COMPARISON OF THE LOGISTICS PERFORMANCE WITH ENTROPY BASED WEIGHTED PRODUCT METHOD

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Highlights

- Logistic Performance Index (LPI) is considered an important criterion for the relative logistics position of countries globally.
- We aim to objectively and analytically evaluate the LPI using the Entropy-based Weighted Product method.
- The LPI is evaluated with a two-stage analytical approach.

ABSTRACT

The most important determinant in the domestic and international commercial activities of countries is the success in logistics activities, and the correct evaluation and use of this indicator. In this study, we aimed to compare the logistics performance of the countries through the Entropy-Weighted Product Method (WPM) by using the Logistics Performance Index (LPI) data of 2023 published by the World Bank.
In this context, the Entropy method was used to determine the importance levels of the criteria to be used when comparing countries. Then, countries were ranked according to their logistics performance using the WPM and the determined criteria weights. The proposed approach is compared with the Entropy-based SAW method and LPI published by the World Bank. According to the obtained results, the rankings of the countries are generally close and the results of the analysis are consistent.

Keywords: Logistics Performance, Logistics Performance Index, Entropy, Weighted Product, SAW

1. Introduction

The logistics performance index (LPI) is recognized as a key indicator for commercial activities, shared as an important statistic of the World Bank and taken into account by countries all over the world. It is considered an important criterion for the relative logistics position of countries globally. LPI provides very useful results in evaluations of logistics processes. Logistics costs constitute an insurmountable competitive barrier to international trade.
It should be noted that an evaluation occurs by averaging the factors included in the LPI. Therefore, the index needs to be calculated with different approaches that are more effective. After being evaluated with multi-criteria decision-making approaches, the aim is to reach general conclusions by comparing it with the index calculated by the World Bank itself.

Since logistics plays an important role in economic growth, development and competitiveness of countries, it is critical to measure a country's logistics capability (Alnıpak et al., 2023). Therefore, it is important to understand the relationship between a country's logistics performance, competitiveness and prosperity (Civelek et al., 2015). Time-consuming, rigid and costly trade rules have a negative impact on competition. Comparing the performance of countries in terms of logistics will lead countries that want to get a share of the global economy to reconsider customs rules, shorten long waiting times at ports, reduce unnecessary physical inspections, bureaucracy (Bayraktar and Şeker, 2024).

To better understand the LPI, which provides a general ranking of countries, more comparisons and benchmarking with Multi-Criteria Decision Making techniques are required. In this study, 38 countries of the world, including Turkey, were compared . For this comparison, important evaluations were made using the integrated Entropy and Weighted Product Method. With the results of this comparison, in which sub-criteria are also evaluated one by one, an attempt has been made to identify the areas where our country is competitive and where it lags behind, to draw inferences for policy makers and the logistics sector. The results obtained from the study were compared with the LPI results and the entropy-based SAW method, and their consistency was tested.

2. Literature Review

The literature research shows, there are numerous studies that analyze data using LPI. Multi-Criteria Decision Making (MCDM) methods were generally preferred in the comparisons made. While some studies used LPI weighting scores (Mešić et al., 2022; Alnıpak, 2024), others preferred to compare LPI scores with their own scores (Ulutaş and Karaköy, 2019).

Rezaei et al. (2018) provided a new perspective to evaluate LPI by applying the BWM method. The study aims to assign weights of the six main factors of LPI, utilizing BWM. It can improve the measurement of logistics performance and aid countries in ensuring strategies for improving their efforts related to logistics activities. Marti et al. (2017) suggested a data envelopment analysis (DEA) approach to measure a valid and more efficient overall logistics performance (DEA-LPI) and provide a comprehensive evaluation under six main components of LPI as a multi-criteria decision-making (MCDM) method. The study evaluated income and geographical area to assess the impact on logistic performance. Ekici et al. (2018) analyzed Global Competitiveness Index (GCI) on logistics performance evaluated by the Logistics Performance Index (LPI)), employing a three-phase approach based on a tree-augmented naive Bayesian network, partial least square path model, and importance-performance map analysis. According to the obtained results, the managers should concentrate on technological readiness, higher education and training, innovation, and market size to simplify expansion in the logistics performance of their countries. Sergi et al. (2021) analyzed the effect of Global Competitiveness Index on the Logistics Performance Index (LPI). There is a connection between the LPI and selected factors in GCI. To this aim, the LPI was employed as the dependent variable, while a linear regression model evaluated some GCI factors' influence using the ANOVA method. Göçer et al. (2022) provided a conceptual perspective for proposing logistics strategies to improve the LPI score of specific countries. The framework involves first the evaluation of countries' logistics strategies and then presenting policy proposals for improving the LPI score of specific countries. Gürler et al. (2024) discussed the logistics performance

