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An analysis of the logistics performance index of EU countries with an integrated MCDM model[1]

Alptekin Ulutaş,[2] Çağatay Karaköy[3]

Abstract: Countries can check the performance of their logistics' activities to determine their competitiveness in trade logistics. One way to check these performances is to analyze the country's LPI value in detail which is released by the WB every two years. When calculating the LPI, six indicators (criteria) are taken into account. The weights (importance level) of these criteria are important for countries which would like to focus more on the most important criteria and move their ranking up in the LPI list. However the WB takes into account indicators (criteria) weights equally when calculating LPI values. In order to overcome this problem some studies have used subjective weighting methods and others have used objective weighting methods. Both methods have advantages and disadvantages. The aim of this study is to integrate two weighting methods (subjective (SWARA) and objective (CRITIC)) in determining the weights of criteria in order to balance the two weighting methods. Unlike other studies in the literature this study combines two weighting methods. Additionally the PIV method, which is seldom used to address any MCDM problem, is used in this study and a new integrated MCDM model is introduced to literature. In this respect this study contributes to the literature.

Keywords: CRITIC, SWARA, PIV, MCDM, LPI, logistics, performance.

JEL codes: M10, M19, C60.

Introduction

With the impact of globalization and the increasingly competitive environment logistics has become one of the most important factors of trade. Influential

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logistics services promote product mobility, ensure product safety and velocity as well as cost reduction when trading between nations (Martí, Puertas, & García, 2014). Additionally nowadays the logistics service industry is accepted as the economy's 'bloodstream' indicating a strong correlation between the demand for logistics services and the economy's situation (Kawa & Anholcer, 2019). Logistics activities are of great importance in addressing transport, storage and packaging problems effectively and particularly to increase the competitiveness of companies and the country. The significant sources of sustainable competitive advantage have been supply chain management and logistics (Çakır, 2017). Nevertheless inefficient logistics have a negative impact on both countries and companies by increasing operational costs and reducing turnover (Martí et al., 2014).

Nowadays markets have become virtual in spatial terms. With the increase in the virtual market and e-commerce the importance of logistics' services is increasing day by day. With the development of technology logistics has become an important topic for both countries and private companies. For the economies of countries logistics is a significant driver (Yildirim & Mercangoz, 2019). Countries can check the performance of their logistics activities to determine their competitiveness in trade logistics. One way to check these performances is to analyze the country's LPI (logistics performance index) value in detail. In order to aid countries in determining the opportunities and challenges which they face in their performance on trade logistics, LPI is a benchmarking instrument formed (Çakır, 2017). The LPI of countries is published every two years by the World Bank (WB). When calculating the LPI six indicators: tracking and tracing (C1), logistics quality and competence (C2), international shipments (C3), customs (C4), timeliness (C5) and infrastructure (C6) are taken into account. The WB makes scoring based (1 to 5) surveys while determining the LPI. Scores (1 to 5) which show that countries with near-five scores have high logistics performance, on the other hand countries with low logistics performance have a score close to one.

Countries try to increase overall LPI scores and to rank higher in the LPI list when developing strategies (Yildirim & Mercangoz, 2019). When developing these strategies countries need to determine which indicator of LPI should be more focused upon. However the WB takes into account indicators (criteria) weights equally when calculating LPI values. This is an obstacle for effective policies to be developed by countries (Yildirim & Mercangoz, 2019). In order to overcome this problem some studies in the literature have used subjective weights for criteria by using subjective weighting methods instead of equal weighting (Rezaei, van Roekel, & Tavasszy, 2018; Yildirim & Mercangoz, 2019). One of the biggest disadvantages of subjective weighting methods is that the results can change depending on the place or the people surveyed. For example, according to the study of Rezaei et al. (2018), sorting of criteria is as follows; C6, C2, C5, C4, C3, and C1. In another attempt to de-

termine criteria weights, according to the study of Yildirim and Mercangoz (2019), sorting of criteria are as follows; C6, C5, C4, C2, C3, and C1. As can be seen the sorting of criteria is different. Instead of subjective weighting methods some studies have used objective weighting methods (Çakır, 2017). The main disadvantage of these methods is that they achieve criteria weights without expert opinions. That is, these methods do not consider the experience of experts in the sector. In this study both types of weighting methods (subjective and objective) will be used to make a balance between the two weighting methods. Thus neither the purely subjective weighting nor the objective weighting will be used. In this study the LPIs of European Union (EU) countries, which is one of the most important trade integrations in the world, will be evaluated with an integrated multi-criteria decision making (MCDM) model comprising CRITIC (criteria importance through intercriteria correlation) method, SWARA (step-wise weight assessment ratio analysis) method and PIV (proximity indexed value) method. The aim of this study is to integrate the two weighting methods (subjective (SWARA) and objective (CRITIC)) in determining the weights of criteria in order to balance between the two weighting methods. Unlike other studies in the literature, this study combines two weighting methods. Additionally the PIV method, which is seldom used to address any MCDM problem, is used in this study and a new integrated MCDM model is introduced to literature. In this respect this study contributes to the literature.

