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Performance Evaluation in Airline Operations Using SD and DNMA Methods Within The Framework of Sustainability: The Case of Turkish Airlines

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Abstract

Sustainability is essential in enabling enterprises to secure a competitive advantage and achieve long-term success. The sustainability activities of airline operations stand out in the evaluation of their performance alongside all other operational activities. Therefore, understanding how sustainability strategies affect performance in airline operations is a matter of significant concern for managers. This study aims to evaluate the performance of airline companies, particularly focusing on sustainability, using the example of Turkish Airlines (THY). In this study, the SD and DNMA methods, which are multi-criteria decision-making methods, were employed for performance evaluation. The weights of the criteria were determined using the SD method, and THY's performance between 2018 and 2022 was evaluated using the DNMA method. According to the analysis results, the three most important criteria are 'Sustainability Rating,' 'Load Factor,' and 'Number of Passengers,' with 2022 identified as the most successful performance year for THY. This study contributes to the literature by integrating sustainability performance in airline operations with both financial and non-financial indicators and by utilizing the SD and DNMA methods in an integrated manner. It is believed that the study provides significant contributions to the evaluation of sustainability practices' performance and can guide future sustainable strategies for THY and airline company managers.

1. Introduction

Sustainability, as defined by Porter and Kramer (2006), Glasby (2002), and Çakar (2007), encompasses meeting present needs without jeopardizing the ability of future generations to meet their own needs, living in harmony with the environment, and ensuring efficient utilization of resources for the social, economic, and environmental needs of future generations.

The three dimensions of sustainability—economic, social, and environmental—are examined within a holistic approach, emphasizing the importance of balancing these components in corporate governance (Dyllick and Hockerts, 2002). When businesses focused on economic interests contemplate their obligations to protect the environment for future generations and address social responsibilities, it becomes imperative to evaluate these dimensions together.

Social Sustainability deals with abstract issues such as education, employment, and ethics, and it pertains to preserving societal values. Basic needs of society such as food, clothing, and shelter are integral to social sustainability. The sustainability of social values and needs is also seen as a crucial step in determining the quality of economic sustainability (Eryılmaz et al., 2019).

Economic Sustainability is defined as preserving and preventing the degradation of capital (Goodland, 2002). At the heart of economic sustainability, which aims to plan the resources needed by future generations from today, lies the question of how each generation will decide how much capital to consume now and how much to accumulate and preserve for future generations (Markulev and Long, 2013, as cited in Bilgili, 2017). At a micro level, it focuses on the effective management of organizations' capital, requiring an optimal balance among various types of capital, including financial capital, tangible assets such as machinery and stocks, and intangible assets such as corporate reputation and technical knowledge.

Environmental Sustainability involves meeting the present and future generations' resource needs without compromising ecosystem health, considering the capacity limits of ecosystems, and ensuring their continued reproduction while meeting society's needs. Actions in environmental sustainability focus on resource conservation, waste management, and renewable energy systems, but true environmental sustainability can only be achieved through sustainable production and consumption practices (Goodland, 1995; Morelli, 2011).

The aviation sector is an integral part of the global economy but also poses challenges to environmental sustainability. It is one of the fastest-growing industries, paralleled by pollution that threatens environmental sustainability. Policymakers, researchers, and industry experts are addressing how to tackle these issues and achieve truly sustainable aviation, balancing the economic and other benefits it brings without pollution, noise, and loss of rural areas (Upham et al., 2012).

The sector's rapid growth, coupled with factors such as increased fuel consumption with the growing number of aircraft, international political disputes, etc., also increases airline costs, making sustainability increasingly important for aviation organizations from all perspectives. The sector has been at the forefront of sustainability efforts since the 1970s, presenting examples such as reducing aircraft engine noise levels, reducing fuel consumption, and using electronic resources and applications to prevent paper waste in ticketing processes and maintenance documents. Efforts to find solutions to problems such as aircraft routes, waiting times, time lost at airports, and inadequate traffic controls also continue (Torum and Yılmaz, 2019).

Sustainability in the aviation sector encompasses a comprehensive range of areas due to the size of stakeholders, including aircraft bodies and propulsion, auxiliary power systems, non-aircraft vehicles, fuel efficiency, airlines, airports, and air traffic control systems. While airlines and airports reflect their sustainability strategies in activity reports or provide separate sustainability reporting among all sector stakeholders, the number of reports is observed to be quite low.

