.4	2	6.4	3	9.7	2	6.4	2	6.4	31	100
Bureaucracy	21	67,7	0	0.0	3	9.7	1	3.2	3	9.7	3	9.7	31	100
Total number of indications	174	56,1	15	4.8	29	9.3	29	9.3	28	7.3	35	11.3	310	100

Source: *Own study based on research results.*

Only 43% of the surveyed companies stated that internal barriers are not significant (i.e., 57% of the respondents clearly confirm the importance of these barriers in inhibiting the implementation process of systems such as cloud computing). With regard to external barriers, the situation is opposite - over 56% of respondents believe that these barriers do not matter for making decisions about the use of cloud computing (i.e. only about 44% of respondents gave a positive answer about the importance of this barrier as a brake in the implementation of this system). Summing up, many enterprises claim that internal barriers are a greater challenge than external barriers, which is the rule in the three systems analyzed above. In general, therefore it should be emphasized that Polish (surveyed) enterprises are not prepared to apply new technological solutions improving the effectiveness of functioning in the field of production and logistics.

When answering the first research question, it should be stated that in the case of internal barriers, significant obstacles to the implementation of cloud computing, in the first place are "the lack of appropriate qualifications of the staff" (73.3%-11/15), and in the second - "low propensity to risk" (65.2%-15/23). Similarly, here and in relation to the previous two systems, lack of resources is dominant - which in the case of this system means a lack of knowledge among employees. The second of the above negative conditions was also indicated in the case of the previous system (Big Data), which undoubtedly proves that there is a reluctance among enterprises to implement new products due to concerns about the "effectiveness" of this system. In general, companies do not like to "experiment" and take the associated risks. In the case of external barriers (for the first time), the further environment was indicated, i.e. the state policy shaping (directly or indirectly) the propensity to implement new systems (including cloud computing). This condition is caused by inappropriate macroeconomic conditions (76.9%-10/13). The next two overlap with the previous system (Big Data), where the dominants are "high implementation costs (75%-12) and" system incompatibility "(72.7%-8/11).

On the one hand, this proves the high level of novelty of this solution - for which you must pay a lot, and on the other hand, the lack of consistency of this system among users, which results from the too short period of use by the interested entities (also the consequence of too high a level of novelty). Referring to the second research question, it should be noted that customers are not too sure about the improvement of the effectiveness of their service as a result of the implementation of this system by the surveyed companies (19 entities indicated a negative impact of this condition - the share of indications in the range from 0 to 19.3 %). Moreover, the second barrier which "collected" the most negative opinions is "lack of communication with the environment" (21 entities marked it as significant - the share ranged from 6.4 to 19.3%).

Summarizing, it should be stated that in the case of internal barriers, the dominant conditions are the lack of resources (including trained personnel or finances) and the reluctance to take risks related to the implementation of new systems, and with regard to external barriers, the main barriers to the lack of cooperation are indicated (closure to the environment), high implementation costs and lack of consistency between the systems (this is the effect of too much novelty of the implemented systems). A marginal negative significance concerns indications of a macroeconomic or "governmental" nature. This may indicate that the "further environment" is not perceived as crucial in the implementation of this type of solutions. The respondents treat them (at least for now) as a neutral factor supporting (or hindering) the implementation of ISL.

To answer the third research question (in which of the analyzed systems the level of the analyzed barriers is the highest), the following data should be analyzed (Table 7).

Table 7. *Summary of the significance levels of individual barriers*

Systems	Level of importance of individual barriers					
	Interial barriers (%)		External barriers (%)		Together (%)	
	Lack of importance	Importance	Lack of importance	Importance	Lack of importance	Importance (advantage)
IoT	46.4	53.6	53.0	47.0	99.4	0.6
Big Data	41.9	58.1	51.9	48.1	93.8	6.2
Cloud computing	43.0	57.0	56.1	43.9	99.1	0.9

Source: *Own study based on research results.*

Based on the above data, it turns out that the Big Data system encounters the highest level of limitation among internal and external barriers. This is indicated, inter alia, by general depictions of the level of significance of the limitations marked by respondents, counted as the advantage (difference) between the insignificance and the significance of barriers in the implementation of individual systems. In this case, it amounts to 6.2%. On the other hand, among internal barriers, the lowest level of importance in limiting implementations occurs in the case of IoT (53.6%), and external barriers in the case of cloud computing (43.9%). In general, IoT is the least burdened with various types of barriers, and Big Data is the most.