The CRITIC method is preferred in this study since it considers the correlations between the criteria. Besides the Entropy method, another objective weighting method uses the logarithmic approach. In this method if the normalized version of a criterion is "0", the logarithmic value cannot be found and this criterion cannot be considered in the evaluation process. The SWARA method is preferred in this study since it is easy to collect data and to compute criteria weights compared to the AHP (analytic hierarchy process). The PIV method is both easy to use and has fewer computation steps and the results are reached quickly. In addition it has been proved by Mufazzal and Muzakkir (2018) that PIV minimizes rank reversal problems compared with other MCDM methods.

This study will continue as follows. In the first section the studies related to logistics performance evaluation and the studies related to the components of the proposed model are presented. The second section shows the proposed methods. In the third section, the logistic performances of the countries will be measured by using the proposed model. In the fourth section, the effects of changes in the weights of the criteria on the ranking of countries will be discussed. The final section, will provide conclusions, managerial implications, limitations and recommendations for future studies.

1. Literature review

In the literature studies on the evaluation of logistics performances are generally done at the firm level. Some of the current studies are summarized as follows. Karbassi Yazdi, Hanne, Osorio Gómez and García Alcaraz (2018) integrated Entropy, Delphi and EAMR methods were used to identify the most appropriate third-party logistics provider for the Iranian automobile industry. They used the Delphi method to identify the criteria, the Entropy method to determine the weights of criteria, and EAMR to rank the alternatives. Chen, Goh and Zou (2018) created a model including fuzzy axiomatic design and extended the regret theory to determine the most appropriate logistics provider for an omni-channel retailer. Authors validated the results of the proposed model by comparison with traditional regret and TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) methods. Singh, Gunasekaran and Kumar (2018) combined fuzzy AHP (analytic hierarchy process) and TOPSIS to identify the most suitable third-party logistics provider among three alternatives for a health food manufacturing company located in India. Authors used fuzzy AHP to determine the weights of criteria and fuzzy TOPSIS to rank the alternatives. Sremac, Stević, Pamučar, Arsić and Matić (2018) developed a hybrid, rough based MCDM model including SWARA (Step-wise Weight Assessment Ratio Analysis), WASPAS (Weighted Aggregated Sum Product Assessment), and Dombi aggregator to identify the best third-party logistics provider among ten alternatives for the chemical industry of Serbia. They took into account eight criteria and the preferences of five experts in the evaluation process. Ecer (2018) combined EDAS (Evaluation Based on Distance from Average Solution) and fuzzy AHP to select the most appropriate third-party logistics provider among four alternatives for a marble quarry located in Turkey. Author considered eleven criteria in the evaluation process. Pamucar, Chatterjee and Zavadskas (2019) presented a hybrid MCDM model based on interval rough numbers consisting of BWM (Best Worst Method), WASPAS and MABAC (Multi Attributive Border Approximation Area Comparison) to choose the optimal third-party logistics provider among six alternatives. Authors took into account five criteria in the assessment process. Ulutaş (2019) integrated Entropy method and EDAS method to evaluate the performance of logistics companies. Author used the Entropy method to identify the weights of criteria and EDAS method to rank logistics companies. Compared to the number of studies on the evaluation of logistic performances at company level, the number of studies on the evaluation of the logistic performance of countries is very few.

Some of the studies related to logistic performance of the countries are summarized as follows. Martí and others (2014) examined the impact that each of the criteria of LPI has on the trade of developing countries by using a grav-

ity model. D'Aleo (2015) used an explanatory linear regression model to analyze the mediator role of LPI on the relationship between the Gross Domestic Product and Global Competitiveness Index from 2007 to 2014 in Europe. As a result the increasing efficiency of the logistics system of a country has a positive effect on wealth. Çakır (2017) proposed a hybrid model including CRITIC, SAW (Simple Additive Weighting) and Peter's fuzzy linear regression to compare the LPIs of OECD countries by considering 2014 data. The author used CRITIC to determine the weights of criteria and SAW and fuzzy linear regression to rank OECD countries. Martí, Martín and Puertas (2017) suggested DEA (Data Envelopment Analysis) to calculate the overall logistics performance synthetic index and to compare the countries' logistics performance by considering LPI. The findings of this study indicate that logistical performances of countries are closely linked to their geography and income. Rezaei and others (2018) proposed BWM to identify weights to components of LPI. They conducted a survey in which 107 experts participated for the calculation of weights. The weights of criteria obtained in this study are C1 (0.102), C2 (0.217), C3 (0.126), C4 (0.159), C5 (0.1601) and C6 (0.2354) respectively. The finding of this study is that infrastructure is the most significant component of LPI. Yildirim and Mercangoz (2019) integrated fuzzy AHP and ARAS-G (Grey Additive Ratio Assessment) to analyze LPI of OECD countries in the period between 2010 and 2018. The finding of this study is that infrastructure is the most significant component of LPI.

