Volume: 7 Issue: 2 Year: 2025 Research Article ISSN: 2667-8063

Identifying Opportunities and Challenges Affecting Logistics 4.0: A Research in Ankara Logistics Base

Abdullah Oktay DÜNDAR[1]* Bedriye Seda KANDUZA[2]

[1] Necmettin Erbakan University, Faculty of Applied Sciences, Department of Logistics Management, Konya, TÜRKİYE

[2] Necmettin Erbakan University, Institute of Social Sciences, Department of Logistics Management, Konya, TÜRKİYE

Article Info

Received: 02/08/2025
Accepted: 19/10/2025
Published: 27/12/2025

Keywords:
Logistics 4.0,
Opportunities,
Challenges,
Ankara Logistics Base

JEL Kodları:
L91, O14, R40

ABSTRACT

The aim of this study is to reveal the extent to which Logistics 4.0 applications have been adopted in the logistics sector in Türkiye, to examine the factors influencing businesses' approaches, and to evaluate the opportunities and challenges in the implementation process. The study was conducted using a face-to-face survey method with 209 logistics companies operating at the Ankara Logistics Base. SPSS 27.0 software was used to analyze the data, employing KMO, Bartlett, ANOVA, Tukey Post-Hoc, and Regression/Correlation analyses. The findings show that the majority of participants are small and medium-sized national companies; large and international companies were found to invest more in digital technologies and be more aware of Logistics 4.0. No "demonstration effect" was observed, with the high costs of Logistics 4.0 technologies cited as the reason. Businesses indicated that strategic and operational opportunities such as new business models, rapid response, and efficiency were a strong source of motivation for transitioning to implementation. However, challenges such as high investment costs, security concerns, lack of qualified personnel, and employee resistance negatively affect adoption. Statistical analyses have revealed that opportunities have a positive impact on implementation, while challenges have a negative impact. Furthermore, it has been determined that the business activity area, number of employees, and level of digital technology usage create significant differences in Logistics 4.0 applications. Consequently, despite the potential for increased efficiency and competitiveness offered by Logistics 4.0, it has been concluded that the Turkish logistics sector, particularly among small businesses, faces significant adoption barriers.

Lojistik 4.0'ı Etkileyen Fırsat ve Zorlukların Belirlenmesi: Ankara Lojistik Üssü'nde Bir Araştırma

Makale Bilgisi

Geliş Tarihi: 02/08/2025
Kabul Tarihi: 19/10/2025
Yayın Tarihi: 27/12/2025

Anahtar Kelimeler:
Lojistik 4.0,
Fırsatlar,
Zorluklar,
Ankara Lojistik Üssü

JEL Codes:
L91, O14, R40

ÖZET

Bu çalışmanın amacı, Lojistik 4.0 uygulamalarının Türkiye'deki lojistik sektöründe ne ölçüde benimsendiğini ortaya koymak, işletmelerin yaklaşımlarını etkileyen faktörleri incelemek ve uygulama sürecindeki fırsatlar ile zorlukları değerlendirmektir. Çalışma, Ankara Lojistik Üssü'nde faaliyet gösteren 209 lojistik işletmesi ile yüz yüze anket yöntemi kullanılarak gerçekleştirilmiştir. Verilerin analizinde SPSS 27.0 yazılımı ile KMO, Bartlett, ANOVA, Tukey Post-Hoc ve Regresyon/Korelasyon analizleri kullanılmıştır. Bulgular, katılımcıların çoğunlukla küçük ve orta ölçekli, ulusal firmalar olduğunu gösterirken; büyük ve uluslararası firmaların dijital teknolojilere daha fazla yatırım yaptığı ve Lojistik 4.0 konusunda daha bilinçli olduğu saptanmıştır. Gösterim etkisi gözlemlenmemiştir, buna neden olarak Lojistik 4.0 teknolojilerinin yüksek maliyetleri gösterilmiştir. İşletmeler, yeni iş modelleri, hızlı yanıt, verimlilik gibi stratejik ve operasyonel fırsatların uygulamaya geçişte güçlü bir motivasyon kaynağı olduğunu belirtmiştir. Ancak, yüksek yatırım maliyetleri, güvenlik endişeleri, kalifiye personel eksikliği ve çalışan direnci gibi zorluklar benimsemeyi olumsuz yönde etkilemektedir. İstatistiksel analizler, fırsatların uygulamaları pozitif, zorlukların ise negatif yönde etkilediğini ortaya koymuştur. Ayrıca, işletme faaliyet alanı, çalışan sayısı ve dijital teknoloji kullanım düzeyinin Lojistik 4.0 uygulamalarında anlamlı farklar yarattığı belirlenmiştir. Sonuç olarak, Lojistik 4.0'ın verimlilik ve rekabetçilik potansiyeline rağmen, Türk lojistik sektöründe, özellikle küçük işletmeler arasında, önemli benimseme engelleriyle karşılaştığı sonucuna varılmıştır.

Bu makaleye atıfta bulunmak için:
Dündar, A.O., & Kanduza, B.S. (2025). Identifying Opportunities and Challenges Affecting Logistics 4.0: A Research in Ankara Logistics Base. *Necmettin Erbakan Üniversitesi Siyasal Bilgiler Fakültesi Dergisi, 7*(2), 254-272.
DOI: 10.51124/jneusbf.2025.117

***Sorumlu Yazar:** Abdullah Oktay DÜNDAR, aodundar@*erbakan.edu.tr*

INTRODUCTION

Logistics is an important field of activity that continuously follows technological, social, and industrial changes (Radivojević & Milosavljević, 2019). Technological advances in recent years, new customer requirements brought about by industrial revolutions, complex logistics networks, and growing and uncertain logistics markets have necessitated that businesses produce new methods, services, and products (Wang, 2016).

The innovations brought about by Industry 4.0 have significantly affected logistics and created the concept of Logistics 4.0. Logistics 4.0 is not only about improving efficiency, responding faster to customer demands, better traceability, and sustainability, but also about integrating advanced technology to transform supply chains. It also affects the core elements of businesses. In summary, Logistics 4.0 offers businesses the opportunity to change their business models (Strandhagen et al., 2017).

The aim of this study is to examine the opportunities and challenges affecting Logistics 4.0 practices. In Turkey, there are insufficient studies examining Logistics 4.0 opportunities and challenges in the context of sustainability for enterprises operating in logistics centers. However, there is no study that examines whether there is a technology demonstration effect between large and small enterprises working very closely in a logistics zone. The study was conducted in 209 logistics enterprises operating in Ankara Logistics Base, and it aimed to provide a roadmap for logistics enterprises to determine their strengths and weaknesses by evaluating the opportunities and challenges in the process of transition to logistics 4.0.

