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A FIELD STUDY EXAMINING BARRIERS TO LOGISTICS 4.0 USING POLYTOPIC FUZZY RANCOM

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Abstract: *Logistics companies are increasingly focusing more on technological transformation and development to save costs and transition to a more flexible structure, and their business objectives are closely tied with this framework. Changing business processes and technological revolutions force logistics companies to become more adaptive and agile, demanding the creation of organizational procedures in this context. To do this, the technology revolution, also known as logistics 4.0, is gaining popularity in the logistics industry and playing an essential role in cost savings for businesses. Logistics 4.0 applications are one approach for implementing procedures in logistics organizations in an effective and efficient manner. However, logistics 4.0 applications encounter many administrative and operational barriers. In this regard, the study identified and weighted barriers to logistics 4.0 applications in logistics companies with corporate identities. The polytopic fuzzy RANCOM approach was employed for this aim. The study found that "costs of implementing logistics 4.0" and "necessity of implementing process-driven management approaches" are the most significant barriers to implementing logistics 4.0, while "existence of cyber-attack threats" is the least important criterion.*

Keywords: *Logistics, logistics 4.0, MCDA, polytopic fuzzy sets, RANCOM*

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1. Introduction

Changing consumer expectations and demands with the phenomenon of globalization have led to the proliferation of technology-based elements and thus to the differentiation and diversification of the activities to be carried out. So much so that the industrial revolution has been effective on logistics activities at every stage, and logistics processes have been affected

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differently in each industrial revolution. Especially in recent years, the development of logistics innovation applications capabilities and its impact on the logistics sector has intensely affected the logistics sector as it affects all sectors. Because Logistics 4.0 are smart applications that enable real-time communication between people and machines as a result of advanced internet usage (Korucuk, 2019).

In this context, logistics 4.0 as a concept has emerged with the integration of innovations brought by psychological and cyber systems into the logistics sector. The concept is generally related to smart products and smart services, and the technology-oriented approach used to define these elements is called "smart logistics." This concept will increase the flexibility levels of companies, thus enabling them to determine a logistics system that can integrate with the changes in market and customer perceptions. Thus, customer satisfaction will increase, production will be optimized, and it will become easier to minimize production and storage costs. In addition, logistics 4.0 consists of subsystems that are connected to other systems and represents a structure that is constantly interacting to ensure its own success (Timm & Lorig, 2015). This concept is given as the inclusion of smart services as well as smart products in logistics (Stock & Seliger, 2016).

In another definition, the logistics 4.0 process is defined as systems supported by digitalization that meet customer demands and expectations individually and every time, at a sustainable cost (Winkelhaus & Grosse 2020). They also stated that logistics 4.0 changes and transforms technologies connected to traditional logistics and provides automation and various enabling technologies in areas such as transportation, storage, coordination, and communication (Facchini et al., 2019).

At the same time, Logistics 4.0 offers various technological innovations to increase the efficiency of logistics operation processes. Increased human-machine interaction, automation, and digitalization provide benefits such as reduced costs, improved delivery times, reduced accident or risk rates, reduced damage, waste, or product losses (Çimen Atlı et al., 2017). Also, logistics 4.0 relies on the cooperation of all technological foundations in order to achieve the change brought about by global competition and changing customer demands. Digitalization is therefore a process that needs to be carried out carefully. Additive manufacturing/3D printing, augmented reality, big data analytics, blockchain technology, cloud services, collaborative planning, forecasting, and replenishment, drones, electronics, data exchange, e-procurement, enterprise resource planning, global positioning systems and general packet radio services (GPS and GPRS), disruptive technologies such as pick-to-light and pick-by-voice, radio frequency, identification, sales and operations planning, the internet of things, transportation management systems, warehouse management systems, wearable technologies, and digital twin have started to integrate high connectivity and mobile technology capabilities (Mercimek & Geçkil, 2021).

