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Determining the Digitalization Levels of Leading Countries in Logistics Performance Index: An Application with CRITIC-TOPSIS Approach

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ABSTRACT

Purpose: This study aims to analyze the digitalization levels of leading countries in the Logistics Performance Index (LPI) based on 2023 data.

Methodology: Six digitalization indices were utilized as criteria, and the top 23 countries in the LPI were included as alternatives to evaluate the relationship between digitalization indices and the logistics performance of these countries. In the study, the CRITIC method was employed to weight the criteria, while the ranking of decision alternatives was carried out using the TOPSIS method.

Findings: The findings of the research indicate that countries ranked high in the LPI also have high ranking in digitalization indices. Using the CRITIC method to determine the importance of the criteria, the analysis revealed that the three most significant indices for the top 23 countries in the LPI, in order of importance, are IDI, WCI, and GII. The ranking of the leading countries in the LPI based on their levels of digitalization, determined using the TOPSIS method, showed that Singapore, the United States, and the Netherlands are the top three countries with the highest levels of digitalization, respectively.

Originality: The literature lacks any research evaluating the digitalization levels of the leading countries in the LPI ranking based on the indices introduced in this study. Given the critical role of digital technologies in influencing the logistics performance of countries, and the absence of a study that comprehensively evaluates LPI and digitalization indices from a holistic perspective, this research is expected to contribute significantly to the existing literature.

Keywords: Logistics Performance Index, Digitalization, Multi Criteria Decision Making, MCDM, Digitalization Indices.

JEL Codes: C4, R41, O18.

Lojistik Performans Endeksinde Önde Gelen Ülkelerin Dijitalleşme Düzeylerinin Belirlenmesi: CRITIC-TOPSIS Yaklaşımı ile Bir Uygulama

ÖZET

Amaç: Bu çalışma, 2023 yılı verilerini temel alarak Lojistik Performans Endeksi'nde (LPI) önde gelen ülkelerin dijitalleşme düzeylerinin analiz edilmesini amaçlamaktadır.

Yöntem: Dijitalleşme indeksleri ile ülkelerin lojistik performansları arasındaki ilişkiyi değerlendirmek için altı dijitalleşme endeksi kriterler olarak, LPI'de ön sıralarda yer alan 23 ülke ise alternatifler olarak analize dahil edilmiştir. Çalışmada, kriterleri ağırlıklandırmak için CRITIC yöntemi kullanılmış, karar alternatiflerinin sıralanması ise TOPSIS yöntemiyle gerçekleştirilmiştir.

Bulgular: Araştırmanın bulguları, LPI'de ilk sıralarda yer alan ülkelerin dijitalleşme endekslerinde de yüksek skorlara sahip olduğunu göstermektedir. Kriterlerin önem düzeylerini belirlemek için CRITIC yöntemi kullanılarak yapılan analizde LPI'deki ilk 23 ülke için en önemli üç endeksin önem sırasına göre IDI, WCI ve GII olduğu ortaya koyulmuştur. LPI'de önde gelen ülkelerin dijitalleşme seviyelerine göre TOPSIS yöntemiyle yapılan sıralamadaysa dijitalleşme seviyesi en yüksek ülkelerin sırasıyla Singapur, ABD ve Hollanda olduğu belirlenmiştir.

Özgünlük: Literatürde, bu çalışmada sunulan endeksler temel alınarak LPI sıralamasındaki lider ülkelerin dijitalleşme düzeylerini değerlendiren herhangi bir araştırmaya rastlanmamıştır. Dijital teknolojilerin ülkelerin lojistik performansını etkilemedeki kritik rolü ve LPI ile dijitalleşme endekslerini bütüncül bir bakış açısıyla kapsamlı bir şekilde değerlendiren bir çalışmanın yokluğu göz önüne alındığında, bu araştırmanın mevcut literatüre önemli bir katkı sağlaması beklenmektedir.

Anahtar Kelimeler: Lojistik Performans Endeksi, Dijitalleşme, Çok Kriterli Karar Verme, ÇKKV, Dijitalleşme Endeksleri.

JEL Kodları: C4, R41, O18.

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1. INTRODUCTION

In an environment where globalization is accelerating and digital technologies are widely used, it is essential for countries to enhance their logistics performance by effectively utilizing digital technologies in international trade and logistics processes. The Logistics Performance Index (LPI) serves as a metric that identifies the adequacy and quality of a country's logistics services, offering a comparative opportunity with other countries worldwide. Through this comparison, it reveals opportunities and threats concerning the logistics performance of nations.

Digitalization has emerged as one of the most significant factors determining the competitive power of countries today, having substantial impacts on their logistics performance. The intensive use of digital technologies makes logistics operations more efficient, transparent, and flexible. Advanced technologies such as Artificial Intelligence (AI), the Internet of Things (IoT), and blockchain, which have proliferated with Industry 4.0, enhance automation and traceability in logistics services while reducing logistics costs. Consequently, countries investing in digital technologies can integrate more easily into the increasingly complex international trade and logistics networks driven by globalization, by ensuring rapid and accurate information flow.

Digitalization serves as a catalyst for enhancing efficiency across various industries, including logistics, by streamlining operations, optimizing resource allocation, and fostering innovation. Through the widespread adoption of digital technologies within a country, production costs are reduced, while optimization and efficiency in manufacturing processes are improved. Functioning as the driving force behind structural transformations in the economy, digital technologies also contribute to advancing logistics performance levels, thereby enabling countries to achieve higher standards in their logistical capabilities. This development creates significant opportunities to facilitate trade between nations. Therefore, the integration of digital technologies into logistics not only enhances operational efficiency but also bolsters the global competitiveness of countries in international trade. The information reporting systems in logistics, by facilitating the planning, coordination, and control of information systems, direct the data collected across organizations. Accordingly, digitalization in the logistics sector provides advantages for stakeholders, including customers and suppliers (Yılmaz, 2024: 20-23). Furthermore, these technologies support the integration of supply chain activities for both large and small logistics companies alike. Digital transformation makes this chain more efficient in terms of cost, operations, and customer service, offering substantial benefits for logistics performance (Foma and Mohammed, 2018: 2). By linking these advancements, digital technologies enable the logistics sector to thrive, ultimately ensuring more seamless collaboration among stakeholders while reinforcing the competitive edge of businesses and nations alike.

This study aims to analyze the digitalization levels of the top 25 countries in the Logistics Performance Index (LPI) based on 2023 data. To achieve this, the CRITIC (Criteria Importance Through Intercriteria Correlation) method was employed to weigh the criteria, while the TOPSIS (The Technique for Order Preference by Similarity to Ideal Solution) method was used for ranking the alternatives to evaluate the relationship between the digitalization indices and the logistics performance of the respective countries. The study considers six digitalization indices as criteria to determine the digitalization levels of countries: the Global Innovation Index (GII), the Networked Readiness Index (NRI), the ICT Development Index (IDI), the World Digital Competitiveness Index (WDCI), the World Competitiveness Index (WCI), and the Government AI Readiness Index (GAIRI). The analysis focuses on the top 25 countries in the LPI, excluding Hong Kong and Taiwan due to the unavailability of data in some digitalization indices, resulting in a final analysis of 23 countries, which are considered as alternatives in the study.

