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ORIGINAL PAPER

DETERMINING THE LOGISTICS MARKET PERFORMANCE OF DEVELOPING COUNTRIES BY ENTROPY AND MABAC METHODS

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ABSTRACT. Background: The levels of logistics market performance of developing countries are published with Agility Emerging Markets Logistics Index (AEMLI) reports. The main purpose of this research is to propose a new model to determine the logistics market performance of developing countries in 2022 and to reorder the developing countries according to their logistics market performance.

Methods: AEMLI indicators have been accepted as the basic criteria for determining the logistics market performance. The importance levels of these criteria have been determined by the Entropy technique. The logistics market performance rankings of developing countries according to the criteria were determined using the Multi-Attributive Border Approximation Area Comparison (MABAC) technique. The data set of 50 developing countries included in the 2022 AEMLI report has been used in the investigation.

Results: According to the proposed new model, the weights of the criteria and logistics market performance rankings of developing countries have been determined. The importance levels of the criteria have been determined as Business Fundamentals (BF), Digital Readiness (DR), International Logistics Opportunities (ILO), and Domestic Logistics Opportunities (DLO), respectively. The ranking based on the new model was compared with the rankings in the 2022 AEMLI report. 21 of the 50 developing countries have improved their rankings. The ranking of 20 countries has been dropped. There is no change in the ranking of 9 countries. Additionally, according to AEMLI, the country with the highest logistics market performance is China, while the country with the best logistics market performance according to the proposed model is the United Arab Emirates (UAE).

Conclusions: Contrary to the literature, Entropy and MABAC techniques were used to rank the logistics market performances of developing countries by making use of AEMLI reports. The issues that countries should focus on in the development of their logistics market performance are shown.

Keywords: Logistics market performance, Developing countries, Entropy, MABAC, MCDM

INTRODUCTION

Logistics and transportation activities are among the important building blocks that enable the realization of global trade [Martí et al., 2014]. Logistics becomes sustainable by creating its own market structure in global trade. Today, global logistics markets are growing and becoming more effective day by day [Doll et al., 2014]. Especially the openness to commercial and logistics development of developing countries makes these countries attractive in terms of logistics market. The geographical, political, cultural, and commercial structure of developing countries plays an active role in the logistics market structure. Therefore, differentiations occur in the logistics market performance of developing countries. This differentiation also changes the impact of logistics performance on international trade [Zaninović et al., 2021]. Furthermore, logistics performance has a significant correlation with macro variables such as global competitiveness [Çemberci et al., 2015], gross domestic product [Uca et al., 2015], corruption [Uca et al., 2016], economic growth [Çelebi et al., 2015].

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Research is carried out to determine and rank the logistics performances of countries. Logistics performance index (LPI) was developed by the World Bank. In the literature, there are many studies that use LPI. The Agility Emerging Markets Logistics Index (AEMLI) was developed to determine the logistics performance of developing countries. AEMLI has been presenting the logistics performance of developing countries on a regular basis every year since 2011. Contrary to LPI, there are few studies using AELMI [Beysenbaev, 2018; Beysenbaev & Dus, 2020; Shestak et al., 2021; Kara, 2022]. The main purpose of this research is to propose a new model, considering the indicators used in the AEMLI reports, which give the logistics market performance and rankings of developing countries. It is also aimed to rank the developing countries of the proposed new model according to their logistics market performances and to compare them with their rankings in AEMLI reports.

Entropy and Multi-Attributive Border Approximation Area Comparison (MABAC) techniques are used to determine the logistics market performance of developing countries. It aims to determine the importance levels of the AELMI indicators based on these techniques and to determine the logistics market performance of developing countries accordingly. For these purposes, in the remainder of the article, a literature review on which MCDM techniques are applied in determining the logistics performance of countries is presented. Then, Entropy and MABAC techniques are explained in the methodology section. In the application part, findings are presented based on the AEMLI data set and indicators. In conclusion, the rankings of the proposed model are compared with the AEMLI rankings.

LİTRETURE REVİEW

Logistics performance is among the main indicators that play an active role in the commercial activities of countries and have a significant correlation with country trade data [Beysanbaev, 2018]. In the literature, efforts are made to determine the logistics performance of countries. Logistics performance index (LPI) and Agility Emerging Markets Logistics Index (AEMLI) are among the indexes developed because of these efforts. LPI is based mainly on survey research. In this context, logistics cost, customs procedures, and investment opportunities of the countries are considered [Martí et al., 2014]. AEMLI is also based on survey-based research. However, it focuses only on the evaluation of the logistics market performance of emerging markets. In this context, *domestic logistics opportunities*, *international logistics opportunities*, *business fundamentals* and *digital readiness* levels of countries are considered (AEMLI, 2022). There are suggestions in the literature that claim that it is necessary to develop LPI [Beysenbaev and Dus, 2020]. At the same time, there are studies in the literature to improve the LPI index [Martí et al., 2017; Rezai et al., 2018]. Additionally, there are steps to develop different indices by using the LPI index [Lu et al., 2019].

Rezai et al. [2018] suggested that LPI scores of countries can be re-determined by determining the importance levels of LPI indicators. In this study, the importance level of the indicators was calculated with the Best Worst method by taking the opinions of 107 experts. There are changes in the LPI scores and rankings of the countries according to the determined importance levels. Criticizing the equal importance of the LPI criteria published by the World Bank, Ulutaş and Karaköy [2019a] suggested that the curvature of the criteria may be different. In this study, the weights were determined using Step-Wise Weight Assessment Ratio Analysis (SWARA) and Criteria Importance Through Intercriteria Correlation (CRITIC) multi-criteria decision making techniques. In addition, the LPI scores of the European Union countries have been redetermined. It has been determined that there are differences between the results obtained and the LPI scores.

