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APPLYING ARTIFICIAL INTELLIGENCE IN THE LOGISTICS SECTOR OF LITHUANIA: PROSPECTS AND OPPORTUNITIES

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Abstract. Logistics has been one of the most important sectors of Lithuania's economy. However, recent economic, social and political challenges significantly impacted sector development, making its representatives search for new ways of business development by changing conservative models with more advanced ones. For instance, changes in the logistics sector affected by the implementation of remote work opportunities have created possibilities for providing logistics-related services across the globe. Most of the attention is being paid to solutions based on the application of artificial intelligence, and the future of logistics sector development is closely dependent on it. The paper aims to discover new prospects in applying artificial intelligence in the logistics sector by bringing forward an overview of the main sector's activities, performing historical economic data analysis and conducting a survey with representatives of leading companies from the logistics sector in Lithuania. The multicriteria method is used in data analysis, helping establish the main prospects in the sector's development.

Keywords: Artificial Intelligence; Internet of Things; Logistics; Multicriteria Analysis

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JEL Classifications: M10, O32, R40

1. Introduction

Lithuania's logistics sector has been crucial to the country's economy. As a complex sector, it includes many sub-sectors, where, according to *Euromonitor International* (2023a), the main ones are:

- Transport and storage are the aggregations of cargo handling, warehousing and travel agencies, communications, and transport.
- Cargo handling, warehousing and travel agencies are an aggregation of cargo handling, storage and warehousing, travel agencies, freight forwarding and other supporting transport activities.
- Post and courier services are an aggregation of courier services and national post.
- Air transport is an aggregation of non-scheduled air transport and scheduled air transport.
- Road passenger and freight transport is an aggregation of freight transport by road, non-scheduled, and scheduled passenger transportation.
- Transport via pipelines is an aggregation of pipelines of petroleum and natural gas and transportation of other liquids.
- Transport via railways is an aggregation of freight services, other transport services and passenger services.
- Water transport is an aggregation of inland water transport and sea and coastal transport.

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According to *Euromonitor International* (2023a) data, the transport and storage sector takes second position by reaching 14,633.2 mln. USD in turnover and letting only the retail and wholesale sectors forward (see Figure 1). Moreover, the compound average growth of the industry may achieve 3.6 per cent annually by 2027, making it one of the fastest-developing sectors of the Lithuanian economy.