CONCEPTUAL FRAMEWORK

Logistics 4.0 is the application of Industry 4.0 technologies in the logistics sector and shares the same principles. Since process efficiency is important in logistics, Logistics 4.0 applications focus on enhancing performance (Horenberg, 2017). The aim of Industry 4.0 is to develop industrial networks and systems that can be controlled within an organizational and technical framework while adapting to changing conditions in an effective, efficient and flexible manner. The aim is to create interconnected complex distributed systems that enable the continuous exchange of information between people and things. In this context, logistics is at the heart of these developments, and the realization of Industry 4.0 is almost impossible to imagine without Logistics 4.0. Logistics 4.0 is the driving force and foundation of Industry 4.0 (Delfmann et al., 2018).

The main topics of interest in Logistics 4.0 are big data and mining, cyber physical systems, Internet of Things, and services. Data mining must be managed properly, taking into account the speed of computation and the volume of data. Cyber-physical systems integrate the physical and digital world using sensors. The internet of things enables users and systems to interact, while the internet of services includes business models, services, and users provided by multiple providers. Important components of Logistics 4.0 include smart services that provide pricing, measurement, and information services, and smart products that help control processes and communicate (Göçmen and Erol, 2018).

Driven mainly by the Internet of things and services, and big data, Logistics 4.0 aims to achieve standardization and labour savings in supply chain management (Wang, 2016). Logistics activities such as transportation, handling, information flow, and inventory management, are affected by Logistics 4.0. The technologies brought by Logistics 4.0 can provide a range of advantages for businesses. These are; finding the optimal route, vehicle, facility and product locations required for product and material transportation with real-time big data analytics, reducing the need for on-site, fast, and on-demand production storage, ensuring control of decision-making and monitoring systems on inventory is provided by autonomous vehicles and robots in warehouses, realizing the information flow without

disruption with cloud-supported networks and smart products, and finally, eliminating logistics boundaries and reducing the whiplash effect with real-time information exchange between actors (Strandhagen et al., 2017).

Logistics 4.0, which serves Industry 4.0, is characterized by chain traceability, resource and time optimization, data integrity and security, digital systems, and interoperability among various stakeholders. Logistics 4.0 helps increase cooperation between supply chain agents, improves visibility and traceability of the entire logistics chain, enables real-time management of cargo flow, and facilitates the use of technological resources. The technological innovations that come with Logistics 4.0 enhance knowledge-based logistics services, integrating systems and services to optimize and manage changes in existing infrastructure or demand in real time. This reduces transit times and costs and improves the customer delivery experience (Barleta et al., 2019).

Digitalization, which radically changes opportunities and market expectations in logistics, is crucial. Advancements in logistics technologies, the diversification of products, the growing need for globalization, and the management of interconnected networks contribute to the increasing complexity of logistics systems. Addressing this complexity necessitates ensuring system transparency, which can only be achieved through the implementation of optimized, automated, and intricate processes. At this point, the technologies provided by Logistics 4.0 facilitate the business processes of enterprises and provide various benefits. IoT enables greater access to the operational parameters of logistics activities in production and service areas. It manages data sets and strengthens customer-controlled activities in logistics services. Logistics 4.0 provides partners with flexible and large-scale access to information through bidirectional and integrated connections. The advancements brought forth by the Industry 4.0 revolution have profoundly shaped the design, planning, and management of internal logistics processes, enabling companies to monitor customer demands and purchase orders in real time. The business can meet demand by planning its resources and capacity in the steps of receiving, storing, and producing the products to be delivered. The transparency and digitalization provided by Logistics 4.0 in production processes ensure that the necessary raw materials and subassemblies are obtained based on the forecast and production plan prepared for procurement. Thanks to the up-to-date plans and production information provided by real-time data, it is possible to the quantity and location of raw materials, thereby enhancing the performance of the supply logistics system (Skapinyecz et al., 2018).

Technological logistics systems using e-commerce and internet applications support physical procurement activities and provide significant cost savings. Businesses conduct their activities related to physical supply sources through developments and innovations in information technology and provide three simple management principles: anticipation, speed, and flexibility. Logistics 4.0 technologies are different from traditional logistics management tools. It facilitates strategic cooperation between businesses as well as the expansion of physical supply sources. In this way, businesses utilize their resources to provide strategic advantages in areas such as communication, stock, production, and transportation (Bardakçi, 2020).

It is possible to list the opportunities that businesses that benefit from Logistics 4.0 will gain as follows (Karadoğan, 2019);

• Thanks to advanced digital technologies, an effective communication network structure will be able to be established in real time between humans and machines,

• Digital infrastructure and superior technology will improve customer service quality,

• Contribute to radically changing the nature, structure and outlook of national and global trade, logistics and supply chains,

• Help national and global markets become more dynamic, competitive and volatile,

• Help the continuous evolution of logistics and supply chain interests and capabilities,

• Rapidly change customer and market needs and expectations,

• Contribute to the development and growth of national and global trade,

• It will help create a dynamic and efficient structure in the digital world,

• Optimize and integrate assets in inbound and outbound logistics,

• Make all supply chain and logistics processes, actors and stages more efficient, transparent, agile and smart,

• Reshaping sellers, buyers and third parties,

• Provide best practices for operations and transportation.

While Logistics 4.0 continues to advance, its adoption remains a complex and challenging process for many organizations. Consequently, businesses are actively seeking decision support systems to facilitate the integration of Logistics 4.0 into their operations. A critical factor in the successful implementation of Logistics 4.0 is the unwavering support and commitment of top management, which must be demonstrated both financially and strategically. Additionally, the establishment of a robust technological infrastructure is a fundamental prerequisite for the effective adoption of Logistics 4.0. The development of such infrastructure can be accelerated through collaborative efforts between the public and private sectors. In this regard, it is essential for governments to be prepared to invest in enhancing technological capabilities to support this transition (Khan et al., 2022).

The challenges affecting the implementation of Logistics 4.0 are listed by Ilin et al. (2019) as follows:

• Lack of standards and data security: In the complex and fragmented logistics industry necessitates that companies need to continuously share data to optimize logistics processes.

• Collecting, processing, and storing data: The ongoing growth in the volume of both structured and unstructured data has intensified the demand for diverse approaches to data storage and processing.

• Lack of digital strategy: Data along the supply chain needs to be vertically and horizontally integrated and available to all parties involved.

According to Bamberger et al. (2017), logistics service providers encounter significant challenges in adopting Logistics 4.0. These challenges include a reluctance among businesses to embrace new business models, difficulties in integrating new technologies with legacy systems, constraints on making new investments due to cash flow and capital requirements, the absence of structured innovation processes, a lack of openness to external ecosystems, and challenges in managing financial risks and uncertainties associated with technological transitions.