Mešić et al. [2022] used LPI criteria to compare the logistics performance of Balkan countries. CRITIC and Measurement Alternatives and Ranking according to Compromise Solution (MARCOS) techniques were used to determine the importance weights of the criteria. According to the findings, the most successful country is Serbia. Martí et al. [2017] determined the efficiency levels of the logistics performance of the countries with the data envelopment analysis method. In this study,

three different scenarios were developed. LPI indicators are considered as input and output variables in all scenarios. In the analysis findings, it has been determined that there are differences in the levels of efficiency of logistics performance of the countries.

Yildirim and Mercangöz [2020] discussed the LPI scores published by the World Bank in 2010-2018 with a fuzzy logic approach. LPI indicators were accepted as evaluation criteria. Fuzzy Analytic Hierarchy Process method was used to determine the weights of the criteria. The gray additive ratio assessment technique (ARAS-G) was used to determine the LPI scores and rankings of the countries. A strong correlation was found between both LPI scores. Mercangöz et al. [2020] determined the LPI scores of the member states and candidate countries of the European Union using the gray approach. The LPI scores of selected countries for selected periods were determined using the Complex Proportional Assessment (CORPAS-G) technique. Based on the findings, a strong correlation was found between both LPI scores.

Isik et al. [2020] calculated the LPI scores of 11 Central and Eastern European countries using Statistical Variance and MABAC techniques. Timeliness was determined as the highest level of importance criterion, and infrastructure was determined as the lowest level of importance criterion. As a result of the LPI score calculations of the selected countries, the 3 countries with the highest LPI scores were determined as the Czech Republic, Poland, and Hungary, respectively. Senir [2021] applied the CRITIC and CORPAS methods to determine the LPI scores of the countries of the European Union and Turkey. The weights of export time, and distance, import time and distance criterion were determined. LPI scores and rankings of selected countries were presented.

Çakır [2016] applied CRITIC, simple additive weighting (SAW), and Peters' fuzzy regression methods to determine the levels of logistics performance of OECD countries. The criterion of logistics performance criterion with the highest importance was determined as tracking and tracking. The logistics performance of the lowest importance has been determined as logistics competence. Based on the importance levels of the criteria, the 2014 LPI scores of the OECD countries were determined. Differences were found between the World Bank LPI rankings, and the rankings obtained. Garca et al. [2015] determined the efficiency levels of the DEA and LPI scores of 141 sample countries. The countries with the highest level of LPI activity were Belgium, Germany, Norway, and Luxembourg.

Ozmen [2019] used the Mahalanobis distance (MD) based TODIM technique (an acronym in Portuguese for Interactive and Multicriteria Decision Making) to determine the logistics performance scores of the OECD countries. Two main criteria and nine sub-criteria were used in the study. The main criteria were determined as logistics performance and volume of transport. LPI indicators are included under the main criterion of logistics performance. In the main criterion, the freight, container and passenger volumes of the countries are used. In addition, the results of traditional TODIM and Improved TODIM results were compared. Oğuz et al. [2019] applied the Technique for Order-Preference by Similarity to Ideal Solution (TOPSIS) technique to determine the LPI scores of seven Asian countries. LPI indicators were determined as criteria. Singapore ranked first in the ranking.

Yalçin and Ayaz [2020] applied Fuzzy AHP and Fuzzy TOPSIS techniques to compare the logistics performances of Turkey and neighboring countries. The importance levels of the criteria were determined by Fuzzy AHP. The performance rankings of the countries were carried out with Fuzzy TOPSIS. Turkey ranked first in the logistics performance ranking. Ulutaş and Karaköy [2019b] used LPI indicators as criteria to determine the logistics performance of G20 countries. The Standard Deviation method was used to determine the importance levels of the criteria. The logistics performance rankings of the countries were determined by the Weighted Aggregated Sum Product Assessment (WASPAS) method. The countries with the highest LPI scores are Germany, Japan, United Kingdom, United States, and France, respectively.

As a result of the literature review, it has been determined that LPI indicators are generally

used as criteria to determine the logistics performance of countries. Furthermore, it has been understood that various MCDM techniques are used to determine the LPI scores and rankings of the countries. The literature review is presented in the Table 1. The focus of this research is on developing countries and the evaluation of these countries in terms of logistics market performance. For this reason, the Agility Emerging Markets Logistics index indicators and data were used in the research.

Table 1. Literature Review

Authors	Criteria	Methodology	Findings
García et al. (2015)	LPI indicators	DEA	The three countries with the highest level of LPI efficiency are Belgium, Germany, Norway, and Luxembourg.
Çakır (2016)	LPI indicators	CRITIC, SAW, and Peters' fuzzy regression	Based on the importance levels of the criteria, the 2014 LPI scores of the OECD countries were determined.
Martí et al. (2017)	LPI indicators	DEA	The efficiency levels of logistics performance of countries have been determined.
Rezai et al. (2018)	LPI indicators	Best Worst	There have been found to be changes in LPI scores and rankings.
Oğuz et al. (2019)	LPI indicators	TOPSIS	The LPI scores of the Asian country were determined. Singapore is the best according to LPI scores.
Ozmen (2019)	LPI indicators, transportation volume	MD-TODIM	The traditional TODIM and Improved TODIM results were compared.
Ulutaş and Karaköy (2019a)	LPI indicators	SWARA and CRITIC	The LPI scores of countries of the European Union have been determined.
Ulutaş and Karaköy (2019b)	LPI indicators	SD and WASPAS	The countries with the highest LPI scores are Germany, Japan, the United Kingdom, the United States, and France, respectively.
Yildirim and Mercangöz (2020)	LPI indicators	Fuzzy AHP and ARAS-G	There is a strong correlation between LPI scores.
Isik et al. (2020)	LPI indicators	SV and MABAC	The 3 countries with the best LPI scores are the Czech Republic, Poland, and Hungary, respectively.
Mercangöz et al. (2020)	LPI indicators	CORPAS-G	There is a strong correlation between LPI scores.
Yalcı and Ayaz (2020)	LPI indicators	Fuzzy AHP and Fuzzy TOPSIS	Turkey is the best in logistics performance ranking.
Senir (2021)	LPI indicators, Export time and distance, Import time and distance	CRITIC and CORPAS	The LPI scores and ranking of selected countries were calculated according to the determined importance levels.
Mešić et al. (2022)	LPI indicators	CRITIC and MARCOS	The most successful country in terms of logistics performance is Serbia.