A review of the related literature reveals various studies that separately examine and evaluate LPI (Adiguzel Mercangoz et al., 2020; Çalık et al., 2023; Chejarla and Vaidya, 2024; Gürler et al., 2024; Işik et al., 2020; Ju et al., 2024; Manavgat et al., 2023; Senir, 2021) and digitalization indices (Amiri and Sangar, 2023; Aytekin et al., 2022; Bánhidi and Dobos, 2024; Erdin and Çağlar, 2023; Fedajev et al., 2024; Lee et al., 2022; Marti and Puertas, 2023; Satı, 2024; Silva et al., 2020; Tunsi and Alidrisi, 2023; Tziogkidis et al., 2020; Vevera et al., 2022; Voronenko et al., 2022) using multi-criteria decision-making methods. However, no study has specifically evaluated the leading countries in the LPI in terms of their digitalization levels with MCDM methods. Given the critical role of digital technologies in influencing the logistics performance of countries, and the absence of a study that comprehensively evaluates LPI and digitalization indices from a holistic perspective, this research is expected to contribute significantly to the existing literature.

In line with the research objectives, the second section of the study offers a comprehensive overview of the Logistics Performance Index (LPI) and presents the performance data of the top 25 countries listed in the LPI rankings. Subsequently, the third section introduces a series of digitalization indices that evaluate countries' innovation capacity, digital infrastructure, access to technology, capability in AI implementation, and overall readiness for digital transformation, all measured through multidimensional indicators. To ascertain the relative significance of these criteria, the CRITIC method was utilized, whereas the TOPSIS method was employed to rank the digitalization levels of the leading LPI countries. Finally, the outcomes obtained from the analysis are critically examined and interpreted in the concluding section of the study.

2. LOGISTICS PERFORMANCE INDEX

The Logistics Performance Index (LPI) is a biennial report published by the World Bank's International Trade Unit, involving the participation of over 1,000 logistics professionals worldwide. The components of the LPI measure the effectiveness of the logistics supply chain, or in other words, logistics performance (Gültekin Yıldırım, 2015). The index not only identifies the challenges countries face in bilateral trade but also provides a harmonized scale for all countries to determine the logistics resources and infrastructure they require or the areas within their logistics activities that they wish to improve. Therefore, the LPI offers insights into a country's commercial logistics performance and provides a benchmark for location selection for various types of operations and supplies essential statistical data for the sector (Martí et al., 2014; Ojala and Celebi, 2015: 7).

LPI is an interactive benchmarking tool designed to help countries identify the challenges and opportunities they face in trade logistics, as well as the measures they can take to improve their performance. The LPI is based on a worldwide survey of logistics professionals, providing feedback on the logistics of the countries in which they operate and the countries with which they trade. It integrates qualitative assessments with the expertise and insights of these businesses and their operational contexts. Consequently, the LPI comprises both qualitative and quantitative data, aiding in the creation of comprehensive logistics profiles for countries (World Bank, 2024).

According to this index, the maximum score that countries can achieve is set at 5. The World Bank's LPI Report evaluates countries under six key components:

- Efficiency of customs and border management processes
- Quality of trade and transport infrastructure
- Ease of arranging competitively priced shipments
- Competence and quality of logistics services
- Ability to track and trace shipments
- Frequency with which shipments reach consignees within the scheduled or expected delivery times

These components are established based on both theoretical and empirical research, as well as the practical experiences of logistics professionals engaged in international freight forwarding (Ministry of Customs and Trade, 2017). The most recent data for the World Bank's Logistics Performance Index was published in 2023.

Table 1. The 25 most successful countries according to LPI score for 2023

No	*Countries*	*LPI Score*	*LPI Ranking*	*No*	*Countries*	*LPI Score*	*LPI Ranking*
1	Singapore	4,3	1	14	Japan	3,9	13
2	Finland	4,2	2	15	Spain	3,9	13
3	Denmark	4,1	3	16	Taiwan	3,9	13
4	Germany	4,1	3	17	Korea Rep.	3,8	17
5	Netherlands	4,1	3	18	USA	3,8	17
6	Switzerland	4,1	3	19	Australia	3,7	19
7	Austria	4,0	7	20	China	3,7	19
8	Belgium	4,0	7	21	Greece	3,7	19
9	Canada	4,0	7	22	Italy	3,7	19
10	Hong Kong	4,0	7	23	Norway	3,7	19
11	Sweden	4,0	7	24	South Africa	3,7	19
12	United Arap Emirates	4,0	7	25	United Kingdom	3,7	19
13	France	3,9	13				

Table 1 presents the ranking of the top 25 countries according to the LPI scores for 2023. In the overall LPI ranking, Singapore holds the first position, followed by Finland, Denmark, Germany, and the Netherlands. Singapore's leading position in 2023, as in previous years like 2007 and 2012 (World Bank, 2024), is closely linked to its advanced port infrastructure and high-level logistics services. It can be noted that major container ports such as Singapore, Hamburg and Rotterdam as key players in global trade, benefit from a range of digital technologies brought by the digital age, including artificial intelligence, the Internet of Things (IoT), and blockchain in handling and information management. This suggests that these technologies have contributed significantly to the leading positions of Singapore, Germany, and the Netherlands in the LPI rankings (Öztemiz, 2023: 155).

A high ranking in the LPI reflects a country's advanced logistics infrastructure and high logistics service quality. This, in turn, reduces costs and positively influences the flow of international trade. Therefore, achieving a leading position in the LPI is essential for a country to enhance its competitiveness in global markets and to sustain economic growth.

3. DIGITALIZATION INDICES

Digitalization is defined as the conversion of analog data and processes into a machine-readable format (West, 2019: 140). This transformation can take various forms, including the conversion of analog measurements into digital formats, the encoding of business and industrial processes, and the transmission of voice as digital signals over the internet (UNCTAD, 2023: 10). As digitalization has become more widespread, new activities have emerged, and existing business sectors have undergone significant transformations.

In the context of rapidly evolving technological innovations, adapting to digital transformation has become imperative for businesses to maintain their competitiveness in the international arena. Digitalization significantly influences data collection, storage, processing, and decision-making processes. The importance of digital transformation has been particularly underscored by the Covid-19 pandemic, which has highlighted the need for the integration of digital technologies into business operations, representing more agile and intelligent ways of conducting business. The pandemic has profoundly impacted supply chains, international trade, and social life worldwide. Consequently, the use of online services has surged, and the digital transformation process has accelerated substantially. This digital transformation, which intensified during the Covid-19 period, did not lose momentum in the period after the pandemic's effects subsided. Given that one of the key drivers of digital transformation, artificial intelligence, is projected to elevate its use in the global cargo drone market to 17.88 billion USD by 2030, the critical role of digital technologies in enhancing the logistics performance of nations should also be acknowledged (Statista, 2024).

In response to these developments, various indices related to digitalization, which has become a critical factor directly affecting international trade and logistics performance, have been established in recent years. These indices are utilized to measure countries' digital capacities, innovation levels, the development of information and communication technologies, the effectiveness of e-government applications, and their digital competitiveness. The establishment of indicators and datasets for measuring digitalization levels plays a crucial role in shaping global competitiveness strategies that impact national economies and logistics processes, as well as in determining the current stage of digitalization in different countries. The information related to these indices is provided below.

The Global Innovation Index (GII) has been published annually since 2011 by the World Intellectual Property Organization (WIPO), in collaboration with the Portulans Institute. The GII serves as a barometer for innovation in an economic and geopolitical environment filled with uncertainties, highlighting both strengths and weaknesses of innovation and ranking the innovation performance of approximately 132 economies. This ranking identifies the world's most innovative economies. Aiming to capture a comprehensive picture of innovation, the index comprises around 80 indicators that encompass various dimensions of each economy, including political environment, education, infrastructure, and knowledge creation (World Intellectual Property Organization-WIPO, 2024).