Technological innovations and new business models brought by Logistics 4.0 have the potential to affect the social, environmental, and economic dimensions of sustainability. The impact on one dimension of sustainability may also affect other dimensions. Therefore, the impact on each dimension should not be evaluated in isolation. For example, creating value from waste not only reduces the environmental impact of the industry but also affects the economy. Logistics 4.0 has some positive impacts on sustainability. From the social aspect of sustainability, this model enables the collaborative consumption of goods and services through service delivery, technology, and sharing schemes. This affects the environmental and economic aspects of sustainability in general. Servitization reduces the environmental impact and waste generation of industrial activities. This is because energy efficiency is

directly linked to resource and material efficiency. Logistics 4.0 technologies such as real-time big data, cyber physical systems, and smart processes can support choice regulation, which involves removing processes that harm the environment and eliminating products that are not safe for consumption. In addition, businesses and society should be encouraged not to dispose of products before their end-of-life and to focus on sustainable production and consumption practices. From an economic perspective, Logistics 4.0 technologies offer businesses increased opportunities in secondary markets by enabling recycling, remanufacturing, and the reuse of products or services, thereby facilitating value generation from waste (Strandhagen et al., 2017).

LITERATURE REVIEW

Horenberg (2017) investigated the implementation of Industry 4.0 technologies by third-party logistics (3PL) service providers. The study revealed that 3PL providers actively contribute to distribution and warehousing operations through the utilization of 3D printing, drones, and autonomous vehicles.

Strandhagen et al. (2017) explored the influence of the production environment on the applicability of Industry 4.0 technologies. Utilizing multiple case studies involving four Norwegian manufacturing firms, the research demonstrates that the implementation of Industry 4.0 in production logistics is closely tied to the production environment. The findings indicate that while enterprises with low production volumes perceive limited potential in Industry 4.0 applications, those with high production volumes identify significantly greater potential.

Keskinkılıç et al. (2018) aimed to measure the perceptions of authorized persons from the regional directorates and agencies of logistics and cargo companies operating in Erzurum, Turkey, towards Logistics 4.0 technologies. Semi-structured interviews were conducted with 6 managers. The study concluded that the regional directorates' ability to strategically evaluate the information technologies is weak. Managers are unaware of the strategies determined by the logistics enterprises. IT personnel may be inadequate in the face of unexpected problems, and supervision is centralized.

Öztemel and Gürsev (2018) examined the perceptions of airline and railway companies holding L1 and L2 service certificates in Turkey regarding the impact of Industry 4.0 on logistics. The study revealed that Industry 4.0 is often misunderstood within the logistics sector.

Saatçioğlu et al. (2018) aimed to examine the transformation to Industry 4.0 in the logistics sector. In this context, they conducted a case study with a company that actively uses Logistics 4.0 implementations in Turkey. It was determined that the company actively uses technologies such as big data, the internet of things, sensors, automation, and smart robots, and that the implementation objectives of Logistics 4.0 in the projects carried out by the company are to reduce environmental damage and costs and to increase traceability.

Karagöz and Doyduk (2019) aimed to determine the perspectives and implementation levels of logistics service providers in Turkey towards Logistics 4.0. The study was conducted using in-depth interviews with 10 companies. It was determined that the enterprises participating in the study used Logistics 4.0 intensively in storage and transportation. It was concluded that employees initially had difficulty accepting Logistics 4.0 implementations, but then they were satisfied with the process. Using SWOT analysis, enterprises identified the strengths, weaknesses, opportunities, and threats of Logistics 4.0. Businesses reported the advantages of Logistics 4.0 as increased service quality in terms of customer, cargo and vehicle tracking, and customer relationship management. They listed the integration gap, information security and high investment costs as disadvantages.

Seyhan (2019) tried to determine how Industry 4.0 can be adapted to the logistics sector, what employees' perspectives are on Logistics 4.0 investments, what benefits it will provide to businesses, what employees' expectations are from Logistics 4.0, what they perceive as threats, and whether there is a difference in their opinions according to demographic variables. As a result of the study conducted on 103 employees working in foreign trade and logistics companies in Turkey, it was concluded that, compared to women, men do not see the risks in Logistics 4.0 investments as insurmountable. It has been observed that employees who have a positive approach to Logistics 4.0 investments argue that the risks can be overcome, while employees who have a negative approach to investments have a low tolerance level for the risks brought by Logistics 4.0.

Marko and Vitliemov (2020) investigated the potential of implementing Supply Chain 4.0 and Logistics 4.0 in automotive factories in Bulgaria. The study reported that blockchain technologies and internet-based assembly lines are of great importance for supply chain and logistics, but inaccurate data and cybersecurity are the main challenges for implementation.

Bag et al. (2020) conducted an empirical study to examine the influence of Logistics 4.0 technologies on organizational performance. In the study conducted with 230 automotive spare parts manufacturers in South Africa, it was reported that environmental, organizational, and technological capabilities have a significant impact on Logistics 4.0 implementations. It was also observed that environmental and technological capabilities have a stronger impact on Logistics 4.0 than organizational capabilities. The study emphasizes the importance of aligning sustainability goals with Logistics 4.0 strategies.

Nantee and Sureeyatanapas (2021) investigated the effects of Logistics 4.0 implementations, particularly automated warehousing systems, on the social, environmental, and economic aspects of firms' sustainability performance. The study proposed a new framework for assessing sustainability in automated warehousing applications. In the study, it was concluded that new technologies may have both positive and negative effects on business performance. Businesses should understand and adapt to the advantages and disadvantages of Logistics 4.0 and conduct comprehensive performance evaluations for a successful transition.

Alkış et al. (2020) conducted in-depth interviews, observations and document reviews with senior and mid-level managers of logistics companies using Industry 4.0. Kappa analysis was used to ensure the reliability of the data. The results show that the purposes of using Industry 4.0 are to save labor, reduce costs, use warehouse capacity effectively, and increase operational efficiency. The study concluded that only enterprises with high budgets can implement Industry 4.0 solutions in the logistics sector.

Woschank and Dallasega (2021) conducted a pilot study to explore the association between Logistics 4.0 technologies and the logistics performance metrics of manufacturing firms operating in Central Europe. The study reported that lean and smart supply chains have a significant impact on logistics performance indicators, and Logistics 4.0 implementations such as information communication technologies and autonomous systems are widely used in manufacturing enterprises.

Jagtap et al. (2020) identified critical technologies within the framework of Food Logistics 4.0, highlighting the associated opportunities and challenges. Technologies such as big data, robotics, automation, and the Internet of Things were emphasized as pivotal in enhancing the efficiency and effectiveness of food logistics operations. The study offers valuable insights for stakeholders in the food supply chain regarding Industry 4.0 technologies, emphasizing their potential to facilitate knowledge transfer and drive innovative solutions. These technologies aim to support the development of a more sustainable food supply chain by minimizing environmental impacts while maximizing overall benefits.

Ferraro et al. (2023) proposed a methodology for selecting the best technology for transportation activities, taking into account sustainable development goals, and tested it in three enterprises to demonstrate its applicability. In the study, it was observed that each enterprise focused on a different dimension of sustainability, with additive manufacturing and collaborative robots reported as the most suitable options for achieving sustainable development goals.

METHODOLOGY

The Aim of the Study

This quantitative research examines the perspectives of logistics firms operating within Ankara Logistics Base, Turkey's first privately established logistics center, on the implementation of Logistics 4.0. Additionally, it explores the opportunities and challenges influencing these implementations. The collected data were analysed using SPSS 27.0 software.