METHODOLOGY

The main purpose of this research is to determine the logistics performance of developing countries using Entropy and MABAC techniques. Furthermore, the aim is to reveal the differences in the weights and country rankings by comparing the findings and the AEMLI reports. In this respect, criteria, sampling, entropy technique, and MABAC technical steps are explained in the methodology section. Then it is passed to the application section.

Criteria and Sampling

The 2022 AEMLI report was used to determine and rank the logistics market performances in developing countries. Within the scope of the research, 4 criteria were used [AEMLI, 2022]. These criteria are *Domestic Logistics Opportunities* (DLO), *International Logistics Opportunities* (ILO), *Business Fundamentals* (BF), and *Digital Readiness* (DR). DLO indicates the degree to which developing countries can meet domestic demand in terms of logistics. The ILO indicates the foreign demand capacity and the capacity for cross-border logistics operations of developing countries. BF demonstrates the strength of the business environment and market independence of developing countries. DR shows the digital

competence capacity of developing countries in terms of logistics. The sample area of the research consists of 50 developing countries. Entropy technique was used to determine the weights of the criteria and the MABAC method was used to determine the in the logistics market performance of developing countries. The research criteria and the sample area are presented in Table 2.

Table 2. Criteria and Sampling

Analysis	Criteria	Period	Sampling
Entropy and MABAC	Domestic Logistics Opportunities, International Logistics Opportunities, Business Fundamentals, Digital Readiness	2022	50 developing countries

Entropy Technique

The concept of entropy was first introduced by Rudolph Clausius in 1865 as a criterion for disorder in thermodynamics. The concept of entropy was introduced by Shannon in 1948 as an expression of uncertainty. A high entropy value indicates high disorder [Zhang et al., 2011]. In the entropy technique, the weights of the criteria are calculated using the data in the decision matrix. The entropy method is very useful for determining the weights of criteria in a MCDM problem because there is no need to evaluate criteria weights. Instead of evaluation, the weights of the criteria are determined in 5 steps [Wang and Lee, 2009; Erol and Ferrell, 2009; Özdağoğlu et al., 2017].

Step 1. *Creating the decision matrix:* The decision matrix D consisting of m alternatives and n criteria is shown in Eq. (1).

$$D = \begin{bmatrix} x_{11} & \cdots & x_{1j} & \cdots & x_{1n} \\ \vdots & \cdots & \vdots & \cdots & \vdots \\ x_{i1} & \cdots & x_{ij} & \dots & x_{in} \\ \vdots & \cdots & \vdots & \cdots & \vdots \\ x_{m1} & \cdots & x_{mj} & \dots & x_{mn} \end{bmatrix} \quad (1)$$

x_{ij} $(i = 1, 2, \dots, m;\ j = 1, 2, \dots, n)$: It is the evaluation of the i^{th} alternative according to the j^{th} criterion.

Step 2. *Normalizing the decision matrix:* To ensure that the criteria values consisting of different units are standard, the normalization process is done with Eq. (2).

$$p_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}};\ \forall i, j \quad (2)$$

p_{ij} : The i^{th} alternative is the normalized value of the value it receives according to the j^{th} criterion.

Step 3. *Finding the entropy value:* With the Eq. (3), the entropy values in the [0,1] range of the criteria are found. The *k* value here is a fixed number and is calculated with Eq. (4).

$$e_{ij} = -k * \sum_{j=1}^{n} p_{ij} * \ln(p_{ij}) \quad (3)$$

$$k = (\ln(m))^{-1} \quad (4)$$

Step 4. *Finding degrees of differentiation:* With the Eq. (5), the degrees of differentiation are calculated by using the entropy values obtained previously.

$$d_j = 1 - e_j \quad (5)$$

Step 5. *Calculation of entropy criterion weights:* As a final step, the weights of the criteria are calculated with Eq. (6).

$$w_j = \frac{d_j}{\sum_{j=1}^{n} d_j} \quad (6)$$

MABAC Technique

The MABAC method, which evaluates alternatives because of the calculations made according to the distances of the criteria to the border proximity area, was developed by Pamučar and Ćirović at the research center in the field of defense logistics at the Defense University in Belgrade in 2015 [Pamučar et al., 2018]. In this method, first the distances of the criterion functions for each alternative to the boundary proximity area are calculated. Then the alternatives are ranked, and the optimal choice is made. This sorting process takes place in the following 6 steps [Pamučar and Ćirović, 2015; Božanić, 2016; Gigović, 2017].