The components of the proposed model (CRITIC and PIV methods) have been used to solve different MCDM problems. The CRITIC method has been used to solve different MCDM problems, such as material selection (Jahan, Mustapha, Sapuan, Ismail, & Bahraminasab, 2012), the evaluation of performance of logistics companies (Çakır & Perçin, 2013), the evaluation of performance of third-party logistics companies (Keshavarz Ghorabaee, Amiri, Zavadskas, & Antuchevičienė, 2017), air conditioner selection (Vujicic, Papic, & Blagojevic, 2017), and the evaluation of performance of a cargo company (Ulutaş & Karaköy, 2019). The SWARA method has been used to solve different MCDM problems such as supplier selection (Alimardani, Hashemkhani Zolfani, Aghdaie, & Tamošaitiene, 2013), packaging design selection (Stanujkic, Karabasevic, & Zavadskas, 2015), personnel selection (Heidary Dahooie, Beheshti Jazan Abadi, Vanaki, & Firoozfar, 2018) and outsourcing provider selection (Perçin, 2019). The PIV method has been used to solve only two MCDM problems which are the selection of e-learning websites (Khan, Ansari, Siddiquee, & Khan, 2019) and the evaluation of experiments (Yahya, Asjad, & Khan, 2019). As can be seen the applications of the PIV method in the literature are very few, therefore, this study uses this method to solve a MCDM problem. The next section will explain the methodology in detail.

2. Methodology

In this study an integrated MCDM model including CRITIC, SWARA and PIV methods is proposed to evaluate the LPIs of European Union (EU) countries. In the first stage the objective weights of criteria are obtained by using the CRITIC method. The subjective weights of criteria are then achieved by using the SWARA method. After this these weights are integrated to determine the combined weights of the criteria. The ranking of EU countries is made by using PIV method. The framework of the proposed model is indicated in Figure 1.

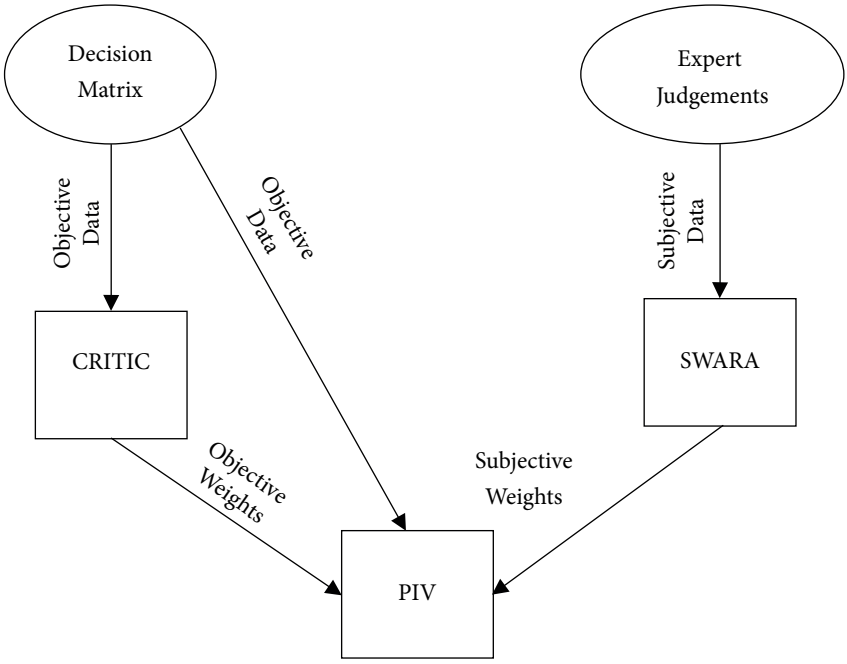

Figure 1. The Framework of the proposed model
Source: Own elaboration.

The following criteria are considered in the evaluation process (World Bank, 2019).

- tracking and tracing (C1),
- logistics quality and competence (C2),
- international shipments (C3),
- customs (C4),
- timeliness (C5),
- infrastructure (C6).