Therefore, refer to the third research question, it should be stated that Big Data is the most difficult factor in the implementation of modern logistics systems, which may indirectly result from the greatest knowledge of this system among the surveyed companies. Hence the high level of identification of the difficulties faced by these entities during its acquisition and implementation.

4.2. Verification of Research Hypotheses

The research questions posed above (and the answers to them) became the basis for the verification of four basic hypotheses *(H1: H2: H3; H4)* subordinated to one main hypothesis H_0. These hypotheses are as follows:

H_0: The existing barriers definitely have a negative impact on the implementation of intelligent systems in logistics among manufacturing companies in Poland.
H_1: The degree of negative impact of barriers on the implementation of ISL depends on the number of used systems.
H_2: The degree of negative impact of barriers on ISL implementation varies and depends on the implemented system.
H_3: The degree of negative impact of barriers on ISL implementation depends on such characteristics of enterprises as: size and age of the enterprise.
H_4: Internal barriers have a greater negative impact on ISL implementation than external barriers.

The main hypothesis *(H_0)* is verified based on the verification of five main hypotheses *(H_1: H_2: H_3; H_4)*. For this purpose (comparison of the average levels of intensity of the studied phenomena), the Kruskal-Wallis test was used. These hypotheses were verified taking into account the six intelligent systems included in this study (three of which were analyzed above, i.e., in point 4.1). These include: Internet of Things (IoT), Big Data, Cloud computing, Blockchain, SMAC and SCADA. An important element facilitating the verification process is assigning numbering (designation) to individual barriers, as presented in the table below (Table 8).

Table 8. *Numbering (marking) of individual barriers used in the verification of hypotheses*

Barriers	Marks	Barriers	Marks
Internal barriers – identified by respondents		External barriers – indicated by respondents	
Lack of adequate resources	B1	No demand from customers	B7
No company development strategy	B2	Lack of communication with the environment	B8
Low risk appetite	B3	Distrust of partners	B9
Staff not qualified	B4	Bad law	B10
Too few employees	B5	Poor macroeconomic conditions	B11
There are no departments implementing ISL	B6	No government support	B12
		High implementation costs	B13
		System incompatibility	B14

		Different goals between partners	B15
		Bureaucracy	B16

Source: *Own elaboration.*

4.2.1 Verification of the Hypothesis H_1

The first step taken is to verify the hypothesis (H1) assuming that the degree of negative impact of barriers on ISL implementation depends on the number of systems used. At the beginning, attempts were made to determine the importance of individual barriers in the context of their negative impact on the use of ISL. As a result of the non-parametric Kruskal-Wallis (K-W) test, the following chi square values ($\chi 2$) were obtained (Table 9).

Table 9. *K-W test results verifying the significance level of individual barriers*

	B1	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**	**B9**	**B10**	**B11**	**B12**	**B13**	**B14**	**B15**	**B16**
Chi kwadrat (χ^2)	12.6	6.5	2.8	3.7	4.6	12.9	14.9	5.9	11.6	7.4	1.8	2.9	13.5	11.3	7.1	11.2
Significance (p)	0.05	0.36	0.82	0,71	0.59	0.45	0.02	0.49	0.07	0.28	0.93	0.81	0.03	0.07	0.3	0.08

Source: *Own elaboration.*

Table 9 above shows that the degree of negative impact of barriers on ISL implementation depends mainly on three barriers - B6, B7 and B13. In their case, the value of the independence test χ^2 (amounts respectively: 12.9; 14.9 and 13.5,) indicates that the degree of their negative impact on the implementation of ISL, due to the type of barriers, depends in these specific cases, because the p value is equal to 0.45, 0.02, and 0.03 all less than 0.05.