Step 1. *Creating the decision matrix:* The decision matrix D consisting of m alternatives and n criteria is shown in Eq. (7).

$$D = \begin{bmatrix} x_{11} & \cdots & x_{1j} & \cdots & x_{1n} \\ \vdots & \cdots & \vdots & \cdots & \vdots \\ x_{i1} & \cdots & x_{ij} & \dots & x_{in} \\ \vdots & \cdots & \vdots & \cdots & \vdots \\ x_{m1} & \cdots & x_{mj} & \dots & x_{mn} \end{bmatrix} \quad (7)$$

x_{ij} $(i = 1, 2, \dots, m;\ j = 1, 2, \dots, n)$: It is the evaluation of the i^{th} alternative according to the j^{th} criterion.

Step 2. *Normalizing the decision matrix:* Normalization is done to ensure that the criteria values consisting of different units are standard. In this process, Eq. (8) is used for maximization oriented criteria (benefit) and Eq. (9) for minimization-oriented criteria (cost).

$$n_{ij} = \frac{x_{ij} - x_i^-}{x_i^+ - x_i^-} \quad (8)$$

$$n_{ij} = \frac{x_{ij} - x_i^+}{x_i^- - x_i^+} \quad (9)$$

x_i^+ are the maximum values of the columns in the normalized decision matrix. x_i^- are the minimum values in the columns of the normalized decision matrix. The normalized decision matrix is shown in Eq. (10).

$$N = \begin{bmatrix} n_{11} & \cdots & n_{1j} & \cdots & n_{1n} \\ \vdots & \cdots & \vdots & \cdots & \vdots \\ n_{i1} & \cdots & n_{ij} & \dots & n_{in} \\ \vdots & \cdots & \vdots & \cdots & \vdots \\ n_{m1} & \cdots & n_{mj} & \dots & n_{mn} \end{bmatrix} \quad (10)$$

Step 3. *Weighting of decision matrix:* The decision matrix is weighted with the help of Eq. (11) by using normalized decision matrix elements and criterion weight values.

$$v_{ij} = w_i * (n_{ij} + 1) \quad (11)$$

Step 4. *Creating the boundary proximity matrix:* With the Eq. 12, the border closeness values of each criterion are calculated. As a result, the boundary proximity field matrix in Eq. 13 is obtained.

$$g_i = \left(\prod_{j=1}^{m} v_{ij}\right)^{\frac{1}{m}} \quad (12)$$

$$G = [g_1 \quad g_2 \quad \dots \quad g_n] \quad (13)$$

Step 5. *Calculating the distances of the decision alternatives to the boundary proximity area:* As a result of the operations in Eq. 14, the distances of each value in the decision matrix from the boundary proximity area are calculated.

$$Q = V - G = \begin{bmatrix} v_{11} - g_1 & \cdots & q_{1j} - g_j & \cdots & q_{1n} - g_n \\ \vdots & \cdots & \vdots & \cdots & \vdots \\ q_{i1} - g_1 & \cdots & q_{ij} - g_j & \dots & q_{in} - g_n \\ \vdots & \cdots & \vdots & \cdots & \vdots \\ q_{m1} - g_1 & \cdots & q_{mj} - g_j & \dots & q_{mn} - g_n \end{bmatrix} = \begin{bmatrix} q_{11} & \cdots & q_{1j} & \cdots & q_{1n} \\ \vdots & \cdots & \vdots & \cdots & \vdots \\ q_{i1} & \cdots & q_{ij} & \dots & q_{in} \\ \vdots & \cdots & \vdots & \cdots & \vdots \\ q_{m1} & \cdots & q_{mj} & \dots & q_{mn} \end{bmatrix} \quad (14)$$

Step 6. *Determining the status of decision alternatives according to boundary proximity area and ranking the alternatives:* The decision alternatives (A_i) are either in the Boundary Proximity Field (G) or the Lower Affinity Field (G^-) or the Upper Affinity Field (Eq. (15)). The more q_{ij} values are in the Upper Affinity Field, the more likely that the alternative is to be the best alternative (Ayçin and Çakın, 2019).

$$A_i \in \begin{cases} G^+ \; if \; q_{ij} > 0 \\ G \; if \; q_{ij} = 0 \\ G^- \; if \; q_{ij} < 0 \end{cases} \quad (15)$$

With the Eq. (16), the criteria functions belonging to each alternative are calculated, and thus the ranking of the alternatives is made.

$$S_i = \sum_{j=1}^{n} q_{ij} \quad (16)$$

APPLICATION

In this study a total of 50 alternatives (m) and 4 criteria (n) were determined, which was conducted to determine the levels of development of the logistics market in developing countries. The study data set is given in Table 3. The weights of the criteria were calculated using the entropy method. Then, the alternatives were listed using the MABAC method.

Entropy Technique Findings

The 5 steps of the entropy technique were performed in order.

Step 1: The decision matrix consisting of 50 alternatives and 4 criteria is shown in Table 3.