In other words, with Logistics 4.0, the real and virtual world can be fully integrated, communication between systems and users can be easily achieved, overall efficiency in the supply chain can be increased and lead times can be shortened, costs can be reduced by designing products through simulation, the risk of error in all processes can be reduced, data analysis can be done more easily, the life of machines can be made longer and more efficient, autonomous decisions can be made, and flexibility can be achieved by increasing supply chain visibility (Oleśków-Szłapka & Stachowiak, 2019). According to Khan et al. (2022), Logistics 4.0 is still evolving and is a difficult concept to adopt initially. For this reason, businesses are looking for a decision support system to help them in the decision-making process to adopt Logistics 4.0. At this point, in order to implement Logistics 4.0, the support and commitment of the top management should be provided both financially and morally. Another factor necessary for the effective adoption of Logistics 4.0 is the development of a technological infrastructure. This infrastructure can be developed in cooperation with the public and private sectors. At this point, the management should be ready to invest in the development of technological infrastructure (Khan et al., 2022).

In another study, the challenges that businesses face in adopting Logistics 4.0 are: businesses are not willing to adopt new business models; they struggle to combine new technologies with legacy systems; they do not make new investments due to cash and capital requirements; they lack structured innovation processes; they are not open to external ecosystems; and they have difficulty managing financial risk and uncertainty (Bamberger et al., 2017).

However, the obstacles encountered in logistics 4.0 applications in enterprises are important and can have negative effects on business efficiency and performance. In particular, the implementation cost of logistics 4.0 transformation in enterprises is high, requiring the purchase of various hardware and software and the application of process-oriented management methods. In addition, it requires the transfer and implementation of Industry 4.0 technologies and poses problems with the availability of data that is difficult to process. Again, logistics 4.0 and digital transformation have not reached sufficient awareness within the general framework of the sector, and there are obligations for the implementing company to transform all systems and supply chains.

Based on all these issues, the study aims to identify the obstacles encountered in logistics 4.0 applications in logistics enterprises with corporate identity in Istanbul and to rank them. For this purpose, a multi-criteria decision analysis approach will be used. This methodology is based on PFSs and RANCOM. RANCOM is simple to use, repeatable, intuitive, and provides consistent ranking analysis, making it suitable for evaluators and specialists with little or no experience in multi-criteria decision analysis. PFSs can model uncertainty in decision-making problems using positive, negative, and neutral membership degrees. In other words, membership, opposition, and neutral degrees are all considered. Furthermore, PFSs are an extension of spherical fuzzy sets, picture fuzzy sets, and q-rung orthopair fuzzy sets. This study will provide a new RANCOM extension, IVIF-RANCOM, for dealing with unclear information. In this context, a PF-RANCOM technique will be used to effectively express uncertainty to solve the problem in this study.

In the following sections of the study, the literature review on the obstacles encountered in logistics 4.0 / logistics 4.0 applications is presented. In the other section, Polytopic Fuzzy Sets (PFSs), which constitute the method of the study, explanations about RANCOM and the application of the method for Istanbul province are examined. In the last part of the study, conclusions and information about future studies are presented.

2. Literature

Some studies in the national and international literature on logistics 4.0 and the obstacles encountered in logistics 4.0 applications are given below.

Timm and Lorig, (2015) aim to discuss two integrative approaches to simulate decision makers and logistics processes in the context of Logistics 4.0.

Domingo Galindo (2016) assessed the challenges of logistics 4.0 for supply chain management and information technology.

Strandhagen, et al. (2017) addressed the challenges in logistics 4.0 implementation, showing current trends and providing a model to relate it to different elements of business operations.

Özdemir and Özgüner (2018) examined the Industry 4.0 revolution in detail and revealed the innovations that this revolution will bring to the logistics sector.

Cimini et al. (2019) a case study analysis is used to present a Logistics 4.0 implementation in a real industrial context and its implications for human work are discussed.

Bag, et al. (2020) investigated the impact of technological capabilities, organizational capabilities and environmental capabilities on logistics 4.0 capabilities and examined the impact of logistics 4.0 capabilities on firm performance.