The Network Readiness Index (NRI) is developed in collaboration with the Portulans Institute, the University of Oxford, and the Saïd Business School. Initially published by the World Economic Forum in 2002, the NRI, as of 2023, evaluates 134 economies based on a wide range of factors related to their readiness to leverage the benefits of the digital revolution. The NRI comprises four main pillars: technology, people, governance, and impact. The technology pillar is divided into sub-indicators of access, content, and future technologies; the people pillar includes sub-indicators assessing individuals, businesses, and governments; the governance pillar encompasses trust, regulation, and inclusion sub-indicators while the impact pillar covers sub-indicators related to economy, quality of life, and Contribution to the sustainable development goals (SDG) (Network Readiness Index, 2024).

The ICT Development Index (IDI) is published by the International Telecommunication Union (ITU). The ICT Development Index (IDI), designed to measure the level of advancement in the information and communication technology (ICT) sector, was a composite indicator published by the ITU from 2009 to 2017. However, due to issues related to data availability and quality, the publication of the IDI was halted in 2018. Following a decision to develop and adopt a new methodology at the ITU's conference in Bucharest in 2022, the index was reintroduced in 2023. The 2023 IDI, based on a new methodology developed through an inclusive and iterative process, covers 169 economies and aims to assess the extent to which connectivity is universal and meaningful worldwide (International Telecommunication Union-ITU, 2024).

The World Digital Competitiveness Index (WDCI) is published by the IMD Business School. The WDCI assesses and measures the capacity and readiness of countries to adopt and explore digital technologies for economic and social transformation. It analyzes and ranks the extent to which countries integrate and explore digital technologies that drive transformation in government practices, business models, and society at large. The evaluation of global digital competitiveness is structured around three main factors: knowledge, technology, and future readiness. Under these three main factors, there are nine sub-factors and a total of 54 criteria that constitute these factors. Countries are ranked based on the total score of these nine sub-factors (IMD, 2024b).

The World Competitiveness Index (WCI) is published by the IMD Business School. First released in 1989, it serves as a comprehensive annual report on the competitiveness of 64 countries and is recognized globally as a benchmark reference. The WCI analyzes and ranks countries based on how effectively they manage their competencies to achieve long-term value creation. The index is based on 336 competitiveness criteria selected through extensive research, incorporating insights from economic literature, international, national, and regional sources, as well as feedback from businesses, government institutions, and academics. These criteria are regularly reviewed and updated to reflect new theories, research, and data as they emerge, and as the global economy evolves (IMD, 2024a).

The Government AI Readiness Index (GAIRI), published by Oxford Insights, has gained prominence in light of recent advances in generative artificial intelligence (AI), significant developments in AI regulation such as the European Union's AI Act, and a notable increase in global AI-related summits. These factors have brought AI technology to the forefront, prompting countries to compete in their preparedness for its adoption. In this context, the Government AI Readiness Index seeks to answer the question: “How ready is a particular government to implement AI in the delivery of public services to its citizens?” The index evaluates readiness across three dimensions: Government, Technology Sector, and Data & Infrastructure. These dimensions encompass a total of 10 sub-dimensions, which are further broken down into 39 indicators. In the 2022 edition of the Index, 181 countries were ranked, and this number increased to 193 in 2023 (Oxford Insights, 2024).

4. LITERATURE REVIEW

LPI is widely recognized as a critical tool for assessing countries' logistics infrastructure and service quality. This index provides a framework for comparing the effectiveness and facilitation of logistics flows between nations. Given the logistics sector's pivotal role in the global economy, countries take various measures to improve their rankings on the LPI. As a result of this, numerous analyses and evaluations are conducted to compare the logistics performance of different countries. In these analyses, Multi-Criteria Decision-Making (MCDM) methods have recently gained prominence. MCDM is influential in operational decision-making processes, as it aids in evaluating multiple criteria and determining their relative importance. Additionally, digital technologies contribute significantly to making logistics operations and supply chains more efficient, transparent, and adaptable. In this context, the importance of digitalization in the logistics sector is substantial. To reveal this impact, digitalization indices published by various institutions have become crucial for comparing countries and guiding policymakers.

According to research conducted in the Web of Science database, no study has been identified that utilizes countries as alternatives based on their Logistics Performance Index (LPI) scores, examines digitalization indices as criteria, and analyzes them using Multi-Criteria Decision Making (MCDM) methods. Studies employing MCDM methods with the LPI adopt a variety of approaches and methodologies. Among the MCDM techniques used are hybrid MCDM (Çalık et al., 2023; Chejarla and Vaidya, 2024), genetic algorithms (Gürler et al., 2024), fuzzy AHP and ARAS-G (Yildirim and Adiguzel Mercangoz, 2020), fuzzy linear regression (Çakır, 2017), data envelopment analysis (DEA) (Markovits-Somogyi and Bokor, 2014; Martí et al., 2017), COPRAS (Adiguzel Mercangoz et al., 2020; Gürler et al., 2024; Senir, 2021), COPRAS-G (Adiguzel Mercangoz et al., 2020) and CRITIC (Çakır, 2017; Chejarla and Vaidya, 2024; Gürler et al., 2024; Ju et al., 2024; Senir, 2021; Ulutaş and Karaköy, 2019).

An examination of these studies reveals that European Union (EU) countries (Ju et al., 2024; Senir, 2021; Ulutaş and Karaköy, 2019), OECD countries (Çakır, 2017; Yildirim and Adiguzel Mercangoz, 2020), and Central and Eastern European countries (Işik et al., 2020) are frequently selected as alternatives based on their LPI scores. Furthermore, a detailed review of the literature indicates significant variations in terms of the methods, data sources, timeframes, and criteria selected for analysis.

Digitalization indices are among the key indicators used to assess countries' digital transformation and innovation capacities, and they serve as an effective criterion for measuring logistics performance. Studies employing digitalization indices frequently utilize the GII (Alidrisi, 2021; Aytekin et al., 2022; Erdin and Çağlar, 2023; Fedajev et al., 2024; Kara et al., 2022; Kaynak et al., 2017; Marti and Puertas, 2023; Satı, 2024; Silva et al., 2020; Tunsi and Alidrisi, 2023; Tziogkidis et al., 2020; Voronenko et al., 2022), the Global