Table 3. Data Set

Country	DLO	ILO	BF	DR	Country	DLO	ILO	BF	DR
China	8,54	9,75	7,06	7,25	Peru	4,7	5,1	4,57	4,52
India	8,01	7,23	5,96	6,74	Pakistan	5,03	4,58	4,33	5,1
UAE	5,58	5,73	9,2	8,63	Kenya	4,55	4,61	4,92	5,43
Malaysia	5,32	5,92	8,19	7,35	Ukraine	4,79	4,97	4,46	4,64
Indonesia	6,34	5,95	5,93	6,47	Iran	5,13	4,23	4,3	5,19
Saudi Arabia	5,35	5,51	8,16	7,07	Argentina	4,86	4,61	3,92	5,03
Qatar	5,79	4,89	7,96	6,52	Ghana	4,57	4,42	4,62	5,14
Thailand	5,13	6,01	5,82	6,54	Sri Lanka	4,49	4,72	4,36	4,82
Mexico	5,54	6,4	5,13	5,4	Nigeria	5,18	4,28	3,53	4,81
Turkey	5,28	5,87	5,87	5,96	Lebanon	4,76	4,6	4,13	4,33
Vietnam	5,02	6,01	5,48	5,75	Tunisia	4,58	4,48	5,03	4,06
Chile	4,87	5,17	7,17	6,14	Algeria	4,84	4,22	4,99	3,96
Russia	5,2	5,67	5,51	5,89	Ecuador	4,49	4,63	4,66	3,75
Oman	4,92	4,89	7,26	5,69	Bangladesh	4,99	4,38	3,44	4,38
Bahrain	4,99	4,68	7,3	5,16	Cambodia	4,4	4,47	4,22	4,34
Brazil	5,5	5,43	3,95	5,58	Paraguay	4,39	4,46	4,23	4,38
Kuwait	5,02	4,57	6,18	5,92	Tanzania	4,56	4,09	4,72	4,14
Philippines	5	5,25	4,38	5,99	Uganda	4,37	4,39	3,88	4,07
Jordan	4,86	4,73	6,7	4,97	Bolivia	4,42	4,46	3,58	3,1
Morocco	4,59	5	6,81	4,34	Ethiopia	4,36	4,36	3,15	3,42
Egypt	5,13	4,65	5,51	5	Mozambique	4,19	4,4	1,41	2,91
Kazakhstan	4,67	4,7	6,2	4,93	Angola	4,3	4,26	1,02	2,8
Uruguay	4,78	4,41	6,08	5,21	Venezuela	4,45	3,86	0,45	3,62
South Africa	4,69	4,95	5	5,17	Myanmar	4,4	4,25	0,69	1,83
Colombia	4,69	5,02	4,52	4,9	Libya	4,4	2,2	0,6	1,64

Step 2: The normalized decision matrix calculated with Eq. (2) is shown in Table 4.

Steps 3-4-5: The entropy values of the criteria were found with Eq. (3), the degree of differentiation with Eq. (5) and the weights of the entropy criteria with Eq. (6) are shown in Table 5.

Table 4. Normalized Decision Matrix

Country	DLO	ILO	BF	DR	Country	DLO	ILO	BF	DR
China	0,034159	0,039407	0,028636	0,029002	Peru	0,018799	0,020613	0,018537	0,018081
India	0,032039	0,029222	0,024175	0,026962	Pakistan	0,020119	0,018511	0,017563	0,020402
UAE	0,022319	0,023159	0,037316	0,034523	Kenya	0,018199	0,018632	0,019956	0,021722
Malaysia	0,021279	0,023927	0,03322	0,029402	Ukraine	0,019159	0,020087	0,01809	0,018561
Indonesia	0,025359	0,024048	0,024053	0,025882	Iran	0,020519	0,017096	0,017441	0,020762
Saudi Arabia	0,021399	0,02227	0,033098	0,028282	Argentina	0,019439	0,018632	0,0159	0,020122
Qatar	0,023159	0,019764	0,032287	0,026082	Ghana	0,018279	0,017864	0,018739	0,020562
Thailand	0,020519	0,024291	0,023607	0,026162	Sri Lanka	0,017959	0,019077	0,017685	0,019282
Mexico	0,022159	0,025867	0,020808	0,021602	Nigeria	0,020719	0,017299	0,014318	0,019242
Turkey	0,021119	0,023725	0,02381	0,023842	Lebanon	0,019039	0,018592	0,016752	0,017321
Vietnam	0,020079	0,024291	0,022228	0,023002	Tunisia	0,018319	0,018107	0,020402	0,016241
Chile	0,019479	0,020896	0,029083	0,024562	Algeria	0,019359	0,017056	0,02024	0,015841
Russia	0,020799	0,022916	0,022349	0,023562	Ecuador	0,017959	0,018713	0,018902	0,015001
Oman	0,019679	0,019764	0,029448	0,022762	Bangladesh	0,019959	0,017703	0,013953	0,017521
Bahrain	0,019959	0,018915	0,02961	0,020642	Cambodia	0,017599	0,018066	0,017117	0,017361
Brazil	0,021999	0,021946	0,016022	0,022322	Paraguay	0,017559	0,018026	0,017157	0,017521
Kuwait	0,020079	0,018471	0,025067	0,023682	Tanzania	0,018239	0,016531	0,019145	0,016561
Philippines	0,019999	0,021219	0,017766	0,023962	Uganda	0,017479	0,017743	0,015738	0,016281
Jordan	0,019439	0,019117	0,027176	0,019882	Bolivia	0,017679	0,018026	0,014521	0,012401
Morocco	0,018359	0,020209	0,027622	0,017361	Ethiopia	0,017439	0,017622	0,012777	0,013681
Egypt	0,020519	0,018794	0,022349	0,020002	Mozambique	0,016759	0,017784	0,005719	0,011641
Kazakhstan	0,018679	0,018996	0,025148	0,019722	Angola	0,017199	0,017218	0,004137	0,011201
Uruguay	0,019119	0,017824	0,024661	0,020842	Venezuela	0,017799	0,015601	0,001825	0,014481
South Africa	0,018759	0,020006	0,020281	0,020682	Myanmar	0,017599	0,017177	0,002799	0,007321
Colombia	0,018759	0,020289	0,018334	0,019602	Libya	0,017599	0,008892	0,002434	0,006561

Table 5. Entropy Values, Differentiation Degrees, and Criterion Weights

	DLO	ILO	BF	DR
e_i	0,997153	0,994877	0,976636	0,990184
d_j	0,002847	0,005123	0,023364	0,009816
w_j	0,069182	0,124499	0,567777	0,238542
e_i	0,997153	0,994877	0,976636	0,990184

MABAC Technique Findings

The 6 steps of the MABAC technique were completed in order.