Karagöz and Bumin Doyduk (2020) studied the perspectives and implementation levels of logistics 4.0 of enterprises providing logistics services in Turkey.

Göncer Demiral (2021) started from the historical development of Industry 4.0 in the conceptual framework and examined its effects on Logistics 4.0.

Taş and Başaran Algöz (2021) made a literature review by examining the industrial revolutions in order and mentioning the components of logistics 4.0.

Dixit and Verma (2022), identified, assessed and contributed to the measurement of new risks for logistics 4.0

Ceran et al. (2022) defined logistics costs in international strategic marketing decisions and logistics 4.0 applications and analytically measured the impact of logistics costs on the profitability of businesses.

Turğut and Gürsoy (2023) analyzed a total of 127 studies on Logistics 4.0 in the Web of Science database between 2015 and 2022.

Ferraro et al., (2023) made the best technology selection for internal material handling within the framework of sustainable logistics 4.0.

Erdal (2024) examined the use of smart technologies in logistics and supply chain management.

Çimen Atlı et al. (2024) revealed the perception of Logistics 4.0 among logistics companies in Turkey, the stage it is at, the level of awareness on the subject, important issues and success factors.

Nila and Roy (2024) identified the critical success factors in logistics 4.0 applications with multi-criteria decision analysis methods.

In the detailed literature review given above, few studies on the obstacles encountered in logistics 4.0 implementation have been identified. At this point, it is thought that the study will contribute to the literature.

3. Methodology

Multi-criteria decision analysis methods are frequently employed in the formulation and resolution of problems with conflicting criteria. In this context, many methods have been developed for different purposes, including weighting, selection, ranking, and classification. Furthermore, the presence of uncertainty in decision-making problems has resulted in the development of fuzzy sets-based extensions of multi-criteria decision analysis methods. The purpose of this study is to determine the importance of the barriers to logistics 4.0 applications. The Polytopic Fuzzy RANCOM technique will be used to achieve the stated aim. The next subsections will provide explanatory information on Polytopic Fuzzy Sets and the Polytopic Fuzzy RANCOM method.

3.1. Polytopic Fuzzy RANCOM

The polytopic fuzzy set (PTFS) was proposed by Bet et al. (2022). PTFS is a generalization of spherical fuzzy sets (SFSs), picture fuzzy sets (PFSs), and q-rung orthopair fuzzy sets (q-ROFSs) to solve decision-making problems including uncertainty and imprecision (Beg et al., 2022; Korucuk & Aytekin, 2024). In this study, we proposed the PTF-RANCOM to determine criteria weight coefficients.

Let X be a universe of discourse. A PTFS Z of X can be written as $Z = \{\langle x, \alpha_Z(x), \eta_Z(x), \zeta_Z(x) \rangle : x \epsilon X\}$. In this context, $\alpha_Z: X \to [0,1]$ depicts the positive membership degree, $\eta_Z: X \rightarrow [0,1]$ denotes the neutral membership degree, and $\zeta_Z: X \rightarrow [0,1]$ is the negative membership degree of $x \epsilon X$ to PTFS Z, where $0 \leq \alpha_Z(x)^q + \eta_Z(x)^q + \zeta_Z(x)^q \leq 1$ (Bet et al., 2022; Aytekin and Korucuk, 2024). To provide simplicity in this study, $\langle \alpha, \eta, \zeta \rangle$ is called PTF number (PTFN). Assume that $z = \langle \alpha, \eta, \zeta \rangle$, $z_1 = \langle \alpha_1, \eta_1, \zeta_1 \rangle$, $z_2 = \langle \alpha_2, \eta_2, \zeta_2 \rangle$ are three PTFNs, then the basic operators, score function ($\mathcal{S}(z)$), and accuracy function ($\mathcal{A}(z)$), and are stated in Eq.s (1)-(7).