Research Population and Sample

The research population consists of logistics enterprises operating at national and international levels within the Ankara Logistics Base. There are 400 logistics enterprises operating in Ankara Logistics Base. Since the population subject to the research was not very large and it was thought that all companies could be reached, they were included in the sample. However, since some companies did not want to share information and participate in the survey due to company policies, a survey was conducted with 209 willing companies.

Data Collection

Before starting the survey, all participants were verbally informed about Logistics 4.0. The demographic section of the research consists of questions that have been adapted to the subject of the study by examining similar studies in the literature. In the study, the Industry 4.0 opportunities, challenges, and implementation scales developed by Müller et al. (2018) were adapted into Turkish and the statements were reorganized to be appropriate for the 'Logistics 4.0' context. The scale statements were evaluated by three experts in the field of logistics to ensure their suitability for the research purpose. Based on expert feedback, the necessary adjustments were made to the scale statements to finalize them. The opportunities scale has three sub-dimensions and includes three statements in the "Strategy" dimension, ten statements in the "Operations" dimension, and three statements in the "Environment and People" dimension. The Challenges scale consists of three sub-dimensions and includes seven statements in the "Competitiveness and Future Viability" dimension, three statements in the "Organizational and Production Suitability" dimension, and five statements in the "Employee Qualifications and Acceptance" dimension. There are three statements in the applicability scale. Cronbach's Alpha values are presented in Table 1.

According to Nunnally (1978), when the Cronbach Alpha value is 0.70 and above, the scale is considered reliable. Since Cronbach's Alpha value is sensitive to the number of questions in the scale or factor, a value of 0.60 and above can be considered an acceptable limit when the number of questions is small (Çinko et al. 2006). In this sense, the reliability of all scales and sub-dimensions used in the data collection tool was found to be at an acceptable level.

Table 1

Cronbach's alpha values

Scales	Number of Statements	Cronbach's Alpha
OPPORTUNITIES		**.849**
Strategy (Str.)	3	**.706**
Operasyonlar (Ope.)	10	**.779**
Environment and People (Env.)	3	**.658**
CHALLENGES		**.785**
Competitiveness and Future Viability (Com.)	7	**.670**
Organizational and Production Fit (Org.)	4	**.718**
Employee Qualifications and Acceptance (Emp.)	5	**.603**
IMPLEMENTATION (Imp.)	3	**.764**

Hypotheses

In accordance with the research questions, the hypotheses were determined as follows.

H_1: The perspectives of enterprises on Logistics 4.0 implementations differ according to their fields of activity.

H_2: The perspectives of enterprises on Logistics 4.0 implementations differ according to the number of employees.

H_3: The perspectives of enterprises on Logistics 4.0 implementations differ according to their rate of use of digital technologies.

H_4: The opportunities of Logistics 4.0 have a positive impact on logistics enterprises' implementation of Logistics 4.0.

H_{4a}: The strategic opportunities of Logistics 4.0 have a positive impact on logistics enterprises' implementation of Logistics 4.0.

H_{4b}: The operational opportunities of Logistics 4.0 have a positive impact on logistics enterprises' propensity to implement Logistics 4.0.

H_{4c}: The environmental and social opportunities of Logistics 4.0 have a positive impact on the propensity of logistics enterprises to implement Logistics 4.0.

H_5: The challenges of Logistics 4.0 negatively affect the propensity of logistics enterprises to implement Logistics 4.0.

H_{5a}: The challenges of Logistics 4.0 related to competitiveness and future viability negatively affect the propensity of logistics enterprises to implement Logistics 4.0.

H_{5b}: The organizational and production adaptation challenges of Logistics 4.0 negatively affect logistics enterprises' propensity to implement Logistics 4.0.

H_{5c}: The challenges of Logistics 4.0 related to the acceptance and qualification of employees negatively affect the propensity of logistics enterprises to implement Logistics 4.0.

Conformity Test for Normal Distribution

To determine whether the data were normally distributed, the skewness and kurtosis coefficients of the relevant variables were examined, and these coefficients are presented in Table 2. The skewness and kurtosis values indicated that the data followed a normal distribution. Skewness and kurtosis values of the variables with ranges of +1.5 to -1.5 (Tabachnick & Fidell, 2013) and +2.0 to -2.0 (George &

Mallery, 2011) indicate a normal distribution.

Table 2

Conformity tests for normal distribution

	Scales	Skewness		Kurtosis	
Opportunities	Str.	-.816	**-.775**	-.083	**.050**
	Ope.	-.601		-.056	
	Env.	-.717		-.034	
Challenges	Com.	-.048	**.203**	-.265	**-.230**
	Org.	.402		-.577	
	Emp.	.137		.144	
Implementations		**-.367**		**-.039**	

RESULTS

Demographic Results

The distribution of the enterprises responding to the questionnaire according to their fields of activity is presented in Table 3 below

Table 3

Distribution of enterprises according to their fields of activity

Fields of Activity	Frequency	Percentage
National Logistics	154	73.7
International Logistics	20	9.6
National / International Logistics	35	16.7
Total	**209**	**100.0**

When the distribution of the enterprises responding to the questionnaire according to their field of activity is analysed, it is determined that 73.7% (154 enterprises) operate nationally, 9.6% (20 enterprises) operate internationally, and 16.7% (35 enterprises) operate both nationally and internationally.

The distribution of enterprises based on their number of employees is presented in Table 4 below.

Table 4

Distribution of enterprises based on their number of employees

Number of Employees	Frequency	Percentage
0 to 9 people	16	7.7
10 to 49 people	151	72.2
50 to 249 people	34	16.3
250 and more people	8	3.8
Total	**209**	**100.0**

When the distribution of enterprises based on their number of employees is analysed, it is seen that 72.2% (151 enterprises) employ 10-49 people, and 16.3% (34 enterprises) employ 50-249 people.

The distribution of enterprises based on sectors they serve is presented in Table 5. Since logistics enterprises serve more than one sector, multiple choices were allowed in this question. Examining the distribution of enterprises by the sectors they serve reveals that 79.4% serve the construction sector, 73.7% the machinery sector, 53.1% the automotive sector, 45.9% the food sector, 37.8% the textile sector, and 44% other sectors.

Table 5

Distribution of enterprises based on sectors they serve

Sector Served	Frequency	Percentage
Textile	79	37.8
Automotive	111	53.1
Food	96	45.9
Construction	166	79.4
Machine	154	73.7
Others	92	44.0
Total	698	334.0

* The sum of the percentages is more than 100% since multiple choices were allowed in the survey.

The distribution according to the rate of use of digital technologies in enterprises is presented in Table 6. The data on technology usage is based on the participants' own statements.

Table 6

Distribution according to the rate of use of digital technologies in enterprises

Rate of Digital Technology Use	Frequency	Percentage
Very advanced (90-100%)	10	4.8
Advanced (75-90%)	41	19.6
Medium (50-75%)	115	55.0
Weak (25-50%)	35	16.7
Very weak (1-25%)	8	3.8
Total	**209**	**100.0**

Of the enterprises that responded to the survey, 55% stated that they use digital technology at a medium level, 19.6% at an advanced level, 4.8% at a very advanced level, and 20.5% at a weak or very weak level.