The sustainability activities of airline operations are a significant factor in evaluating their performance, along with all other operational activities. Performance, viewed in the broadest sense as the degree of achievement of defined objectives, involves airlines utilizing various indicators based on predetermined goals in their performance analysis. Table 1 summarizes some of the key indicators used in performance analysis in airline operations (Leidtka, 2002: 111).

Table 1. Performance Measurement Indicators in Airline Operations

Category	Measure
FPMs – Financial Performance Measures	
Return on Investment	Return on Assets (F1A), Return on Equity (F1B), Return on Sales (F1C)
Financial Leverage	Debt to Assets (F2A), Debt to Equity (F2B), Long-term Debt/Assets (F2C)
Short-term Liquidity	Current Ratio (F3A), Quick Ratio (F3B)
Cash Position	Cash/Assets (F4A), Cash/Current Liabilities (F4B), Cash/Sales (F4C)
Capital Turnover	Sales/Assets (F5A), Sales/Equity (F5B), Sales/ (Long-term Debt+Equity) (F5C)
Receivables Turnover	Receivables Turnover (F6)
Cash Flow	CFFO/Assets (F7A), CFFO/Equity (F7B), CFFO/Sales (F7C)
NFPMs – Non-Financial Performance Measures	
Service Quality	On-time Flight Percentage (N1A), Percentage of Regularly Scheduled Flights Late 70% of the Time (N1B), Mishandled Baggage Reports per 1,000 Passengers (N1C), Involuntary Denied Boardings per 10,000 Passengers
Passenger Safety	Accidents and Incidents per Flight Hour (N2A), per Mile Flown (N2B), per Departure (N2C)
Customer Satisfaction	Consumer Complaints per 100,000 Passengers (N3)
Labor Efficiency	Available Seat Miles per Employee (N4A), Aircraft Miles per Employee (N4B), Departures per Employee (N4C)
Fixed Asset Efficiency	Passenger Load Factor (N5A), Airborne Hours per Plane (N5B), Aircraft Miles per Plane (N5C)
Materials Efficiency	Available Seat Miles per Gallon of Fuel (N6A), Aircraft Miles per Gallon of Fuel (N6B), Departures per Gallon of Fuel (N6C)
Passenger Volume	Percentage of Major Airline Revenue Seat Miles (N7A), Percentage of Major Airline Passengers (N7B)

Leidtka (2002) classified the performance indicators used in the measurement of airline companies' performance under two main categories. Financial Performance Metrics (FPMs) include criteria aimed at evaluating the company's financial condition, profitability, and financial sustainability, while Non-Financial Performance Metrics (NFPMs) consist of factors that assess the company’s operational success and customer-focused processes, such as operational efficiency, customer satisfaction, service quality, and workforce productivity.

In the literature, it is recognized that relying solely on financial criteria or solely operational criteria is often insufficient for determining the performance of airline operations. Neglecting comprehensive and significant indicators such as sustainability activities results in the inability to evaluate the business from a broad perspective in performance assessment.

The aim of this study is to evaluate the sustainability-oriented performance of airline companies by integrating both financial and non-financial indicators. This study, which uses the SD and DNMA methods in an integrated manner from multi-criteria decision-making approaches, contributes to the literature by filling the existing gap in airline performance evaluation research.

Firstly, relevant studies in the literature were reviewed, followed by an explanation of the methodology used in the study. The application findings were presented, and the results obtained were discussed.

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2. Materials and Methods

In the literature, it is observed that different criteria are considered in measuring the performance of airline operations, with very few studies incorporating sustainability performance. Table 2 presents basic examples from these studies, as well as examples from other studies where Multi-Criteria Decision-Making Methods such as SD and DNMA are used for performance measurement. It is also noted that there are studies focusing on the relationship between sustainability scores and performance in sectors other than the aviation industry (Sinha et al., 2022; Kalia and Aggarval, 2022; Trisnowati et al., 2022; Xie et al., 2019; Velte, 2017; Brammer et al., 2006).