$$z_1 \oplus z_2 = \langle \left(\alpha_1^q + \alpha_2^q - \alpha_1^q \alpha_2^q\right)^{1/q}, \eta_1 \eta_2, \zeta_1 \zeta_2 \rangle \tag{1}$$

$$z_1 \otimes z_2 = \langle \alpha_1 \alpha_2, \eta_1 \eta_2, \left(\zeta_1^q + \zeta_2^q - \zeta_1^q \zeta_2^q\right)^{1/q} \rangle \tag{2}$$

$$z^\lambda = \langle \alpha^\lambda, \eta^\lambda, \left(1 - (1 - \zeta^q)^\lambda\right)^{1/q} \rangle \tag{3}$$

$$z\lambda = \langle \left(1 - (1 - \alpha^q)^\lambda\right)^{1/q}, \eta^\lambda, \zeta^\lambda \rangle \tag{4}$$

$$z^c = \langle \zeta, \eta, \alpha \rangle \tag{5}$$

$$\mathcal{S}(z) = \frac{1 + \alpha^q + \eta^q - \zeta^q}{3} \tag{6}$$

$$\mathcal{A}(z) = \frac{1 + \max(\alpha^q, \eta^q) - \zeta^q}{2} \tag{7}$$

PTF weighted aggregation (PTFWA) operator is given in Eq. (8), where z_i is PTFN for $i = 1, \dots, m$. In Eq. (8), k denotes the weight vector, where $k = 1, \dots, r$.

$$PTFWA(z_1, \dots, z_n) = \langle \left(\left(1 - \prod_{i=1}^{m} \left(1 - \alpha_i^q\right)^{k_i} \right)^{1/q} \right), \prod_{i=1}^{m} \eta_i^{k_i}, \prod_{i=1}^{m} \zeta_i^{k_i} \rangle \tag{8}$$

PTF-RANCOM implementation steps are given below (Więckowski et al., 2023).

Step 1. Criteria and experts (or decision-makers) are determined. $C_1, \dots, C_n$ denotes criteria, while $E_1, \dots, E_r$ shows experts.

Step 2. Experts evaluate the importance level of criteria. For this purpose, the linguistic terms listed in Table 1 are employed (Korucuk & Aytekin, 2024; Aytekin & Korucuk, 2024).

Table 1. Linguistic terms for evaluation of criteria.

		Corresponding PTFNs		
Linguistic Terms	Codes	α	η	ζ
Very Very High Importance	VVH	0.95	0.05	0.05
Very High Importance	VHI	0.85	0.15	0.15
High Importance	HIG	0.7	0.3	0.3
Slightly More Importance	SMI	0.55	0.45	0.45
Moderate Importance	MOI	0.5	0.5	0.5
Slightly Low Importance	SLI	0.45	0.55	0.55
Low Importance	LOI	0.3	0.3	0.7
Very Low Importance	VLI	0.15	0.15	0.85
Very Very Low Importance	VVL	0.05	0.05	0.95

The importance of each criterion is shown by $\iota_{jk} = \langle \alpha_{jk}, \eta_{jk}, \zeta_{jk} \rangle$.

Step 3. The weight coefficients of experts (λ_k) are determined, where $\sum_{k=1}^{r} \lambda_k = 1$, and $0 \leq \lambda_k \leq 1$.

Step 4. The integrated PTF importance values of criteria are obtained via PTFWA operator. Eq. (9) is used for this purpose, where $k = 1, \dots, r$ and $j = 1, \dots, n$.

$$\iota_j = \langle \left(\left(1 - \prod_{k=1}^{r} \left(1 - \alpha_{jk}^{q}\right)^{\lambda_k} \right)^{1/q} \right), \prod_{k=1}^{r} \eta_{jk}^{\lambda_k}, \prod_{k=1}^{r} \zeta_{jk}^{\lambda_k} \rangle \quad (9)$$

Step 5. The crisp value of ι_j is obtained by applying Eq. (6).

Step 6. The ranking order of criteria ($ϟ_j$) is obtained based on $S(\iota_j)$ values. The criterion with the highest score places first in the ranking. At the same time, the criteria are sorted from largest to smallest based on their $S(\iota_j)$ values.