evaluation model to find criteria weights using genetic algorithms (GA). Then, eleven methods measured the logistics performance of EU countries using 33 indicators.
Although LPI is a frequently used research topic in the literature, there is no study that addresses the Entropy-based Weighted Product method in the proposed way.

3. Methodology

In multi-criteria decision-making methods, there are two basic processes: weighting the criteria according to their importance levels and ranking the alternatives using the obtained weight values. In this section, the algorithm application stages of the methods will be presented, regarding the Entropy Method used in weighting the criteria and the WP Method used in ranking the alternatives.

3.1 Entropy Method

The entropy method is applied to calculate the relative ranking of criteria based on the DM produced from the hierarchical model. The basic steps of the Entropy method are shortened as follows:

Step 1 – Construction the decision matrix.

$$\begin{bmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{bmatrix}_{m*n}$$

where x_{ij}: The success value of alternative i according to criterion j, $i = 1,2, \ldots, m$ and $j = 1,2, \ldots, n$.

Step 2- Normalization of decision matrix.

$$r_{ij} = \frac{x_{ij}}{\sum_{i=1}^{j} x_{ij}}$$

where r_{ij} is the normalized value of the criteria/sub-criteria rate

Step 3- Obtaining entropy values of the criteria.

The entropy value measures the degree of uncertainty among the set of alternatives in the decision-making process when no choice can be made between the criteria.

$$e_j = -k \sum_{j=1}^{n} r_{ij} \ln(r_{ij}) \qquad i = 1 \ldots m \; j = 1 \ldots n$$

$$k = 1/\ln(m)$$

where k is the entropy constant, e_j is entrophy value

Step 4- Computing the degree of diversification based on the entropy values.

$$d_j = 1 - e_j$$

Step 5-Measurement of entropy criteria weights.

$$w_j = \frac{d_j}{\sum_{i=1}^{m} d_j}$$

$$\sum_{i=1}^{n} w_j = 1$$

where w_j is the degree of significance of criterion j.

3.2 Weighted Product Method

Weighted Product (WP) is one of the practical and efficient methods used for solving MCDM problems. The WP method utilizes multiplication to connect attribute values,

where the value of each is multiplied by the weight for that criterion. The steps for using the WP method are as follows.

$$w_j = \frac{w_j}{\sum w_j}$$

Weights are used as exponents. Multiplying all attributes by weight with a positive exponent for the profit attribute and by weight with a negative exponent for the cost attribute can optimize the decision-making process.

$$S_i = \prod_{j=1}^{n} x_{ij}^{w_j}$$

4. Application of The Method

The LPI is an interactive benchmarking tool created to help countries identify the challenges and opportunities they face in their trade logistics performance and what they can do to improve their performance. In the evaluation of the index, logistics experts are asked a Likert-type question for each criterion. The average of the answers given to these questions determines the logistics performance scores of the countries. The average of the six determined scores forms the logistics performance scores of the countries.

Three of these six performance criteria are affected by external factors, namely government procedures and policies, while the other three criteria are related to the company providing the service. These criteria and their general purposes are as follows:

- Customs procedures process: Evaluates the speed and efficiency of customs procedures. In addition to border security, the convenience provided in customs, the prevention of unnecessary procedures, and the increase in predictability are aimed at the rapid progress of the process.
- Infrastructure quality: The aim is to increase the quality of the logistics infrastructure with agreements made between countries on trade and transportation, privileges, communication and information technologies.
- Ease of arranging shipments at competitive prices: The aim is to ensure that all domestic and foreign logistics companies can provide services under equal conditions, exempt from additional taxes and at competitive prices.
- Competence and quality in logistics services: The aim is to increase the competence of logistics service providers in areas such as customs clearance and document preparation, storage, packaging and handling, and information sharing and terminal services.
- Traceability of shipments is important because customers want to immediately identify any problems that may occur in product supply in order to take precautions or ensure that the process is proceeding smoothly. In order to ensure control and prevent potential problems, the goal is to monitor the transportation process and provide visibility by sharing this information with the customer instantly.
- On-time arrival: The aim is to ensure that shipments reach their destination at the planned time and to increase reliability in keeping promises.