Table 2. Literature Review

The author/authors of the study	The subject/topic of the study.	Methodology.
Examples of Studies Evaluating the Performance of Airline Operations.		
Schefczyk, (1993)	Measurement of the Operational Performance of Airline Operations	Data Envelopment Analysis
Scheraga, (2004)	Measuring the Efficiency of Airline Operations	Data Envelopment Analysis and Tobit Regression Model
Kiracı and Bakır, (2018)	Examining the Performance of Airline Operations Before and After the Global Financial Crisis	CRITIC and EDAS
Tsai et al. (2011)	Evaluating the E-Marketing and E-Service Performance of Airlines in Taiwan	DEMATEL, ANP and VIKOR
Aydoğan (2011)	Measurement of the Performance of Turkish Aviation Companies	Rough Set-AHP and Fuzzy TOPSIS
Badi and Abdulshaded(2019)	Evaluating the Performance of Airline Operations in Libya	AHP and FUCOM
Özdağoğlu et al. (2020)	Evaluating the Performance of Airlines Operating at Isparta Süleyman Demirel Airport	BWM, MAIRCA and MABAC
Ustaömer et al. (2021)	Evaluating and Comparing the Efficiency of Turkish Airlines Before and After the Pandemic	Data Envelopment Analysis
Keleş, (2022)	Measurement of Turkish Airlines' Performance Over the Years	CRITIC and MABAC
Wang (2008)	Evaluating the Financial Performance of Taiwanese Airlines	Grey Relational Analysis, Fuzzy TOPSIS
Ömürbek and Kınay (2013)	Measurement of the Financial Performance of Airlines Listed on the Istanbul and Frankfurt Stock Exchanges	TOPSIS
Wanke et al. (2015)	Evaluating the Performance of Airlines Operating in Asia	TOPSIS/Markov Chain Monte Carlo Method
Barros and Wanke (2015)	Evaluating the Efficiency of African Airlines	TOPSIS, Neural Networks, DEAP
Akgün and Soy Temür (2016)	Pegasus and Türk Hava Yolları Companies' Financial Performance Measurement	TOPSIS
Asker, (2018)	Analysis of Efficiency in Traditional Airline Operations	Data Envelopment Analysis
Avcı and Çınaroğlu (2018)	Evaluation of Financial Performance of Airlines Operating in Europe	AHP-Based TOPSIS
Trabzon, (2022).	Financial Performance Measurement of Airlines Listed on Borsa Istanbul (BIST)	TOPSIS
Öncü et al. (2013)	Measurement of Financial Efficiency of Airlines Operating in	Data Envelopment Analysis
Asker, (2021)	Comparison of Financial and Operational Efficiency of Low-Cost Airlines	Data Envelopment Analysis
Heydari et al. (2020)	Assessment of Financial and Operational Performance of Airlines Operating in Iran	Data Envelopment Analysis
Macit and Göçer, (2020)	Measurement of Financial Performance of Airlines Listed on Borsa Istanbul (BIST)	Grey Relational Analysis (GRA)
Soltanzadeh Omrani (2018)	Evaluation of Performance of Airlines Operating in Iran	Data Envelopment Analysis

Studies on Performance Evaluation of Airline Operations: Research Examining Sustainability Performance		
Abdi et al. (2020)	The Impact of Sustainability on Firm Value and Financial Performance in Airline Operations	Panel Data Analysis
Sisman et al. (2020)	The Impact of ESG Data on Financial Performance in Airline Operations	Panel Data Analysis
Abdi et al. (2021)	The Impact of ESG Data on Firm Value and Financial Performance in Airline Operations	Panel Data Analysis
Ay et al. (2023)	The Effect of Sustainability Performance on the Financial Performance of Airline Companies During the COVID-19	Panel Data Analysis
Kiracı et al. (2022)	Analysis of Factors Influencing the Sustainable Success of Airline Companies During the COVID-19 Pandemic	IT2FAHP IT2FDEMATEL
Kiracı (2022)	Sustainability and Financial Performance: A Study of the Airline Sector	Data Envelopment Analysis
Examples of Studies Applying Multi-Criteria Decision-Making Methods such as SD and DNMA		
Liao et al. (2019)	Evaluation of Lung Cancer Screening Process	DNMA
Nie et al. (2019)	Location Selection for Shopping Mall	DNMA
Lai et al. (2020)	Selection of Cloud Service Providers	DNMA
Saha et al. (2022)	Selection of Waste Treatment Method	DNMA
Ecer et al. (2022)	Assessment of Economic Freedom: The Case of OPEC Countries	DNMA
Hezam et al. (2022)	Assessment of Alternative Fuel Vehicles from a Sustainability Perspective	DNMA
Ünal (2019)	Measurement of Financial Success of Private Equity Commercial	SD, WASPAS
Bağcı and Yiğiter (2019)	Financial Performance Analysis of Companies Operating in the Energy Sector	SD, WASPAS
Aydın (2020)	Financial Measurement of Foreign Deposit Banks	SD, COPRAS
Işık (2020)	Evaluation of Financial Performance of Development and Investment Bank	SD, MABAC, WASPAS
Koşaroğlu (2020)	Financial Analysis of Banks	SD, EDAS
Demir (2022)	Performance Analysis of Anadolu Insurance Company Over the Years	SD, PSI, BAYES, MABAC
Karaköy et al. (2023)	Analysis of Economic Freedom Indexes of Former Soviet Union Countries	SD, CoCoSo
Pala (2023)	Performance Analysis in the Food Sector	SD, WISP