Results of Factor Analysis and Descriptive Statistics of the Scales

Kaiser-Meyer-Olkin (KMO) and Bartlett's tests were conducted to test the construct validity of the scales. As the statements in the Challenges Scale were negative, reverse coding was used to analyse them. According to Field (2000), a data set is suitable for factor analysis if the KMO value is greater than 0.50. This indicates that the sample size is sufficient for factor analysis. Additionally, Bartlett's Sphericity Test must be significant ($p < 0.05$). This indicates that there is sufficient correlation between the variables to perform factor analysis. The results of the KMO and Bartlett tests are shown in Table 7.

Tablo 7

KMO and Bartlett Tests Results of the Scales

		Opportunities			Challenges			Imp.
		Str.	**Ope.**	**Env.**	**Com.**	**Org.**	**Emp.**	**Imp.**
KMO Measure of Sampling Adequacy.		.657	.747	.626	.753	.751	.620	.700
Bartlett Sphericity Test	Approx. Chi-Square	123.636	465.979	92.987	319.474	153.763	72.496	173.374
	df	3	45	3	21	6	10	3
	Sig.	.000	.000	.000	.000	.000	.000	.000

According to the results of the analysis, the KMO value for all scales was greater than 0.50 (KMO>0.50) and the p-value for the Bartlett's Sphericity Test was less than 0.05 (p<0.05). These results

demonstrate that the dataset contained sufficient sample adequacy for factorisation and meaningful correlations for factor analysis.

Factor analysis was applied to determine the loading levels of the scale items on the relevant factors, thereby establishing construct validity. When interpreting these results, we used the criterion proposed by Tabachnick and Fidell (2007) as a basis, which states that an item's factor loading should be at least 0.32. The results of the factor analysis and the descriptive statistics for the examined scales are presented in detail in Table 8.

Table 8

Findings on descriptive statistics of the scales (n=209)

FACTORS AFFECTING LOGISTICS 4.0 IMPLEMENTATIONS	Factor Load	Mean	Std. Deviation
STRATEGY		**4.1691**	**.63978**
Logistics 4.0 allows us to create new business models.	.748	4.41	.715
Logistics 4.0 enables us to create leading solutions for our customers.	.843	4.27	.739
Logistics 4.0 enables us to create solutions that are hard to imitate.	.802	3.83	.945
OPERATIONS		**3.9986**	**.48333**
Logistics 4.0 enables cost reductions through interconnection.	.567	3.59	.997
Logistics 4.0 allows for increased quality.	.566	4.36	.652
Logistics 4.0 enables greater traceability.	.552	4.47	.597
Logistics 4.0 reduces non-value-added activities.	.637	3.79	.904
Logistics 4.0 enables lower inventory levels.	.702	3.84	.965
Logistics 4.0 enables reduced documentation processes and more efficient management.	.614	3.85	.902
Logistics 4.0 enables increased production flexibility.	.578	3.79	.906
Logistics 4.0 provides increased speed and reactive capabilities.	.626	3.80	.846
Logistics 4.0 enables improved load balancing.	.494	4.03	.805
Logistics 4.0 enables the intelligent use of machine data.	.439	4.45	.686
ENVIRONMENT AND PEOPLE		**3.9219**	**.80977**
Logistics 4.0 enables age-appropriate working environments.	.761	3.62	1.072
Logistics 4.0 enables a reduction in monotonous and repetitive work.	.832	3.95	1.050
Logistics 4.0 reduces waste and environmental impact.	.717	4.19	1.029
COMPETITIVENESS AND FUTURE VIABILITY		**2.9788**	**.62916**
Logistics 4.0 renders our enterprise dependent upon other enterprises.	.679	2.90	1.081
Logistics 4.0 makes our enterprise replaceable due to standardization.	.807	3.14	1.069
Logistics 4.0 causes us to lose the value of direct customer contact.	.745	3.11	1.226
Logistics 4.0 makes our enterprise replaceable due to open-source software.	.636	3.04	.935
Logistics 4.0 will cause us to lose the market niche that has enabled our success.	.560	2.07	1.047
Logistics 4.0 requires high-cost solutions, resulting in a loss of flexibility.	.600	2.86	1.191
Logistics 4.0 makes our enterprise more usable by increasing our transparency.	.748	3.73	1.032
ORGANIZATIONAL AND PRODUCTION FIT		**2.3828**	**.80414**
Implementing Logistics 4.0 is not feasible for our enterprise.	.787	2.24	1.000
It is not possible to implement Logistics 4.0 because customer	.684	2.35	1.013

demands have their own characteristics.			
Our enterprise has insufficient standardization for implementing Logistics 4.0.	.750	2.76	1.256
For our enterprise, the costs outweigh the benefits of Logistics 4.0.	.731	2.18	1.081
EMPLOYEE QUALIFICATIONS AND ACCEPTANCE		**2.7895**	**.58349**
Our employees do not trust Logistics 4.0 technologies.	.705	2.17	.940
Our employees fear dependency on Logistics 4.0 technologies.	.680	2.66	1.050
We anticipate, that our employees may not fully embrace Logistics 4.0.	.670	2.18	1.057
We are aware that our employees currently lack Logistics 4.0 expertise.	.499	4.05	.979
Our employees fear the data transparency that Logistics 4.0 will bring.	.597	2.89	1.014
IMPLEMENTATION		**3.7289**	**.73443**
Our suppliers think that Logistics 4.0 important to implement.	.832	3.20	.988
Our enterprise think that Logistics 4.0 important to implement.	.670	4.37	.639
Our customers think that Logistics 4.0 important to implement.	.726	3.62	.999

The factor loadings for all the variables range from 0.439 to 0.843. All loadings exceed the accepted lower limit of 0.32. This suggests that all items effectively represent their respective factors, thereby contributing to construct validity.

When the data in Table 8, are analysed, it is seen that enterprises strongly agree that Logistics 4.0 provides significant opportunities in developing new business models, offering innovative solutions to customers, ensuring traceability in logistics processes, increasing quality by using data more intelligently, and reducing waste and environmental impacts. Enterprises agreed moderately with the statements that Logistics 4.0 poses threats in terms of market loss due to process transparency and standardization, and negativities in creating customer value as a result of reduced customer contact; and moderately with the statements that it poses threats in terms of insufficient employee qualifications.

Relationship Between Scale Statements

A correlation analysis was conducted to examine the relationship between logistics implementations and the scale statements, with the results summarized in Table 9 below. In the table, the relationship between logistics implementations and the factors affecting logistics implementations is analysed by correlation analysis. The analysis revealed a moderate positive correlation between logistics implementations and strategy ($r = 0.557$, $p < 0.05$), as well as between logistics implementations and operations ($r = 0.560$, $p < 0.05$). Additionally, a weak positive correlation was identified between logistics implementations and the environment and people ($r = 0.374$, $p < 0.05$).