Step 1: The decision matrix is the same as in Table 3.

Table 6. Normalized Decision Matrix with MABAC Method

Country	DLO	ILO	BF	DR	Country	DLO	ILO	BF	DR
China	1	1	0,755429	0,802575	Peru	0,117241	0,384106	0,470857	0,412017
India	0,878161	0,666225	0,629714	0,729614	Pakistan	0,193103	0,315232	0,443429	0,494993
UAE	0,31954	0,46755	1	1	Kenya	0,082759	0,319205	0,510857	0,542203
Malaysia	0,25977	0,492715	0,884571	0,816881	Ukraine	0,137931	0,366887	0,458286	0,429185
Indonesia	0,494253	0,496689	0,626286	0,690987	Iran	0,216092	0,268874	0,44	0,507868
Saudi Arabia	0,266667	0,438411	0,881143	0,776824	Argentina	0,154023	0,319205	0,396571	0,484979
Qatar	0,367816	0,356291	0,858286	0,69814	Ghana	0,087356	0,29404	0,476571	0,500715
Thailand	0,216092	0,504636	0,613714	0,701001	Sri Lanka	0,068966	0,333775	0,446857	0,454936
Mexico	0,310345	0,556291	0,534857	0,537911	Nigeria	0,227586	0,275497	0,352	0,453505
Turkey	0,250575	0,486093	0,619429	0,618026	Lebanon	0,131034	0,317881	0,420571	0,384835
Vietnam	0,190805	0,504636	0,574857	0,587983	Tunisia	0,089655	0,301987	0,523429	0,346209
Chile	0,156322	0,393377	0,768	0,643777	Algeria	0,149425	0,26755	0,518857	0,331903
Russia	0,232184	0,459603	0,578286	0,608011	Ecuador	0,068966	0,321854	0,481143	0,30186
Oman	0,167816	0,356291	0,778286	0,579399	Bangladesh	0,183908	0,288742	0,341714	0,391989
Bahrain	0,183908	0,328477	0,782857	0,503577	Cambodia	0,048276	0,300662	0,430857	0,386266
Brazil	0,301149	0,427815	0,4	0,563662	Paraguay	0,045977	0,299338	0,432	0,391989
Kuwait	0,190805	0,313907	0,654857	0,612303	Tanzania	0,085057	0,250331	0,488	0,357654
Philippines	0,186207	0,403974	0,449143	0,622318	Uganda	0,041379	0,290066	0,392	0,347639
Jordan	0,154023	0,335099	0,714286	0,476395	Bolivia	0,052874	0,299338	0,357714	0,20887
Morocco	0,091954	0,370861	0,726857	0,386266	Ethiopia	0,03908	0,286093	0,308571	0,254649
Egypt	0,216092	0,324503	0,578286	0,480687	Mozambique	0	0,291391	0,109714	0,181688
Kazakhstan	0,110345	0,331126	0,657143	0,470672	Angola	0,025287	0,272848	0,065143	0,165951
Uruguay	0,135632	0,292715	0,643429	0,51073	Venezuela	0,05977	0,219868	0	0,283262
South Africa	0,114943	0,364238	0,52	0,505007	Myanmar	0,048276	0,271523	0,027429	0,027182
Colombia	0,114943	0,37351	0,465143	0,466381	Libya	0,048276	0	0,017143	0

Step 2: Since all criteria are maximization oriented, the decision matrix was normalized as shown in Table 6 using Eq. (8).

Step 3: With Eq. (11), the weighted decision matrix in Table 7 was obtained. The weights of the criteria in Eq. (11) were calculated with Eq. (6).

Step 4: With Eq. (12), the border proximity area values for each criterion were calculated, and the border proximity area matrix is shown in Table 8.