In the literature, it is observed that different criteria are considered in measuring the performance of airline operations, with very few studies incorporating sustainability performance. Table 2 presents basic examples from these studies, as well as examples from other studies where Multi-Criteria Decision-Making Methods such as SD and DNMA are used for performance measurement. It is also noted that there are studies focusing on the relationship between sustainability scores and performance in sectors other than the aviation industry (Sinha et al., 2022; Kalia and Aggarval, 2022; Trisnowati et al., 2022; Xie et al., 2019; Velte, 2017; Brammer et al., 2006).

In the literature review focusing on studies on the performance of airline operations, no study was found that examines both sustainability performance and financial/non-financial indicators together. Additionally, there is no study found that utilizes SD and DNMA methods together for measuring sustainability and performance in airline operations. Given that a few studies within the aviation sector focusing on sustainability mainly concentrate on financial performance and often prefer panel data analysis as the research method, it is evaluated that this study will contribute to filling the gap in the literature.

3. Metodology

In this study, the SD and DNMA methods, which are current multi-criteria decision-making techniques, have been utilized.

SD (Standard Deviation) and DNMA (Double Normalization-based Multiple Aggregation) methods are commonly used contemporary techniques within multi-criteria decision-making (MCDM) approaches. The SD method is an effective technique for determining the weight of criteria based on the standard deviation approach, calculating the variability and importance of each criterion (Pala, 2023). The DNMA method is a flexible and reliable decision-making technique that combines linear and vector normalization techniques to rank alternatives in a way that they are closest to the expected value (Wu and Liao, 2019). While SD helps in understanding the dynamic relationships between indicators,
DNMA provides a comprehensive ranking mechanism by integrating multiple criteria.
In this study, the combined use of SD and DNMA methods ensures that the weights of the criteria are determined objectively and provides more reliable results during the performance evaluation process. Literature shows that the DNMA method has been applied in various fields such as healthcare (Liao et al., 2019), shopping mall location selection (Nie et al., 2019), and sustainable fuel vehicle assessment (Hezam et al., 2022). However, as there is no study in the literature, especially in the aviation sector, that uses both SD and DNMA methods together, this study is considered to make a significant contribution to the literature.

3.1. SD (Standard Deviation) method

SD process is in Table 2 (Pala, 2023, 67).

i:alternative;i=1,2,3,…,m

j:criterion;j=1,2,3,…,n

x_ij:performance value

h_ij:normalized value first step

t_ij:normalized value

(t_j) ̅:average

σ_j:standard deviation

w_j:weigh

Table 3. SD method

Step	Equation	Equation no
Decision matrix	$D = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \dots & \dots & \dots & \dots \\ x_{m1} & x_{m2} & \dots & x_{mn} \end{bmatrix}$	(1)
Normalization first step	$h_{ij} = \left[\frac{x_{ij} - \min_j x_{ij}}{\max_j x_{ij} - \min_j x_{ij}} \right]$	(2)
Normalization benefit criterion	$t_{ij} = h_{ij}$	(3)
Normalization cost criterion	$t_{ij} = -h_{ij} + \max_j h_{ij} + \min_j h_{ij}$	(4)
Standard deviation	$\sigma_j = \sqrt{\frac{\sum_{i=1}^{m} (t_{ij} - \bar{t_j})^2}{m}}$	(5)
Weight	$w_j = \frac{\sigma_j}{\sum_{j=1}^{n} \sigma_j}$	(6)

3.2. DNMA (Double Normalization-based multiple Aggregation) method

DNMA process is in Table 3 (Özçil, 2020, 59-61).

