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PERFORMANCE MEASUREMENT OF THE LOGISTICS COMPANIES ON THE FORTUNE 500 BY SWARA AND MEREC-BASED CRADIS METHODS

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Abstract:

The aim of this study is to evaluate the performance of logistics companies on the Fortune 500 Turkey list using the SWARA-MEREC based CRADIS methods. The weight of criteria was determined by subjective and objective approaches, namely SWARA and MEREC, respectively. The performance of companies was ranked by the CRADIS method. The findings highlighted that net sales (NS) and export (EXP) were most and least important criteria, respectively. The result of the CRADIS method showed that Netlog, Borusan and Ekol had the highest performance, while Noatum, BDP International and Horoz had the lowest performance in 2022, respectively. The reliability and robustness of the proposed model was tested with sensitivity and comparative analyses. The results of the sensitivity analysis and comparative analysis showed that the proposed model provides consistent results.

Key words: *Logistics, Fortune 500 Turkey, SWARA, MEREC, CRADIS*

1. Introduction

Logistics and supply chain management are not new phenomena. From the building of the pyramids to the technological revolution, the flow of goods and information have been conducted by logistics activities. Thus, logistics has been considered as one of the important components in the development of nations throughout the history of mankind (Christopher, 2022). Today's, with the help of advanced communication and transportation technologies, the logistics activities have become more and more important globally. Creating effective logistics strategies has become crucial to maintaining a competitive advantage (Ochego & Wycliffe, 2020). Especially, in the last few years, the global economy has witnessed an unprecedented amount of uncertainty due to the COVID-19 epidemic. As a matter of fact, the disruption of the global supply chain has negatively affected the countries both socially and economically. Parallel to this, the importance of the logistics and supply chains has emerged once again during the pandemic (Vilko & Hallikas, 2023). Accordingly, the performance evaluation plays a major role in the modern scope, and its highly valued by the companies and governments (Zhang & Tan, 2012).

According to Bu (2021), the performance evaluation refers to the use of specific indicators, evaluation standards and certain procedures through quantitative and qualitative research methods for a certain period. In the current competitive environment, the adequate evaluation of the performance of companies is quite important not only for themselves but also for their investors and stakeholders. Besides that, the performance

measurement is one of the vital tools for determining the internal strengths and weaknesses and external opportunities and threats of the companies. So far, some methods and approaches have been developed to analyze the performance of companies. However, the development of mathematical approaches for ranking and the proposition of criteria is important point in the evaluation (Farrokh et al., 2016). Furthermore, financial indicators are widely used to evaluate the performance of companies because of the importance of financial ratios for investors and stakeholders. The measurement of the financial performance of companies are involving complex process, such as multiple indicators and alternatives (Ersoy, 2023). Correspondingly, the performance measurement can be expressed as a Multi-Criteria Decision-Making (MCDM) problem. Aldalou & Perçin (2020) stated that MCDM methods are one of the effective tools to evaluation of the performance of companies.

Previous studies have revealed that MCDM methods are actively used to measurement the performance of companies on the Fortune 500 Turkey list. For instance, automotive industry (Çınaroğlu, 2019), logistics industry (Özbek, 2018), energy industry (Avcı, 2019) has investigated by various MCDM methods. In the light of this information, the current study aims to investigate the performance of logistics companies on the Fortune 500 Turkey list using the integrated MCDM methods. In this study, two weighting methods (SWARA-MEREC) were used to calculate the weight of criteria. Also, the aggregated weighting method (AWM) was utilized to combine the results obtained from the weighting methods. The performances of logistics companies were evaluated by one of the up-to-date methods (CRADIS). The present study aims to make several contributions to existing literature: (1) To the best of author's knowledge, this is the first study to examine the performance of logistics companies on the Fortune 500 list with SWARA and MEREC-based CRADIS methods. (2) In this study, the subjective and objective weighting methods were used at the same time. (3) The validity and robustness of the proposed model was tested through two ways; firstly, the sensitivity analysis was conducted to monitor the effect of contribution factor values on rankings. Secondly, the comparative analyses were applied to observe the changing of the ranking. Also, the spearmen correlation coefficient was also used to determine which method deviates most from the other methods.

The remaining part of the paper is structured as follows: The second section demonstrates the previous research on this field. The third section associates with the methodologies used in this study. The fourth section presents the application steps and findings of the research. Finally, the conclusion gives a summary and critique of the findings.

2. Literature Review

In this part, the previous research on relevant field is presented. Especially, in the last decade, many publications have been conducted to evaluate the logistics performance in a national and international context. Also, the MCDM methods are widely used to measurement of logistics performance. Some studies are shown in below:

Table 1. Previous research on logistics performance

Author(s)	Year	Methods	Topic
Çakır & Perçin	2013	CRITIC-SAW-TOPSIS-VIKOR	Performance measurement of the logistics companies on Fortune 500 list.
Çakır	2017	CRITIC-SAW-Peter's fuzzy regression	Analysis of the logistics performance of Organization of Economic Cooperation and

			Development (OECD) countries.
Ayaydın et al.	2017	Grey relational analysis (GRA)	Evaluation of the performance of logistics companies on Fortune 500 list.
Özbek & Demirkol	2018	SWARA-GRA	Performance analysis of the logistics companies on Fortune 500 list.
Rezaei et al.	2018	Best-worst method (BWM)	Measuring the relative importance of the logistics performance index indicators.
Özbek	2018	SWARA-COPRAS-GRA-TOPSIS	Analysis of the logistics companies on Fortune 500 list
Ulutaş & Karaköy	2019	SWARA-CRITIC-PIV	Logistics performance measurement of European Union (EU) countries.
Ersoy & Tehci	2020	Data envelopment analysis (DEA)	Performance evaluation of the logistics companies on Fortune 500 list.
Isik et al.	2020	SV-MABAC	Measurement of logistics performance of Central and Eastern European (CEE) countries
Toslak et al.	2022	MEREC-WEDBA	Investigation of the performance of a logistics company by years.
Isik	2022	Grey Entropy-FUCOM-EDAS-M	Analysis of the performance of the logistics companies on Fortune 500 list.
Mešić et al.	2022	CRITIC-MARCOS	Evaluation of the logistics performance of the Western Balkan countries.
Alaca & Ulutaş	2022	SWARA-ENTROPY-CODAS	Examining the performance of the logistics companies on Fortune 500 list.
Kara et al.	2022	ENTROPY-MABAC	Investigation of the logistics market performance of developing countries.
Özekenci	2023	SWARA-CRITIC-CoCoSo	Assessing the logistics market performance of developing countries.
Yürüyen et al.	2023	SV-MEREC-CRITIC-LOPCOW-MACONT	Evaluation of the performance of the logistics companies on Fortune 500 list.
Ersoy	2023	IDDWS-CoCoSo	Analyzing the financial performance of Fortune 500 companies.