Table 1 provides LPI values obtained from the World Bank.

Table 1. Decision matrix (LPI values for 2023 year) (World Bank)

Country	Customs Score	Infrastructure Score	International shipments Score	Logistics competence Score	Tracking & tracing Score	Timeliness Score
Germany	4.09	4.38	3.83	4.26	4.22	4.4
Netherlands	3.97	4.23	3.76	4.12	4.08	4.3
Sweden	3.95	4.22	3.88	4.04	4.02	4.32
Belgium	3.74	4.03	3.97	4.1	4.11	4.4
Singapore	4	4.14	3.72	4.08	4.05	4.34
United Kingdom	3.85	4.09	3.69	4.04	4.1	4.32
Japan	3.91	4.19	3.61	4.03	4.03	4.24
Austria	3.71	4.07	3.78	4.04	4.13	4.22
Hong Kong. China	3.85	4.02	3.85	3.94	3.95	4.18
United States	3.76	4.1	3.54	3.93	4.13	4.14
Denmark	3.88	3.89	3.59	3.98	3.94	4.26
Finland	3.89	3.95	3.56	3.88	4.1	4.17
Switzerland	3.75	4.07	3.57	3.92	4.02	4.2
United Arab Emirates	3.66	3.98	3.76	3.83	3.89	4.23
France	3.63	4	3.6	3.82	3.99	4.17
Luxembourg	3.67	3.84	3.68	3.83	3.78	4.27
Canada	3.7	3.91	3.45	3.9	3.91	4.03
Spain	3.57	3.79	3.72	3.78	3.78	4.04
Australia	3.76	3.92	3.4	3.76	3.83	4
Norway	3.62	3.84	3.48	3.75	3.83	3.96
Italy	3.44	3.82	3.55	3.68	3.84	4.09
New Zealand	3.58	3.79	3.27	3.69	3.73	4.1
Korea. Rep.	3.43	3.75	3.43	3.63	3.75	3.96
Taiwan	3.42	3.67	3.54	3.68	3.67	3.93
Ireland	3.45	3.5	3.53	3.69	3.79	3.85
Czech Republic	3.34	3.38	3.65	3.65	3.68	3.98
China	3.28	3.73	3.57	3.58	3.63	3.86
Portugal	3.24	3.23	3.59	3.54	3.69	4.03
South Africa	3.29	3.39	3.53	3.42	3.56	3.85
Qatar	3.18	3.43	3.62	3.46	3.53	3.78
Poland	3.26	3.17	3.57	3.49	3.49	3.94
Hungary	3.18	3.31	3.29	3.27	3.61	3.82
Israel	3.32	3.33	2.93	3.44	3.5	3.89
Thailand	3.13	3.17	3.4	3.29	3.38	3.75
Malaysia	3.06	3.3	3.43	3.34	3.32	3.6
Estonia	3.3	3.13	3.19	3.15	3.2	3.8
Turkiye	2.94	3.36	3.19	3.23	3.37	3.68
Iceland	3.02	3.18	3	3.48	3.38	3.72

Table 2 shows the normalized decision matrix.