Table 9

Relationship between Scale Statements

Scales	Str.	Ope.	Env.	Com.	Org.	Emp.	Imp.
Str.							
Ope.	.533						
Env.	.449	.552					
Com.	-.448	-.221	-.240				
Org.	-.584	-.474	-.434	.513			
Emp.	-.415	-.431	-.294	.341	.376		
Imp.	.557	.560	.374	-.370	-.633	-.474	

Conversely, the results indicated a weak negative correlation between logistics implementations

and competitiveness and future viability ($r = -0.370$, $p < 0.05$), a moderate negative correlation with organizational and production suitability ($r = -0.633$, $p < 0.05$), and a weak negative correlation with employee qualifications and acceptance ($r = -0.474$, $p < 0.05$).

Results on the Hypotheses

The hypotheses established with the help of parametric or nonparametric statistical tests were analysed based on whether the averages of the scale expressions in the research show normal distribution or not.

H_1 analysis revealed a statistically significant difference in Logistics 4.0 implementations across the various fields of activity of the enterprises ($F = 40.060$; $p < 0.001$). To identify the source of this disparity, a post hoc analysis was conducted, which confirmed that the variances were homogeneous. The Tukey test results indicated that the difference was predominantly in favour of National-International logistics ($\bar{X}= 4.419$). In light of these findings, hypothesis **H_1** is supported and accepted.

H_2 results indicated a statistically significant difference in Logistics 4.0 implementations based on the number of employees within the enterprises ($F = 29.004$; $p < 0.001$). A post hoc analysis was conducted to identify the source of this difference, and given the homogeneity of variances, the Tukey test revealed that the disparity predominantly favored enterprises with 250 or more employees ($\bar{X}=4.41$). In accordance with these findings, hypothesis **H_2** is accepted.

H_3 analysis revealed a statistically significant difference in Logistics 4.0 implementations based on the rate of digital technology adoption by enterprises ($F = 35.716$; $p < 0.001$). To identify the source of this difference, a post hoc analysis was conducted, which confirmed the homogeneity of variances. The Tukey test results indicated that the disparity was primarily in favour of enterprises with advanced levels of digital technology usage ($\bar{X}=4.43$). In light of these findings, hypothesis **H_3** is supported and accepted.

H_4 results of the analysis revealed that the impact of opportunities on logistics implementations is statistically significant ($F=119.443$; $p<0.001$). The regression equation representing the linear relationship between the variables is expressed as: Logistics Implementations $=0.043+0.918$ (Opportunities). The adjusted R^2 value of 0.363 indicates that approximately 36% of the variance in logistics implementations can be explained by opportunities. Based on these findings, hypothesis **H_4** is supported and accepted

H_{4a} results demonstrated that the effect of strategic opportunities on Logistics 4.0 implementations is statistically significant ($F=93.266$; $p<.001$). The regression equation representing the linear relationship between the variables is formulated as: Logistics Implementations $= 1.062 + 0.640$ (Strategic Opportunities). The adjusted R^2 value of 0.307 indicates that approximately 30% of the variance in logistics implementations can be attributed to strategic opportunities. In light of these findings, hypothesis **H_{4a}** is supported and accepted.

H_{4b} results indicated that the effect of operational opportunities on Logistics 4.0 implementations is statistically significant ($F=94.610$; $p<.001$). The regression equation representing the linear relationship between the variables is expressed as: Logistics 4.0 Implementations $= 0.326 + 0.851$ (Operational Opportunities). The adjusted R^2 value of 0.310 suggests that approximately 31% of the variance in Logistics 4.0 implementations can be explained by operational opportunities. Based on these findings, hypothesis **H_{4b}** is supported and accepted.

H_{4c} results revealed that the effect of environmental and social facilities on Logistics 4.0 implementations is statistically significant ($F=33.619$; $p<.001$). The regression equation representing the linear relationship between the variables is formulated as: Logistics 4.0 Implementations $= 2.399 + 0.339$

(Environmental and Social Facilities). The adjusted R^2 value of 0.136 indicates that approximately 13% of the variance in Logistics 4.0 implementations can be attributed to environmental and social facilities. In light of these findings, hypothesis $\mathbf{H_{4c}}$ is supported and accepted.

$\mathbf{H_5}$ results demonstrated that the effect of challenges on Logistics 4.0 implementations is statistically significant (F=122.536; p<.001). The regression equation representing the linear relationship between the variables is expressed as: Logistics 4.0 Implementations = 6.126 - 0.865 (Challenges). The adjusted R^2 value of 0.369 indicates that approximately 36% of the variance in Logistics 4.0 implementations is negatively associated with challenges. Based on these findings, hypothesis $\mathbf{H_5}$ is supported and accepted.

$\mathbf{H_{5a}}$ results revealed that the effect of competitiveness and future viability on Logistics 4.0 implementations is statistically significant (F=32.878, p<.001). The regression equation representing the linear relationship between the variables is formulated as: Logistics 4.0 Implementations = 5.016 - 0.432 (Competitiveness and Future Viability). The adjusted R^2 value of 0.133 indicates that approximately 13% of the variance in Logistics 4.0 implementations is negatively associated with competitiveness and future viability. In light of these findings, hypothesis $\mathbf{H_{5a}}$ is supported and accepted.

$\mathbf{H_{5b}}$ results indicated that the effect of organizational and production adaptation on Logistics 4.0 implementations is statistically significant (F=138.698, p<.001). The regression equation representing the linear relationship between the variables is expressed as: Logistics 4.0 Implementations = 5.107 - 0.578 (Organizational and Production Adaptation). The adjusted R^2 value of 0.398 suggests that approximately 39% of the variance in Logistics 4.0 implementations is negatively associated with organizational and production adaptation. Based on these findings, hypothesis $\mathbf{H_{5b}}$ is supported and accepted.

$\mathbf{H_{5c}}$ results demonstrated that the effect of employee acceptance and qualifications on Logistics 4.0 implementations is statistically significant (F=60.033, p<.001). The regression equation representing the linear relationship between the variables is formulated as: Logistics 4.0 Implementations = 5.394 - 0.597 (Employee Acceptance and Qualifications). The adjusted R^2 value of 0.221 indicates that approximately 21% of the variance in Logistics 4.0 implementations is negatively associated with employee acceptance and qualifications. In light of these findings, hypothesis $\mathbf{H_{5c}}$ is supported and accepted

DISCUSSION

This study examined the perspectives of logistics companies on Logistics 4.0 technologies in quantitative terms, considering both opportunities and challenges. Data obtained from companies operating at the Ankara Logistics Base revealed a significant correlation between company size (area of operation and number of employees) and opinions regarding Logistics 4.0 applications. The vast majority of participants were found to be relatively small businesses operating at the national level (72.2% had 10–49 employees). While large businesses tended to operate internationally and invest in digital technologies, small businesses were found to allocate fewer resources to such investments. This finding aligns with the common observations of studies such as Khan et al. (2022), which highlight the critical role of top management support and financial investment in the adoption of Logistics 4.0, and Perotti and Santacruz (2022), which emphasize the low level of digital maturity among SMEs. However, it was concluded that the expected technology demonstration effect did not materialize in logistics centers, and that the main reason for this was that the high investment costs of Logistics 4.0 prevented its widespread adoption among small businesses. This specific finding is supported by the observation made by Moeuf et al. (2020) and Müller et al. (2018) that Industry 4.0 technologies are costly for SMEs and access to them is difficult.