As can be seen above, a considerable amount of research has been published on logistics performance using various MCDM methods. In recent years, the performance measurement of logistics companies in Fortune 500 has been investigated significantly (Çakır & Perçin, 2013; Özbek, 2018; Isik, 2022; Yürüyen et al., 2023). However, there is no studies have been found which evaluation of the performance of logistics companies in Fortune 500 using the SWARA-MEREC based CRADIS methods. Thus, this study aims to contribute to existing literature by proposing a new MCDM model.

3. Methodology

In this part, the brief information about the methodologies used in this study is given. For this investigation, two weighting methods were used as a subjective (SWARA) and objective (MEREC). Also, the weighting was combined with the AWM. After the determination of the weight of criteria, the alternatives were ranked using the CRADIS method. The application steps for each method are explained below.

3.1. SWARA Method

The Stepwise Weight Assessment Ratio Analysis (SWARA) method was proposed by Kersuliene, Zavadskas and Turkis in 2010. It is a well-known method used to determine criterion weights with a subjective approach. The steps of the SWARA method are as follows [Keršuliene et al., 2010; Alinezhad & Khalili, 2019]:

Step 1. At first, the criteria are prioritized in terms of relative importance, determined by decision-makers.

Step 2. Then, the coefficient (*K*) of criteria for each decision-maker is determined using Eq. [1].

$$K_j = \begin{cases} 1 & if \quad j = 1 \\ S_j + 1 & if \quad j > 1 \end{cases}; \quad j = 1, \dots\dots\dots\dots\dots\dots, n \qquad [1]$$

Step 3. At this stage, Eq. [2] is used to compute the initial weight of criteria for each decision-maker.

$$K_j = \begin{cases} 1 & if \quad j = 1 \\ \frac{q_j}{K_j} & if \quad j > 1 \end{cases}; \qquad j = 1, \dots\dots\dots\dots\dots\dots, n \qquad [2]$$

Step 4. Eq. [3] is applied to determine the relative weight of criteria for each decision maker.

$$w_j = \frac{q_j}{\sum_{j=1}^{n} q_i} \qquad [3]$$

Step 5. The values are arranged in descending order, producing the final ranking.

3.2. MEREC Method

Method based on the Removal Effects of Criteria (MEREC) method was proposed by Keshavarz-Ghorabaee et al. in 2021. It's a new objective weighting method for determining the criteria weights. This method utilizes each criterion's removal effect on the performance of alternatives to calculate the criteria weights. The steps of the MEREC method are as follows (Ghorabaee et al., 2021):

Step 1. The decision matrix is constructed.

Step 2. The decision matrix is normalized based on Eqs. (4-5).

$$N_{ij} = \left\{ \frac{min_{x_{kj}}}{x_{ij}} \right\} if\ j\ \in B \quad [4]$$

$$N_{ij} = \left\{ \frac{x_{ij}}{max_{x_{kj}}} \right\} if\ j \in B$$

Step 3. The overall performance of the alternatives *(S_i)* is calculated using Eq. (6).

$$N_{ij} S_i = \ln\left(1 + \left(\frac{1}{m}\sum_j \left|\ln(N_{ij}\right|\right)\right) \quad [6]$$

Step 4. According to Eq. (7), the performance of the alternatives by removing each criterion is computed.

$$S'_{ij} = \ln\left(1 + \left(\frac{1}{m}\sum_{k,k\neq j} \left|\ln(N_{ij}\right|\right)\right) \quad [7]$$

Step 5. The summation of absolute deviations is calculated using Eq. (8).

$$E_j = \sum_i \left|S'_{ij} - S_i\right| \quad [8]$$

Step 6. The final weights of criteria are determined based on Eq. (9).

$$w_i = \frac{E_i}{\sum_K E_k} \quad [9]$$

3.3. Aggregated Weighting Method (AWM)

Based on Eq. (10), the aggregated weight is determined (Ighravwe & Babatunde, 2018; Ali et al., 2020]);

$$W_{Aggregated} = \Delta W_{sj} + (1 - \Delta) W_{oj} \quad [10]$$

where W_{sj} and W_{oj} represent the subjective and objective weights of the criteria, respectively and Δ symbolizes the contribution factor. Keshavarz Ghorabaee et al. [2017] suggested using values of Δ from 0 to 1. For this study, Δ = 0.5 was considered.

3.4. CRADIS Method

Compromise Ranking of Alternatives from Distance to Ideal Solution (CRADIS) method was developed by Puška et al. in 2021. This method is a combination of steps regarding various MCDM techniques, namely ARAS, MARCOS and TOPSIS. Therefore, it's not a new method, however it is a new approach. The steps of the CRADIS method are shown below (Puška et al., 2021):

Step 1. The decision matrix is created.

Step 2. The decision matrix is normalized using Eq. (11-12).

[11]

$$n_{ij} = \frac{x_{ij}}{x_{jmax}}$$

$$n_{ij} = \frac{x_{jmin}}{x_{ij}}$$

Step 3. Based on Eq. (13), the aggravated decision matrix is obtained.

