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COMPARATIVE ASSESSMENT OF FINANCIAL PERFORMANCE AMONG AIR NAVIGATION SERVICE PROVIDERS

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Abstract

The significant expansion of the aviation industry highlights the crucial need for financial resilience and strategic governance among stakeholders, particularly emphasizing the essential role of air navigation service providers (ANSPs). The aim of the study was to present a model for the assessment and comparison of the financial performance of seventeen ANSPs. The financial performance of the seventeen ANSPs was evaluated using nine financial ratios, with the combined scores subsequently analyzed using the TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method over a five-year period (2018-2022). The study revealed that DSNA demonstrated resilience in the face of the crisis, whereas ENAIRE was unable to sustain its previous financial performance among the seventeen ANSPs over the past years. It is recommended that further analyses be conducted using a range of criteria, that financial strategies for crisis resilience be investigated, and that global aviation trends across regions be explored.

Keywords: *Air navigation service, Aviation, Financial performance, Multiple-criteria decision making, TOPSIS.*

JEL Classification Codes: *C02, G01, R42.*

HAVA SEYRÜSEFER HİZMET SAĞLAYICILARI ARASINDA FİNANSAL PERFORMANSIN KARŞILAŞTIRMALI DEĞERLENDİRMESİ

Öz

Havacılık endüstrisindeki gelişme süreci paydaşlar arasında mali dayanıklılık ve stratejik yönetimin önemini vurgulamakta ve özellikle hava seyrüsefer hizmet sağlayıcıları (HSHS) öne çıkarmaktadır. Hava seyrüsefer hizmet sağlayıcıların finansal performansının değerlendirilmesi havacılık sektörünün genel direncini ve sürekliliğini değerlendirmek açısından önemlidir. Bu çalışmanın amacı, hava seyrüsefer hizmet sağlayıcıların finansal performansını karşılaştırmalı olarak incelemektir. Bu amaçla hava seyrüsefer hizmet sağlayıcıların finansal performansı dokuz finansal oranla beş yıllık dönemi (2018-2022) kapsayacak şekilde TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) yöntemi kullanılarak analiz edilmiş ve sıralanmıştır. Sonuç olarak DSNA'nın krize rağmen güçlü bir yapıya sahip olduğu, ancak ENAIRE'in geçmiş yıllardaki finansal performansını sürdüremediğini bulunmuştur. Gelecekteki çalışmalarda benzer analizlerin farklı kriterlerle daha detaylı olarak incelenmesi, kriz direnci için finansal stratejilerin araştırılması ve bölgeler arası küresel havacılık trendlerinin araştırılması önerilmektedir.

Anahtar kelimeler: *Çok kriterli karar verme, Finansal performans, Hava seyrüsefer hizmeti, Havacılık, TOPSIS.*

JEL Kodları: *C02, G01, R42.*

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1.INTRODUCTION

The aviation sector has undergone substantial advancements since the inception of its first commercial flight (Ryley, 2017; Spearman, 2006). Currently, the sector is entering a transformative phase with the integration of unmanned aerial vehicles (Erceg & Kilic, 2021; Konert & Kotlinski, 2018). This evolution positions the aviation industry as a crucial contributor to the global economy through its various components (Hasan et al., 2021; Maurice & Burleson, 2012). Aviation has been one of the first sectors to be influenced by various variables, including economic, political, and health-related factors, over the past few years (Caprian, Lom, & Caprian, 2023; Chattopadhyay, 2015). One of the key components of this sector, responsible for air traffic control, flight information services, and search and rescue operations (Abeyratne, 2012; Matus & Materna, 2021; Schmitt et al., 2016), air navigation service providers (ANSPs) play a critical role in ensuring the stability and sustainability of the aviation industry.