The study also found that as the rate of digital technology use increases, businesses' knowledge levels about Logistics 4.0 also rise. This situation parallels the common view in the studies by Khan et al. (2022), which argues that information management and analytical competencies are decisive in application success, and Moeuf et al. (2020), which emphasizes the critical role of data usage, simulation tools, and training.

The strategic, operational, environmental, and social opportunities offered by Logistics 4.0 (such as increased competitive advantage, flexibility, efficiency, new business models, resource savings, and waste reduction) positively encourage the transition to technology. These opportunities align with the strategic, operational, environmental, and social benefits identified in the studies by Perotti and Santacruz (2022) and Müller et al. (2018), which view process optimization, increased flexibility, sustainability, and customer satisfaction as key gains.

However, the challenges posed by Logistics 4.0 are negatively impacting future implementation. According to the study findings, internal challenges include the need for organizational and production adaptation, employee qualifications, and reluctance to adopt technology. External challenges include high investment costs, security issues, data transparency threats, and a lack of qualified personnel. Çalışkan et al. (2025) and Perotti and Santacruz (2022) emphasize financial constraints and high investment costs as the most significant obstacles, supporting this finding. Furthermore, the security concerns, data integration issues, and employee qualifications reported by Çalışkan et al. (2025), the workforce resistance and adaptation issues reported by Khan et al. (2022), and the critical importance of human behavior for technology adaptation reported by Cimini et al. (2020) are consistent with the internal challenges identified in this study.

This study has identified the potential opportunities and challenges of Logistics 4.0. It has also revealed that this relatively new concept has not yet been widely adopted or implemented, particularly by small businesses.

CONCLUSION

Today, the advancement of technology used for logistics activities, evolving customer demands, and growing market structures have introduced new dimensions to logistics. Contemporary production strategies have evolved into multifaceted frameworks that not only fulfill customer demands, but also achieve this with minimal cost, superior quality, and rapid delivery times. This approach reflects a shift from merely addressing customer requirements to optimizing the entire production process to enhance efficiency and competitiveness. The development of technology has affected logistics, as well as many other fields, and the logistics sector has experienced significant progress. Logistics 4.0 is a relatively new concept that encompasses technologies appropriate to today's production vision and has great potential. Logistics 4.0 offers businesses advanced information and solutions. With its digital infrastructure, the entire supply chain process is carried out systematically, minimizing errors and losses. There is significant demand for Logistics 4.0 technologies among enterprises; however, the majority of organizations continue to conduct their logistics operations through conventional methods. This reluctance to transition is primarily due to factors such as high initial investment costs, a shortage of skilled personnel, and an absence of digital culture within these enterprises. Furthermore, many businesses only superficially understand Logistics 4.0 rather than fully integrating it into their operational frameworks.

As a result, Logistics 4.0 represents a new technology and application area. Since there is no consensus among surveyed enterprises on the meaning of the concept, the results obtained are specific to the application area. Since it is unclear whether the surveyed businesses are fully utilizing Logistics 4.0, future research should focus on the results of implementations in enterprises that actively use these

technologies rather than measuring businesses' perspectives. Since the study was conducted with businesses operating in the Ankara Logistics Base, the generalizability of the results is limited. Conducting a study with a larger sample size would contribute to obtaining more generalizable results. Additionally, since most of the surveyed enterprises operate nationally, differences between national and international enterprises could be more clearly observed by conducting a study with a larger sample of international enterprises. Future studies could consider enterprise size. Enterprise size may allow businesses to benefit from technological facilities and qualified personnel. These opportunities could increase the likelihood that more enterprises will implement Logistics 4.0.

Ethical Statement

This study was produced from the master's thesis titled "Lojistik 4.0 Uygulamalarını Etkileyen Fırsatların ve Zorlukların Sürdürülebilirlik Bağlamında Belirlenmesi: Ankara Lojistik Üssü'nde Bir Araştırma", submitted in 2023 under the supervision of Assoc. Prof. Abdullah Oktay Dündar.

Ethics Committee Approval

Ethics Committee Approval dated 03.11.2022 and numbered 2022/86 was obtained from Necmettin Erbakan University Social Sciences and Humanities Scientific Research Ethics Committee.

Financing

The study was not supported financially.

Conflict of Interest

There is no conflict of interest.

REFERENCES

Alkiş, G., Piritini, S., & Ertemel, A. V. (2020). Lojistik sektöründe endüstri 4.0 uygulamalarinin operasyonel verimliliğe etkisi. *Business & Management Studies: An International Journal*, *8*(1), 371-395. https://doi.org/10.15295/bmij.v8i1.1341

Bag, S., Gupta, S., & Luo, Z. (2020). Examining the role of logistics 4.0 enabled dynamic capabilities on firm performance. *The International Journal of Logistics Management*, *31*(3), 607-628. https://doi.org/10.1108/IJLM-11-2019-0311

Bamberger, V., Nansé, F., Schreiber, B., & Zintel, M. (2017). Logistics 4.0 – facing digitalization-driven disruption. Prism, *1*, 38-50. Access address: https://www.adlittle.co.kr/sites/default/files/prism/logistics_section.pdf

Bardakçi, H. (2020). Benefits of digitalization in international. *International Journal of Social Science and Economic Research*, *5*(06), 1476-1489. https://doi.org/10.46609/IJSSER.2020.v05i06.009

Barleta, E. P., Pérez, G., & Sánchez, R. J. (2019). Industry 4.0 and the emergence of logistics 4.0. Access address: https://www.cepal.org/en/publications/45455-industry-40-and-emergence-logistics-40

Caliskan, A., Eryilmaz, S., & Ozturkoglu, Y. (2025). Investigating the effects of barriers and challenges on Logistics 4.0 in the era of evolving digital technology. *Journal of Modelling in Management*, *20*(3), 949-973. https://doi.org/10.1108/JM2-01-2024-0026

Cimini, C., Lagorio, A., Pirola, F., & Pinto, R. (2021). How human factors affect operators' task evolution in Logistics 4.0. *Human Factors and Ergonomics in Manufacturing & Service Industries*, *31*(1), 98-117. https://doi.org/10.1002/hfm.20872

Çinko, M., Sipahi, B., & Yurtkoru, E. S. (2006). *Sosyal bilimlerde spss ile veri analizi*. İstanbul: Beta Yayınları.