Table 2. Studies using MCDM methods with LPI and digitalization indices

No	*Author(s)/Year*	*Article Title*	*Indexes Used*	*MCDM method(s) Used*
1	Chejarla and Vaidya (2024)	A hybrid multi-criteria decision-making approach for longitudinal data	LPI	CRITIC, MULTIMOORA
2	Gürler et al. (2024)	Determining criteria weights with genetic algorithms for multi-criteria decision-making methods: The case of logistics performance index rankings of European Union countries	LPI	CRITIC, Entropy, Equal, ARAS, CoCoSo, CODAS, COPRAS, EDAS, GRA, MABAC, MARCOS, MOORA, OCRA, WASPAS
3	Ju et al. (2024)	A novel approach for the assessment of logistics performance index of EU countries	LPI	CRITIC, MEREC, Entropy, Fuzzy ROV
4	Çalık et al. (2023)	Novel integrated hybrid multi-criteria decision-making approach for logistics performance index	LPI	AHP-TOPSIS, AHP-VIKOR, AHP-CODAS
5	Manavgat et al. (2023)	Global scale integrated logistics performance analysis and its spillover effect	LPI, LSCI, ETI, AQTI	ROC-WASPAS
6	Senir (2021)	Comparison of domestic logistics performances of Turkey and European Union countries in 2018 with an integrated model	LPI	CRITIC-COPRAS
7	Adiguzel Mercangoz et al. (2020)	Time period based COPRAS-G method: Application on the logistics performance index	LPI	COPRAS-G
8	Işik et al. (2020)	The assessment of the logistics performance index of CEE countries with the new combination of SV and MABAC methods	LPI	SV, MABAC
9	Yildirim et al. (2020)	Evaluating the logistics performance of OECD countries by using fuzzy AHP and ARAS-G	LPI	ARAS-G
10	Ulutaş and Karaköy (2019)	An analysis of the logistics performance index of EU countries with an integrated MCDM model	LPI	SWARA, CRITIC, PIV
11	Çakır (2017)	Measuring logistics performance of OECD countries via fuzzy linear regression	LPI	CRITIC-SAW, TOPSIS, VIKOR
12	Martí et al. (2017)	A Dea-Logistics performance index	LPI	DEA
13	Markovits-Somogyi and Bokor (2014)	Assessing the logistics efficiency of European countries by using the DEA-PC methodology	LPI	DEA-PC
14	Bánhidi and Dobos (2024)	Measuring digital development: ranking using data envelopment analysis (DEA) and network readiness index (NRI)	NRI	DEA/WEI-CWA
15	Fedajev et al. (2024)	Western Balkan countries' innovation as determinant of their future growth and development	GII, EIS	Entropy-PROMETHEE
16	Satı (2024)	Comparison of the criteria affecting the digital innovation performance of the European Union (EU) member and candidate countries with the entropy weight-TOPSIS method and investigation of its importance for SMEs	GII, GCI, NRI	Entropy-TOPSIS
17	Amiri and Sangar (2023)	Assessing the ICT development in Iranian cities: The strategy to accelerate digital advancement	IDI	DEA-CCR, MPI

Table 2. (*Continued*)

No	*Author(s)/Year*	*Article Title*	*Indexes Used*	*MCDM method(s) Used*
18	Erdin and Çağlar, (2023)	National innovation efficiency: a DEA-based measurement of OECD countries	GII	DEA
19	Marti and Puertas, (2023)	Analysis of European competitiveness based on its innovative capacity and digitalization level	GII, DESI	TOPSIS
20	Tunsi and Alidrisi, (2023)	The innovation-based human development index using PROMETHEE II: The context of G8 countries	GII	PROMETHEE II
21	Aytekin et al., (2022)	Global innovation efficiency assessment of EU member and candidate countries via DEA-EATWIOS multi-criteria methodology	GII	DEA-EATWIOS
22	Kara et al., (2022)	Determination of logistics innovation performance index with Entropy and combined compromise solution techniques	GII, AEMLI	Entropy-CoCoSo
23	Lee et al., (2022)	Economic resilience in the early stage of the COVID-19 pandemic: An across-economy comparison	WCI, GCI	DEA
24	Vevera et al., (2022)	A multi-criteria approach for the calculation of a complex indicator of Cyber Security and Digital Development	GCI, NCSI, IDI, NRI	COPRAS
25	Voronenko et al., (2022)	Challenges to Ukraine's innovative development in a digital environment	GII	DEA
26	Alidrisi (2021)	The development of an efficiency-based global green manufacturing innovation index: An input-oriented DEA approach	GII	DEA
27	Silva et al., (2020)	Multicriteria decision choices for investment in innovative upper-middle income countries	GII	AHP-PROMETHEE
28	Tziogkidis et al., (2020)	A data envelopment analysis and local partial least squares approach for identifying the optimal innovation policy direction	GII	DEA
29	Ziemba and Becker, (2019)	Analysis of the digital divide using fuzzy forecasting	IDI	NEAT F-PROMETHEE
30	Kaynak et al., (2017)	Comparing the innovation performance of EU candidate countries: an entropy-based TOPSIS approach	GCI, IUS, KAM, GII	Entropy-TOPSIS

Competitiveness Index (GCI) (Kaynak et al., 2017; Lee et al., 2022; Satı, 2024; Vevera et al., 2022), the NRI (Bánhidi and Dobos, 2024; Satı, 2024; Vevera et al., 2022), and the IDI (Amiri and Sangar, 2023; Vevera et al., 2022; Ziemba and Becker, 2019) indices.

In studies utilizing these indices, the entropy method is commonly employed for weighting the criteria (Fedajev et al., 2024; Kara et al., 2022; Kaynak et al., 2017; Satı, 2024). For ranking alternatives based on these criteria, various MCDM methods are used, including DEA (Alidrisi, 2021; Amiri and Sangar, 2023; Aytekin et al., 2022; Bánhidi and Dobos, 2024; Erdin and Çağlar, 2023; Lee et al., 2022; Tziogkidis et al., 2020; Voronenko et al., 2022), PROMETHEE (Fedajev et al., 2024; Silva et al., 2020; Tunsi and Alidrisi, 2023; Ziemba and Becker, 2019), and TOPSIS (Kaynak et al., 2017; Marti and Puertas, 2023; Satı, 2024).

Upon reviewing the literature, it is observed that these studies predominantly focus on themes such as innovation, economic resilience, and cybersecurity. There is also a trend toward developing new indices, and while some studies are country-specific, focusing on nations like Iran, others target specific regions or groups of countries, such as the European Union, OECD, and the Balkans. Based on these findings, Table 2 summarizes studies that analyze the Logistics Performance Index (LPI) and digitalization indices using MCDM methods.

The findings obtained from the literature reveal that the Logistics Performance Index (LPI) and various digitalization indices are generally analyzed independently. However, considering the increasingly strategic impact of digital technologies on logistics performance, it becomes evident that studies adopting an integrated approach to examine these two domains in conjunction are rather limited. In this context, the present study aims to address this gap by offering a multi-criteria analysis of the digitalization levels of countries that rank highly in the LPI, thus making a meaningful contribution to the existing body of literature.

5. METHODOLOGY

Objective weighting techniques, such as entropy method, CRITIC, do not rely on the opinions or preferences of experts; rather, they use particular computational procedures based on the original data or decision matrix (Mazurek and Strzałka, 2022). The degree of conflict or correlation between criteria as well as the variation (standard deviation) in the criteria values are taken into account by the CRITIC method when determining the significance of criteria (Krishnan et al., 2021). This ensures objectivity by determining weights based on the inherent data structure, which makes it especially helpful when working with precise numbers.

TOPSIS was developed by Hwang and Yoon (1981) on the premise that the alternative that is selected should be the one that is most distant from the negative-ideal solution and the one that is closest to the ideal solution. TOPSIS is a practical solution for problems addressed from both normative and decision-maker perspectives (Hwang and Yoon, 1981). It is commonly known that the TOPSIS method works well in situations involving multi-criteria decision-making (MCDM), especially when the options for a decision are assessed in light of multiple conflicting criteria (Deng and Chan, 2011; Wang et al., 2016). The positive ideal solution seeks to maximize beneficial criteria while minimizing cost-related criteria, whereas the negative ideal solution aims to maximize cost criteria and minimize beneficial criteria (Behzadian et al., 2012: 13052). Shih et al. (2007) claim that TOPSIS has the benefits of strong logic, quick computation, rationality, and clear visualization. According to Lima Junior et al. (2014), TOPSIS was more adaptable to modifications than the traditional Analytic Hierarchy Process (AHP) approach in the assessment system. In order to determine the countries with the highest level of digitalization among the leading countries in terms of logistics performance, TOPSIS is used as the MCDM technique.