$i: alternative; i = 1,2,3, \dots, m$

$j: criterion; j = 1,2,3, \dots, n$

$x_{ij}: performance\ value$

$x_{ij}^1: linear\ normalization$

$x_{ij}^2: vector\ normalization$

$u_1(a_i): total\ weighted\ lienar\ normalization$

$r_1(a_i): first\ type\ rank$

$u_2(a_i): second\ integration\ function\ for\ linear\ normalization$

$r_2(a_i): second\ type\ rank\ (ascending\ order)$

$u_3(a_i): third\ integration\ function$

$r_3(a_i): third\ type\ rank$

$u_1^N(a_i): first\ normalized\ integration\ function$

$u_2^N(a_i): second\ normalized\ integration\ function$

$u_3^N(a_i): third\ normalized\ integration\ function$

Table 4. DNMA process

Step	Equation	Equation no
Linear normalization (benefit criterion)	$x_{ij}^1 = 1 - \left| \frac{x_{ij} - \max_j x_{ij}}{\max_j x_{ij} - \min_j x_{ij}} \right|$	(7)
Linear normalization (cost criterion)	$x_{ij}^1 = 1 - \left| \frac{x_{ij} - \min_j x_{ij}}{\max_j x_{ij} - \min_j x_{ij}} \right|$	(8)
Vector normalization (benefit criterion)	$x_{ij}^2 = 1 - \frac{\left| x_{ij} - \max_j x_{ij} \right|}{\sqrt{\sum_{i=1}^{m} (x_{ij})^2 + \left(\max_j x_{ij} \right)^2}}$	(9)
Vector normalization (cost criterion)	$x_{ij}^2 = 1 - \frac{\left| x_{ij} - \min_j x_{ij} \right|}{\sqrt{\sum_{i=1}^{m} (x_{ij})^2 + \left(\min_j x_{ij} \right)^2}}$	(10)
Total weighted linear normalization	$u_1(a_i) = \sum_{j=1}^{n} [w_j x_{ij}^1]$	(11)
Second integration function for linear normalization	$u_2(a_i) = \max_j [w_j (1 - x_{ij}^1)]$	(12)
Second integration function (vector normalization)	$u_3(a_i) = \prod_{j=1}^{n} [x_{ij}^{2\ w_j}]$	(13)
The first normalized integration function	$u_1^N(a_i) = \frac{u_1(a_i)}{\sqrt{\sum_{i=1}^{m} [u_1(a_i)]^2}}$	(14)

The second normalized integration function	$$u_2^N(a_i) = \frac{u_2(a_i)}{\sqrt{\sum_{i=1}^{m}[u_2(a_i)]^2}}$$	(15)
The third normalized integration function	$$u_3^N(a_i) = \frac{u_3(a_i)}{\sqrt{\sum_{i=1}^{m}[u_3(a_i)]^2}}$$	(16)
Final value	$$S_i = \sqrt{\varphi[u_1^N(a_i)]^2 + (1-\varphi)\left[\frac{m - r_1(a_i) + 1}{\frac{m(m+1)}{2}}\right]^2} - \sqrt{\varphi[u_2^N(a_i)]^2 + (1-\varphi)\left[\frac{r_2(a_i)}{\frac{m(m+1)}{2}}\right]^2} + \sqrt{\varphi[u_3^N(a_i)]^2 + (1-\varphi)\left[\frac{m - r_3(a_i) + 1}{\frac{m(m+1)}{2}}\right]^2}$$	(17)

4. Application

In the study, the most commonly used financial and non-financial performance indicators in the literature for measuring the performance of airline companies have been employed as criteria. The descriptions and measurement units of these criteria are provided in Table 5. All criteria are benefit-oriented.

Decision matrix is in Table 6. The scores for THY (Turkish Airlines) for the criteria between 2018 and 2022 are presented in Table 5. The study evaluates Turkish Airlines' (THY) performance between 2018 and 2022. In the sustainability reporting of airlines, using different criteria in different periods makes it difficult to monitor performance (Kasa, Göçmen, & Sümer, 2025). To address this issue, global reporting frameworks have been established to standardize the criteria for publishing sustainability reports. Among these, the Global Reporting Initiative (GRI) Standards Series, prepared in 2016 and implemented in 2018, is the most widely preferred and used framework (Güney & Dinler, 2021). The GRI Standards adopted by THY ensure more consistent and comparable sustainability reporting in the airline industry, facilitating performance monitoring. Another key reason for selecting this period is that it covers the pre-pandemic, pandemic, and recovery phases, offering a comprehensive analysis of the changes in the aviation sector. Evaluating a longer period would require considering the impact of different economic and sectoral dynamics. Furthermore, since 2022 marks the recovery period for Turkish Airlines, the strategic decisions taken during this time and their impacts can be observed more clearly, supporting the study with up-to-date findings. Future studies analyzing longer periods could provide a broader understanding of the general trends in the industry