[13]

$$v_{ij} = n_{ij} \,.\, w_j$$

Step 4. The ideal and anti-ideal solution is determined according to Eqs. (14-15).

[14]

$$t_i = max v_{ij}$$

[15]

$$t_{ai} = min v_{ij}$$

Step 5. The deviations from ideal and anti-ideal solutions are computed using Eqs. (16-17).

[16]

$$d^+ = t_i - v_{ij}$$

[17]

$$d^- = v_{ij} - t_{ai}$$

Step 6. According to Eqs. (18-19), the grades of the deviation of individual alternatives from ideal and anti-ideal solutions are determined.

[18]

$$s_i^+ = \sum_{j=1}^{n} d^+$$

[19]

$$s_i^- = \sum_{j=1}^{n} d^-$$

Step 7. Based on Eqs. (20-21), the utility function for each alternative is calculated.

[20]

$$K_i^+ = \frac{s_0^+}{s_i^+}$$

[21]

$$K_i^- = \frac{s_i^-}{s_0^-}$$

Step 8. The final order is obtained using Eq. (22).

[22]

$$Q_i = \frac{K_i^+ + K_i^+}{2}$$

The best alternative is the one that has the greatest value Q_i

4. Applications and Results

In this section, the application results are shown separately. For this investigation, the performance evaluation of logistics companies on Fortune 500 has been conducted using the SWARA and LOPCOW-based CRADIS methods. The data was obtained from "Fortune 500 Turkey" website. Based on Fortune 500 Turkey (2022) list, a total of seven logistics companies were determined. These companies are as follows: Netlog, Ekol, Borusan, Mars, Noatum, BDP International and Horoz. Additionally, some criteria were excluded in this study due to the negative value and lack of data. Hereby, alternatives (logistics companies) were evaluated within the scope of a total of eight criteria. These criteria are as follows: net sales, net sales change, earnings before interest and sales, earnings before interest and sales change, total assets, equity, export amount and number of employees. Table 2 illustrates a brief overview of criteria used in this study.

Table 2. Characteristics of the criteria

Criteria	Abbreviation	Type	Unit	Source
Net sales	NS	Benefit	TL	Özbek (2018) Işık (2022) Alaca & Ulutaş (2022) Yürüyen et al., (2023)
Net sales change	NSC	Benefit	%	
Earnings before interest and sales	EBIT	Benefit	TL	
Earnings before interest and sales change	EBITC	Benefit	%	
Total assets	TA	Benefit	TL	
Equity	EQ	Benefit	TL	
Export amount	EXP	Benefit	TL	
Number of employees	EMP	Cost	Person	

It can be seen above, the alternatives were evaluated using the eight criteria. A seven of eight criteria is associated with benefit and only one criterion is associated with cost. In addition, the opinions of four experts were taken in calculating the criterion weights based on the subjective approach. Table 3 demonstrates the demographic information of experts.

Table 3. Background of the experts

No	Gender	Experience	Expertise	Occupation	Educational status
DM1	Male	15-20 years	Finance	Private sector / Top manager	Ph.D.
DM2	Female	10-15 years	Finance	Academician	Ph.D.
DM3	Male	15-20 years	Finance / Accounting	Private sector / Top manager	Ph.D.
DM4	Female	5-10 years	International trade	Academician	Ph.D.

As can be seen from the table (above), the experts included in this study are people who has high experience and education in both the private sector and academically. Moreover, it appears that the criteria used in performance evaluation are compatible with the areas of expertise of the people included in the study. In the following sections, the results obtained from the SWARA, LOPCOW and CRADIS methods are presented, respectively.

4.1. The results obtained from the SWARA method.

Firstly, the criteria were prioritized based on relative importance, determined by each decision makers (DM). The relative importance value of each DM is presented in Table 4.

Table 4. Evaluation of the criteria by DM.

Criteria	DM_1	DM_2	DM_3	DM_4	GM
NS	5	4	3	5	4,16
NSC	3	3	4	3	3,22
EBIT	2	2	1	2	1,68
EBITC	1	1	2	1	1,19
TA	6	5	5	6	5,48

EQ	7	6	7	7	6,74
EXP	4	7	6	4	5,09
EMP	8	8	8	8	8,00

Afterwards, the coefficient of criteria (*K*), the initial weight of criteria (*q*) and the relative weight of criteria (*w*) for each DM was calculated using Eqs. (1-3), and its results are demonstrated in Table 5-8, respectively.

Table 5. The ratings obtained from first DM.

Criteria	GM	Rank	S_j	K_j	q_j	w_j
NS	4,16	4	-	1,000	1,0000	0,1965
NSC	3,22	3	0,10	1,100	0,9091	0,1786
EBIT	1,68	2	0,20	1,200	0,7576	0,1488
EBITC	1,19	1	0,10	1,100	0,6887	0,1353
TA	5,48	6	0,30	1,300	0,5298	0,1041
EQ	6,74	7	0,10	1,100	0,4816	0,0946
EXP	5,09	5	0,30	1,300	0,3705	0,0728
EMP	8,00	8	0,05	1,050	0,3528	0,0693
				Sum	5,0901	

Table 6. The ratings obtained from second DM.

Criteria	GM	Rank	S_j	K_j	q_j	w_j
NS	4,16	4	-	1,000	1	0,2757
NSC	3,22	3	0,30	1,300	0,7692	0,2121
EBIT	1,68	2	0,40	1,400	0,5495	0,1515
EBITC	1,19	1	0,40	1,400	0,3925	0,1082
TA	5,48	6	0,30	1,300	0,3019	0,0832
EQ	6,74	7	0,20	1,200	0,2516	0,0694
EXP	5,09	5	0,25	1,250	0,2013	0,0555
EMP	8,00	8	0,25	1,250	0,1610	0,0444
				Sum	3,6269	

Table 7. The ratings obtained from third DM.