In this study, the digitalization levels of leading countries in logistics performance index were analyzed and evaluated using the CRITIC and TOPSIS (The Technique for Order Preference by Similarity to an Ideal Solution) methods. The CRITIC method is based on determining the significance of criteria weights. The TOPSIS method, on the other hand, stands out as one of the MCDM methods used to rank decision alternatives in terms of importance and utility. Within the scope of the study, six digitalization indices (global innovation index (GII), network readiness index (NRI), ICT development index (IDI), world digital competitiveness index (WDCI), world competitiveness index (WCI), government AI readiness index (GAIRI)) were selected as criteria. The leading 23 countries in logistics performance index were included in the analysis as alternatives. It is expected that the countries will obtain the highest values from these criteria to rank high in the digitalization. Therefore, it is accepted that the country with the highest weighted value in the analyses is at the forefront in terms of digitalization level.

5.1. CRITIC Method

In contrast to subjective methods, objective methods in MCDM do not require any initial information or decisions from the decision-makers (Mahmoody Vanolya and Jelokhani-Niaraki, 2021). Therefore, in objective methods, only the structure of the data available in the decision matrix is evaluated to determine the weights. Accordingly, in this study, which is based on the data of the digitalization indices, the CRITIC method, which aims to determine objective weights with relative importance in MCDM problems, was preferred.

The CRITIC method was first introduced among MCDM methods by a study conducted by (Diakoulaki et al., 1995). In the CRITIC method, objective weights are obtained by calculating the actual data of each evaluation criterion. In other words, the data in the decision matrix are sufficient to calculate the weights of the criteria (Ayçin, 2020: 76). The application steps of the CRITIC method, which involves a solution process consisting of a total of five steps, are as follows (Ayçin, 2020: 76-84).

CRITIC method consists of five stages:

(1) Formation of the Decision Matrix
(2) Normalization of the Decision Matrix
(3) Construction of the Correlation Coefficient Matrix
(4) Calculation of the C_j Values
(5) Calculation of Criteria Weights

The variables involved in the application stages of the method are as follows:

A_i: decision alternative $(i = 1, 2, \ldots, m)$

C_j: j^{th} evaluation criterion $(j = 1, 2, \ldots, n)$

X_{ij}: the value of the i^{th} alternative according to the j^{th} evaluation criterion

X_j^{max}: the maximum value of the decision alternatives according to the j^{th} criterion

X_j^{min}: the minimum value of the decision alternatives according to the j^{th} criterion

r_{ij}: the normalized value of the i^{th} alternative according to the j^{th} evaluation criterion

ρ_{jk}: the correlation coefficients between any j^{th} and k^{th} criteria

σ_j : the standard deviation of the j^{th} criterion $(j = 1,2, \ldots, n)$

w_j: the weight of the j^{th} evaluation criterion $(j = 1,2, \ldots, n)$

Step 1: *Formation of the Decision Matrix*

In the first step of the method, the decision matrix, denoted by X and consisting of X_{ij} values, is formed as shown in Equation 1.

$$X = \begin{bmatrix} X_{11} & X_{12} & \ldots & X_{1n} \\ X_{21} & X_{22} & \ldots & X_{2n} \\ \vdots & \vdots & \ldots & \vdots \\ X_{m1} & X_{m2} & \ldots & X_{mn} \end{bmatrix} \begin{matrix} A_1 \\ A_2 \\ \vdots \\ A_m \end{matrix} \quad (1)$$

Step 2: *Normalization of the Decision Matrix*

In decision-making problems, values related to criteria with different units should be standardized to fall within the [0,1] range through the normalization process. The normalization process is conducted using Equation 2 for benefit-oriented criteria and Equation 3 for cost-oriented criteria. In this study, the criteria considered are benefit oriented. Therefore, Equation 2 has been utilized for the normalization process.

$$r_{ij} = \frac{x_{ij} - x_j^{min}}{x_j^{max} - x_j^{min}} \ldots\ldots\ldots\ldots j = 1,2, \ldots, n \quad (2)$$

$$r_{ij} = \frac{x_j^{max} - x_{ij}}{x_j^{max} - x_j^{min}} \ldots\ldots\ldots\ldots j = 1,2, \ldots, n \quad (3)$$

Step 3: *Construction of the Correlation Coefficient Matrix*

In this step, a correlation coefficient matrix, consisting of linear correlation coefficients (ρ_{jk}), is constructed to measure the degree of relationships among the evaluation criteria. The correlation coefficients are calculated as shown in Equation 4.

$$P_{jk} = \frac{\sum_{i=1}^{m}(r_{ij} - \overline{r_j}) \cdot (r_{ik} - \overline{r_k})}{\sqrt{\sum_{i=1}^{m}(r_{ij} - \overline{r_j})^2 \cdot \sum_{i=1}^{m}(r_{ik} - \overline{r_k})^2}} \qquad j, k = 1,2, \ldots, n \quad (4)$$

Step 4: *Calculation of C_j Values*

The CRITIC method aims to derive information in MCDM problems from the contrast intensity and conflicts present in the evaluation criteria. In this context, Equations 5 and 6 should be utilized to calculate the C_j values, which combine both properties and represent the total information contained in the j^{th} criterion.

$$C_j = \sigma_j \cdot \sum_{k=1}^{m}(1 - \rho_{jk}) \qquad j, k = 1,2, \ldots, n \quad (5)$$

$$\sigma_j = \sqrt{\frac{\sum_{i=1}^{m}(r_{ij} - \overline{r_j})^2}{m-1}} \quad (6)$$

Step 5: *Calculation of Criteria Weights*

In the final stage of the method, the weighted values (w_j) of the criteria are obtained by proportioning the C_j value of each criterion to the sum of the C_j values of all criteria. The weighted values of the criteria are calculated using Equation 7.

$$w_j = \frac{C_j}{\sum_{k=1}^{n} C_j} \quad (7)$$

5.2. TOPSIS Method

The application of the TOPSIS method, which involves a solution process consisting of a total of seven steps, are as follows (Ayçin, 2020: 292-296; Çakir and Perçin, 2013; Hwang and Yoon, 1981: 130-133; Jahanshahloo et al., 2006):

Step 1: *Construction of the decision matrix*

In the decision matrix, the rows contain the decision points to be ranked, and the columns contain the evaluation criteria. The matrix A given below is referred to as the initial matrix. In this matrix, m is the number of decision alternatives and n is the number of criteria to be used in the evaluation and this equation is shown as follows (Equation 8):

$$A_{ij} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \cdot & & & \cdot \\ \cdot & & & \cdot \\ \cdot & & & \cdot \\ a_{m1} & a_{m2} & \cdots & a_{mn} \end{bmatrix} \tag{8}$$

Step 2: *Construction of the standard decision matrix*

The standard decision matrix is obtained by normalizing the decision matrix. The value of each criterion (a_{ij}) in the decision matrix is squared and all values in the column where these squares are located are summed to obtain a total column value. The decision matrix is normalized by dividing each a_{ij} value by the square root of the sum of the column in which it is located in Equation 9.

$$r_{ij} = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{m}(a_{ij})^2}} \qquad (i = 1,\ldots,m, ve\ j = 1\ldots,n) \tag{9}$$

The representation of the standard decision matrix (R) created after calculating the r_{ij} values is shown in Equation 10.

$$R_{ij} = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \cdot & & & \cdot \\ \cdot & & & \cdot \\ \cdot & & & \cdot \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix} \tag{10}$$