The next step is H_1 verification. For this purpose, the results obtained above were used - referring only and exclusively to those barriers which managed to "prove" their negative impact on the use of ISL among the surveyed enterprises (this applies to the following barriers, B6, B7 and B13). This part of the hypothesis was verified on the basis of non-parametric tests for mean values. The table below presents the average levels of negative impact (significance) of the number of systems in the case of the B6 barrier (Table 10).

Table 10. *Descriptive statistics of the studied sample according to the negative importance of the B6 barrier and the number of used systems*

Number of used systems	Number of enterprises	Average level of importance	Standard deviation
0	45	0.741111	1.208040
1	23	0.296522	0.706571
2	17	0.352941	0.924593
3	9	0.536667	0.987712
4	3	1.610000	2.368818
5	4	1.375000	0.928314
6	2	0.00	0.0

Source: *Own elaboration.*

Table 10 above shows that the highest values of the average significance level (negative impact) in the case of the B6 barrier occur for the four and five systems used. This is confirmed by the table below, which specifies the significance test results for means by number of systems (Table 11).

Table 11. *The value of the significance test for multiple comparisons - barrier B6*

Used systems	0	1	2	3	4	5	6
0		1.000000	1.000000	1.000000	0.013568	1.000000	1.000000
1	1.000000		1.000000	1.000000	0.028554	1.000000	1.000000
2	1.000000	1.000000		1.000000	0.026264	1.000000	1.000000
3	1.000000	1.000000	1.000000		0.044873	1.000000	1.000000
4	0.013568	0.028554	0.026264	0.044873		0.049873	0.027045
5	1.000000	1.000000	1.000000	1.000000	0.049873		1.000000
6	1.000000	1.000000	1.000000	1.000000	0.027045	1.000000	

Source: *Own elaboration.*

Table 11 above shows that the use of four, five and six systems is statistically significant from the point of view of negative impact. However, considering the average level of the value, it should be assumed that this relationship takes place for the number of two systems used (four and five). Therefore, it should be stated that the verification of this hypothesis in the case of the B6 barrier was positive. Generally, it was possible to determine that the degree of negative impact depends on the number of systems used. Of course, it is an open question to investigate the direction of this impact (whether the negative impact increases or decreases with an increase in the number of ISLs).

In the case of the B7 barrier, the average levels of negative impact (significance) of the number of systems are presented in the table below (Table 12).

Table 12. *Descriptive statistics of the studied sample according to the negative importance of the B7 barrier and the number of used systems*

Number of used systems	Number of enterprises	Average level of importance	Standard deviation
0	45	0.437333	0.781058
1	23	0.399130	0.643830
2	17	0.696471	1.212879
3	9	0.777778	1.153861
4	3	3.390000	1.206773
5	4	1.125000	1.040080
6	2	0.00	0.00

Source: *Own elaboration.*

These data show that the highest average level of significance of this barrier was achieved for the use of four systems. The remaining values are much lower, which indicates a relatively low importance of the number of systems used (negative impact) on the implementation of ISL among the surveyed companies. It is important, however, that with a small research sample, it was possible to establish a relationship between the number of ISLs used and the existence and negative impact of barriers. The existence of this relationship in the case of the B7 barrier is confirmed by the table below (Table 13).

Table 13. *The value of the significance test for multiple comparisons - barrier B7*

Used systems	0	1	2	3	4	5	6
0		1.000000	1.000000	1.000000	0.013568	1.000000	1.000000
1	1.000000		1.000000	1.000000	0.028554	1.000000	1.000000
2	1.000000	1.000000		1.000000	0.026264	1.000000	1.000000
3	1.000000	1.000000	1.000000		0.044873	1.000000	1.000000
4	0.013568	0.028554	0.026264	0.044873		0.049873	0.027045
5	1.000000	1.000000	1.000000	1.000000	0.049873		1.000000
6	1.000000	1.000000	1.000000	1.000000	0.027045	1.000000	

Source: *Own elaboration.*

As in the case of B6 (also here), it is statistically significant to use four, five and six systems in the context of negative impact. Considering the average level of significance, it can be concluded that this relationship is most visible in the case of the four ISLs used. Hence, the verification of the impact of the negative significance depending on the number of systems used in relation to B7 was positive - as in the case of B6.