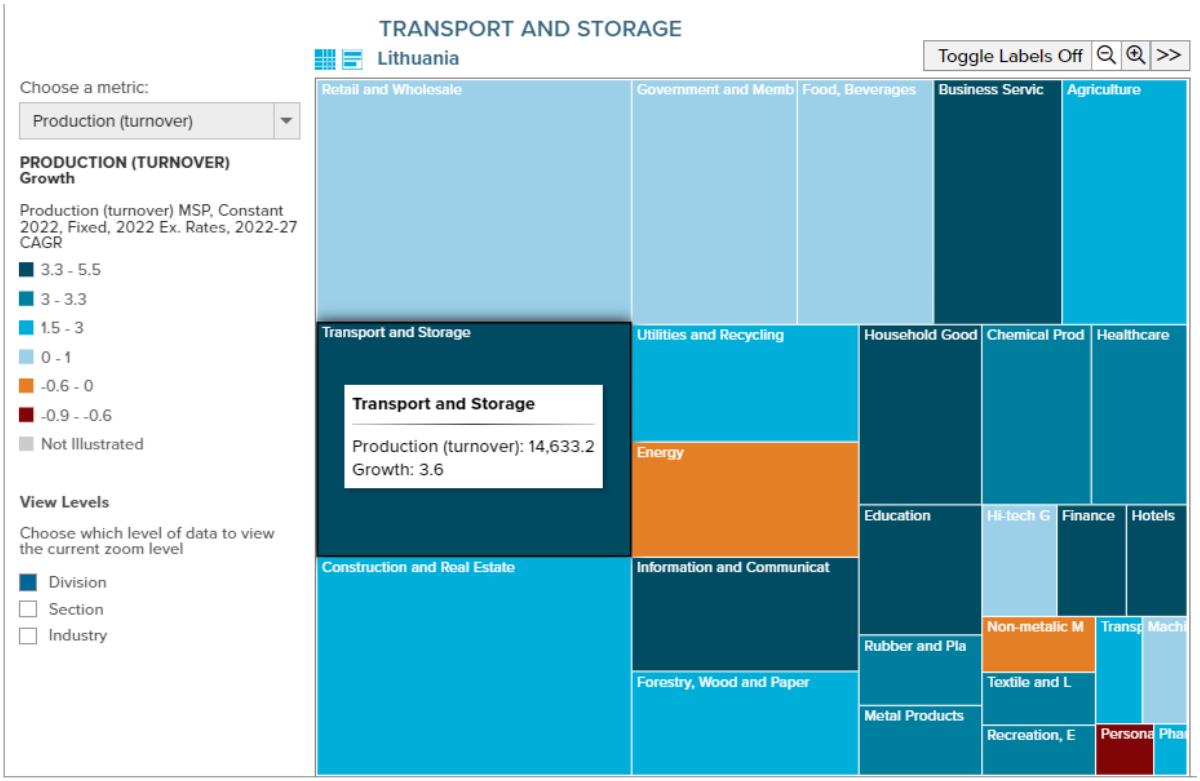


Figure 1. Transport and storage, among other sectors of the Lithuanian economy

Source: Euromonitor International, 2023a

Despite the challenging geopolitical situation, Lithuanian exports and imports of the transport and storage sector flourish (Table 1). Regarding 2022 data, the main countries of Lithuanian exports were Japan (7,431.2 mln. USD), the United States of America (3,849.1 mln. USD) and the United Kingdom (1,309.1 mln. USD), while imports came mainly from Switzerland (1,518.1 mln. USD), the USA (1,078.1 mln. USD) and Japan (959.5 mln. USD). It reflects flexibility in Lithuanian politics and a fast decision-making process in Lithuanian enterprises.

Table 1. Lithuanian imports and exports in transport and storage in 2017-2022, mln. USD

	2017	2018	2019	2020	2021	2022
Imports	2,304.1	2,663.4	2,941.9	2,558.3	3,486.1	4,156.1
Exports	6,327.8	7,715.3	9,019.8	8,211.9	10,654.0	12,516.8

Source: Euromonitor International, 2023a

As a result, all types of transport demonstrate promising results in cargo turnover, except road transport and oil pipelines. This can be explained by terminating economic relations with the Republic of Belarus and the Russian Federation (Table 2).

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Table 2. Cargo turnover by all types of transport in Lithuania in 2018-2022, thousand tkm

	2018	2019	2020	2021	2022
Railway transport	16 884 825	16 180 599	15 864 679	14 565 850	7 375 058
Road transport	43 590 351	53 117 436	55 291 543	57 755 186	53 772 526
Inland water transport	1 200	1 622	1 164	3 809	10 583
Air transport	77	82	8 101	578	2 799
Oil pipeline	326 443	329 541	209 342	130 133	107 526
All types of transport	60 802 897	69 629 280	69 629 280	72 455 555	61 268 493

Source: State Data Agency "Statistics Lithuania", 2023

However, some negative changes might also be observed in the logistics sector's development. For instance, after gaining an impressive 31 rank in 2017, the Logistics Performance Index Rank has lost 12 ranking points in 2022 compared to the situation back then. Although the overall Logistics Performance Index Score remains relatively stable, the biggest challenge might be evaluating the timeliness of international shipments, tracking and tracing consignments, and quality of logistics services. The Logistics Performance Index Score reflects perceptions of a country's logistics based on the efficiency of the customs clearance process, quality of trade- and transport-related infrastructure, ease of arranging competitively priced shipments, quality of logistics services, ability to track and trace consignments, and frequency with which shipments reach the consignee within the scheduled time (Euromonitor International, 2023b) (see Table 3).