Delfmann, W., Hompel, M., Kersten, W., Schmidt, T., & Stölzle, W. (2018). Logistics as a science – central research questions in the era of the fourth industrial revolution. *Logistics Research*, *11*(9), 1-13. https://doi.org/10.23773/2018_9

Ferraro, S., Cantini, A., Leoni, L., & De Carlo, F. (2023). Sustainable logistics 4.0: a study on selecting the best technology for internal material handling. *Sustainability, 15*(9), 7067. https://doi.org/10.3390/su15097067

Field, A. (2000). *Discovering Statisticsusing SPSS for Windows*. New Delhi: Sage Publications.

George, D., & Mallery, P. (2011). *SPSS For Windows Step By Step: A Simple Study Guide And Reference*. Boston: Pearson.

Göçmen, E., & Erol, R. (2018). The transition to industry 4.0 in one of the Turkish logistics company. *International Journal of 3D Printing Technologies and Digital Industry*, *2*(1), 76-85.

Horenberg, D. (2017). Applications within logistics 4.0: a research conducted on the visions of 3PL service providers (Bachelor's thesis) *University of Twente*, Enschede, Netherlands.

Ilin, V., Simić, D., & Saulić, N. (2019). Logistics industry 4.0: challenges and opportunities. *4th Logistics International Conference*, 293-301, Serbia.

Jagtap, S., Bader, F., Garcia-Garcia, G., Trollman, H., Fadiji, T., & Salonitis, K. (2020). Food logistics 4.0: opportunities and challenges. *Logistics, 5*(1), 2. https://doi.org/10.3390/logistics5010002

Karadoğan, D. (2019). Lojistik 4.0: Gelecek Nesil Lojistik Teknik inovasyonları ve en iyi uygulamaları. K. Çetinkaya, P. Demircioğlu , K. Özsoy, & B. Duman (Ed.) *Sanayi 4.0 Teknolojik Alanları ve*

Uygulamaları (s. 457-464). Ankara: Pegem Akademi.

Karagöz, B., & Doyduk, H. B. B. (2020). Lojistik 4.0 uygulamaları ve lojistik firmalarının bakış açısı. *İnsan ve İnsan*, *7*(23), 37-51. https://doi.org/10.29224/insanveinsan.513453

Keskinkılıç, M., Yıldız, İ., & Tüzemen, A. (2018). Lojistik ve kargo kurumlarının lojistik 4.0 açısından değerlendirilmesi: Erzurum ilinde nitel bir uygulama. *IV. Uluslararası Kafkasya-Orta Asya Dış Ticaret ve Lojistik Kongresi*, 799-805, Aydın.

Khan, S., Singh, R., Haleem, A., Dsilva, J., & Ali, S. S. (2022). Exploration of critical success factors of logistics 4.0: a dematel approach. *Logistics, 6*, 1-14. https://doi.org/10.3390/logistics6010013

Khan, S., Singh, R., Sá, J. C., Santos, G., & Ferreira, L. P. (2022). Modelling of determinants of logistics 4.0 adoption: insights from developing countries. *Machines, 10*(12), 1242. https://doi.org/10.3390/machines10121242

Markov, K., & Vitliemov, P. (2020, June). Logistics 4.0 and supply chain 4.0 in the automotive industry. *IOP conference series: materials science and engineering*, *Vol. 878*, No. 1, p. 012047). IOP Publishing. Access address: https://iopscience.iop.org/article/10.1088/1757-899X/878/1/012047/pdf

Moeuf, A., Lamouri, S., Pellerin, R., Tamayo-Giraldo, S., Tobon-Valencia, E., & Eburdy, R. (2020). Identification of critical success factors, risks and opportunities of Industry 4.0 in SMEs. *International Journal of Production Research*, *58*(5), 1384-1400. https://doi.org/10.1080/00207543.2019.1636323

Müller, J. M., Kiel, D., & Voigt, K. I. (2018). What drives the implementation of industry 4.0? the role of opportunities and challenges in the context of sustainability. *Sustainability, 10*(1), 247. https://doi.org/10.3390/su10010247

Nantee, N., & Sureeyatanapas, P. (2021). The impact of logistics 4.0 on corporate sustainability: a performance assessment of automated warehouse operations. *Benchmarking: An International Journal, 28*(10), 2865-2895. https://doi.org/10.1108/BIJ-11-2020-0583

Nunnally, J. C. (1978). *Psychometric theory.* New York: McGraw-Hill.

Öztemel, E., & Gürsev, S. (2018). Türkiye'de lojistik yönetiminde endüstri 4.0 etkileri ve yatırım imkanlarına bakış üzerine anket uygulaması. *Marmara Fen Bilimleri Dergisi, 30*(2), 145-154. https://doi.org/10.7240/marufbd.408560

Perotti, S., Bastidas Santacruz, R. F., Bremer, P., & Beer, J. E. (2022). Logistics 4.0 in warehousing: a conceptual framework of influencing factors, benefits and barriers. *The International Journal of Logistics Management, 33*(5), 193-220. https://doi.org/10.1108/IJLM-02-2022-0068

Radivojević, G., & Milosavljević, L. (2019). The concept of logistics 4.0. *4th Logistics International Conference*, 283-292, Belgrade.

Saatçioğlu, Ö. Y., Kök, T. T., & Özispa, N. (2018). Endüstri 4.0 ve lojistik sektörüne yansımalarının örnek olay kapsamında değerlendirilmesi. *Süleyman Demirel Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi, 23*, 1675-1696.

Seyhan, Ç. (2019). Lojistik 4.0: endüstri 4.0'ın lojistik sektörüne uyarlanması üzerine bir araştırma. (Unpublished Master Thesis) *Marmara University Institute of Social Sciences*, İstanbul.

Skapinyecz, R., Illés , B., & Bányai, Á. (2018). Logistic aspects of industry 4.0. IOP Conf. Series: Materials Science and Engineering, *448*, 1-11. Access address: https://iopscience.iop.org/article/10.1088/1757-899X/448/1/012014/pdf

Strandhagen, J. O., Vallandingham, L. R., Fragapane, G., Strandhagen, J. W., Stangeland, A. B., & Sharma, N. (2017). Logistics 4.0 and emerging sustainable business models. *Advances in Manufacturing, 5*(1), 1-12. https://doi.org/10.1007/s40436-017-0198-1

Strandhagen, J. W., Alfnes, E., Strandhagen, J. O., & Vallandingham, L. R. (2017). The fit of industry 4.0 applications in manufacturing logistics: a multiple case study. *Advances in Manufacturing, 5*, 344-358. https://doi.org/10.1007/s40436-017-0200-y

Tabachnick, B. G., Fidell, L. S., & Ullman, J. B. (2007). *Using multivariate statistics*. Boston: Pearson.

Wang, K. (2016). Logistics 4.0 Solution: New Challenges and Opportunities. *International Workshop of Advanced Manufacturing and Automation* (s. 68-74). UK. Atlantis Press.

Woschank, M., & Dallasega, P. (2021). The impact of logistics 4.0 on performance in manufacturing companies: a pilot study. *Procedia Manufacturing, 55*, 487-491. https://doi.org/10.1016/j.promfg.2021.10.066