All criteria used in this study are beneficial criteria so equations related to cost criteria in the proposed model are not indicated.

2.1. CRITIC method

Diakoulaki, Mavrotas and Papayannakis (1995) introduced the CRITIC method. The CRITIC method will be used to obtain the objective weights of criteria as follows (Madić & Radovanović, 2015).

Step 1: Decision Matrix ($B=[b_{ij}]_{m\times n}$) is structured as follows:

$$B=[b_{ij}]_{m\times n}=\begin{bmatrix} b_{11} & b_{12} & \cdots & b_{1n} \\ b_{21} & b_{22} & \cdots & b_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ b_{m1} & b_{m2} & \cdots & b_{mn} \end{bmatrix}. \quad (1)$$

Step 2: This matrix is normalized by equation 2:

$$t_{ij}=\frac{b_{ij}-b_j^{min}}{b_j^{max}-b_j^{min}}. \quad (2)$$

Step 3: Taking into account the standard deviation (σ_j) of each criterion and the correlations (c_{jk}) of the criteria with each other, the objective weights of each criterion are obtained:

$$w_{jo}=\frac{h_j}{\sum_{k=1}^{n} h_k}, \quad (3)$$

where,

$$h_j=\sigma_j\sum_{k=1}^{n}(1-c_{jk}). \quad (4)$$

2.2. SWARA method

The SWARA (introduced by Keršuliene, Zavadskas, & Turskis, 2010) method is utilized to obtain the subjective weights of criteria. The steps of the SWARA method are presented as follows (Stanujkic et al., 2015).

Step 1: Depending on their expected significances criteria are listed in descending order.

Step 2: Criteria are compared among themselves. The *j*th criterion and *j* + 1th criterion are compared. In the criteria comparison, "comparative importance of average value" (d_j) is used (Keršuliene et al., 2010). This value is between 0 and 1 value and it is multiples of five (Adalı & Işık, 2017).

Step 3: The coefficient g_j is computed as follows:

$$g_j = \begin{cases} 1 & j = 1 \\ d_j + 1 & j > 1 \end{cases}. \quad (5)$$

Step 4: The recalculated weight (f_j) is calculated as follows:

$$f_j = \begin{cases} 1 & j = 1 \\ \dfrac{f_{j-1}}{g_j} & j > 1 \end{cases}. \quad (6)$$

Step 5: Subjective weights (w_{js}) of criteria are obtained as follows:

$$w_{js} = \frac{f_j}{\sum_{j=1}^{n} f_j}. \quad (7)$$

The integration of criteria weights (objective (obtained in CRITIC method) and subjective (obtained in SWARA method)) will be made by using following equation (Zavadskas & Podvezko, 2016):

$$w_{jc} = \frac{w_{jo} w_{js}}{\sum_{j=1}^{n} w_{jo} w_{js}}. \quad (8)$$

In equation 8, w_{jc} is the combined weights of criteria.

2.3. PIV method

The PIV method was developed by Mufazzal and Muzakkir (2018) as follows.
Step 1: Decision Matrix is structured. This step has been made in equation 1.
Step 2: This matrix is normalized by using equation 9:

$$a_{ij} = \frac{b_{ij}}{\sqrt{\sum_{i=1}^{m} b_{ij}^2}}. \quad (9)$$

Step 3: The combined weights of criteria are multiplied by the normalized values using the following equation:

$$v_{ij} = w_{jc} \times a_{ij}. \quad (10)$$

Step 4: The Weighted Proximity Index (e_{ij}) is obtained by using equation 11:

$$e_{ij} = v_{max} - v_{ij}. \quad (11)$$

Step 5: The Overall Proximity Value (OPV) (z_i) is calculated by using equation 12. The alternative having the least value of OPV is identified as the best alternative:

$$z_i = \sum_{j=1}^{n} e_{ij} . \tag{12}$$

3. Application

In this section the proposed model is applied to 2018 LPI data of EU countries (All data used in this study were retrieved from World Bank, 2019). The decision matrix is indicated in Table 1.