Table 3. Logistics performance indices in Lithuania in 2017-2022

	2017	2018	2019	2020	2021	2022
Logistics Performance Index Rank	31.0	54.0	50.0	46.0	45.0	43.0
Logistics Performance Index Score	3.5	3.0	3.1	3.2	3.2	3.3
- Logistics Performance Index: Efficiency of Customs and Border Clearance	3.3	2.8	2.9	3.0	3.1	3.1
- Logistics Performance Index: Quality of Trade and Transport Infrastructure	3.3	2.7	2.9	3.0	3.2	3.3
- Logistics Performance Index: Ease of Arranging International Shipments	3.3	2.8	2.9	3.0	3.2	3.3
- Logistics Performance Index: Quality of Logistics Services	3.4	3.0	3.1	3.1	3.1	3.1
- Logistics Performance Index: Tracking and Tracing Consignments	3.5	3.1	3.1	3.1	3.1	3.1
- Logistics Performance Index: Timeliness of International Shipments	4.1	.3.6	3.6	3.6	3.6	3.6

Source: World Bank, 2023; Euromonitor International, 2023b

Many companies apply various new technology-based methods and tools to improve different aspects of the Logistics Performance Index, including remote work opportunities and possibilities in providing logistics-related services globally. Therefore, more attention should be paid to solutions based on artificial intelligence applications.

Therefore, the paper aims to discover new prospects for applying artificial intelligence in logistics. The objectives include theoretical background analysis, revealing the main directions in using artificial intelligence solutions, and surveys with representatives of the leading companies operating in the logistics sector in Lithuania. The multicriteria method is used in data analysis, helping establish the main prospects in the sector's development.

2. Theoretical background analysis

The roots of the application of artificial intelligence solutions might be found in the Internet of Things (IoT) development process. According to Hassan (2018), Kevin Ashton devised the term "Internet of Things" for a new computer application that automatically collects data around us to automatically control many daily activities in 1999. Nowadays, the Internet of Things might be understood as a model for smart applications (Atzori et al., 2010), any smart solution developed based on IoT technology, including devices, services, application appliances, platforms, and ecosystems (Qinxia et al., 2021), or any Internet system designed to collect data and then exchange and analyze information (Ram Kumar et al., 2016). (Ahmad et al., 2020) provide

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a list of main IoT products, such as wearable devices, advanced metering infrastructure, agricultural drones, autonomous robots, remote monitoring systems, and fire alarm systems, and mention fleet management as one of the examples.

IoT markets are rapidly growing, and service providers ensure a wide range of IoT-based solutions to facilitate various aspects of life (Naem et al., 2022). By analysing theoretical sources, four aspects of the Internet of Things can be distinguished:

- Consumer IoT,
- Business IoT,
- Infrastructure IoT,
- Industrial IoT.

Consumer IoT, as the name suggests, proposes a consumer-oriented approach to help new consumers choose IoT products that best serve their needs from available products (Naem et al., 2022). In other words, IoT is based on ideas to connect and create communication among every living and dead object (Arif et al., 2019). In short, authors tend to analyse behavioural patterns (Subiyakto et al., 2023; Zhang & Peer, 2023) and improved experience of customers (Hoffman & Novak, 2018), supported with IoT application here.

Business IoT investigates the impact of IoT-based innovations on business models and patterns. For instance, Yin (2022) analyzes changes in the sharing economy affected by IoT big data, and Hanafizadeh et al. (2021) use business model innovation (BMI) to describe the efforts made by the business to find new business logic or new ways of value creation. Interestingly, Kulakli & Arikan (2023) have shown that scientific publications on the Internet of Things about business model innovation have increased gradually since 2019.