Criteria	GM	Rank	S_j	K_j	q_j	w_j
NS	4,16	4	-	1,000	1,0000	0,2288
NSC	3,22	3	0,10	1,100	0,9091	0,2080
EBIT	1,68	2	0,30	1,300	0,6993	0,1600
EBITC	1,19	1	0,10	1,100	0,6357	0,1454
TA	5,48	6	0,40	1,400	0,4541	0,1039
EQ	6,74	7	0,50	1,500	0,3027	0,0693
EXP	5,09	5	0,50	1,500	0,2018	0,0462
EMP	8,00	8	0,20	1,200	0,1682	0,0385

	Sum	4,3709

Table 8. The ratings obtained from fourth DM.

Criteria	GM	Rank	S_j	K_j	q_j	w_j
NS	4,16	4	-	1,000	1,0000	0,1919
NSC	3,22	3	0,20	1,200	0,8333	0,1599
EBIT	1,68	2	0,10	1,100	0,7576	0,1454
EBITC	1,19	1	0,10	1,100	0,6887	0,1322
TA	5,48	6	0,15	1,150	0,5989	0,1149
EQ	6,74	7	0,25	1,250	0,4791	0,0919
EXP	5,09	5	0,05	1,050	0,4563	0,0876
EMP	8,00	8	0,15	1,150	0,3968	0,0761
				Sum	5,2106	

Lastly, the arithmetic means and geometric mean of criteria was computed. By determining the final ranking of criteria, the values were arranged in a descending order. Table 9 illustrates the final ranking of criteria.

Table 9. Results of SWARA method

Criteria	AM	GM	Rank
NS	0,2232	0,2208	1
NSC	0,1897	0,1884	2
EBIT	0,1514	0,1513	3
EBITC	0,1303	0,1295	4
TA	0,1015	0,1008	5
EQ	0,0813	0,0804	6
EXP	0,0655	0,0636	7
EMP	0,0571	0,0548	8

According to results obtained from the SWARA method, NS, NSC and EBIT were the most important criteria, while EMP, EXP and EQ were the least important criteria, respectively.

4.2. The results obtained from the MEREC method.

At first, decision matrix is constructed based on the data obtained from the Fortune 500 Turkey list. Initial decision matrix which shows each alternative's values regarding each criterion, and it is presented in Table 10.

Table 10. Decision matrix

Alternatives/ Criteria	NS	NSC	EBIT	EBITC
Netlog	20.123.275.910,00	109.2	1.636.078.430,00	199.5
Ekol	12.055.140.002,73	101.2	927.845.576,87	90
Borusan	11.331.600.132,00	122.2	729.104.484,00	369.3

Mars	8.574.368.833,00	126.5	1.176.203.225,00	136.9
Noatum	6.571.478.913,00	130.6	746.113.377,00	125.3
BDP International	4.928.325.497,00	127.4	337.030.622,00	105.6
Horoz	2.845.548.572,00	109.8	286.193.561,00	326.2
Alternatives/ Criteria	**TA**	**EQ**	**EXP**	**EMP**
Netlog	12.228.087.839,00	2.164.163.290,00	10.708.132.203,00	14.000
Ekol	9.209.501.707,89	3.102.650.783,07	10.165.833.994,78	8.977
Borusan	8.298.615.564,00	4.103.844.839,00	8.298.615.564,00	4.544
Mars	6.027.348.751,00	4.346.695.761,00	4.095.875.560,48	2.086
Noatum	1.189.523.671,00	629.770.350,00	2.306.999.927,99	194
BDP International	1.130.916.433,00	467.542.705,00	4.891.634.742,00	271
Horoz	1.492.639.493,00	161.621.414,00	1.168.036.925,00	1.656

According to Eqs. (4-5), the decision matrix was normalized based on the beneficial or non-beneficial type of criteria, and the results are shown in Table 11.

Table 11. Normalized decision matrix

Alternatives/ Criteria	NS	NSC	EBIT	EBITC	TA	EQ	EXP	EMP
Netlog	0,1414	0,9267	0,1749	0,4511	0,0925	0,0747	0,1091	1,0000
Ekol	0,2360	1,0000	0,3084	1,0000	0,1228	0,0521	0,1149	0,6412
Borusan	0,2511	0,8282	0,3925	0,2437	0,1363	0,0394	0,1408	0,3246
Mars	0,3319	0,8000	0,2433	0,6574	0,1876	0,0372	0,2852	0,1490
Noatum	0,4330	0,7749	0,3836	0,7183	0,9507	0,2566	0,5063	0,0139
BDP International	0,5774	0,7943	0,8492	0,8523	1,0000	0,3457	0,2388	0,0194
Horoz	1,0000	0,9217	1,0000	0,2759	0,7577	1,0000	1,0000	0,1183

Then, Eq. (6) was used to calculate the overall performance of the alternatives and the results are shown in Table 12.

Table 12. The values of S_i

Alternatives	S_i
Netlog	0,9043
Ekol	0,8264
Borusan	0,9278
Mars	0,8798
Noatum	0,7390
BDP International	0,6641
Horoz	0,3871

Based on Eq. (7), the alternatives' overall performances were calculated by removing each criterion (S_{ij}') and the results are presented in Table 13.

Table 13. The values of S_{ij}'

Alternatives/ Criteria	NS	NSC	EBIT	EBITC	TA	EQ	EXP	EMP
				S_{ij}'				
Netlog	0,8001	0,9005	0,8120	0,8632	0,7760	0,7636	0,7854	0,9043
Ekol	0,7441	0,8264	0,7599	0,8264	0,7045	0,6501	0,7004	0,8018
Borusan	0,8570	0,9184	0,8804	0,8554	0,8241	0,7536	0,8258	0,8705
Mars	0,8209	0,8681	0,8036	0,8578	0,7890	0,6926	0,8125	0,7758
Noatum	0,6878	0,7237	0,6801	0,7191	0,7360	0,6544	0,6976	0,4441
BDP International	0,6281	0,6492	0,6535	0,6538	0,6641	0,5933	0,5674	0,3713
Horoz	0,3871	0,3801	0,3871	0,2713	0,3632	0,3871	0,3871	0,1872

Eq. (8) was utilized to calculate the summation of absolute deviations and the results are presented in Table 14.