Table 1. Decision matrix

Criteria / EU Countries	C1	C2	C3	C4	C5	C6
Austria	4.087098	4.083611	3.87753	3.714068	4.250803	4.181584
Belgium	4.051289	4.130972	3.994913	3.663064	4.410293	3.984249
Bulgaria	3.015289	2.881315	3.233723	2.937588	3.313491	2.762986
Croatia	3.01282	3.096154	2.929487	2.978555	3.593939	3.01282
Republic of Cyprus	3.147619	3.004762	3.147619	3.051648	3.622711	2.892454
Czechia	3.703427	3.715632	3.746009	3.286673	4.13362	3.4646
Denmark	4.176078	4.007843	3.530159	3.918058	4.407843	3.95873
Estonia	3.206675	3.147851	3.262154	3.322037	3.798684	3.098638
Finland	4.323166	3.887269	3.562732	3.815046	4.279861	4.003472
France	3.999365	3.838338	3.545295	3.589643	4.152037	3.99688
Germany	4.239401	4.31065	3.858998	4.092256	4.392114	4.374447
Greece	3.175104	3.055823	3.303071	2.839182	3.662264	3.172495
Hungary	3.670508	3.213207	3.22188	3.354866	3.785941	3.270945
Ireland	3.623034	3.595856	3.423977	3.357716	3.756367	3.293335
Italy	3.854946	3.655042	3.512059	3.472044	4.126595	3.852904
Latvia	2.787563	2.69255	2.744904	2.79657	2.878851	2.983
Lithuania	3.123323	2.955624	2.78999	2.846491	3.646595	2.729618
Luxembourg	3.61474	3.757625	3.371425	3.527956	3.903863	3.631442

Malta	2.8	2.8	2.7	2.697778	3.005445	2.9
Netherlands	4.024758	4.087875	3.682287	3.917559	4.253336	4.207611
Poland	3.505663	3.580044	3.678499	3.253458	3.954262	3.208902
Portugal	3.719307	3.705938	3.826492	3.17135	4.125922	3.247268
Romania	3.264727	3.073653	3.176497	2.580718	3.681887	2.906903
Slovakia	2.985348	3.139194	3.101099	2.789011	3.139194	3
Slovenia	3.266667	3.052381	3.187912	3.418681	3.695238	3.261905
Spain	3.834502	3.800271	3.82952	3.620888	4.063369	3.83987
Sweden	3.876315	3.976896	3.915837	4.049361	4.284866	4.239947
United Kingdom	4.107993	4.04983	3.672469	3.772005	4.329937	4.032786

Source: (World Bank, 2019).

Equation 2 is applied to the decision matrix (indicated in Table 1) to achieve the normalized decision matrix. This matrix is indicated in Table 2.

Table 2. Normalized decision matrix

Criteria / EU Countries	C1	C2	C3	C4	C5	C6
Austria	0.8463	0.8597	0.9094	0.7498	0.8959	0.8827
Belgium	0.823	0.889	1	0.7161	1	0.7628
Bulgaria	0.1483	0.1167	0.4122	0.2361	0.2838	0.0203
Croatia	0.1467	0.2494	0.1772	0.2632	0.4669	0.1722
Republic of Cyprus	0.2345	0.1929	0.3457	0.3116	0.4857	0.099
Czechia	0.5964	0.6323	0.8078	0.467	0.8193	0.4468
Denmark	0.9042	0.8129	0.6411	0.8848	0.9984	0.7473
Estonia	0.2729	0.2814	0.4341	0.4904	0.6006	0.2244
Finland	1	0.7383	0.6662	0.8166	0.9148	0.7745
France	0.7891	0.7081	0.6528	0.6675	0.8314	0.7705
Germany	0.9455	1	0.895	1	0.9881	1
Greece	0.2524	0.2245	0.4657	0.171	0.5116	0.2693
Hungary	0.575	0.3218	0.403	0.5122	0.5923	0.3291
Ireland	0.5441	0.5583	0.5591	0.514	0.573	0.3427

Italy	0.6951	0.5948	0.6271	0.5897	0.8148	0.6829
Latvia	0	0	0.0347	0.1428	0	0.154
Lithuania	0.2187	0.1626	0.0695	0.1758	0.5013	0
Luxembourg	0.5387	0.6582	0.5185	0.6267	0.6693	0.5483
Malta	0.0081	0.0664	0	0.0774	0.0827	0.1036
Netherlands	0.8057	0.8623	0.7586	0.8844	0.8975	0.8986
Poland	0.4676	0.5485	0.7556	0.4451	0.7022	0.2914
Portugal	0.6068	0.6263	0.8699	0.3907	0.8143	0.3147
Romania	0.3107	0.2355	0.368	0	0.5244	0.1078
Slovakia	0.1288	0.276	0.3097	0.1378	0.17	0.1644
Slovenia	0.312	0.2224	0.3768	0.5544	0.5331	0.3236
Spain	0.6818	0.6846	0.8723	0.6882	0.7735	0.675
Sweden	0.709	0.7937	0.9389	0.9716	0.9181	0.9182
United Kingdom	0.8599	0.8388	0.751	0.7881	0.9475	0.7923

Source: Own estimation.

By using equation 3 the objective weights of criteria are obtained. Table 3 presents the objective weights of criteria.

Table 3. The objective weights of criteria

Criteria	w_{jo}
C1	0.1351
C2	0.1193
C3	0.2254
C4	0.1829
C5	0.1571
C6	0.1801

Source: Own estimation.