Step 3: *Construction of weighted standard decision matrix (Equation 11)*

c

$$V_{ij} = \begin{bmatrix} w_1 r_{11} & w_2 r_{12} & \cdots & w_n r_{1n} \\ w_1 r_{21} & w_2 r_{22} & \cdots & w_n r_{2n} \\ \cdot & & & \cdot \\ \cdot & & & \cdot \\ \cdot & & & \cdot \\ w_1 r_{m1} & w_2 r_{m2} & \cdots & w_n r_{mn} \end{bmatrix} \tag{11}$$

Step 4: *Determination of positive ideal (A*) and negative ideal (A-) solution*

At this stage, the ideal solution values are determined by utilizing the weighted decision matrix. These ideal solution values are evaluated in two groups as positive ideal and negative ideal. A^* indicates the best performance (max) value in the weighted normalized matrix, while A^- indicates the worst performance (min) values. Here, $A^*$is the positive ideal solution (Equation 12) and A^- is the negative ideal solution (Equation 13).

$$A^* = \left\{(\max_i v_{ij} \middle| j \in J), (\min_i v_{ij} | j \in J'\right\} \qquad A^* = \{v_1^*,\ v_2^*, \ldots, v_n^*\} \tag{12}$$

$$A^- = \left\{(\min_i v_{ij} \middle| j \in J), (\max_i v_{ij} | j \in J'\right\} \qquad A^- = \{v_1^-,\ v_2^-, \ldots, v_n^-\} \tag{13}$$

In both formulas, J indicates maximization and J' indicates minimization values.

Step 5: *Calculation of the distance to positive and negative ideal solution points*

At this stage, the deviations of each criterion from the positive and negative solution points are calculated. Euclidean Distance Approach is used for this calculation. In this step, S_i^* values, which indicate the distances of the alternatives to the positive ideal solution points, and S_i^- values, which indicate the distances to the negative ideal solution points, are calculated in Equation 14 and Equation 15.

$$S_i^* = \sqrt{\sum_{j=1}^{n}(v_{ij} - v_j^*)^2} \tag{14}$$

$$S_i^- = \sqrt{\sum_{j=1}^{n}(v_{ij} - v_j^-)^2} \tag{15}$$

The number of positive ideal and negative ideal distance measures should be equal to the number of decision alternatives used in the matrix.

Step 6: *Calculating the relative proximity to the ideal solution point*

In the calculation of relative proximity, the distances to the positive ideal and negative ideal solution points are used. The purpose of this calculation is to reveal the share of the negative ideal distance measure in the total distance. The C_i^* value, which indicates the proximity of the alternatives to the positive ideal solution point, is calculated using Equation 16.

$$C_i^* = \frac{S_i^-}{S_i^- + S_i^*} \tag{16}$$

The C_i^* value takes a value between, $0 \leq C_i^* \leq 1$. A value close to 1 indicates that it is close to the positive ideal solution, while a value close to 0 indicates that it is close to the negative ideal solution.

Step 7: *Ranking the preference order*

In the last stage, C_i^* values are ranked according to their magnitude and an evaluation between decision alternatives can be made. The one with the highest C_i^* value is the first alternative in the ranking.

6. IMPLEMENTATION

In this section, tables presenting the values obtained from calculations using the formulas specified in the methodology are provided.

6.1. Determination of Criterion Weights Using the CRITIC Method

In the application, a data set was utilized in which the 23 countries constituting the decision alternatives were evaluated based on their digitalization indices' scores and formed a decision matrix (Table 3).

Table 3. Decision matrix for the CRITIC method

Criterion Direction	*max*	*max*	*max*	*max*	*max*	*max*
Countries / Criteria	*GII*	*NRI*	*IDI*	*WDCI*	*WCI*	*GAIRI*
Australia	49.7	70.36	94.0	85.28	83.02	73.89
Austria	53.2	69.13	92.5	81.10	78.16	72.37
Belgium	49.9	67.02	88.2	85.95	89.69	67.28
Canada	53.8	71.99	87.2	91.98	86.21	77.07
China	55.3	67.31	84.4	84.41	82.10	70.94
Denmark	58.7	74.06	96.9	96.93	100.00	73.91
Finland	61.2	76.19	96.7	94.05	89.73	77.37
France	56.0	70.17	89.4	78.65	71.05	76.07
Germany	58.8	74.00	87.3	80.86	80.47	75.26
Greece	37.5	53.02	83.7	54.70	55.12	57.95
Italy	46.6	62.2	86.4	64.39	63.32	67.63
Japan	54.6	71.06	92.0	75.43	67.84	75.08
Korea Rep.	58.6	74.48	93.8	94.80	75.71	75.65
Netherlands	60.4	76.04	93.5	98.10	95.58	74.47
Norway	50.7	69.7	90.9	85.96	86.43	72.71
Singapore	61.5	76.81	97.4	97.40	97.44	81.97
South Africa	30.4	45.85	80.5	48.61	40.19	47.28
Spain	45.9	64.77	91.4	76.62	67.22	67.47
Sweden	64.2	75.68	93.9	94.12	91.86	72.55
Switzerland	67.6	74.76	91.6	96.24	99.13	68.57
United Arap Emirates	43.2	62.43	96.4	88.86	90.52	70.42
United Kingdom	62.4	72.75	92.8	83.12	75.48	78.57
USA	63.5	76.91	96.6	100.00	91.14	84.80

The normalization process in Table 4 has been conducted utilizing Equation 2 due to the benefit-oriented nature of the criteria in the study.

Table 4. Normalized decision matrix for the CRITIC method

Criterion Direction	*max*	*max*	*max*	*max*	*max*	*max*
Countries/Criteria	*GII*	*NRI*	*IDI*	*WDCI*	*WCI*	*GAIRI*
Australia	0.519	0.789	0.799	0.714	0.716	0.709
Austria	0.613	0.750	0.710	0.632	0.635	0.669
Belgium	0.524	0.682	0.456	0.727	0.828	0.533
Canada	0.629	0.842	0.396	0.844	0.769	0.794
China	0.669	0.691	0.231	0.697	0.701	0.631
Denmark	0.761	0.908	0.970	0.940	1.000	0.710
Finland	0.828	0.977	0.959	0.884	0.828	0.802
France	0.688	0.783	0.527	0.585	0.516	0.767
Germany	0.763	0.906	0.402	0.628	0.673	0.746
Greece	0.191	0.231	0.189	0.119	0.250	0.284
Italy	0.435	0.526	0.349	0.307	0.387	0.542
Japan	0.651	0.812	0.680	0.522	0.462	0.741
Korea Rep.	0.758	0.922	0.787	0.899	0.594	0.756
Netherlands	0.806	0.972	0.769	0.963	0.926	0.725
Norway	0.546	0.768	0.615	0.727	0.773	0.678
Singapore	0.836	0.997	1.000	0.949	0.957	0.925
South Africa	0.000	0.000	0.000	0.000	0.000	0.000
Spain	0.417	0.609	0.645	0.545	0.452	0.538
Sweden	0.909	0.960	0.793	0.886	0.864	0.674
Switzerland	1.000	0.931	0.657	0.927	0.985	0.567
United Arap Emirates	0.344	0.534	0.941	0.783	0.841	0.617
United Kingdom	0.860	0.866	0.728	0.672	0.590	0.834
USA	0.890	1.000	0.953	1.000	0.852	1.000

The correlation coefficient matrix, consisting of linear relationship coefficients between criteria $[(P_{jk})]$, is presented in Table 5.