Table 14. The values of E_j

Criteria	NS	NSC	EBIT	EBITC	TA	EQ	EXP	EMP
	0,1042	0,0039	0,0924	0,0411	0,1284	0,1407	0,1189	0,0000
	0,0823	0,0000	0,0665	0,0000	0,1219	0,1763	0,1260	0,0246
	0,0707	0,0094	0,0473	0,0723	0,1037	0,1742	0,1019	0,0572
E_j	0,0589	0,0116	0,0761	0,0220	0,0908	0,1872	0,0673	0,1040
	0,0513	0,0153	0,0589	0,0200	0,0030	0,0847	0,0415	0,2950
	0,0360	0,0149	0,0106	0,0103	0,0000	0,0708	0,0967	0,2928
	0,0000	0,0069	0,0000	0,1157	0,0238	0,0000	0,0000	0,1999
Total	0,4034	0,0621	0,3518	0,2815	0,4716	0,8339	0,5523	0,9734
E_k	3,9299							

According to Eq. (9), each criterion's weight was computed, and the final weights of the criteria is shown in Table 15.

Table 15. Results of MEREC method

w_j	NS	NSC	EBIT	EBITC	TA	EQ	EXP	EMP
	0,1026	0,0158	0,0895	0,0716	0,1200	0,2122	0,1405	0,2477

The results of MEREC method showed that EMP, EQ and EXP were the most important criteria, respectively. Besides that, EBIT, EBITC and NSC were the least important criteria, respectively.

4.3. The results obtained from the AWM.

Eq. (10) was used to combine the results obtained from the subjective (SWARA) and objective (MEREC) methods. Table 15 shows the criteria weight determined by each method.

Table 15. Results of AWM

Criteria	SWARA	MEREC	AWM	Final rank
NS	0,2208	0,1026	0,1617	1
NSC	0,1884	0,0158	0,1021	6
EBIT	0,1513	0,0895	0,1204	4
EBITC	0,1295	0,0716	0,1006	8
TA	0,1008	0,1200	0,1104	5
EQ	0,0804	0,2122	0,1463	3
EXP	0,0636	0,1405	0,1020	7
EMP	0,0548	0,2477	0,1512	2

According to results from the SWARA method, NS, NSC and EBIT were the most important criteria, while EQ, EXP and EMP were the least important criteria. Based on the results of MEREC method, EMP, EQ and EXP were the most important criteria, while EBIT, EBITC and NSC were the least important criteria. The results obtained from the AWM pointed out that NS, EMP and EQ were the most important criteria, while NSC, EXP and EBITC were the least important criteria. The results of three different weighting methods are presented in Figure 1.

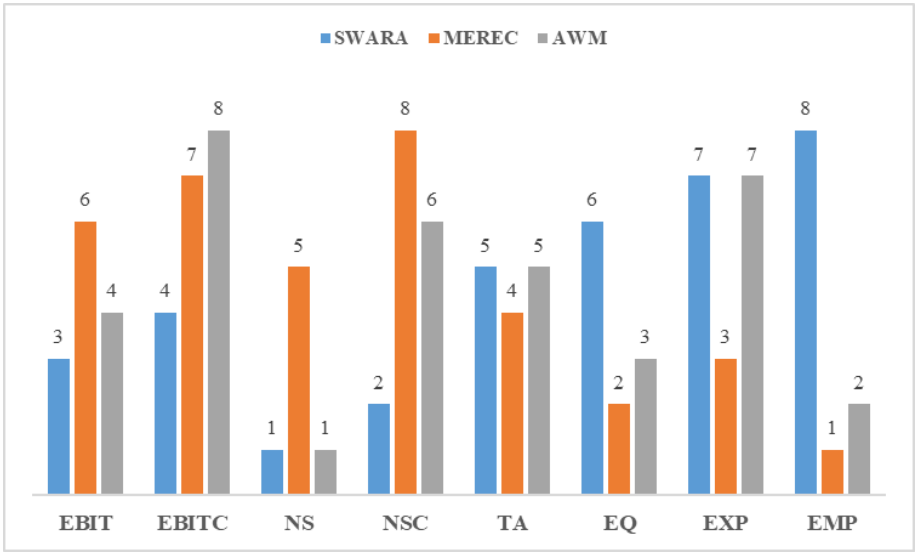

Figure 1. The overall results of the criteria

4.4. The results obtained from the CRADIS method.

Once the weight of criteria was determined, the alternatives were ranked using the CRADIS method, and the results are presented in this section. Firstly, the decision matrix was formed, and it's shown in Table 16.

Table 16. Decision matrix

Alternatives/ Criteria	NS	NSC	EBIT	EBITC
Netlog	20.123.275.910,00	109.2	1.636.078.430,00	199.5
Ekol	12.055.140.002,73	101.2	927.845.576,87	90
Borusan	11.331.600.132,00	122.2	729.104.484,00	369.3
Mars	8.574.368.833,00	126.5	1.176.203.225,00	136.9
Noatum	6.571.478.913,00	130.6	746.113.377,00	125.3
BDP International	4.928.325.497,00	127.4	337.030.622,00	105.6
Horoz	2.845.548.572,00	109.8	286.193.561,00	326.2
Alternatives/ Criteria	**TA**	**EQ**	**EXP**	**EMP**
Netlog	12.228.087.839,00	2.164.163.290,00	10.708.132.203,00	14.000
Ekol	9.209.501.707,89	3.102.650.783,07	10.165.833.994,78	8.977
Borusan	8.298.615.564,00	4.103.844.839,00	8.298.615.564,00	4.544
Mars	6.027.348.751,00	4.346.695.761,00	4.095.875.560,48	2.086
Noatum	1.189.523.671,00	629.770.350,00	2.306.999.927,99	194
BDP International	1.130.916.433,00	467.542.705,00	4.891.634.742,00	271
Horoz	1.492.639.493,00	161.621.414,00	1.168.036.925,00	1.656

According to Eq. (11-12), the decision matrix was normalized, and the results are presented in Table 17.