Infrastructure IoT deals with the appropriate ecosystem creation needed to apply IoT-related solutions successfully. Teckshawer (2023) analyzes the ramifications of 5G technology for enterprises in developing countries and highlights how 5G technology might boost IoT capabilities through higher device densities, lower latency, and faster data transmission rates. Shankar & Maple (2023) examine the effects of ethics and technology on the security of IoT-enabled systems in smart city infrastructure and present a Secure Smart City Infrastructure using Blockchain and Deep Learning (SSCI-BDL) framework to ensure privacy protection and trustworthiness among IoT communication in smart cities.

Finally, *Industrial IoT* provides a complex understanding of IoT-related applications that change business principles in specific industrial areas and directly impact artificial intelligence applications. Flores-García et al. (2023) propose a data model for multichannel communication that facilitates IoT-enabled digital service for smart production logistics, essential for capturing, processing, and transferring information across products, services, and software databases (see Table 4).

Table 4. Main aspects of Industrial IoT

Aspects of Industrial IoT:	Research areas in logistics:	Authors:
Autonomous robots	Unmanned vehicles, Autonomous Mobile Robot (AMR), Automated Guided Vehicle (AGV), Robot operating system (ROS), Cyber-physical system (CPS), Intelligent logistics system (IIS), Simultaneous localization and mapping (SLAM)	Hsiang-Chen et al., 2023; Chang et al., 2023
3D printing	Computer-assisted methods, distribution networks, logistics consulting services, customization, reverse logistics	Ehler, 2023; Demir, Eyers & Huang, 2021; Esenduran, Leitizia, Ovchinnikov, 2022; Boon, van Wee, 2018
Augmented reality	Smart materials, binoculars, wearable technology, virtual reality	Rejeb et al., 2021; Reif, Walch, 2008
Simulation	Transportation planning, assistive listening systems	Demir, Eyers & Huang, 2021
Big data analytics	Software frameworks, big data, technological innovations, customer satisfaction, edge computing, predictive analytics	von Stietencron, 2022; Guan, 2020; Bag et al., 2021; Sodero, Jin & Barratt, 2019; Govindan et al., 2018

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Cloud computing	Blockchains, multicasting (computer networks), intelligence levels, information storage, retrieval systems, quality of service	Fan, 2022; Fu et al., 2021; Wang, Yin & Wang, 2023
Cybersecurity	Supply chain management, quantum computing, security systems, wired telecommunications carriers, Internet Publishing and Broadcasting and Web Search Portals, Security Systems Services, Internet security, encryption protocols	Cheung, Bell & Bhattachariya, 2020; Enache, 2023

Source: conducted by authors

Based on a literature review, the Industrial IoT comprise the relevant and vital aspects for assessing the impact of the newest solutions on transport and logistics-related challenges. According to Boon and van Wee (2018), location, needs, and transport resistance are essential. The city-level hubs can coordinate material flows and gather expertise faster, mass-individualisation and personification dictate the need for changes, and more efficient distribution networks optimize the process of materials shipping.

According to Manners-Bell and Lyon (2023), the benefits of the Internet of Things include:

- Monitoring the status of assets, parcels and people in real-time.
- Measuring how assets are performing (and what they will do next).
- Reducing fuel costs by optimization of fleet routes.
- Automating business processes to eliminate manual interventions.
- Optimizing how people, systems and assets work together and coordinate their activities.
- Applying analytics to identify wider improvement opportunities and best practices.
- Mentoring inventory to reduce stock-outs (see Figure 2 below).