Table 5. Correlation coefficient values between criteria

Criteria	*GII*	*NRI*	*IDI*	*WDCI*	*WCI*	*GAIRI*
GII	1.0000	0.9445	0.6112	0.8230	0.7434	0.8002
NRI	0.9445	1.0000	0.7235	0.8948	0.8039	0.9024
IDI	0.6112	0.7235	1.0000	0.7812	0.7101	0.7212
WDCI	0.8230	0.8948	0.7812	1.0000	0.9351	0.7918
WCI	0.7434	0.8039	0.7101	0.9351	1.0000	0.6755
GAIRI	0.8002	0.9024	0.7212	0.7918	0.6755	1.0000

The weighted values calculated for all criteria and their weights are presented in Table 6. Upon examining the w_j values, it is observed that, as a result of the analysis, the three most important criteria among the eight digitalization indices for the leading 23 countries in LPI are IDI, WCI, and GII, respectively. These criteria are followed by GAIRI, WDCI and NRI. The prominence of IDI, WCI, and GII as the top three criteria can be attributed to their fundamental roles in shaping a nation's digital infrastructure, innovative capacity and competitive landscape. A nation's level of information and communication technology development is measured by the IDI. These technologies are essential for effective logistics operations, enabling real-time data interchange, and improving supply chain transparency. However, because a competitive economic structure encourages investments in digitalization and technological adaptation, the WCI highlights the strong correlation between digitalization and a nation's overall economic competitiveness, which includes elements like infrastructure, business efficiency, and innovation capabilities. These elements are all essential for developing a strong logistics sector. The importance of the GII can be explained by the fact that digitalization is directly related to innovation and that nations that prioritize innovative practices are better positioned to optimize their logistics performance through advanced technologies and processes. According to this ranking, nations looking to improve their logistics performance should give top priority to full digital development, concentrating not only on infrastructure but also on establishing competitive economic environments that encourage and stimulate innovation.

Table 6. Calculation of C_j values and determination of criteria weights (w_j)

Criteria	*GII*	*NRI*	*IDI*	*WDCI*	*WCI*	*GAIRI*
GII	0.0000	0.0555	0.3888	0.1770	0.2566	0.1998
NRI	0.0555	0.0000	0.2765	0.1052	0.1961	0.0976
IDI	0.3888	0.2765	0.0000	0.2188	0.2899	0.2788
WDCI	0.1770	0.1052	0.2188	0.0000	0.0649	0.2082
WCI	0.2566	0.1961	0.2899	0.0649	0.0000	0.3245
GAIRI	0.1998	0.0976	0.2788	0.2082	0.3245	0.0000
σ_j	0.2421	0.2490	0.2744	0.2636	0.2488	0.2057
Degrees of Differentiation						
C_j	0.2609	0.1820	0.3987	0.2041	0.2817	0.2281
Importance Degrees of Criteria						
w_j	0.1677	0.1170	0.2563	0.1312	0.1811	0.1466

6.2. Determination of Best Alternative Using the TOPSIS Method

In the second part of the analysis, the digitalization levels of the leading countries in LPI as alternatives were compared by TOPSIS method based on the criteria weight values determined by CRITIC. The first step was to use the weights of the criterion to generate a weighted normalized decision matrix. Table 7 shows the weighted normalized decision matrix.

Table 7. Weighted normalized decision matrix

Countries	*GII*	*NRI*	*IDI*	*WDCI*	*WCI*	*GAIRI*
Australia	0.032	0.025	0.055	0.027	0.038	0.031
Austria	0.034	0.024	0.054	0.026	0.036	0.031
Belgium	0.032	0.023	0.052	0.028	0.041	0.028
Canada	0.034	0.025	0.051	0.030	0.040	0.032
China	0.035	0.024	0.049	0.027	0.038	0.030
Denmark	0.037	0.026	0.057	0.031	0.046	0.031
Finland	0.039	0.027	0.057	0.030	0.041	0.033
France	0.036	0.025	0.052	0.025	0.033	0.032
Germany	0.038	0.026	0.051	0.026	0.037	0.032
Greece	0.024	0.019	0.049	0.018	0.025	0.024
Italy	0.030	0.022	0.051	0.021	0.029	0.029
Japan	0.035	0.025	0.054	0.024	0.031	0.032
Korea Rep.	0.037	0.026	0.055	0.030	0.035	0.032
Netherlands	0.039	0.027	0.055	0.031	0.044	0.031
Norway	0.032	0.024	0.053	0.028	0.040	0.031
Singapore	0.039	0.027	0.057	0.031	0.045	0.035
South Africa	0.019	0.016	0.047	0.016	0.018	0.020
Spain	0.029	0.023	0.054	0.025	0.031	0.028
Sweden	0.041	0.026	0.055	0.030	0.042	0.031
Switzerland	0.043	0.026	0.054	0.031	0.046	0.029
United Arab Emirates	0.028	0.022	0.056	0.029	0.042	0.030
United Kingdom	0.040	0.025	0.054	0.027	0.035	0.033
USA	0.041	0.027	0.057	0.032	0.042	0.036
Positive Ideal Solution	0.043	0.027	0.057	0.032	0.046	0.036
Negative Ideal Solution	0.019	0.016	0.047	0.016	0.018	0.020

The distances of alternative destinations to the positive and negative ideal solution points and their relative proximity to the ideal solution according to the criteria in the digitalization indices evaluated by TOPSIS method are given in Table 8. As a result of the calculation of the weights of the specified criteria and the calculation of the relative distances to the ideal solution, the ranking of the digitalization levels of countries included in the study is given in Table 9. Accordingly, among the leading countries in LPI, the most digitalized countries are Singapore, the USA, and Netherlands, respectively. These countries are followed by Denmark, Switzerland, Sweden, Finland, Canada, Korea Rep., and United Kingdom.

Table 8. Ideal discrimination solutions and their relative proximity to the ideal solution

Countries	*Si**	*Si-*	*Ci**	*Ranking*
Australia	0.015629	0.030664	0.662384	13
Austria	0.01629	0.029209	0.641975	16
Belgium	0.016309	0.03104	0.655558	14
Canada	0.01318	0.033492	0.717603	8
China	0.016056	0.030289	0.65355	15
Denmark	0.007443	0.040491	0.844725	4
Finland	0.00726	0.038497	0.841328	7
France	0.017896	0.028429	0.613694	18
Germany	0.01422	0.032109	0.693071	11
Greece	0.035624	0.010079	0.220527	22
Italy	0.026747	0.019079	0.416335	21
Japan	0.019519	0.027107	0.581372	19
Korea Rep.	0.013445	0.033384	0.71289	9
Netherlands	0.007064	0.039612	0.84866	3
Norway	0.014915	0.031396	0.677935	12
Singapore	0.004321	0.041975	0.906667	1
South Africa	0.045377	0	0	23
Spain	0.023652	0.022141	0.483504	20
Sweden	0.007304	0.039086	0.842551	6
Switzerland	0.007779	0.041927	0.843498	5
United Arap Emirates	0.01836	0.031389	0.630951	17
United Kingdom	0.013562	0.033432	0.71141	10
USA	0.004868	0.04153	0.89509	2

Table 9. Ranking of countries as alternatives by criteria

Countries	*Ci**	*Ranking*
Singapore	0.906667133	1
USA	0.895089851	2
Netherlands	0.848659588	3
Denmark	0.844724925	4
Switzerland	0.843498348	5
Sweden	0.842550848	6
Finland	0.841328243	7
Canada	0.717602565	8
Korea Rep.	0.712889683	9
United Kingdom	0.711409947	10
Germany	0.693070548	11
Norway	0.677934714	12
Australia	0.662383693	13
Belgium	0.655558083	14
China	0.653550048	15
Austria	0.641974507	16
United Arab Emirates	0.630950729	17
France	0.613693736	18
Japan	0.581371786	19
Spain	0.48350422	20
Italy	0.416335353	21
Greece	0.220526908	22
South Africa	0	23

7. CONCLUSION

The concept of digitalization, driven by ongoing advancements in technology, has emerged as one of the most critical factors in international trade, and logistics activities and enhancing productivity in manufacturing, as well as strengthening global competitiveness. Digitalization accelerates access to information, fostering innovation and increasing the capacity of countries to adapt to rapid changes in the global economy, trade, and logistics operations. With the advent of Industry 4.0, advanced technologies such as big data analytics, artificial intelligence, the IoT, and blockchain are driving significant transformations within the logistics sector.