Step 7. The ranking comparison matrix $B = \left[b_{gj}\right]_{n \times n}$ is formed using Eq. (11), where $g, j = 1, \dots, n$.

$$b_{gj} = \begin{cases} 1 & , \ if \ ϟ_g < ϟ_j \\ 0.5 & , \ if \ ϟ_g = ϟ_j \\ 0 & , \ if \ ϟ_g > ϟ_j \end{cases} \quad (10)$$

As seen in Eq. (10), if the ranking order of criterion g equals the ranking order of criterion j, then $b_{gj} = 0.5$

Step 8. The horizontal vector of the summed criteria weights (h_j) is obtained via Eq. (11).

$$h_j = \sum_{g=1}^{n} b_{jg} \quad (11)$$

Step 9. The weight coefficients of criteria are obtained via Eq. (12).

$$w_j = \frac{sc_j}{\sum_{j=1}^{n} sc_j} \quad (13)$$

where $0 \leq w_j \leq 1$ and $\sum_{j=1}^{n} w_j = 1$.

4. Results

This study investigated the barriers that businesses encounter when implementing Logistics 4.0. For this purpose, the PTF-RANCOM method is employed. A list of the barriers is given in Table 2.

Table 2. The list of criteria

Codes	Criteria	Source(s)
C1	Costs of implementing logistics 4.0	Oleśków-Szłapka and Agnieszka Stachowiak, (2019).
C2	Necessity of implementing process-driven management approaches	Korucuk et al.,(2023).
C3	Problems with data usability that are challenging to handle	Erdoğdu (2021).
C4	Insufficient awareness of digital transformation within the sector	Szymańska, et al., (2017).
C5	Challenge of establishing a network of IT service providers and the necessity of continuous communication	Erdoğdu (2021).

C6	Existence of cyber-attack threats	Görçün et al., (2024)
C7	Employees' resistance to transformation	Aytekin et al., (2024).
C8	Difficulty in changing and transforming organizational structures	Aytekin et al., (2023).

Three experts with experience in this area were interviewed in order to find a solution to the studied problem. The experts hold positions as logistics operations managers and warehouse managers. Table 3 presents the linguistic assessments of the experts with respect to the criteria.

Table 3. The linguistic evaluations of criteria

	C1	C2	C3	C4	C5	C6	C7	C8
Expert 1	VVH	VVH	HIG	HIG	VHI	SMI	VHI	HIG
Expert 2	VHI	HIG	HIG	HIG	HIG	SMI	HIG	HIG
Expert 3	HIG	VHI	HIG	VHI	HIG	HIG	HIG	VHI

The integrated PTF importance values of criteria are given in Table 4. Besides, $S(\iota_j)$ and $ϟ_j$ values are presented in Table 4.

Table 4. The integrated PTF importance values

	C1			C2			C3			C4		
	α	H	ζ	α	η	ζ	α	η	ζ	α	η	ζ
ι_j	0.8747	0.1310	0.1310	0.8747	0.1310	0.1310	0.7000	0.3000	0.3000	0.7662	0.2381	0.2381
$S(\iota_j)$	0.5564			0.5564			0.4477			0.4833		
$ϟ_j$	1			1			7			3		
	C5			C6			C7			C8		
	α	H	ζ	α	η	ζ	α	η	ζ	α	η	ζ
ι_j	0.7662	0.2381	0.2381	0.6127	0.3931	0.3931	0.7662	0.2381	0.2381	0.7662	0.2381	0.2381
$S(\iota_j)$	0.4833			0.4100			0.4833			0.4833		
$ϟ_j$	3			8			3			3		