Table 7. Weighted Decision Matrix

Country	DLO	ILO	BF	DR	Country	DLO	ILO	BF	DR
China	0,123444	0,222147	0,889216	0,383623	Peru	0,068958	0,153738	0,745066	0,300505
India	0,115924	0,185074	0,825535	0,368095	Pakistan	0,073641	0,146088	0,731172	0,318163
UAE	0,081445	0,163006	1,013104	0,425639	Kenya	0,06683	0,146529	0,765328	0,328211
Malaysia	0,077756	0,165801	0,954633	0,386667	Ukraine	0,070235	0,151825	0,738697	0,304158
Indonesia	0,092228	0,166243	0,823798	0,359875	Iran	0,07506	0,140938	0,729435	0,320904
Saudi Arabia	0,078181	0,159769	0,952897	0,378143	Argentina	0,071229	0,146529	0,707436	0,316032
Qatar	0,084424	0,150648	0,941318	0,361397	Ghana	0,067114	0,143734	0,74796	0,319381
Thailand	0,07506	0,167125	0,81743	0,362006	Sri Lanka	0,065979	0,148147	0,732908	0,309638
Mexico	0,080877	0,172863	0,777485	0,327297	Nigeria	0,075769	0,141674	0,684858	0,309334
Turkey	0,077188	0,165066	0,820325	0,344347	Lebanon	0,06981	0,146382	0,719593	0,29472
Vietnam	0,073499	0,167125	0,797747	0,337953	Tunisia	0,067256	0,144616	0,771696	0,286499
Chile	0,071371	0,154767	0,895584	0,349828	Algeria	0,070945	0,140791	0,76938	0,283455
Russia	0,076053	0,162123	0,799484	0,342216	Ecuador	0,065979	0,146823	0,750276	0,277061
Oman	0,07208	0,150648	0,900794	0,336127	Bangladesh	0,073073	0,143145	0,679648	0,296242
Bahrain	0,073073	0,147559	0,90311	0,31999	Cambodia	0,064702	0,144469	0,724803	0,295024
Brazil	0,08031	0,158593	0,709173	0,332778	Paraguay	0,06456	0,144322	0,725382	0,296242
Kuwait	0,073499	0,14594	0,838271	0,343129	Tanzania	0,066972	0,138879	0,753749	0,288935
Philippines	0,073215	0,155944	0,734066	0,345261	Uganda	0,064276	0,143292	0,70512	0,286804
Jordan	0,071229	0,148294	0,868375	0,314205	Bolivia	0,064986	0,144322	0,687753	0,257271
Morocco	0,067398	0,152266	0,874743	0,295024	Ethiopia	0,064134	0,142851	0,662859	0,267014
Egypt	0,07506	0,147117	0,799484	0,315119	Mozambique	0,061722	0,143439	0,562128	0,251486
Kazakhstan	0,068533	0,147853	0,839429	0,312988	Angola	0,063283	0,14138	0,53955	0,248137
Uruguay	0,070094	0,143587	0,832482	0,321512	Venezuela	0,065411	0,135495	0,506552	0,273103
South Africa	0,068817	0,151531	0,769959	0,320295	Myanmar	0,064702	0,141233	0,520446	0,218604
Colombia	0,068817	0,152561	0,742171	0,312074	Libya	0,064702	0,111074	0,515236	0,212819

Table 8. Boundary Proximity Matrix

	DLO	ILO	BF	DR
g_i	0,072527	0,150816	0,757273	0,312347

Step 5: The distances of each value in the decision matrix to the boundary proximity area were calculated by performing the operations in Eq. (14). These values are given in Table 9.

Step 6: As a result of the values obtained with Eq. (16), the alternatives are ranked. The ranking of developing countries is given in Table 10.

RESULTS AND CONCLUSION

The levels of the logistics market performance of developing countries are presented in the AELMI reports. The main purpose of this research is to recalculate the logistics market performances of countries using Entropy and MABAC techniques. It is also the comparison of the scores obtained with the data in the AELMI reports. In this context, 2022 logistics market performance data for developing countries were obtained from AELMI reports. Afterwards, the Entropy technique was applied to determine the importance levels of the four basic criteria. Considering the weights of the criteria, the criterion with the highest level of importance is the BF (0. 567777). The other weights of other criteria are DR (0.238542), ILO (0.124499), and DLO (0.069182), respectively. When the criteria weights are compared, the weight of the DR is about half of the BF. The weight of the ILO is about half that of the DR. The weight of the DLO is about half of the ILO. According to these findings, it can be said that BF is by far the most important factor in determining the levels of the logistics market performance of specific countries. This indicates that developing countries should turn to the BF compared to other criteria to increase their logistics market performance. To increase the scores of the BF of the countries, the following

points should be developed: (i) Ensuring stability and controlling inflation levels, (ii) Increasing the country's market accessibility level and ensuring local stability, (iii) Reducing domestic crime and violence, (iv) Correct implementation of credit and debt dynamics, (v) Improving the fight against corruption, (vi) and establishing the legal regulatory environment. According to the weights of other criteria, developing countries should focus on the level of accessibility to the international logistics market rather than national logistics markets. In addition, what is more important than focusing on nations and international markets is that countries develop efforts to improve their digital capabilities.

Table 9. Distances of Decision Alternatives to Boundary Proximity Area

Country	DLO	ILO	BF	DR	Country	DLO	ILO	BF	DR
China	0,050917	0,071332	0,131943	0,071276	Peru	-0,00357	0,002922	-0,01221	-0,01184
India	0,043397	0,034258	0,068262	0,055748	Pakistan	0,001114	-0,00473	-0,0261	0,005816
UAE	0,008918	0,012191	0,255831	0,113291	Kenya	-0,0057	-0,00429	0,008055	0,015863
Malaysia	0,005229	0,014986	0,19736	0,07432	Ukraine	-0,00229	0,00101	-0,01858	-0,00819
Indonesia	0,019702	0,015427	0,066525	0,047528	Iran	0,002533	-0,00988	-0,02784	0,008556
Saudi Arabia	0,005654	0,008954	0,195624	0,065795	Argentina	-0,0013	-0,00429	-0,04984	0,003685
Qatar	0,011898	-0,00017	0,184045	0,04905	Ghana	-0,00541	-0,00708	-0,00931	0,007034
Thailand	0,002533	0,01631	0,060157	0,049659	Sri Lanka	-0,00655	-0,00267	-0,02436	-0,00271
Mexico	0,00835	0,022047	0,020212	0,01495	Nigeria	0,003242	-0,00914	-0,07241	-0,00301
Turkey	0,004661	0,01425	0,063052	0,032	Lebanon	-0,00272	-0,00443	-0,03768	-0,01763
Vietnam	0,000972	0,01631	0,040474	0,025606	Tunisia	-0,00527	-0,0062	0,014423	-0,02585
Chile	-0,00116	0,003952	0,138311	0,03748	Algeria	-0,00158	-0,01002	0,012107	-0,02889
Russia	0,003526	0,011308	0,042211	0,029869	Ecuador	-0,00655	-0,00399	-0,007	-0,03529
Oman	-0,00045	-0,00017	0,143521	0,023779	Bangladesh	0,000546	-0,00767	-0,07763	-0,01611
Bahrain	0,000546	-0,00326	0,145837	0,007643	Cambodia	-0,00783	-0,00635	-0,03247	-0,01732
Brazil	0,007783	0,007777	-0,0481	0,02043	Paraguay	-0,00797	-0,00649	-0,03189	-0,01611
Kuwait	0,000972	-0,00488	0,080998	0,030782	Tanzania	-0,00555	-0,01194	-0,00352	-0,02341
Philippines	0,000688	0,005129	-0,02321	0,032913	Uganda	-0,00825	-0,00752	-0,05215	-0,02554
Jordan	-0,0013	-0,00252	0,111102	0,001858	Bolivia	-0,00754	-0,00649	-0,06952	-0,05508
Morocco	-0,00513	0,001451	0,11747	-0,01732	Ethiopia	-0,00839	-0,00796	-0,09441	-0,04533
Egypt	0,002533	-0,0037	0,042211	0,002772	Mozambique	-0,0108	-0,00738	-0,19515	-0,06086
Kazakhstan	-0,00399	-0,00296	0,082156	0,00064	Angola	-0,00924	-0,00944	-0,21772	-0,06421
Uruguay	-0,00243	-0,00723	0,075209	0,009165	Venezuela	-0,00712	-0,01532	-0,25072	-0,03924
South Africa	-0,00371	0,000715	0,012686	0,007947	Myanmar	-0,00783	-0,00958	-0,23683	-0,09374
Colombia	-0,00371	0,001745	-0,0151	-0,00027	Libya	-0,00783	-0,03974	-0,24204	-0,09953