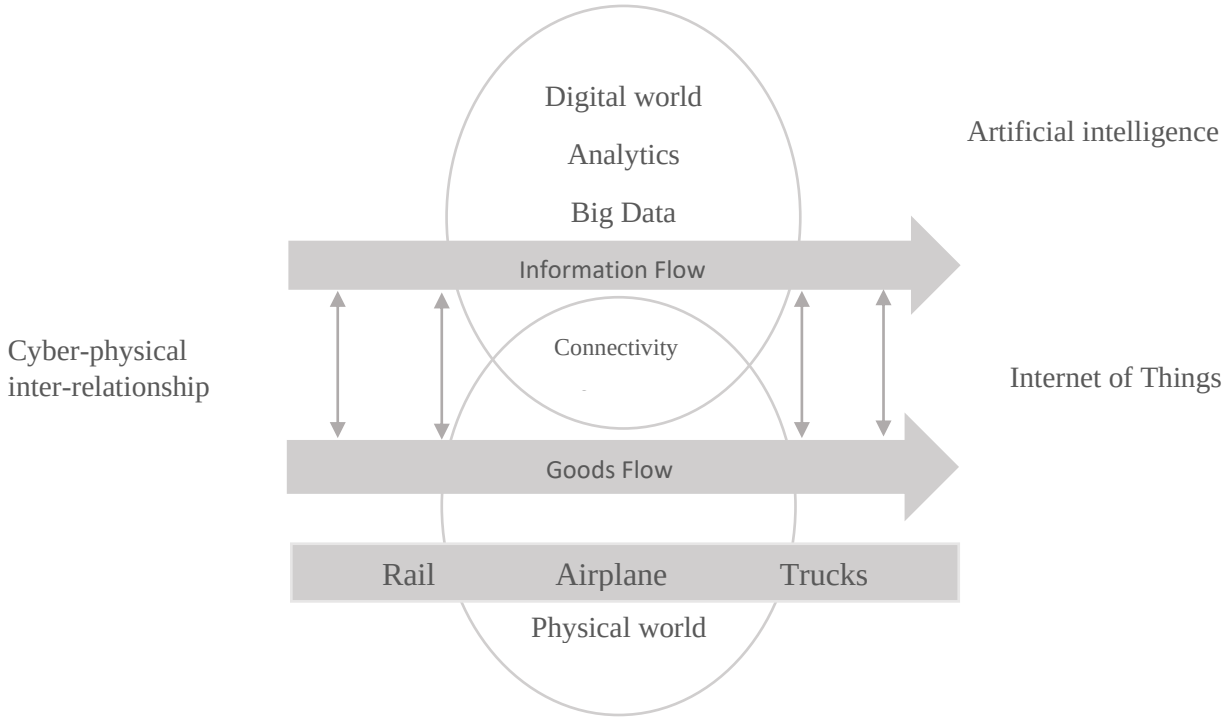


Figure 2. The cyber-physical relationship in the supply chain
Source: Manners-Bell, Lyon, 2023

Manners-Bell and Lyon (2023) highlight the main directions in applying artificial intelligence in logistics:

- Connected consumers.
- Autonomous vehicles.
- Delivery flexibility.
- Warehouse automation.

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Connected consumers. Artificial intelligence (AI) has the power to revolutionize the way *businesses interact with their customers* (Mclean & Osei-Frimpong, 2019) and radically change the marketplace (Bock et al., 2020). Specifically, AI advances can improve the *customer experience* by increasing companies' knowledge about their preferences and buying patterns (Evans, 2019). Deploying AI technologies strategically at different key customer contact posts can bring significant benefits to companies and a possible increase in customer satisfaction (Ameen et al., 2021). Therefore, AI increases *customer satisfaction* in service delivery (Aguiar-Costa et al., 2022).

Autonomous vehicles. There is undoubtedly a big potential for autonomous vehicles shortly, and their numbers are rising dramatically (Jadhav et al., 2023). For example, nowadays, a smart car's effective driving direction and precise lane location can be determined based on the current driving lane. Xianping & Xueliang (2021) state that the ultimate goal of developing autonomous vehicles is to establish an automated platform connected and informatized by integrating humans and cars, capable of implementing real-time, all-weather, and efficient autonomous driving. Moreover, the authors believe that autonomous driving technology can significantly increase social productivity and produce tremendous social benefits while improving the way people travel. Nurgaliev, Eskander & Lis (2023) investigate the use of drones and autonomous vehicles in logistics and delivery. The authors indicate high transportation costs, difficulty in meeting customer demands, and environmental concerns as main challenges; however, integrating drone and autonomous vehicle technology can address these challenges by reducing transportation costs, increasing speed and reliability of delivery, and improving efficiency. Using drones and autonomous vehicles can bring significant benefits such as increased efficiency, cost savings, improved safety, accessibility, and real-time tracking (Nurgaliev, Eskander & Lis, 2023).