Table 5. The weighting results of PTF-RANCOM

	Ranking Comparison Matrix										
	C1	C2	C3	C4	C5	C6	C7	C8	h_j	w_j	Ranking
C1	0.5000	0.5000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	7.0000	0.2188	1
C2	0.5000	0.5000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	7.0000	0.2188	1
C3	0.0000	0.0000	0.5000	0.0000	0.0000	1.0000	0.0000	0.0000	1.5000	0.0469	7
C4	0.0000	0.0000	1.0000	0.5000	0.5000	1.0000	0.5000	0.5000	4.0000	0.1250	3
C5	0.0000	0.0000	1.0000	0.5000	0.5000	1.0000	0.5000	0.5000	4.0000	0.1250	3
C6	0.0000	0.0000	0.0000	0.0000	0.0000	0.5000	0.0000	0.0000	0.5000	0.0156	8
C7	0.0000	0.0000	1.0000	0.5000	0.5000	1.0000	0.5000	0.5000	4.0000	0.1250	3
C8	0.0000	0.0000	1.0000	0.5000	0.5000	1.0000	0.5000	0.5000	4.0000	0.1250	3

According to findings given in Table 5, the most important criteria are C1 (costs of implementing logistics 4.0) and C2 (necessity of implementing process-driven management approaches). On the other hand, the importance ranking order of the criteria is C1~ C2> C4~ C5~ C7~ C8> C3> C6.

5. Conclusions

One of the ways to ensure customer satisfaction in today's businesses and to get ahead of competitors is through the effective use of technology, i.e. logistics 4.0 applications. Especially logistics 4.0 applications provide added value to businesses and increase productivity. However, logistics 4.0 applications in enterprises cannot be realized at the desired level and face various obstacles and difficulties. This situation causes loss of efficiency and performance especially in logistics enterprises and negatively affects business processes. Therefore, the relevant issue is one of the sensitive issues that logistics business managers should focus on and pushes them to think in this perspective.

In this framework, the study investigated the obstacles encountered in logistics 4.0 applications in logistics enterprises with corporate identity in Istanbul. According to the results of the study, the most important factors regarding the obstacles encountered in logistics 4.0 implementations are "Costs of implementing logistics 4.0", "Necessity of implementing process-driven management approaches", "Insufficient awareness of digital transformation within the sector", Challenge of establishing a network of IT service providers and the necessity of continuous", 'Employees' resistance to transformation" and "Difficulty in changing and transforming organizational structures". The obstacles encountered in logistics 4.0 applications with the least importance level are "Existence of cyber-attack threats" and "Problems with data usability that are challenging to handle", respectively.

The results obtained within the scope of the study bring the cost phenomenon, effective process approach and digital transformation awareness to the forefront. Because the phenomenon of competition, which is a consequence of globalization in enterprises, has made the management and perception level of costs and processes difficult and made service and management systems complex in geographical locations. In order to manage these complex processes, businesses in particular must make extensive use of information, communication and the internet, which are the key components of logistics 4.0. In this way, in addition to increasing productivity, logistics 4.0 will provide competitiveness in all units of enterprises from production to logistics, from finance to human resources.

In addition, the success of logistics 4.0 can actually be possible by ensuring the security of business data and protecting it against attacks. Therefore, it can be considered as another issue that businesses should make more effort to provide a secure technological infrastructure applicable to the success of logistics 4.0.

Also, it is foreseen that logistics 4.0 applications will help the integration of the supply chain, efficient use of information communication infrastructure, real-time collaboration, supply chain quality management and logistics processes integration. In this context, smart logistics processes and activities can be created with augmented reality, big data, simulation, smart objects, 3D printing, cloud computing, vertical and horizontal system integration and autonomous robots, which are the instruments on which the logistics 4.0 concept is based, so it will be possible to make the smart value chain structure applicable at the distribution and production stage.

The results of the study reveal the problems related to logistics 4.0 in logistics enterprises and offer various ideas and strategies to business managers within the framework of technological transformation. At this point, the results of the study can be considered as a road map in eliminating the above-mentioned risks and problems, as well as a guide in filling an important gap. Moreover, the study can be evaluated with other multi-criteria decision analysis approaches or other parametric or non-parametric methods in the future.

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References

Aytekin, A. (2022). Çok kriterli karar analizi. Nobel Bilimsel.