Digital technologies play a crucial role in making supply chains more efficient, transparent, and flexible. Integrating these technologies into logistics processes facilitates the automation and traceability of logistics operations, reduces logistics costs, and enhances customer service levels. The use of digital technologies in areas such as data collection, decision support systems, and process automation significantly contributes to the operational efficiency of logistics processes. Therefore, countries that effectively utilize these technologies are expected to experience improvements in their logistics performance.

LPI is a vital metric for assessing a country's logistics capabilities at an international level, also directly impacting the efficiency of international trade. Improving countries' logistics performance and achieving a competitive edge in the global market are closely related to assessing and analyzing their levels of digitalization. Various indices exist to measure and evaluate the digitalization levels of countries. Ranking highly on these indices can enable countries to excel in the logistics sector, where the intensive use of information and communication technologies and digitalization is critical. In line with this perspective, this study analyzes the digitalization levels of countries that rank high on the Logistics Performance Index using CRITIC and TOPSIS, two MCDM methods. The analysis focuses on the top 25 countries in the LPI, excluding Hong Kong and Taiwan due to data unavailability in some digitalization indices, resulting in a final analysis of 23 countries. These 23 countries are considered as alternatives in the study. Digitalization indicators such as the GII, NRI, IDI, WDCI, WCI, and GAIRI are included as criteria in the analysis.

The aim of this study is to rank the top 23 countries in the Logistics Performance Index (LPI) according to their levels of digitalization and to identify the most significant digitalization indices for countries leading in logistics performance. Using the CRITIC method to determine the importance levels of the criteria, the analysis reveals that among the six digitalization indices considered, the three most important indices for the top 23 countries in the LPI are, in order of significance, the IDI, the WCI, and the GII.

IDI measures a country's information and communication technology infrastructure and the extent of its usage. To enhance their logistics performance to the highest levels, countries must ensure the rapid and accurate flow of information within logistics operations. One of the most critical factors in maintaining this uninterrupted information flow is the presence of an effective and efficient digital infrastructure. This infrastructure is essential for optimizing logistics operations, enhancing the transparency of supply chains, and strengthening data-driven decision-making processes. Therefore, the IDI, which includes universal connectivity indicators and meaningful connectivity indicators, emerges as a vital data source for countries aiming to elevate their logistics performance to the forefront.

WCI is a critical indicator for assessing a country's global competitiveness and is closely linked to its logistics performance. Countries with high competitiveness are able to allocate more resources to research and development efforts aimed at enhancing their logistics services. Nations ranking higher on the WCI possess advantages in terms of the digitalization of customs processes and the integration of digital technologies into shipment tracking and traceability infrastructures. This leads to more efficient and effective logistics processes within these countries. Moreover, nations with a global competitive edge are better positioned to attract more investments into their logistics sector and strengthen international collaborations. Therefore, the WCI emerges as a significant criterion among the digitalization parameters for countries that lead in logistics performance indices.

GII reflects a country's capacity for innovation, its technological outputs, and the ability to transform these outputs into economic value. The logistics sector constantly requires innovation to optimize processes, reduce costs, enhance efficiency, and develop sustainable logistics solutions. Therefore, countries with high GII scores are likely to excel in effectively leveraging digital technologies in logistics processes and developing innovative business models. Accordingly, GII emerges as the third most critical criterion for countries that rank highly in the LPI.

Based on the weight values of the criteria, the leading countries in the LPI were ranked according to their levels of digitalization using the TOPSIS method. The results indicate that among the leading countries in the LPI, Singapore, the United States, and the Netherlands have the highest digitalization levels, respectively. Singapore ranks second in the IDI index, fourth in the WCI, and fifth in the GII in 2023. Singapore's consistent top-five positioning across these indices, alongside its generally high ranking in the LPI, underscores the nation's significant emphasis on digital technologies. The continuous development of Singapore's digital infrastructure is attributed to strong public policies on digitalization, government incentives for ICT advancements in both private and public sectors, and a skilled workforce in the ICT sector (Erh, 2023). The integration of digital technologies into logistics management significantly enhances logistics performance. The Port of Singapore is one of the busiest container ports globally, offering rapid and efficient services through its high-tech terminals. Additionally, Changi Airport serves as a crucial hub for passenger and cargo transport, ranking first among the world's top 100 airports in 2023 (Skytrax, 2024). A country's leading position in maritime and air transport is closely linked to the integration of digital technologies into the logistics sector. Therefore, Singapore's prominence in digitalization indices reflects the widespread adoption of digital technologies by logistics businesses in the country.

The United States ranks seventh in the IDI index, ninth in the WCI, and third in the GII in 2023. The United States' presence in the top ten of these digitalization indices aligns with the North American logistics market surpassing USD 2 trillion by 2020, positioning it as the second-largest logistics market after the Asia-Pacific region. The market's projection to quadruple by 2050 (Placek, 2023), combined with the significant role of U.S. companies as major exporters of information technologies, positions the United States as a favorable environment for achieving high logistics performance levels.

The Netherlands ranked twentieth in the IDI index, fifth in the WCI, and seventh in the GII in 2023. The Netherlands' strong performance in the WCI and GII can be attributed to a high percentage (79%) of its population possessing digital skills, 7.2% of the employed workforce being ICT specialists, exceeding the EU average, and the country's leadership in the semiconductor equipment industry, critical for digital technologies. Furthermore, the Netherlands outperforms EU averages in indicators related to big data, cloud computing, and artificial intelligence, supported by government efforts to digitize public services (European Commission, 2024: 4). In the Port of Rotterdam, the digitalization of customs processes significantly reduces handling times by accelerating container processing. Additionally, the digitalization of rail transport linked to the port facilitates efficient management of container-train traffic by enhancing information flow among shippers, rail operators, and terminals (Rotterdam Port, 2024). In terms of gross weight of maritime freight handled at main EU ports, the Netherlands led EU countries in the third and fourth quarters of 2023, with approximately 130 million tons of goods transported each quarter (Eurostat, 2024). The presence of the Port of Rotterdam, one of the busiest container ports in the world, and the country’s initiatives in integrating digital technologies into the logistics sector underscore the significant role of digitalization in enhancing logistics performance in the Netherlands.

As with many studies, this research also has certain limitations. First, only six indices were selected for the chosen countries within the scope of digitalization indices. This number could be increased by incorporating additional indices, such as the Digital Economy and Society Index (DESI), particularly for studies involving EU countries. Second, it is possible to achieve different results using various weighting and multi-criteria decision-making (MCDM) methods. Third, if the indices used in this study are updated with new data in the future, repeating these analyses may yield different outcomes. Fourth, by utilizing indices data from different years, the study results can be compared over time with a focus on more specific country groups. Lastly, the results obtained using multiple MCDM methods can be compared to provide a more comprehensive understanding.

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Compliance with Ethical Standards
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It was declared by the author that scientific and ethical principles have been followed in this study and all the sources used have been properly cited.

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