Table 2. Normalized Decision matrix

Country	Customs Score	Infrastructure Score	International shipments Score	Logistics competence Score	Tracking & tracing Score	Timeliness Score
Germany	1	1	0.964	1	1	1
Netherlands	0.970	0.965	0.947	0.967	0.966	0.977
Sweden	0.965	0.963	0.977	0.948	0.952	0.981
Belgium	0.914	0.920	1	0.962	0.973	1
Singapore	0.977	0.945	0.937	0.957	0.959	0.986
United Kingdom	0.941	0.933	0.929	0.948	0.971	0.981
Japan	0.955	0.956	0.909	0.946	0.954	0.963
Austria	0.907	0.929	0.952	0.948	0.978	0.959
Hong Kong. China	0.941	0.917	0.969	0.924	0.936	0.95
United States	0.919	0.936	0.891	0.922	0.978	0.940
Denmark	0.948	0.888	0.904	0.934	0.933	0.968
Finland	0.951	0.90	0.896	0.910	0.971	0.947
Switzerland	0.916	0.929	0.899	0.920	0.952	0.954
United Arab Emirates	0.894	0.908	0.947	0.899	0.921	0.961
France	0.887	0.913	0.906	0.896	0.945	0.947
Luxembourg	0.897	0.876	0.926	0.899	0.895	0.970
Canada	0.904	0.892	0.869	0.915	0.926	0.915
Spain	0.872	0.865	0.937	0.887	0.895	0.918
Australia	0.919	0.894	0.856	0.882	0.907	0.909
Norway	0.885	0.876	0.876	0.880	0.907	0.9
Italy	0.841	0.872	0.894	0.863	0.909	0.929
New Zealand	0.875	0.865	0.823	0.866	0.883	0.931
Korea. Rep.	0.838	0.856	0.863	0.852	0.888	0.9
Taiwan	0.836	0.837	0.891	0.863	0.869	0.893
Ireland	0.843	0.799	0.889	0.866	0.898	0.875
Czech Republic	0.816	0.771	0.919	0.856	0.872	0.904
China	0.801	0.851	0.899	0.840	0.861	0.877
Portugal	0.792	0.737	0.904	0.830	0.874	0.915
South Africa	0.804	0.773	0.889	0.802	0.843	0.875
Qatar	0.777	0.783	0.911	0.812	0.836	0.859
Poland	0.797	0.723	0.899	0.819	0.827	0.895
Hungary	0.777	0.755	0.828	0.767	0.855	0.868
Israel	0.811	0.760	0.738	0.807	0.829	0.884
Thailand	0.765	0.723	0.856	0.772	0.800	0.852
Malaysia	0.748	0.753	0.863	0.784	0.786	0.818
Estonia	0.806	0.714	0.803	0.739	0.758	0.863
Turkiye	0.718	0.767	0.803	0.758	0.798	0.836
Iceland	0.738	0.726	0.755	0.816	0.800	0.845

Table 3 shows the entropy values of the decision matrix.

Table 3. Entropy values

Country	Customs Score	Infrastructure Score	International shipments Score	Logistics competence Score	Tracking & tracing Score	Timeliness Score
Germany	-0.106	-0.107	-0.101	-0.105	-0.103	-0.101
Netherlands	-0.103	-0.104	-0.099	-0.102	-0.100	-0.1
Sweden	-0.103	-0.104	-0.102	-0.101	-0.099	-0.100
Belgium	-0.099	-0.100	-0.103	-0.102	-0.101	-0.101
Singapore	-0.104	-0.102	-0.099	-0.102	-0.100	-0.100
United Kingdom	-0.101	-0.102	-0.098	-0.101	-0.101	-0.100
Japan	-0.102	-0.103	-0.096	-0.101	-0.100	-0.098
Austria	-0.098	-0.101	-0.100	-0.101	-0.101	-0.098
Hong Kong. China	-0.101	-0.100	-0.101	-0.099	-0.098	-0.097
United States	-0.099	-0.102	-0.095	-0.099	-0.101	-0.097
Denmark	-0.102	-0.098	-0.096	-0.100	-0.098	-0.099
Finland	-0.102	-0.099	-0.096	-0.098	-0.101	-0.097
Switzerland	-0.099	-0.101	-0.096	-0.099	-0.099	-0.098
United Arab Emirates	-0.097	-0.100	-0.099	-0.097	-0.097	-0.098
France	-0.097	-0.100	-0.096	-0.097	-0.099	-0.097
Luxembourg	-0.098	-0.097	-0.098	-0.097	-0.095	-0.094
Canada	-0.098	-0.098	-0.093	-0.098	-0.097	-0.095
Spain	-0.096	-0.096	-0.099	-0.096	-0.095	-0.095
Australia	-0.099	-0.098	-0.092	-0.096	-0.096	-0.094
Norway	-0.097	-0.097	-0.094	-0.092	-0.096	-0.094
Italy	-0.093	-0.097	-0.095	-0.094	-0.096	-0.096
New Zealand	-0.096	-0.096	-0.090	-0.094	-0.094	-0.096
Korea. Rep.	-0.093	-0.095	-0.093	-0.093	-0.095	-0.094
Taiwan	-0.0931	-0.094	-0.095	-0.094	-0.093	-0.093
Ireland	-0.093	-0.091	-0.095	-0.094	-0.095	-0.092
Czech Republic	-0.091	-0.088	-0.097	-0.094	-0.093	-0.094
China	-0.090	-0.095	-0.096	-0.092	-0.092	-0.092
Portugal	-0.089	-0.085	-0.095	-0.092	-0.093	-0.095
South Africa	-0.090	-0.089	-0.095	-0.089	-0.091	-0.092
Qatar	-0.088	-0.089	-0.097	-0.090	-0.090	-0.091
Poland	-0.09	-0.084	-0.096	-0.091	-0.090	-0.093
Hungary	-0.088	-0.087	-0.090	-0.086	-0.092	-0.091
Israel	-0.091	-0.087	-0.083	-0.090	-0.090	-0.093
Thailand	-0.087	-0.084	-0.092	-0.087	-0.088	-0.090
Malaysia	-0.085	-0.087	-0.093	-0.088	-0.086	-0.087
Estonia	-0.090	-0.083	-0.088	-0.081	-0.084	-0.091
Turkiye	-0.083	-0.088	-0.088	-0.086	-0.087	-0.089
Iceland	-0.085	-0.084	-0.084	-0.091	-0.088	-0.090