Aytekin, A., Korucuk, S., & Karamaşa, Ç. (2023). The Barriers Related to Smart Manufacturing Systems and an Application for the Selection of Innovation Management Model: The Case of Samsun Province. In Automation and Innovation with Computational Techniques for Futuristic Smart, Safe and Sustainable Manufacturing Processes (pp. 91-110). Cham: Springer International Publishing.

Aytekin, A., Bozkurt, E., Orakçı, E., Uysal, M., Simic, V., Korucuk, S., & Pamucar, D. (2024). A bipolar neutrosophic combined compromise solution-based hybrid model for identifying blockchain application barriers and Benchmarking consensus algorithms. Engineering Applications of Artificial Intelligence, 133, 108343.

Aytekin, A., & Korucuk, S. (2024). Evaluating performance-based logistics in manufacturing through polytopic fuzzy SWARA: A criterion assessment approach. Journal of Engineering Management and Systems Engineering, 3(2), 65-71.

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.

Beg, I., Abbas, M., & Asghar, M. W. (2022). Polytopic fuzzy sets and their applications to multiple-attribute decision-making problems. International Journal of Fuzzy Systems, 24(6), 2969-2981.

Ceran, Y., Ortakarpuz, M., & Erkoçak, H. E. (2022). Uluslararası Stratejik Pazarlama Kararları ve Lojistik 4.0 Bağlamında Lojistik Maliyetler ile Karlılık İlişkisi. Avrupa Bilim Ve Teknoloji Dergisi, (35), 102-110.

Cimini, C., Lagorio, A., Pirola, F., & Pinto, R. (2019). Exploring human factors in Logistics 4.0: Empirical evidence from a case study. Ifac-Papersonline, 52(13), 2183-2188.

Çimen Atlı, E., Eroğlu, F., & Şekkeli, Z. H. (2024). Endüstri 4.0'in Lojistikte Yansimalari: Lojistik 4.0 Uygulamalari Üzerine Bir Örnek Olay İncelemesi. Yönetim Bilimleri Dergisi, 22(Özel Sayı: Endüstri 4.0 ve Dijitalleşmenin Sosyal Bilimlerde Yansımaları), 1753-1781. https://doi.org/10.35408/comuybd.1516467

Domingo Galindo, L. (2016). The challenges of logistics 4.0 for the supply chain management and the information technology (Master's thesis, NTNU).

Dixit, V., & Verma, P. (2022). Identification, assessment, and quantification of new risks for Logistics 4.0. International Journal of Logistics Research and Applications, 27(6), 906–930. https://doi.org/10.1080/13675567.2022.2100331

Erdal, N. (2024). 4.0 Lojistik Ve Tedarik Zinciri Yönetiminde Akıllı Teknolojilerin Kullanımı: Akıllı Eldiven Örneği. The Journal of Academic Social Science, 148(148), 62-77.

Erdoğdu, M. (2021). Development of Logistics Management and Relationship with Industry. International Journal on Engineering, Science and Technology, 3(2), 91-112.

Facchini, F., Oleśków-Szłapka, J., Ranieri, L., & Urbinati, A. (2019). A maturity model for logistics 4.0: An empirical analysis and a roadmap for future research. Sustainability, 12(1), 86.

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.

Gönçer Demiral, D. (2021). Endüstri 4.0'ın Lojistik Boyutu: Lojistik 4.0. IBAD Sosyal Bilimler Dergisi, (9), 231-251.

Görçün, Ö. F., Mishra, A. R., Aytekin, A., Simic, V., & Korucuk, S. (2024). Evaluation of Industry 4.0 strategies for digital transformation in the automotive manufacturing industry using an integrated fuzzy decision-making model. Journal of Manufacturing Systems, 74, 922-948.

Karagöz, B., & Bumin Doyduk, H. B. (2020). Lojistik 4.0 Uygulamaları ve Lojistik Firmalarının Bakış Açısı. İnsan Ve İnsan, 7(23), 37-51. https://doi.org/10.29224/insanveinsan.513453948.