After obtaining the objective weights (presented in Table 3), the SWARA method is applied to achieve the subjective weights of criteria. The data for the SWARA method were obtained from three managers from three leading logistics companies with activities in EU countries. Table 4 presents the results of the SWARA method for the first manager.

Table 4. The results of the SWARA method for first manager

Criteria	Ranking	Criteria order	d_j	g_j	f_j	w_{js}
C1	6	C6		1	1	0.2635
C2	2	C2	0.35	1.35	0.7407	0.1952
C3	5	C5	0.30	1.30	0.5698	0.1501
C4	4	C4	0.05	1.05	0.5427	0.1430
C5	3	C3	0.10	1.10	0.4934	0.1300
C6	1	C1	0.10	1.10	0.4485	0.1182

Source: Own estimation.

The same process is made for other experts. All individual subjective weights of criteria are integrated with a geometric mean. Table 5 indicates the integrated subjective weights of criteria.

Table 5. The integrated subjective weights of criteria

Criteria	w_{js}
C1	0.1266
C2	0.2155
C3	0.1190
C4	0.1554
C5	0.1482
C6	0.2316

Source: Own estimation.

By using equation 8 the subjective (presented in Table 5) and objective (shown in Table 3) weights of criteria are combined. Table 6 indicates the combined weights of criteria.

Table 6. The combined weights of criteria

Criteria	w_{jc}
C1	0.1049
C2	0.1577
C3	0.1645
C4	0.1743
C5	0.1428
C6	0.2558

Source: Own estimation.

After obtaining the combined weights of criteria (shown in Table 6), equation 9 in the PIV method is applied to the Decision Matrix (indicated in Table 1) to normalize it. The normalized decision matrix (for the PIV method) is indicated in Table 7.

Table 7. Normalized decision matrix (PIV)

Criteria / EU Countries	C1	C2	C3	C4	C5	C6
Austria	0.2141	0.2179	0.2129	0.2078	0.2058	0.2245
Belgium	0.2122	0.2204	0.2194	0.2049	0.2136	0.2139
Bulgaria	0.158	0.1537	0.1776	0.1643	0.1604	0.1484
Croatia	0.1578	0.1652	0.1609	0.1666	0.174	0.1618
Republic of Cyprus	0.1649	0.1603	0.1728	0.1707	0.1754	0.1553
Czechia	0.194	0.1982	0.2057	0.1839	0.2002	0.186
Denmark	0.2188	0.2138	0.1938	0.2192	0.2134	0.2126
Estonia	0.168	0.1679	0.1791	0.1858	0.1839	0.1664
Finland	0.2265	0.2074	0.1956	0.2134	0.2072	0.215
France	0.2095	0.2048	0.1947	0.2008	0.201	0.2146
Germany	0.2221	0.23	0.2119	0.2289	0.2127	0.2349
Greece	0.1663	0.163	0.1814	0.1588	0.1773	0.1703
Hungary	0.1923	0.1714	0.1769	0.1877	0.1833	0.1756
Ireland	0.1898	0.1919	0.188	0.1878	0.1819	0.1768
Italy	0.2019	0.195	0.1929	0.1942	0.1998	0.2069
Latvia	0.146	0.1437	0.1507	0.1564	0.1394	0.1602
Lithuania	0.1636	0.1577	0.1532	0.1592	0.1766	0.1466
Luxembourg	0.1894	0.2005	0.1851	0.1974	0.189	0.195
Malta	0.1467	0.1494	0.1483	0.1509	0.1455	0.1557
Netherlands	0.2108	0.2181	0.2022	0.2192	0.206	0.2259
Poland	0.1836	0.191	0.202	0.182	0.1915	0.1723
Portugal	0.1948	0.1977	0.2101	0.1774	0.1998	0.1744
Romania	0.171	0.164	0.1744	0.1444	0.1783	0.1561
Slovakia	0.1564	0.1675	0.1703	0.156	0.152	0.1611
Slovenia	0.1711	0.1629	0.1751	0.1912	0.1789	0.1751
Spain	0.2009	0.2028	0.2103	0.2026	0.1968	0.2062
Sweden	0.2031	0.2122	0.215	0.2265	0.2075	0.2277
United Kingdom	0.2152	0.2161	0.2017	0.211	0.2097	0.2165

Source: Own estimation.

By using equation 10 the weighted normalized decision matrix is obtained presented in Table 8.