The last barrier which, as a result of the verification of the first part of this hypothesis, turned out to be important from the point of view of ISL implementation, is B13. In its case, the descriptive statistics are presented in the next table (Table 14).

Table 14. *Descriptive statistics of the studied sample according to the negative importance of the B13 barrier and the number of used systems*

Number of used systems	Number of enterprises	Average level of importance	Standard deviation
0	45	0.681333	1.092380
1	23	0.043478	0.208514
2	17	0.470588	1.198256
3	9	0.222222	0.666667
4	3	1.443333	2.499927
5	4	0.167500	0.335000
6	2	0.00	0.00

Source: *Own elaboration.*

Based on these data, conclusions can be drawn like those for the previous barriers (B6 and B7). The B13 barrier has the greatest negative significance in relation to the use of four systems. This is evidenced by the highest average level of (negative) importance for this number of systems. This is also confirmed by the table for the significance level for B13 (Table 15).

Table 15. *The value of the significance test for multiple comparisons - barrier B13*

Used systems	0	1	2	3	4	5	6
0		0.249217	1.000000	1.000000	0.001247	1.000000	1.000000
1	0.249217		1.000000	1.000000	0.049403	1.000000	1.000000
2	1.000000	1.000000		1.000000	0.013595	1.000000	1.000000
3	1.000000	1.000000	1.000000		0.038653	1.000000	1.000000
4	0.001247	0.049403	0.013595	0.038653		0.034217	0.024217
5	1.000000	1.000000	1.000000	1.000000	0.034217		1.000000
6	1.000000	1.000000	1.000000	1.000000	0.024217	1.000000	

Source: *Own elaboration.*

The above data show a negative impact when using four, five and six systems. However, considering the average level of significance, it should be assumed that the greatest significance of a negative impact concerns the use of the four ISLs. This time, it was possible to prove (to a limited extent) the relationship between the number of systems used and the negative impact of the B13 barrier.

Summing up, the H_1 hypothesis was partially positively verified. It was not possible to determine the negative impact of all barriers and the number of all systems on the implementation of ISL among the surveyed companies. However, the above verification of this hypothesis showed that the barriers (in this case three) affect the application of ISL and that the number of systems is associated with a negative impact on the propensity to implement such solutions. Unfortunately, the verification of this hypothesis did not answer the question - does the number of implemented systems decrease or increase the level of negative impact of the discussed barriers? Moreover, it was not an assumption of this research hypothesis.

4.2.2 Verification of the Hypothesis H_2

Another hypothesis to be verified is H2, assuming that the degree of negative impact is varied and depends on the barriers and the implemented system. The first step is to determine, as in the case of the previous hypothesis *(H_1)*, which of the barriers are statistically significant in the context of a negative impact on the use of ISL. For this purpose, the non-parametric Kruskal-Wallis (K-W) test was used, where the following chi squared values were obtained (Table 16).

Table 16. *K-W test results verifying the significance level of individual barriers*

	B1	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**	**B9**	**B10**	**B11**	**B12**	**B13**	**B14**	**B15**	**B16**
Chi kwadrat (χ^2)	6.40	2/41	1.85	2.68	3.30	3.16	4.53	1.21	4/41	27.30	6.01	19.02	7.22	3.56	3.53	2.80
Significance (p)	0.26	0.78	0.86	0.74	0.65	0.67	0.47	0.94	0.49	0.00	0.35	0.00	0.20	0.61	0,61	0.70

Source: *Own elaboration.*

The above data shows that in the case of only two barriers, one can speak of a negative impact on the implementation of ISL. This applies to B10 and B12. In their case, the values of the Chi square test are respectively: 27.3 and 19.02, with p equal to, respectively, 0.0001 and 0.0002 both less than 0.005.

Therefore, it should be stated that the negative impact was statistically confirmed in relation to only the two above-mentioned barriers. This is an "effect", as previously noted, of the small size of the research sample - it can be expected that the number of barriers would be greater if the sample size were also greater.