Table 10. Ranking of Developing Countries

AEMLI Ranking	Country	S_i	Proposed Model Ranking	AEMLI Ranking	Country	S_i	Proposed Model Ranking
1	China	0,325467	2	26	Peru	-0,0247	30
2	India	0,201665	6	27	Pakistan	-0,0239	29
3	UAE	0,390231	1	28	Kenya	0,013935	24
4	Malaysia	0,291895	3	29	Ukraine	-0,02805	32
5	Indonesia	0,149181	10	30	Iran	-0,02663	31
6	Saudi Arabia	0,276027	4	31	Argentina	-0,05174	36
7	Qatar	0,244825	5	32	Ghana	-0,01477	26
8	Thailand	0,128659	11	33	Sri Lanka	-0,03629	34
9	Mexico	0,06556	20	34	Nigeria	-0,08133	41
10	Turkey	0,113963	12	35	Lebanon	-0,06246	39
11	Vietnam	0,083362	17	36	Tunisia	-0,0229	28
12	Chile	0,178587	7	37	Algeria	-0,02839	33
13	Russia	0,086913	16	38	Ecuador	-0,05282	37
14	Oman	0,166686	8	39	Bangladesh	-0,10085	43
15	Bahrain	0,150769	9	40	Cambodia	-0,06396	40
16	Brazil	-0,01211	25	41	Paraguay	-0,06246	38
17	Kuwait	0,107877	14	42	Tanzania	-0,04443	35
18	Philippines	0,015524	23	43	Uganda	-0,09347	42
19	Jordan	0,109141	13	44	Bolivia	-0,13863	44
20	Morocco	0,096469	15	45	Ethiopia	-0,1561	45
21	Egypt	0,043817	21	46	Mozambique	-0,27419	46
22	Kazakhstan	0,07584	18	47	Angola	-0,30061	47
23	Uruguay	0,074712	19	48	Venezuela	-0,3124	48
24	South Africa	0,017638	22	49	Myanmar	-0,34798	49
25	Colombia	-0,01734	27	50	Libya	-0,38913	50

When the country rankings determined by the MABAC method are compared with the rankings presented in the AELMI 2022 report, changes are observed in the country rankings. Countries that have increased their ranking according to their position in the new proposed ranking are UAE, Malaysia, Saudi Arabia, Qatar, Chile, Oman, Bahrain, Kuwait, Jordan, Morocco, Kazakhstan, Uruguay, South Africa, Kenya, Ghana, Tunisia, Algeria, Ecuador, Paraguay, Tanzania, and It is Uganda. The countries whose rankings decreased are China, India, Indonesia, Thailand, Mexico, Turkey, Vietnam, Russia, Philippines, Colombia, Peru, Pakistan, Ukraine, Iran, Argentina, Sri Lanka, Nigeria, Lebanon, and Bangladesh. The countries whose ranking has not changed are Egypt, Cambodia, Bolivia, Ethiopia, Mozambique, Angola, Venezuela, Myanmar, and Libya. The country with the highest-ranking increase is Mexico. The countries that fell the most in the ranking were Oman, Bahrain, Jordan, Ghana, and Tunisia. Additionally, according to the proposed new model, the country with the highest logistics market performance is UAE, and the lowest country is Libya.

In the literature, it is known that there are differences in the logistics performance rankings of countries as a result of research on logistics performance indexes with various MCDM techniques [García et al. 2015; Çakır, 2016; Martí et al., 2017; Rezai et al., 2018; Oğuz et al., 2019; Ozmen, 2019; Yildirim and Mercangöz, 2020; Yalçin and Ayaz, 2020; Mešić et al., 2022]. With this research, it has been proven that there are changes in the logistics market performance rankings of developing countries. At this point, the results of the research and the results obtained in the literature have been determined to show parallelism. It is recommended that researchers identify datasets from different periods of AEMLI reports with different MCDM techniques and compare the results obtained with these research results.

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