Table 8. Weighted normalized decision matrix

Criteria / EU Countries	C1	C2	C3	C4	C5	C6
Austria	0.0225	0.0344	0.0350	0.0362	0.0294	0.0574
Belgium	0.0223	0.0348	0.0361	0.0357	0.0305	0.0547
Bulgaria	0.0166	0.0242	0.0292	0.0286	0.0229	0.0380
Croatia	0.0166	0.0261	0.0265	0.0290	0.0248	0.0414
Republic of Cyprus	0.0173	0.0253	0.0284	0.0298	0.0250	0.0397
Czechia	0.0204	0.0313	0.0338	0.0321	0.0286	0.0476
Denmark	0.0230	0.0337	0.0319	0.0382	0.0305	0.0544
Estonia	0.0176	0.0265	0.0295	0.0324	0.0263	0.0426
Finland	0.0238	0.0327	0.0322	0.0372	0.0296	0.0550
France	0.0220	0.0323	0.0320	0.0350	0.0287	0.0549
Germany	0.0233	0.0363	0.0349	0.0399	0.0304	0.0601
Greece	0.0174	0.0257	0.0298	0.0277	0.0253	0.0436
Hungary	0.0202	0.0270	0.0291	0.0327	0.0262	0.0449
Ireland	0.0199	0.0303	0.0309	0.0327	0.0260	0.0452
Italy	0.0212	0.0308	0.0317	0.0338	0.0285	0.0529
Latvia	0.0153	0.0227	0.0248	0.0273	0.0199	0.0410
Lithuania	0.0172	0.0249	0.0252	0.0277	0.0252	0.0375
Luxembourg	0.0199	0.0316	0.0304	0.0344	0.0270	0.0499
Malta	0.0154	0.0236	0.0244	0.0263	0.0208	0.0398
Netherlands	0.0221	0.0344	0.0333	0.0382	0.0294	0.0578
Poland	0.0193	0.0301	0.0332	0.0317	0.0273	0.0441
Portugal	0.0204	0.0312	0.0346	0.0309	0.0285	0.0446
Romania	0.0179	0.0259	0.0287	0.0252	0.0255	0.0399
Slovakia	0.0164	0.0264	0.0280	0.0272	0.0217	0.0412
Slovenia	0.0179	0.0257	0.0288	0.0333	0.0255	0.0448
Spain	0.0211	0.0320	0.0346	0.0353	0.0281	0.0527
Sweden	0.0213	0.0335	0.0354	0.0395	0.0296	0.0582
United Kingdom	0.0226	0.0341	0.0332	0.0368	0.0299	0.0554

Source: Own estimation.

After this equation 11 is used to obtain e_{ij} values. Then the OPV (z_i) is computed by using equation 12. Table 9 indicates the OPV values and the rankings of countries.

Table 9. The Results of the Proposed Model

Criteria / EU Countries	z_i	Rankings
Austria	0.0118	4
Belgium	0.0126	5
Bulgaria	0.0672	25
Croatia	0.0623	22
Republic of Cyprus	0.0612	21
Czechia	0.0329	12
Denmark	0.0150	7
Estonia	0.0518	19
Finland	0.0162	8
France	0.0218	9
Germany	0.0018	1
Greece	0.0572	20
Hungary	0.0466	17
Ireland	0.0417	16
Italy	0.0278	11
Latvia	0.0757	27
Lithuania	0.0690	26
Luxembourg	0.0335	13
Malta	0.0764	28
Netherlands	0.0115	3
Poland	0.0410	15
Portugal	0.0365	14
Romania	0.0636	23
Slovakia	0.0658	24
Slovenia	0.0507	18
Spain	0.0229	10
Sweden	0.0092	2
United Kingdom	0.0147	6

Source: Own estimation.

According to the results of the proposed model (indicated in Table 9), the top 10 rankings of EU countries are as follows; Germany, Sweden, Netherlands, Austria, Belgium, United Kingdom, Denmark, Finland, France and Spain.

4. Discussion

Countries intend to increase overall LPI scores and to rank higher in the LPI list when developing strategies (Yildirim & Mercangoz, 2019). Countries need to identify which indicator (criterion) of LPI should be focused more on in developing strategies. In this study two types of weighting methods (SWARA (subjective) and CRITIC (objective)) were used to identify which criterion is most effective on LPI. The order of importance of the criteria varied according to the method used. For instance the criteria according to the CRITIC method (indicated in Table 3) are as follows: C3 > C4 > C6 > C5 > C1 > C2. According to the results of the CRITIC method the most important criterion is determined as international shipments (C3). On the other hand the criteria according to the SWARA method (presented in Table 5) are as follows: C6 > C2 > C4 > C5 > C1 > C3 and the most important criterion is determined as infrastructure (C6). When the results of CRITIC and SWARA methods (shown in Table 6) are combined with equation 8 the order of criteria is as follows: C6 > C4 > C3 > C2 > C5 > C1. According to the combined results of methods the most important criterion is determined as infrastructure (C6). The C6 criterion, which is selected twice as the most important criterion, is determined as the most important criterion according to the dominance theory (Brauers & Zavadskas, 2011). Changes in the weights of criteria can lead to changes in the ranking of countries. Table 10 shows the country rankings by criteria weights.