Table 4 provides a summary of entropy, weight values, and their rankings.

Table 4. Entropy and weight values of factors

Entropy	0.998989	0.998733	0.999445	0.99923	0.999333	0.999617
Weights	0.217238	0.272349	0.119374	0.165467	0.143335	0.082237
Ranks	2	1	5	3	4	6

Table 5 presents the obtained entropy-based WP scores.

Table 5. The obtained Entropy based WP values

Country	**Score**	**Rank**
Germany	4.206341	1
Netherlands	4.080322	2
Sweden	4.068189	3
Belgium	4.009405	6
Singapore	4.050202	4
United Kingdom	3.998568	7
Japan	4.010206	5
Austria	3.969143	8
Hong Kong. China	3.951531	9
United States	3.933329	10
Denmark	3.901483	13
Finland	3.915026	11
Switzerland	3.914968	12
United Arab Emirates	3.863834	14
France	3.850014	15
Luxembourg	3.806062	17
Canada	3.813952	16
Spain	3.749367	19
Australia	3.786669	18
Norway	3.740192	20
Italy	3.702191	21
New Zealand	3.677083	22
Korea. Rep.	3.635807	23
Taiwan	3.620598	24
Ireland	3.591792	25
Czech Republic	3.535331	27
China	3.580047	26
Portugal	3.449448	28
South Africa	3.449025	29
Qatar	3.442185	30
Poland	3.39254	31
Hungary	3.352577	33
Israel	3.36134	32
Thailand	3.282136	35
Malaysia	3.294146	34
Estonia	3.238029	38
Turkiye	3.248239	36
Iceland	3.239013	37

To demonstrate the consistency and validity of the methodology, a comparison of results is presented in Table 6. The same countries (Germ., Neth., Sweden) ranked first in all three methods