Table 5. Description of Criteria

Criterion		Description	Unit of Measurement
K1	Available Seat Kilometers	Total number of seats sold multiplied by the distances of flight legs	Seat*Km
K2	Sustainability Rating	Rating of the airline's environmental, social, and governance sustainability activities (SandP Global Consulting)	Score
K3	Number of Passengers	Number of traveling passengers	Quantity
K4	Cargo Mail Tons	Total air cargo carried for the relevant year	Tons
K5	Load Factor	Ratio of revenue passenger kilometers (passenger * km) to offered seat kilometers	Percentage ratio
K6	Destination Served	Flight points on a city-by-city basis	Quantity
K7	Number of Aircraft	Number of aircraft owned or leased by the airline company	Quantity
K8	Earnings Per Share	Ratio of net profit to outstanding shares of the airline company	USA (Sent)
K9	Number of Employees	Total number of employees in the airline company	Quantity
K10	Net Income/Loss for the Period	Net profit or loss for the company for the relevant year	Million Dollars (USD)
K11	Revenue Passenger Kilometers	Total revenue generated by multiplying the distances of flight legs by the number of seats sold	Km*Seat
K12	Labor Productivity	Ratio of offered seat kilometers to the total number of personnel	Percentage ratio
K13	Flight Hours	Average daily flight hours per passenger aircraft	Hour

The performance measurement criteria (K1-K13) used in this study were determined by considering commonly used financial and operational indicators as well as sustainability-focused criteria for evaluating the performance of airline companies (Asker, 2018; THY, 2022 Annual Report). In addition to frequently used indicators in the airline industry, such as Available Seat Kilometers (K1), Load Factor (K5), and Number of Passengers (K3), next-generation criteria like Sustainability Rating (K2) were also included to measure sustainability performance (Abdi et al., 2021; Sisman et al., 2020).

The selected criteria were obtained from Turkish Airlines' annual reports for the 2018-2022 period (THY, 2022) and are commonly used in the performance evaluation of other airlines in the industry. The necessity for defining new criteria in performance measurement depends on the company's strategic objectives and developments in the sector. For instance, environmental sustainability-focused criteria such as carbon footprint and the percentage of renewable energy usage could be incorporated into performance evaluations in the future

Table 6. Decision matrix

Years	2018	2019	2020	2021	2022
K1	182.030.829	187.717.317	74.960.299	127.768.987	201.734.516
K2	21	20	44	47	51
K3	75.167.807	74.282.218	27.950.200	44.787.730	71.817.525
K4	1.413.401	1.544.342	1.487.233	1.879.552	1.678.953
K5	81.9	81.6	71	67.9	80.6
K6	310	321	324	333	337
K7	332	350	363	370	394
K8	0.55	0.57	-0.61	0.69	1.97
K9	149.131.349	153.202.555	53.249.000	86.701.053	162.665.250
K10	68.0769	63.6524	26.1477	46.4074	68.3383
K11	12:16	12:40	06:28	08:19	10:50

In the study, the weights of the criteria were first determined using the SD method. The scores for the normalization process, which is the first step of the SD method, are provided in Table 7. Standard deviation and weights are in Table 8.

Table 7. Normalization (SD)

t_{ij}	2018	2019	2020	2021	2022
K1	0.8446	0.8894	0.0000	0.4166	1.0000
K2	0.0323	0.0000	0.7742	0.8710	1.0000
K3	1.0000	0.9812	0.0000	0.3566	0.9290
K4	0.0000	0.2809	0.1584	1.0000	0.5697
K5	1.0000	0.9786	0.2214	0.0000	0.9071
K6	0.0000	0.4074	0.5185	0.8519	1.0000
K7	0.0000	0.2903	0.5000	0.6129	1.0000
K8	0.4496	0.4574	0.0000	0.5039	1.0000
K9	0.8763	0.9135	0.0000	0.3057	1.0000
K10	0.9938	0.8889	0.0000	0.4802	1.0000
K11	0.9355	1.0000	0.0000	0.2984	0.7043

Table 8. σ_j, w_j values

	σ_j	w_j
K1	0.3722	0.0897
K2	0.4302	0.1037
K3	0.4046	0.0975
K4	0.3525	0.0850
K5	0.4240	0.1022
K6	0.3514	0.0847
K7	0.3331	0.0803
K8	0.3171	0.0764
K9	0.3948	0.0952
K10	0.3864	0.0931
K11	0.3830	0.0923

When evaluating the weights of the criteria, it is observed that Turkish Airlines' sustainability rating criterion (K2) stands out among all criteria (with a wj value of 0.1037). The load factor criterion (K5), which is widely used in the literature as an important measure reflecting the commercial success and operational efficiency of airline companies, follows closely behind the sustainability rating criterion with a wj value of 0.1022. High load factors are associated with more effective flight planning, increased profitability, and economic sustainability. Moreover, aircraft that are fuller and managed with accurate capacity reduce waste generation and carbon emissions, thus being linked to environmental sustainability as well. Overall, when evaluating the weights of the criteria, it is seen that Turkish Airlines' sustainability performance stands out among all criteria, and it is as important as the load factor criterion, which is commonly used in measuring the performance of airline operations. Additionally, Turkish Airlines' performance between 2018 and 2022 has been evaluated using the DNMA method. DNMA linear normalization results are in Table 9.