The next step related to H_2 is to estimate the level of statistical significance for only these two barriers, i.e. B10 and B12. Descriptive statistics on the former are presented below (Table 17).

Table 17. *Descriptive statistics of the studied sample according to the negative importance of the B13 and implemented systems*

Implemented system	Number of enterprises	Average level of importance	Standard deviation
Internet of Things (1)	33	1.696970	1.862204
Big Data (2)	37	1.891892	1.911715
Cloud computing (3)	99	0.646465	1.416471
Blockchain (4)	7	2.285714	2.288689
SMAC (5)	8	2.250000	2.251983
SCADA (6)	12	1.000000	1.414214

Source: *Own elaboration.*

Table 17 indicates the greatest differentiation of the negative impact of all systems in relation to cloud computing (in relation to B10). Therefore, it can be concluded that such differences exist, and indeed it depends on the specific ISL (in this case system 3). This is confirmed by the significance levels in the table below (Table 18). The above data show that statistically significant is the differentiation of the negative impact between cloud computing and Big Data and the Internet of Things. Thus, in the case of the B10 barrier, such a phenomenon takes place, which allows for a positive verification of the assumed hypothesis H_2.

Table 18. *The value of the significance test for multiple comparisons - barrier B10*

Implemented system	1	2	3	4	5	6
Internet of Things (1)		1.000000	0.037970	1.000000	1.000000	1.000000
Big Data (2)	1.000000		0.011147	1.000000	1.000000	1.000000
Cloud computing (3)	0.037970	0.011147		0.347743	0.446716	1.000000
Blockchain (4)	1.000000	1.000000	0.347743		1.000000	1.000000
SMAC (5)	1.000000	1.000000	0.446716	1.000000		1.000000
SCADA (6)	1.000000	1.000000	1.000000	1.000000	1.000000	

Source: *Own elaboration.*

The same applies to the B12 barrier. Using non-parametric tests for mean values. The results obtained are listed below (Table 19).

Table 19. *Descriptive statistics of the studied sample according to the negative importance of the B12 and implemented systems*

Implemented system	Number of enterprises	Average level of importance	Standard deviation
Internet of Things (1)	100	0.450000	1.175293
Big Data (2)	37	1.297297	1.927360
Cloud computing (3)	31	1.096774	1.832209
Blockchain (4)	7	2.285714	2.214670
SMAC (5)	8	2.000000	2.203893
SCADA (6)	12	2.000000	2.335497

Source: *Own elaboration.*

These data indicate the differentiation of the negative impact of the B12 barrier in the case of the Internet of Things in relation to all other ISLs (to the greatest extent to Blockchain). However, as shown in the below table, this differentiation is not statistically significant - it does not occur within the intersystem framework, but within individual systems (Table 20).

Table 20. *The value of the significance test for multiple comparisons - barrier B12*

Implemented system	**1**	**2**	**3**	**4**	**5**	**6**
Internet of Things (1)		0.632697	1.000000	0.041041	1.000000	0.443156
Big Data (2)	0.632697		1.000000	1.000000	1.000000	1.000000
Cloud computing (3)	1.000000	1.000000		1.000000	1.000000	1.000000
Blockchain (4)	0.041041	1.000000	1.000000		1.000000	1.000000
SMAC (5)	1.000000	1.000000	1.000000	1.000000		1.000000
SCADA (6)	0.443156	1.000000	1.000000	1.000000	1.000000	

Source: *Own elaboration.*

Therefore, in the case of the B12 barrier, significant differences exist for the Internet of Things and Blockchain systems. Thus, it can be concluded that in the case of B12 the level of differentiation exists and relates to specific ISLs.

To sum up, the hypothesis was only partially positively verified. This is because of the fact, it was not possible to statistically prove the existence of a relationship between the negative impact of the barriers and the systems used in relation to all sixteen barriers and all six systems. This is probably the "effect" (as in the case of the verification of the previous hypothesis H_1) that the sample size is too small. Nevertheless, it is important that the existence of such dependencies has been indicated, which in practice may mean that the negative impact in the case of individual barriers may depend on the applied ISL.