***Delivery flexibility*.** Delivery flexibility is essential in some specific areas, such as healthcare. Hassanzadeh, Atyabi & Dinarvand (2019) evaluate the significance of artificial intelligence in drug delivery system design. The problem might be solved in logistics by optimizing transportation routines from a network perspective of supply and demand nodes (Lam, 2021).

Warehouse automation. Li et al. (2021) think that warehouse management can solve its problems by improving the main aspects of warehouse design and planning and integrated warehouse management.

The list of central aspects of applying artificial intelligence in logistics is still being determined. For instance, Klumpp & Ruiner (2022) highlight the importance of the human factor, especially in digital logistics; Pawlicka & Bal (2022) investigate possibilities of implementing AI and sustainable supply chain finances for innovative omnichannel logistics, and Emam et al. (2021) suggest algorithms to solve complex and multimodal problems that face transportation logistics sector.

3. Research objective and methodology

The research aims to discover new prospects for applying artificial intelligence in logistics. The empirical research has a double objective: first, to discuss the importance of established theoretical directions using AI in logistics sector development, and second, to evaluate how results may be implemented on the company's managerial level by improving logistics to achieve better business results.

The research methodology consists of three parts:
1. Delphi analysis with experts in the logistics sector.
2. Interviews with logistics sector representatives.
3. Evaluation of interviews' results based on multicriteria analysis of opinions.

The ***Delphi method*** supports decision-making processes when selecting or implementing objectives (Kozak & Frączkiewicz-Wronka, 2023). It generates consensus among experts dealing with complex issues (Robertson et al., 2017). It is a unique type of survey when a group of anonymously participating respondents with good knowledge of logistics are selected to evaluate and analyse a topic. In the empirical research, the Delphi method

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allowed us to establish the importance of various theoretical directions in logistics sector development supported by AI applications.

Interview is the broadly used qualitative method of gathering information about a specific area. According to Bazaras et al. (2009), the results of the interviews can indicate critical trends affecting the logistics sector. In the empirical research, the representatives of companies operating in Lithuania's logistics sector provided their opinions regarding AI application-related topics.

Multicriteria analysis of opinions represents. Commonly, experts' opinions differ (Podvezko, 2011). Therefore, assessing the degree of compatibility of their views is crucial. This method ranks possible alternatives when respondents evaluate all indices depending on their opinions and acquired knowledge (Ambrusevič, 2016). The degree of compliance provides information regarding representatives of the results (Kardelis, 2002).

By having compatible opinions, multicriteria data analysis has to be performed, revealing the opinion of one respondent and representing the results of all participating specialists (Malhotra and Birks, 2012). An expert survey helps identify the most critical indexes according to the experts' opinions (Podvezko, 2011).

The correlation coefficient can quantify the agreement between two respondents. Suppose the number of respondents is greater than two. In that case, the group's compatibility level is indicated by the concordance coefficient *W*, which is calculated based on the ranking of the analyzed objects.

Ranking is a procedure where the most critical object gets a rank equal to one, the second most important gets the rank of two, and the last in terms of importance gets the rank *m*. Equivalent indicators get the same arithmetic average of values. The Kendall concordance coefficient is linked to the sum of the ranks of each object about all respondents:

$$c_i = \sum_{j=1}^{r} c_{ij}$$

where, c_i – matrix of objects evaluations;
i – rank of an object given by a respondent j $(i = 1, 2, \ldots, m)$;
r – number of respondents.