Table 17. Normalized decision matrix

Alternatives/ Criteria	NS	NSC	EBIT	EBITC	TA	EQ	EXP	EMP
Netlog	1,0000	0,8361	1,0000	0,5402	1,0000	0,4979	1,0000	0,0139
Ekol	0,5991	0,7749	0,5671	0,2437	0,7531	0,7138	0,9494	0,0216
Borusan	0,5631	0,9357	0,4456	1,0000	0,6787	0,9441	0,7750	0,0427
Mars	0,4261	0,9686	0,7189	0,3707	0,4929	1,0000	0,3825	0,0930
Noatum	0,3266	1,0000	0,4560	0,3393	0,0973	0,1449	0,2154	1,0000
BDP International	0,2449	0,9755	0,2060	0,2859	0,0925	0,1076	0,4568	0,7159
Horoz	0,1414	0,8407	0,1749	0,8833	0,1221	0,0372	0,1091	0,1171

The normalized decision matrix was weighted based on Eq. (13), and the results are shown in Table 18.

Table 18. Weighted normalized decision matrix.

Alternatives/ Criteria	NS	NSC	EBIT	EBITC	TA	EQ	EXP	EMP
Netlog	0,1617	0,0854	0,1204	0,0543	0,1104	0,0728	0,1020	0,0021
Ekol	0,0969	0,0791	0,0683	0,0245	0,0832	0,1044	0,0969	0,0033
Borusan	0,0911	0,0955	0,0537	0,1006	0,0749	0,1381	0,0791	0,0065
Mars	0,0689	0,0989	0,0866	0,0373	0,0544	0,1463	0,0390	0,0141
Noatum	0,0528	0,1021	0,0549	0,0341	0,0107	0,0212	0,0220	0,1512

BDP International	0,0396	0,0996	0,0248	0,0288	0,0102	0,0157	0,0466	0,1083
Horoz	0,0229	0,0858	0,0211	0,0888	0,0135	0,0054	0,0111	0,0177

Eqs. (14-15) was used to determine the ideal and anti-ideal solutions which represents the maximum and minimum values of the alternatives. The results of the ideal and anti-ideal solutions of the alternatives were presented in Table 19 and 20, respectively.

Table 19. Ideal solution

Alternatives/ Criteria	NS	NSC	EBIT	EBITC	TA	EQ	EXP	EMP
Netlog	0,0000	0,0764	0,0413	0,1074	0,0513	0,0889	0,0597	0,1596
Ekol	0,0648	0,0826	0,0934	0,1372	0,0786	0,0573	0,0649	0,1585
Borusan	0,0707	0,0662	0,1081	0,0612	0,0868	0,0236	0,0827	0,1553
Mars	0,0928	0,0628	0,0752	0,1245	0,1073	0,0154	0,1227	0,1477
Noatum	0,1089	0,0596	0,1068	0,1276	0,1510	0,1405	0,1398	0,0105
BDP International	0,1221	0,0621	0,1369	0,1330	0,1515	0,1460	0,1151	0,0535
Horoz	0,1389	0,0759	0,1407	0,0729	0,1483	0,1563	0,1506	0,1440
min	0,0000	0,0596	0,0413	0,0612	0,0513	0,0154	0,0597	0,0105

Table 20. Anti-ideal solution

Alternatives/ Criteria	NS	NSC	EBIT	EBITC	TA	EQ	EXP	EMP
Netlog	0,1596	0,0833	0,1183	0,0522	0,1083	0,0707	0,1000	0,0000
Ekol	0,0948	0,0770	0,0662	0,0224	0,0811	0,1023	0,0948	0,0012
Borusan	0,0890	0,0934	0,0516	0,0985	0,0728	0,1360	0,0770	0,0044
Mars	0,0668	0,0968	0,0845	0,0352	0,0523	0,1442	0,0369	0,0120
Noatum	0,0507	0,1000	0,0528	0,0320	0,0086	0,0191	0,0199	0,1492
BDP International	0,0375	0,0975	0,0227	0,0267	0,0081	0,0136	0,0445	0,1062
Horoz	0,0208	0,0837	0,0190	0,0867	0,0114	0,0033	0,0090	0,0156
max	0,1596	0,1000	0,1183	0,0985	0,1083	0,1442	0,1000	0,1492

According to Eqs. (16-17), the deviation of alternatives from ideal and anti-ideal solutions were calculated. Then, the deviation score of individual alternatives from ideal and anti-ideal solutions were computed based on Eqs. (18-19). Finally, the utility function for each alternative and the value of CRADIS method were calculated using Eqs. (20-22), and it's shown in Table 21.

Table 21. Results of CRADIS method

Alternatives	s_i^+	K_i^+	s_i^-	K_i^-	Q_i	Rank
Netlog	0,5847	0,5115	0,6925	0,7080	0,6098	1
Ekol	0,7374	0,4056	0,5398	0,5519	0,4787	3
Borusan	0,6545	0,4570	0,6227	0,6366	0,5468	2
Mars	0,7484	0,3996	0,5287	0,5406	0,4701	4
Noatum	0,8448	0,3540	0,4324	0,4420	0,3980	5
BDP International	0,9203	0,3250	0,3568	0,3648	0,3449	6

Horoz	1,0275	0,2910	0,2496	0,2552	0,2731	7
S_0	0,2991		0,9781			

The results of CRADIS method showed that Netlog, Borusan and Ekol had the highest performance, while Noatum, BDP International and Horoz had the lowest performance in 2022. According to Iman & Helton (1988), the usefulness of any model depends on the validation and robustness of its results. However, there is no consensus on how to determine the sensitivity analysis. So far, many researchers have recommended various sensitivity analyses to monitor the reliability of the results (Triantaphyllou & Sanches, 1997; Peng et al., 2011; Junior et al., 2014; Maliene et al., 2018; Yagmahan & Yılmaz, 2023). In the following section, the reliability of the proposed model was tested with sensitivity analysis and compative analysis.