4.2.3 Verification of the Hypothesis H3

The third hypothesis given for the verification is H3, according to which the degree of negative impact of barriers on ISL implementation depends on such characteristics of enterprises as: size and age of the enterprise. This verification will be carried out in a similar way as in the case of the two previous hypotheses (H1 and H2). The first step is therefore to find out which of the barriers are statistically significant from the point of view of a negative impact on the use of ISL (Table 21).

Table 21. *K-W test results verifying the significance level of individual barriers.*

Barriers	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**	**B9**	**B10**	**B11**	**B12**	**B13**	**B14**	**B15**	**B16**
Chi kwadrat (χ^2)	4.44	6.67	5.82	4.07	4.94	3.15	7.30	5.36	7.52	8.32	7.17	7.96	4.38	3.88	5.51	3.69
Significance (p)	*0.21*	*0.08*	*0.12*	*0.25*	*0.17*	*0.36*	*0.06*	*0.14*	*0.05*	*0.04*	*0.06*	*0.047*	*0.22*	*0.27*	*0.13*	*0.29*

Source: *Own eleboration.*

The table above shows that for the first factor, which is the size of the enterprise, the B10 and B12 barriers are statistically significant. In their case, the chi-square test values are 8.22 and 7.96, respectively, with p equal (in both cases) 0.04 <0.05. Thus, as in the case of the previous hypotheses - also here the negative impact can be "attributed" to only some (two) barriers. When analyzing the averages, it can be concluded that the greatest differences in terms of negative impact (the average level of importance) occur in the comparison of medium-sized enterprises with other groups (this applies to B10). Regarding B12, the situation is identical - the greatest differentiation is also in the case of medium-sized enterprises and all the others (Table 22).

Table 22. *Descriptive statistics of the studied sample according to the negative importance of size enterprises (B10 and B12).*

Size of the enterprise	Number of enterprises	Average level of importance	Standard deviation
Dla B10			
Micro	13	0.436154	1,168821
Small	17	0.637059	0.786017
Medium	20	0.158500	0.445105
Big	53	0.649057	1.101478
Dla B12			
Micro	13	0.539231	1.151329
Small	17	0.528824	0.840906
Medium	20	0.033500	0.149817
Big	53	0.471698	1.020075

Source: *Own elaboration.*

However, taking into account the significance for B10, it should be stated that the differentiation in significance applies only to small and medium-sized enterprises. The situation is slightly different in the case of the B12 barrier. Here, the relationship between the means and other groups was confirmed by the significance test, and thus it can be concluded that for B12 the hypothesis was verified positively, i.e. that the degree of negative impact depends on the size of the entitle (Table 23). On the other hand, for B10, the verification is only partially positive, as it shows a significant difference between medium-sized and small enterprises. However, it seems important that for both barriers such relationships exist, which confirms (in a general sense) the relationship between size and negative impact.

Table 23. *The value of the significance test for multiple comparisons – for enterprise size (B10 i B12)*

Size of the enterprise	Micro	Small	Medium	Big
For B10				
Micro		0.791299	1.000000	1.000000
Small	0.791299		0.017405	1.000000
Medium	1.000000	0.017405		0.305654
Big	1.000000	1.000000	0.305654	
For B12				
Micro		1.000000	0.034566	1.000000
Small	1.000000		0.018247	1.000000
Medium	0.034566	0.018247		0.043862
Big	1.000000	1.000000	0.043862	

Source: *Own elaboration.*

Another condition considered in this hypothesis is the age of the enterprise. The first step is to identify which of the barriers (or all?) are relevant to negatively impact the use of ISL (Table 24).