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.

Korucuk, S. (2019). Lojistik .4.0 ve Uygulanabilirliği, Yayın Yeri:Akademisyen Yayınevi, Editör:Selçuk Korucuk, M. Esra Atukalp, Basım sayısı:1, Sayfa sayısı:184,, Bölüm Sayfaları:1 -19.

Korucuk, S., Tirkolaee, E. B., Aytekin, A., Karabasevic, D., & Karamaşa, Ç. (2023). Agile supply chain management based on critical success factors and most ideal risk reduction strategy in the era of industry 4.0: application to plastic industry. Operations Management Research, 16(4), 1698-1719.

Korucuk, S., & Aytekin, A. (2024). Assessing the problems encountered by companies using e-logistics via a Polytopic fuzzy methodology: A case of Giresun province. Spectrum of Engineering and Management Sciences, 2(1), 36-45.

Mercimek, A. F., & Geçkil, T. (2021). Endüstri 4.0'ın lojistik sektörüne uygulanması: Lojistik 4.0. Five Zero, 1(1), 57-77.

Nila, B., & Roy, J. (2024). Analysis of Critical Success Factors of Logistics 4.0 using D-number based Pythagorean Fuzzy DEMATEL method. Decision Making Advances, 2(1), 92–104. https://doi.org/10.31181/dma21202430

Oleśków-Szłapka, J., & Stachowiak, A. (2019). The framework of logistics 4.0 maturity model. In Intelligent systems in production engineering and maintenance (pp. 771-781). Springer International Publishing.

Özdemir, A., & Özgüner, M. (2018). Endüstri 4.0 Ve Lojistik Sektörüne Etkileri: Lojistik 4.0. İşletme Ve İktisat Çalışmaları Dergisi, 6(4), 39-47.

Strandhagen, J. O., Vallandingham, L. R., Fragapane, G., Strandhagen, J. W., Stangeland, A. B. H., & Sharma, N. (2017). Logistics 4.0 and emerging sustainable business models. Advances in Manufacturing, 5, 359-369.

Stock T., & Seliger, G., (2016). Opportunities of Sustainable Manufacturing in Industry 4.0. Procedia CIRP, 40, 536-541.

Szymańska, O., Adamczak, M., & Cyplik, P. (2017). Logistics 4.0-a new paradigm or set of known solutions?. Research in Logistics & Production, 7.

Taş, A., & Başaran Algöz, S. (2021). Lojistik Sektörü Özelinde Endüstri 4.0 Farkındalık. Düzeyleri Üzerine Bir Araştırma. Karamanoğlu Mehmetbey Üniversitesi Sosyal Ve Ekonomik Araştırmalar Dergisi, 23(41), 404-417.

Timm, I, J, & Lorig, F, (2015). Logistics 4.0-A Challenge for Simulation. In: Winter Simulation Conference (WSC). IEEE, 3118-3119.

Turğut, M., & Gürsoy, İ. (2023). Lojistik 4.0 Üzerine Yapılan Araştırmaların Bibliyometrik Analizi. Cumhuriyet Üniversitesi İktisadi Ve İdari Bilimler Dergisi, 24(1), 96-113. https://doi.org/10.37880/cumuiibf.1180817

Więckowski, J., Kizielewicz, B., Shekhovtsov, A., & Sałabun, W. (2023). RANCOM: A novel approach to identifying criteria relevance based on inaccuracy expert judgments. Engineering Applications of Artificial Intelligence, 122, 106114.

Winkelhaus, S., & Grosse, E. H. (2020). Logistics 4.0: a systematic review towards a new logistics system. International Journal of Production Research, 58(1), 18-43.

Yılmaz, Ü., & Duman, B. (2019). Lojistik 4.0 Kavramına Genel Bir Bakış: Geçmişten Bugüne Gelişim ve Değişimi. Bilecik Şeyh Edebali Üniversitesi Sosyal Bilimler Dergisi, 4(1), 186-200.