4.5. Sensitivity and Comparative Analyses

In this study, the reliability of the proposed model was tested through two steps. The first step was to carry out by changing the value of contribution factor (Δ). As mentioned in the methodology section, the value of Δ was considered 0,5 for this study. However, it is important to observe whether there is a change in the ranking due to the change in Δ value. Accordingly, the sensitivity analysis was conducted under ten scenarios in this study. Table 22 demonstrates the rank of alternatives based on different scenario.

Table 22. Sensitivity analysis scenarios

Alternatives	Δ=0,1	Δ=0,2	Δ=0,3	Δ=0,4	Δ=0,5	Δ=0,6	Δ=0,7	Δ=0,8	Δ=0,9	Δ=1,00
Netlog	1	1	1	1	1	1	1	1	1	1
Ekol	3	3	3	3	3	3	3	3	3	3
Borusan	2	2	2	2	2	2	2	2	2	2
Mars	4	4	4	4	4	4	4	4	4	4
Noatum	5	5	5	5	5	5	5	5	5	5
BDP International	6	6	6	6	6	6	6	6	6	6
Horoz	7	7	7	7	7	7	7	7	7	7

According to results obtained from the sensitivity analysis, Netlog, Borusan and Ekol stand out as the companies with the highest performance in 2022. Additionally, it can be observed that Netlog outperforms over others in all scenarios. It can be concluded that the ranking of the alternatives does not change by modifying the Δ value. Thus, the robustness and reliability of the proposed model were validated by the sensitivity analysis. However, it's important to compare the results obtained from the method used in this study with other MCDM methods. Therefore, the comparison results of the CRADIS and other MCDM methods are presented in the following section.

4.6. Comparative Analysis

The second step was to compare the ranking order with various MCDM methods, namely ARAS, MARCOS, SAW and MABAC. These methods were selected due to differences in their calculation. For instance, MARCOS method associated with the deviation from an ideal and anti-ideal solution. SAW method focuses on the sum of the

values of the weighted normalized decision matrix. MABAC method related to deviation from the average value of alternatives. ARAS method performs ranking based on the utility function relative to the optimal solution (Puška et al., 2023). Therefore, it can be concluded that all methods used in the comparative analysis have different approaches. Table 23 demonstrates the ranking results obtained from the different MCDM methods.

Table 23. Rank of alternatives

Alternatives	CRADIS	ARAS	MARCOS	SAW	MABAC
Netlog	1	1	1	1	2
Ekol	3	3	3	3	4
Borusan	2	2	2	2	1
Mars	4	4	4	4	3
Noatum	5	5	5	5	5
BDP International	6	6	6	6	6
Horoz	7	7	7	7	7

The results obtained by other methods have shown that the ranking does not change significantly. Almost in all methods, the best-ranked alternative is Netlog, while the worst-ranked alternative is Horoz. Furthermore, the results have shown that the results obtained by the CRADIS method do not differ significantly from the results obtained from the other methods. Based on this, it can be concluded that the results of the CRADIS method are confirmed with the results of other methods. Figure 2 demonstrates the results obtained from the different MCDM methods.

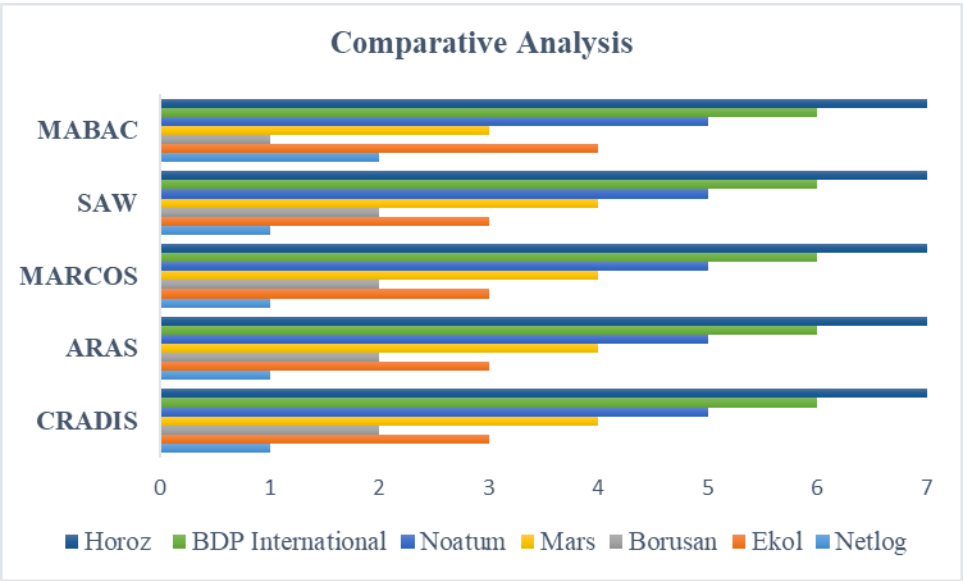

Figure 2. The overall results of the alternatives

In this study, the spearmen correlation coefficient was also used to determine which method deviates most from the other methods. As stated by Kou et al. (2012), the spearmen correlation measures the similarity between two sets of rankings. The largest value of the correlation coefficient indicates a good agreement between a MCDM method and other MCDM methods. Table 24 illustrates the values of correlation coefficient for each method.

Table 24. Spearman correlation values

	CRADIS	ARAS	MARCOS	SAW	MABAC
CRADIS	**1,0000**	1,0000	1,0000	1,0000	0,9286
ARAS		**1,0000**	1,0000	1,0000	0,9286
MARCOS			**1,0000**	1,0000	0,9286
SAW				**1,0000**	0,9286
MABAC					**1,0000**

The results of the spearmen correlation coefficient have shown that the MABAC method has the largest deviation from the results of other methods. The deviation of the CRADIS method in comparison with the ARAS, MARCOS and SAW methods is the same. Thus, it can be concluded that there is a highest correlation between the CRADIS method and other methods. However, some differences have observed between the CRADIS and MABAC methods. Overall, it can be stated that the ranking of alternatives does not change significantly. Based on these analyses, the proposed model which is SWARA and MEREC based-CRADIS methods are confirmed.