Table 24. *K-W test results verifying the relevance of individual barriers.*

Barriers	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**	**B9**	**B10**	**B11**	**B12**	**B13**	**B14**	**B15**	**B16**
Chi kwadrat (χ^2)	3.84	3.69	4.20	4.17	2.88	3.53	2.89	3.29	2.98	3.09	3.52	2.57	5.32	6.83	6.36	6.63
Significance (p)	0.14	0.15	0.12	0.12	0.23	0.17	0.23	0.19	0.22	0.21	0.17	0.27	0.07	0.033	0.042	0.036

Source: *Own elaboration.*

The above data indicate that in the context of "age", three out of sixteen barriers are statistically significant (B14, B15, B16) in terms of negative impact on the use of ISL. These include: B14, B15 and B16. In their case, the chi-quadratic tests are respectively, 6.83, 6.36 and 6.63, while the significance levels p reach the following values, 0.03, 0.04, and 0.03 all less than 0.05. When analyzing the average level of significance (in the case of age), it should be noted that the greatest differentiation occurs between the first group (the initial enterprises) and the other groups, and this in relation to all three barriers (Table 25).

Table 25. *Descriptive statistics of the test sample according to the negative importance of barriers B14, B15 and B16 and the age of the enterprise*

Age of the enterprise	Number of enterprises	Average level of importance	Standard deviation
For B14			
Up to 3 years (initial)	4	0.000000	0.828294
Up to 10 years	10	1.350000	1.709795

(developing))			
Over 10 years (mature)	89	0.335281	
For B15			
Up to 3 years (initial)	4	0.082500	0.712422
Up to 10 years (developing))	10	1.284000	1.680577
Over 10 years (mature)	89	0.264045	0.165000
For B16			
Up to 3 years (initial)	4	0.000000	0.855853
Up to 10 years (developing))	10	1.133000	1.539834
Over 10 years (mature)	89	0.335393	0.000000

Source: *Own elaboration.*

The level of differentiation from the point of view of significance is shown in the Table below (Table 26).

***Table 26**. The value of the significance test for multiple comparisons - the age of the enterprise (B14, B15 and B16)*

Age of enterprise	Up to 3 years (initial)	Up to 10 years (developing))	Over 10 years (mature)
For B14			
Up to 3 years (initial)		0.031866	1.000000
Up to 10 years (developing))	0.031866		0.038153
Over 10 years (mature)	1.000000	0.038153	
For B15			
Up to 3 years (initial)		0.046442	1.000000
Up to 10 years (developing))	0.046442		0.018465
Over 10 years (mature)	1.000000	0.018465	
For B16			
Up to 3 years (initial)		0.039249	1.000000
Up to 10 years (developing))	0.039249		0.027259
Over 10 years (mature)	1.000000	0.027259	

Source: *Own elaboration.*

The above data allow to confirm (and specify in more detail) the existence of relationships (differences) between these groups. Thus, they are visible between start-ups and developing and developing and mature enterprises, and this is true for all three barriers. Therefore, in relation to them, it can be stated that the hypothesis has been positively verified. This means that the degree of negative impact depends on the age of the enterprise (in the case of these three barriers).

Summing up, the H_3 hypothesis was partially positively verified, as the existence of a relationship was only demonstrated in relation to some barriers and groups of enterprises (both in terms of size and age of the studied entities). It is possible (as in the case of the previous hypotheses) that the small size of the research sample had a negative impact on their verification.

4.2.4 Verification of the Hypothesis H4

Another verified hypothesis is H4, assuming that internal barriers have a greater negative impact on ISL implementation than external barriers. The first element of this verification is to assess the existing dependence (correlation) between the dependent variables (internal and external barriers). This was done using the r Pearson correlation, which gave the value r = 0.883 (for N = 98 and for p = 0.0001 <0.05). This proves a strong relationship between these two dependencies, which allows the determination of average values of their negative impact on ISL implementation. As a result of the estimation, the results presented in the table below were obtained (Table 27).

Table 27. *Descriptive statistics of the test sample according to the negative importance for both: internal and external barriers*

Division of barriers	Number of enterprises	Average level of importance	Standard deviation	Standard error
Internal barriers	98	1.0482	1.38575	0.13998
External barriers	98	0.8439	1.23649	0.12490

Source: *Own elaboration.*

The above data clearly show the advantage of negative significance of internal barriers over external ones. Based on this, it can already be concluded that the first ones are a greater obstacle for the surveyed companies in the implementation of ISL. To confirm this thesis, the Student's t-test was performed (for dependent trials), which gave the following results (Table 28).