Table 6. Comparison of the obtained values with other approaches

Entropy based SAW			Entropy based Weighted Product			World Bank LPI Index		
Country	Score	Rank	Country	Score	Rank	Country	LPI Score	Rank
Germany	0.995	1	Germany	4.206	1	Germany	4.19	1
Netherlands	0.965	2	Netherlands	4.080	2	Netherlands	4.07	2
Sweden	0.963	3	Sweden	4.068	3	Sweden	4.07	3
Singapore	0.958	4	Singapore	4.050	4	Belgium	4.05	4
Belgium	0.949	5	Japan	4.010	5	Singapore	4.05	5
Japan	0.949	6	Belgium	4.009	6	United Kingdom	4.01	6
United Kingdom	0.946	7	United Kingdom	3.998	7	Japan	3.99	7
Austria	0.939	8	Austria	3.969	8	Austria	3.99	8
Hong Kong. China	0.935	9	Hong Kong. China	3.951	9	Hong Kong. China	3.96	9
United States	0.931	10	United States	3.933	10	United States	3.92	10
Finland	0.927	11	Finland	3.915	11	Denmark	3.92	11
Switzerland	0.926	12	Switzerland	3.914	12	Finland	3.92	12
Denmark	0.923	13	Denmark	3.901	13	Switzerland	3.91	13
United Arab Emirates	0.914	14	United Arab Emirates	3.863	14	United Arab Emirates	3.89	14
France	0.911	15	France	3.850	15	France	3.86	15
Canada	0.902	16	Canada	3.813	16	Luxembourg	3.84	16
Luxembourg	0.901	17	Luxembourg	3.806	17	Canada	3.81	17
Australia	0.896	18	Australia	3.786	18	Spain	3.78	18
Spain	0.887	19	Spain	3.749	19	Australia	3.77	19
Norway	0.885	20	Norway	3.740	20	Norway	3.74	20
Italy	0.876	21	Italy	3.702	21	Italy	3.73	21
New Zealand	0.870	22	New Zealand	3.677	22	New Zealand	3.68	22
Korea. Rep.	0.860	23	Korea. Rep.	3.635	23	Korea. Rep.	3.65	23
Taiwan	0.857	24	Taiwan	3.620	24	Taiwan	3.65	24
Ireland	0.851	25	Ireland	3.591	25	Ireland	3.63	25
China	0.847	26	China	3.580	26	Czech Republic	3.62	26
Czech Republic	0.838	27	Czech Republic	3.535	27	China	3.6	27
Portugal	0.819	28	Portugal	3.449	28	Portugal	3.56	28
South Africa	0.817	29	South Africa	3.449	29	South Africa	3.51	29
Qatar	0.815	30	Qatar	3.442	30	Qatar	3.5	30
Poland	0.805	31	Poland	3.392	31	Poland	3.5	31

Israel	0.796	32	Israel	3.361	32	Hungary	3.41	32
Hungary	0.794	33	Hungary	3.352	33	Israel	3.39	33
Malaysia	0.780	34	Malaysia	3.294	34	Thailand	3.36	34
Thailand	0.778	35	Thailand	3.282	35	Malaysia	3.34	35
Turkiye	0.769	36	Turkiye	3.248	36	Estonia	3.3	36
Estonia	0.767	37	Iceland	3.239	37	Turkiye	3.29	37
Iceland	0.767	38	Estonia	3.238	38	Iceland	3.29	38

As shown in the comparison table, very similar results were obtained. While Turkey ranked 37th according to the LPI score evaluation, it improved to rank 36th in the entropy-based WP and entropy-based SAW methods. The ranking for each country can be observed using the three applied methods applied.

5. Conclusions Future Directions

In this study, a more objective and consistent assessment is sought with a two-stage integrated approach instead of averaging the six factors included in the LPI score calculation shared by the World Bank. In this study, the logistics performance of 38 countries, including Turkey, was compared using the 2023 data of the logistics performance index (LPI) developed by the World Bank and published every 2 years to assess the logistics activities of these countries. Entropy and weighted product methods, which are multi-criteria decision making (MCDM) methods, were used in the analysis. Customs, infrastructure, international shipments, logistics competence, timing (punctuality), cargo tracking, and traceability indicators, in the Logistics Performance Index published by the World Bank, were used as criteria in the analysis. In the study, first, the importance levels (weights) of the criteria to be used in the comparison were determined by the Entropy method. Then, the logistics rankings of the countries were determined by the WP method using criteria weights.

In order for Turkey to rank higher in logistics performance comparisons, the authorities should take into account the logistics performance of other countries. The government should pay due attention to the three most important criteria used in benchmarking (customs, infrastructure, and logistics competence), and in this context, customs should be improved, infrastructure facilities developed, and develop logistics competencies

In future research, more comprehensive results can be obtained by using different multi-criteria decision-making methods to add new criteria and alternatives.

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