Table 9. x_{ij}^{1} values

	2018	2019	2020	2021	2022
K1	0.8446	0.8894	0.0000	0.4166	1.0000
K2	0.0323	0.0000	0.7742	0.8710	1.0000
K3	1.0000	0.9812	0.0000	0.3566	0.9290
K4	0.0000	0.2809	0.1584	1.0000	0.5697
K5	1.0000	0.9786	0.2214	0.0000	0.9071
K6	0.0000	0.4074	0.5185	0.8519	1.0000
K7	0.0000	0.2903	0.5000	0.6129	1.0000
K8	0.4496	0.4574	0.0000	0.5039	1.0000
K9	0.8763	0.9135	0.0000	0.3057	1.0000
K10	0.9938	0.8889	0.0000	0.4802	1.0000
K11	0.9355	1.0000	0.0000	0.2984	0.7043

Table 10. x_{ij}^{2} values

	2018	2019	2020	2021	2022
K1	0.9525	0.9662	0.6941	0.8215	1.0000
K2	0.7028	0.6929	0.9306	0.9604	1.0000
K3	1.0000	0.9944	0.6999	0.8069	0.9787
K4	0.8852	0.9174	0.9034	1.0000	0.9506
K5	1.0000	0.9984	0.9427	0.9264	0.9932
K6	0.9663	0.9800	0.9838	0.9950	1.0000
K7	0.9312	0.9512	0.9656	0.9734	1.0000
K8	0.5328	0.5394	0.1511	0.5789	1.0000
K9	0.9590	0.9713	0.6686	0.7699	1.0000
K10	0.9982	0.9676	0.7079	0.8482	1.0000
K11	0.9849	1.0000	0.7656	0.8356	0.9307

$u_1(a_i), u_2(a_i), u_3(a_i)$ are in Table 10.

When considering all the performance criteria addressed in the study, as stated in Table 13, the year 2022 stands out as Turkish Airlines' most successful year between 2018 and 2022.

The year 2022 marked the beginning of the aviation sector's recovery from the impacts of the COVID-19 pandemic. Turkish Airlines emerged as one of the airlines that benefited most from this recovery by responding swiftly and effectively to the increasing travel demand and continuing to invest in human resources, in contrast to other airlines (THY, 2022 Annual Report).

Table 11. $u_1(a_i), u_2(a_i), u_3(a_i)$ values

	$u_1(a_i)$	$u_2(a_i)$	$u_3(a_i)$
2018	0.5754	0.1003	0.8926
2019	0.6541	0.1037	0.8977
2020	0.2004	0.0975	0.7165
2021	0.5086	0.1022	0.8592
2022	0.9197	0.0366	0.9864

$u_1^N(a_i), u_2^N(a_i), u_3^N(a_i)$ are in Table 11.

Table 12. $u_1^N(a_i), u_2^N(a_i), u_3^N(a_i)$ values

	$u_1^N(a_i)$	$u_2^N(a_i)$	$u_3^N(a_i)$
2018	0.4171	0.4890	0.4563
2019	0.4741	0.5053	0.4589
2020	0.1452	0.4753	0.3662
2021	0.3686	0.4980	0.4392
2022	0.6666	0.1782	0.5042

Table 13. Final Values and Ranks

	S_i	Rank
2018	0.3058	3
2019	0.3319	2
2020	0.0272	5
2021	0.2023	4
2022	0.8199	1

Thanks to its extensive flight network, increased human resources, renewed fleet structure, dynamic capacity management, robust cargo operations, and sustainability efforts, Turkish Airlines maximized the benefits of the rising demand. In 2022, Turkish Airlines also received numerous awards for its sustainability performance (e.g., the "Bronze" award from Ecovadis in 2021 and the "Silver" award in 2022, recognition as the "Most Sustainable Flag Carrier Airline" by World Finance in 2022, and "Airline of the Year in Sustainability Innovation" by CAPA - Centre for Aviation in 2022, etc.) (THY, 2023).

According to the research findings, the year 2019 is considered the second most successful year for Turkish Airlines. Although it represents a positive period in terms of overall performance, it falls short compared to the performance in 2022.