The mean squared deviation is expressed by the deviation of c_i comparing to average value $\bar{c}$:

$$S = \sum_{i=1}^{m} (c_i - \bar{c})^2$$

Average value $\bar{c}$ is calculated by using the following formula:

$$\bar{c} = \frac{1}{2} r(m+1)$$

Concordance coefficient is the ratio of dispersion *S* and its possible maximum value:

$$W = \frac{12S}{r^2 m(m^2 - 1)}$$

In case of compatible opinions, the value of concordance coefficient *W* is equal *1*; if the value differ, *W is* near *0*. Concordance coefficient can be for Simple Additive Weighting data analysis, if χ^2exceeds critical value $\chi_{cr}{}^2$. It indicates, that respondents' opinions can be considered as compatible:

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$$\chi^2 = \frac{12S}{rm(m+1)}$$

For Simple Additive Weighting data analysis, a matrix of weighted normalized values is formed:

$$\tilde{r}_{ij} = \frac{r_{ij}}{\sum_{j=1}^{n} r_{ij}}$$

where, $\tilde{r}_{ij}$ - *i*-indicators normalized value for *j*-object; r_{ij} - *i*-indicator mean for *j*-object.

The total of all weighted normalized values for each object need to be calculated:

$$S_i = \sum_{i=1}^{m} \omega_i \tilde{r}_{ij},$$

where, w_i – weight of *i*-indicator; $\tilde{r}_{ij}$ - normalized *i*-indicator for *j*-object.

The biggest value of *Sj* shows the opinion of a certain respondent, who expresses the opinion of all respondents.

4. Results and discussion

In the Delphi survey, 5 experts were selected for participation. During the first round, each expert anonymously provided their list of main areas of logistics suitable for artificial intelligence applications. During the following rounds, the experts evaluated a general list of suggestions from all members. Finally, seven subjects were considered suitable for artificial intelligence applications: autonomous vehicles, big data analysis, cloud computing, connected consumers, cybersecurity, delivery flexibility, and warehouse automation.

During the interviews 8, respondents representing business units operating in the logistics sector were asked to express their opinions to evaluate the main direction of AI applications suitable for their companies. They had to assess theoretically established directions from the answers of the Delphi survey with anonymous experts (see Table 5).

Table 5. The matrix of the ranging of the evaluation of respondents

Nr.	Evaluated objects	Respondents								Sum of ranges	Mean squared deviation
		Nr.1	Nr.2	Nr.3	Nr.4	Nr.5	Nr.6	Nr.7	Nr.8		
1	Autonomous vehicles	2,5	1,5	3	1,5	1,5	1	2	4	17	413,44
2	Big data analysis	6,5	6,5	6,5	6	6,5	5	5,5	5,5	48	113,78
3	Cloud computing	6,5	6,5	6,5	6	4	2,5	5,5	7	44,5	51,36
4	Connected consumers	2,5	3,5	1,5	1,5	1,5	7	5,5	2	25	152,11
5	Cybersecurity	5	5	4,5	3,5	4	5	5,5	5,5	38	0,44
6	Delivery flexibility	2,5	1,5	4,5	3,5	6,5	5	2	2	27,5	96,69
7	Warehouse automation	2,5	3,5	1,5	6	4	2,5	2	2	24	117,78
	Total	28,0	28,0	28,0	28,0	28,0	28,0	28,0	28,0	224,00	1105,61

Source: conducted by authors

The concordance coefficient *W* expresses the reliability of the expertise, as the degree of agreement between the opinions of respondents is quite high: $W = \frac{12S}{r^2 m(m^2-1)} = \frac{12\times1105,61}{64\times7\times(49-1)} = 0,56$.