According to the results of the combined weights of criteria (indicated in Table 10), the top 10 rankings of EU countries are as follows; Germany, Sweden, Netherlands, Austria, Belgium, United Kingdom, Denmark, Finland, France, and Spain. The ranking of some of the top 10 countries does not change according to the change in criteria weights. These countries are Germany, Sweden, Austria, and Finland. The ranking of the other six countries changes with respect to criteria weights. Belgium is in the third rank in objective weighting and original ranking (equal weights of criteria), on the other hand, it is in the fifth rank in subjective weighting and combined weighting. Conversely, Netherlands is the fifth rank in objective weighting and original ranking, on the other hand, it is the third rank in subjective weighting and combined weighting. The United Kingdom is the sixth in objective weighting, subjective weighting, and combined weighting, however, it is seventh in the original ranking. Denmark is the seventh rank in objective weighting and combined weighting and it is sixth in subjective weighting and original ranking. Spain is ninth in objective weighting but it is tenth in other weightings. Conversely, France is the tenth rank in

Table 10. The changing of the LPI ranking w.r.t. criteria weights

Rankings EU Countries	Rankings with w_{jo}	Rankings with w_{js}	Rankings with w_{jc}	Original ranking w.r.t. LPI
Austria	4	4	4	4
Belgium	3	5	5	3
Bulgaria	24	25	25	24
Croatia	23	22	22	23
Republic of Cyprus	21	21	21	21
Czechia	12	12	12	12
Denmark	7	6	7	6
Estonia	19	19	19	19
Finland	8	8	8	8
France	10	9	9	9
Germany	1	1	1	1
Greece	20	20	20	20
Hungary	17	17	17	17
Ireland	16	16	16	16
Italy	11	11	11	11
Latvia	27	27	27	28
Lithuania	26	26	26	26
Luxembourg	14	13	13	14
Malta	28	27	28	27
Netherlands	5	3	3	5
Poland	15	15	15	15
Portugal	13	14	14	13
Romania	22	23	23	22
Slovakia	25	24	24	25
Slovenia	18	18	18	18
Spain	9	10	10	10
Sweden	2	2	2	2
United Kingdom	6	6	6	7

Sources: (World Bank, 2019) and own estimation.

objective weighting but is ninth in other weightings. It can be seen that changes in the weights of criteria partially affect the ranking of countries. Therefore criteria weights need to be accurately determined.

Conclusions

In this study the LPIs of European Union (EU) countries, which is one of the most important trade integrations in the world, was evaluated with an integrated MCDM model comprising CRITIC, SWARA and PIV methods. The CRITIC method was used to the obtain the objective weights of the criteria. The SWARA method was used to obtain the subjective weights of the criteria. Then, subjective and objective weights of the criteria were integrated to determine the combined weights. When the results of the CRITIC and SWARA methods (presented in Table 6) were combined the order of criteria was as follows: C6 > C4 > C3 > C2 > C5 > C1. According to the results of the proposed model (indicated in Table 9 and Table 10), the top 10 rankings of EU countries are as follows; Germany, Sweden, Netherlands, Austria, Belgium, United Kingdom, Denmark, Finland, France and Spain. In the discussion section, it was observed that change in weights of criteria affects the ranking of countries partially. Therefore, the criteria weights need to be accurately determined. This study does not consider the weights of criteria unilaterally (objective or subjective). This study used two weighting methods (subjective (SWARA) and objective (CRITIC)) to determine the weights of criteria unlike other studies. In this respect this study brings a new perspective to LPI assessment. Additionally, the PIV method, which is seldom used to address any MCDM problem, was used and a new integrated MCDM model was introduced to the literature thus making a new contribution. The managers of logistics companies wishing to invest in EU countries can determine the country in which they would like to invest with the help of the methods presented here. In addition, the managers of logistics companies can determine which criteria should be focused upon more by checking the weights of the criteria obtained in the study. Although this is a micro-based solution the company is expected to contribute to the LPI value of the country where it is located. Although this study brings a new perspective to the literature it has some limitations. Firstly, only EU countries have been evaluated. More detailed research can be made by increasing the number of countries. Secondly, the data used in the SWARA method was obtained from three experts. Results can be made more powerful by obtaining data from more experts. Thirdly, only one year (2018) was taken into account in the analysis. By considering more years the analysis can be enriched.

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