For the examined periods, the years 2018 and 2021 are considered to be of moderate performance level. These years represent periods where the company demonstrated stable performance but did not reach its highest level of success.

Regarding the years 2018-2019, it is possible to say that increasing fuel prices, global economic uncertainties, and intensified competition were factors affecting performance in the aviation sector.

According to the research findings, the year 2020 marks the lowest performance. The year 2020 was the year when the COVID-19 pandemic most significantly impacted the aviation sector. Travel restrictions and quarantines led to a significant decrease in travel demand, and Turkish Airlines' passenger load factors also declined significantly. Towards the end of 2021, vaccination efforts accelerated worldwide, and travel restrictions were eased, leading to an increase in travel demand. This resulted in a surge in cargo transportation, which became a significant source of revenue for airlines during the early stages of the pandemic. Turkish Airlines benefited from this situation thanks to its strong cargo operations.

5. Conclusion

Sustainability holds critical importance in gaining a competitive advantage and ensuring long-term success in the airline sector. Airline companies can enhance their financial performance while fulfilling their environmental and social responsibilities by prioritizing sustainability at the core of their strategies and operations. Many airlines have begun developing and implementing sustainability-focused strategies and practices to reduce environmental impacts, use resources more efficiently, and fulfill social responsibilities.

The sustainability activities of airline operations are a significant factor in evaluating their performance, along with all other operational activities. However, it is observed that very few studies consider sustainability performance as a performance indicator for airline companies. Often, the focus is solely on financial criteria or solely on operational criteria, leading to the neglect of comprehensive and significant indicators such as sustainability activities and preventing the evaluation of the company from a broader perspective.

In this study, the performance of Turkish Airlines was evaluated within the framework of sustainability. The main objective of the study is to emphasize the importance of sustainability in the airline sector and analyze how this criterion affects the performance of airline companies. The research findings indicate that Turkish Airlines' sustainability practices are a significant factor in performance evaluation and stand out among other performance criteria. Particularly, it has been determined that sustainability performance should be considered alongside key performance indicators commonly used in the airline industry, such as the load factor.

Turkish Airlines' performance between 2018 and 2022 was evaluated on a yearly basis using eleven criteria. In the evaluation process, contemporary multi-criteria decision-making methods, including SD and DNMA, were integrated. The SD method was utilized to determine the weights of the criteria, while the DNMA method was employed to analyze Turkish Airlines' performance during the specified period.

In the evaluation of criterion weights using the SD method, the top three criteria with the highest weights were "Sustainability rating," "Load factor," and "Number of passengers," respectively. The criterion with the lowest weight was "Earnings per share." These results indicate that sustainability performance is a more meaningful indicator than traditional criteria in determining the performance of airline operations. Earnings per share is used to measure financial performance and generally reflects profitability over a specific period. It can be stated that sustainability and operational efficiency are more effective in evaluating long-term success compared to other criteria.

In the performance evaluation of Turkish Airlines (THY) between 2018 and 2022 using the DNMA method, it is observed that Turkish Airlines' performance varied over time, with the highest performance occurring in 2022. The analysis of Turkish Airlines' performance indicates significant improvement after the post-pandemic recovery period. The increase in personnel productivity and sustainability scores in 2022 highlights Turkish Airlines' emphasis on environmental and social responsibility and its alignment with sustainable practices in the industry. This comprehensive analysis fills the gap in the literature by integrating sustainability performance with financial and non-financial indicators, demonstrating how Turkish Airlines responded to industry challenges with flexibility and strategic adaptation.

Given the low performance in 2020, the need for strategic measures to mitigate weaknesses and enhance resilience during crises becomes evident. When faced with global crises like COVID-19, it is observed that companies with high sustainability performance tend to perform better, and their resilience is higher. (Aksoy, 2020; Abdi et al., 2020; Ay et al., 2023).

The study demonstrates that prioritizing sustainability in airline operations can enhance their long-term success and competitiveness. Additionally, it shows that integrated performance evaluation using multi-criteria decision-making methods such as SD and DNMA can provide valuable insights to airline company managers.

The study emphasizes the necessity of integrating sustainability into airline performance evaluation frameworks. Future research could discuss the impact of sustainability-focused investments and technological advancements on aviation performance. Since the study focuses on a single airline company, expanding the analysis to compare multiple airline companies could provide a more comprehensive understanding of sustainability's role in airline industry performance. Additionally, considering alternative criteria beyond what is presented in Turkish Airlines' reports could further enhance the comprehensiveness of sustainability assessments.

Ethical approval

Not applicable.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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