The obtained results can be used for Simple Additive Weighting data analysis, as χ^2exceeds critical value $\chi_{cr}{}^2$:

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$$\chi^2 = \frac{12S}{rm(m+1)} = \frac{12 \times 1105{,}61}{8 \times 7 \times (7+1)} = 26{,}94$$

$$\chi_{lim}{}^2 = \chi^2_{(v=m-1\,;\,\alpha=0{,}05)} = 12{,}59$$

The results of the Simple Additive Weighting data analysis are provided in Table 6 below:

Table 6. The matrix of weighed normalised values

Evaluated objects	Respondents							
	Nr.1	Nr.2	Nr.3	Nr.4	Nr.5	Nr.6	Nr.7	Nr.8
Autonomous vehicles	0,1897	0,1138	0,2277	0,1138	0,1138	0,0759	0,1518	0,3036
Big data analysis	1,3929	1,3929	1,3929	1,2857	1,3929	1,0714	1,1786	1,1786
Cloud computing	1,2913	1,2913	1,2913	1,1920	0,7946	0,4967	1,0926	1,3906
Connected consumers	0,2790	0,3906	0,1674	0,1674	0,1674	0,7813	0,6138	0,2232
Cybersecurity	0,8482	0,8482	0,7634	0,5938	0,6786	0,8482	0,9330	0,9330
Delivery flexibility	0,3069	0,1842	0,5525	0,4297	0,7980	0,6138	0,2455	0,2455
Warehouse automation	0,2679	0,3750	0,1607	0,6429	0,4286	0,2679	0,2143	0,2143
Total	4,5759	**4,5960**	4,5558	4,4252	4,3739	4,1551	4,4297	4,4889

Source: conducted by authors

The results obtained show that the opinion of respondent Nr. 2 reflects the opinions of the whole group at the best level. According to experts' evaluation of all evaluated objects regarding their importance, tier 1 includes autonomous vehicles and delivery flexibility, tier 2 – connected consumers and warehouse automation, tier 3 – includes cybersecurity, and tier 4 – big data analysis and cloud computing.

Conclusions

The logistics sector remains one of the largest and most important sectors in the structure of the Lithuanian economy. However, historical economic data analysis revealed negative aspects of its development. Although all types of transport demonstrate promising results in cargo turnover, road transport and oil pipeline cargo turnover are declining. The termination of economic relations with the Republic of Belarus and the Russian Federation can explain that. Moreover, the Logistics Performance Index Score analysis indicated the main challenge in evaluating the timeliness of international shipments, tracking and tracing consignments, and quality of logistics services. It is concluded that in order to improve different aspects of the Logistics Performance Index, many companies apply various new technology-based methods and tools, including remote work opportunities and possibilities in providing logistics-related services across the globe. Therefore, more attention should be paid to solutions based on artificial intelligence applications.

Theoretical background analysis established the roots of the application of artificial intelligence solutions in the development process of the Internet of Things, which was divided into four aspects: consumer IoT, business IoT, infrastructure IoT, and Industrial IoT. The last, industrial IoT, provides a complex understanding of IoT-related applications that change business principles in specific industrial areas and directly impact artificial intelligence applications. The most significant impact of industrial IoT is established in the following areas: autonomous robots, 3D printing, augmented reality, simulation, big data analytics, cloud computing, and cybersecurity. Detailed scientific literature analysis highlighted the main directions in applying artificial intelligence in logistics: connected consumers, autonomous vehicles, delivery flexibility, and warehouse automation.

The results obtained from theoretical background analysis were tested by conducting empirical research. It aimed to discuss the importance of established theoretical directions applying AI in logistics sector development and, second, to evaluate how results may be implemented on the company's managerial level by improving logistics to achieve better business results. Therefore, a complex research methodology was used, consisting of Delphi analysis with experts of the logistics sector, interviews with logistics sector representatives, and

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evaluation of interviews' results based on a multicriteria analysis of opinions. As a result, the following prospects in applying artificial intelligence in the sector's development were established: regarding the importance of tier 1 includes autonomous vehicles and delivery flexibility; tier 2 – connected consumers and warehouse automation; tier 3 – cybersecurity; and, finally, tier 4 – big data analysis and cloud computing.

Limitations of the research are related to the narrow scope of participants and the quite general nature of results at the end. This can be explained by the early stages of artificial intelligence application and the need for practical evidence from Lithuanian business practices. However, the results distinguish the main directions in logistics sector development and provide a structural sequence for further investigation.

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