5. Discussion and Conclusion

In today's globalized world, the performance measurement is more than managing and monitoring the day-to-day activities of the business. Performance measurement is important in motivating decision makers when creating strategies for the business to achieve its goals. Over the last few decades, the performance measurement has been carried out by the financial indicators (Neely et al., 2005; Kotane & Kuzmina-Merlino, 2012; Mashovic, 2018; Bandono & Nugroho, 2023). As mentioned in the literature review, MCDM methods are widely used to analyze the performance of companies. Since many researchers have reported that considering both objective and subjective methods will yield more comprehensive and realistic results (Saad et al., 2014; Paramanik et al., 2022; Puška et al., 2023) However, much of the available literature on the evaluation of the performance was carried out with either objective or subjective approaches. The starting point of this study was to enhance the number of research which includes both objective and subjective methods. Correspondingly, the goal of the current research was to performance measurement of the logistics companies using the integrated MCDM methods. This paper has proposed a new model which aim was to examine the performance of the logistics companies on the Fortune 500 Turkey list, looking at eight different criteria. Here, a hybrid approach based on the SWARA, MEREC and CRADIS methods was used to evaluate the performance of logistics companies.

In this study, the SWARA and MEREC methods were used to calculate the weight of criteria. Additionally, the AWM was used to combine the results obtained from each method. According to the results obtained by the SWARA and MEREC methods showed that net sales (NS) and number of employees (EMP) was the most important criteria, while export (EXP) and earnings before interest and sales change (EBITC) was the least important criteria, respectively. Surprisingly, significant differences have been observed between the objective and subjective approaches. These results showed that using both objective and subjective methods are enabled to get more comprehensive results. The results of the conducted research showed that Netlog achieved the highest results based on the observed criteria, while the Horoz achieved the lowest results.

These results were confirmed by the sensitivity analysis and comparative analysis. Based on the results obtained by the sensitivity analysis showed that there is no correlation was observed between the ranking of companies and changing the Δ value. More clearly, the performance of the logistics companies were constant for all scenarios. Afterwards, the results obtained by the proposed model was compare with several methods such as ARAS, MARCOS, SAW and MABAC. The comparative analysis results showed that the companies with the highest and lowest performance were almost the same as the results obtained from the proposed model. Besides that the spearman correlation analysis was conducted to observe the correlation between methods. According to correlation analysis, there is a significant correlation has been found between the proposed model and other MCDM methods. As expexted, the Netlog, Borusan and Ekol have the highest performance in all scenarios. These companies play a key role in the development of logistics industry with the number of exports, international investments and other financial supports. On the other hand, it can be stated that other important players in the logistics industry such as Noatum, BDP International and Horoz performed slightly worst performance.

The results of this study will now be compared to the findings of previous work. The findings of the current study are consistent with those of Çakır and Perçin (2013) who found that the Borusan showed the highest performance, while the Horoz showed the relatively worst performance. Additionally, this findings are in agreement with Özbek's (2018) research which revealed that the Netlog and Ekol were the top-three rankings, while the Horoz was the last-three rankings. Furthermore, the findings obtained from this study are consistent with those of Ulutaş (2018) who found that the Netlog and Ekol showed the best performance, while the Horoz showed the worst performance. Moreover, the present findings seem to be consistent with other study (Işık, 2022) which found that the Ekol was among the best performing companies, while the Horoz was among the relatively worst performing companies. In accordance with the present findings, it can be concluded that logistics companies in the Fortune 500 Turkey list have shown similar performance in the last decades. In other words, the companies who performed the highest or lowest performance are almost the same in different period of time.

The logistics industry plays a crucial role in the development of global economy. It is mainly associated with trade expansion, economic growth, and global connectivity. In fact, the efficiency of supply chain, international trade facilitation, cost optimization, innovation and technology adaptation, job creation and environmental sustainability are compliance with the logistics industry. Consequently, It has become a cornerstone of modern commercial activity due to its direct effects on companies, customers, and every aspects of the economy. For that reason, in the logistics industry, performance measurement is critical for assessing and enhancing a range of operational elements. By regularly monitoring and analyzing these performance indicators, logistics companies could identify areas for improvement, optimize their operations, and increases efficiency as well as customer satisfaction. Furthermore, it allows companies to stay competitive and adjust to changing circumstances in the market.

Taken together, some recommendations are made for decision-makers in logistics companies: By investing in emerging technologies such as artificial intelligence, blockchain, big data and internet of things, the workforce and business processes could be made more efficient. In particular, blockchain and artificial intelligence are widely used to increase the performance of companies in logistics industry (Călinescu, 2022). Additionally, companies may increase their net sales by finding different markets for export. In other words, companies might expand their operation area into regions with high export and growth potential. For instance, the popularity of the African region is increasing each day. Besides that, companies may evaluate their current financial situation with the help of earnings before interest and sales. Thus, companies can achieve more effective

results when making investment decisions or long-term planning. Overall, it is believed that the results obtained from this study will gain insight to decision makers in logistics industry.

The current research has certain limitations. The first limitation is that the number and selection of criteria. Although this study was designed to various criteria as possible, the future research might be designed to expand the criteria to make more comprehensive evaluation. The second limitation is that this study was conducted only by logistics companies listed on the Fortune 500 Turkey list. Future research might examine the logistics companies listed on the Fortune Global 500 list. It would be interesting to compare the performance of companies on Fortune 500 Turkey and Fortune Global 500. Moreover, this study has revealed that the proposed model can be used with other new methods such as IDOCRIW, LOPCOW, CoCoSo and MACONT.

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