Table 28. *Student t-test for dependent trials*

Division of barriers	Number of enterprises	Average	Standard deviation	Standard error	T-student test	Significance (p)
Internal barriers and external barriers	97	0.20430	0.65000	0.06566	3.111	0.002

Source: *Own elaboration.*

The analysis of the above data using the Student's t-test for dependent samples showed that the mean of internal barriers (1.0482) differs statistically significantly from the mean of external barriers (0.8439) for t (97) = 3.111 and p = 0.002 <0.05. Hence, it can be unequivocally stated that internal barriers are "more important" than external ones, constituting a much greater obstacle in the implementation of the discussed logistics systems. Thus, the H_4 hypothesis was verified positively. This confirms the conclusions obtained in the analysis of the structure indicators presented in point 4.1. Based on the results of partial verification, H_0 should also be positively verified, which means that the existing barriers definitely have a negative impact on the implementation of intelligent systems in logistics among manufacturing companies in Poland.

5. Conclusions

The above considerations contained in this article allow for drawing several important conclusions. Firstly, the definitions of Logistics 4.0 are semantically similar to each other. Their focal point is the use of cyber-physical systems "equipped" with artificial intelligence to increase the automation of production and logistics processes. Secondly, barriers constitute a serious problem in the implementation of ISL among economic entities wishing to modernize customer service and thus improve their competitiveness on the market. In the literature on the subject, the classification of barriers applies only to selected systems and in the subject scope. Third, the level of negative impact of individual barriers varies greatly and depends on the system used. Fourth, the biggest negative impact among Polish (surveyed) enterprises is the Big Data system, and the lowest is IoT. Fifth, the division into internal and external barriers indicates that the first ones has a greater negative significance in the process of ISL implementation.

Moreover, among the former, the lack of resources and the reluctance to take investment risk are "key", while the latter group (internal) is dominated by, lack of willingness to cooperate, high costs of ISL implementation and the lack of compatibility between the systems offered on the market. Sixth, the assumed hypotheses were only partially positively verified. This is the effect of too small a sample. Nevertheless, some conclusions can be drawn from this. It is undeniable that the negative impact of individual barriers varies and applies only to selected cases. As a result of the verification of the first hypothesis, it was proved that the number of systems used (in this case 4) is related to the negative impact of barriers on the propensity to implement ISL.

Then, as a result of the verification of the second hypothesis, the existence of a relationship between the barriers and the systems used was proved - the negative impact in the case of individual barriers depends on the system used. On the other hand, when verifying the third hypothesis, it was found that factors such as the size and age of the enterprise are important (in the case of certain barriers) from the point of view of their negative impact on the propensity to implement ISL. In the final stage of hypothesis verification, it was possible to prove a greater (negative) significance of internal barriers over external ones, which confirmed the conclusions drawn as a result of the analysis of structure indicators in the previous section of this article.

Finally, it is worth considering the limitations of the research presented in this article. First, a limited number of systems were selected for analysis (in the first part - the three most frequently used in practice; in the second - six (all) that were included in this study). This limitation is important as it does not consider the majority of ISLs used in practice. However, general indications show that only these three are the most popular now - hence researching more of them now seems pointless. It will take several years for the number of systems covered by this type of study to increase until they become more common in Poland. Secondly, as has been mentioned many times in this article, too small a sample made it impossible to fully verify the assumed hypotheses. Such a small sample is the result of the low level of maneuverability, which is the result of a small population of production and logistics companies implementing intelligent systems in Poland and the poor awareness of entrepreneurs regarding the importance of such solutions. This idea, although it is known among Polish entities, is not used on a "large scale".

The consequences of the "small size" are, the lack of representativeness of the sample (too small size) and the lack of generalizations in the national context (Bielawska-Zakrzewska, 2011). The last limitation seems to be the lack of specificity in the concept of "intelligent logistics". While the concepts of "e-logistics" or "industry 4.0" are common and widely discussed, the concept of "intelligent logistics" is not very "popular" (Dembińska *et al.*, 2018). The same is true of the barriers to ISL implementation. Their description in the literature on the subject is rather sparse and concerns only specific systems, not logistics 4.0 in general.

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