The majority of ANSPs are financed through two principal models: direct funding from user charges and indirect funding from governmental budgets or specific funds. The majority of ANSPs worldwide employ a combination of direct user charges and alternative sources for their financing (Tomova, 2016). It is of great importance for ANSPs to have a robust financial foundation. Furthermore, ANSPs are required to invest in high-tech infrastructure and maintain and update this infrastructure regularly (Papavramides & Molinari, 2002). Moreover, the employment of trained personnel and the implementation of continuous training programs have a significant impact on financial resources. Consequently, financial sustainability and effective resource management are foundational elements that shape the role of ANSPs within the industry (Arblaster, 2018; Materna, 2019; Ölçen & Alnıpak, 2023; Standfuss & Schultz, 2018; Tomova, 2017).

Commercial revenues play a significant role in the economics of European ANSPs, as the main sources of funding for these providers are the direct fees charged to airspace users (user-pay) for air navigation services, aligning completely with the recommendations outlined in ICAO Doc 9082 (Tomova, 2016). To facilitate this user-pay system, the European Organization for the Safety of Air Navigation (EUROCONTROL) plays a crucial role. As an intergovernmental organization comprising 42 member states and two observer states, EUROCONTROL functions as a pan-European entity dedicated to enhancing aviation safety across the continent. One of its key functions is operated through the Central Route Charges Office (CRCO), which collects en-route and aerodrome approach charges on behalf of ANSPs (Carreras-Maide, Lordan, & Sallan, 2020; Uslu & Cavcar, 2002). This centralized system makes the collection process easier and ensures that air navigation services in Europe are financed efficiently.

The increased competition in the aviation sector has prompted ANSPs to pursue a more competitive and efficient position in terms of financing, extending beyond the traditional scope of air traffic control services. ANSPs are engaging in significant commercial activities through structural changes (Tomova, 2016). However, the increasing prevalence of crises, particularly financial downturns, pandemic events, and political tensions, have resulted in significant economic challenges for ANSPs, as have other components of the sector in recent years (Bilotkach et al., 2015; Ölçen & Alnıpak, 2023).

In this context, the periodic analysis of financial performance by ANSPs is of significant importance. The assessment of financial performance represents a pivotal stage in the process of understanding the status of the entity in question, identifying potential risks, and ensuring its future sustainability. A significant gap exists in the current literature regarding the application of analytical and model-based approaches to assess the financial performance of ANSPs. This gap may result in decision-makers and stakeholders in the sector being unable to assess the financial performance of ANSPs or anticipate future risks.

The study aims to address this gap by analyzing ANSPs' financial performance using a well-established method called the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). The following section presented an analysis of the aviation sector's responses to financial crises, with a particular focus on the role of the TOPSIS method in financial assessment processes, supported by relevant literature. Subsequently, the application of the TOPSIS method to the analysis of ANSPs' financial performance was discussed. This analysis will contribute to a clearer understanding of ANSPs' financial performance and provide valuable insights for

stakeholders when making strategic decisions. Moreover, this research can serve as a basis for future studies aimed at ensuring the long-term stability of the aviation sector.

2.LITERATURE

2.1.Crisis in the aviation sector

The aviation sector has been subject to a series of crises throughout its historical development (Gürçam, 2022). Energy crises, economic downturns, terrorist attacks, and pandemics have resulted in considerable fluctuations within the sector. These crises are regarded as a significant economic risk factor within the aviation industry (Caprian, Lom & Caprian, 2023).

The 1973 oil crisis marked the first major crisis to affect the aviation sector (Randall, 2014). The 1973 oil crisis witnessed a sharp increase in oil prices, which caused challenges in fuel costs and operational expenses for airlines (Issawi, 1978). The United States, a dominant force in the aviation industry, faced economic challenges due to its reliance on foreign oil, leading to subsequent economic strain (Mork & Hall, 1980; Zulkifli & Haqeem, 2022). The financial issues caused by the oil crisis resulted in job losses and a significant decline in aircraft prices (Archibald & Reece, 1977). Furthermore, the crisis prompted changes to aviation business practices and a shift towards aircraft that consume fuel more efficiently (Gorham, Gross & Snipes, 1975).

The Iran-Iraq War (1980-1988) had a significant impact on the aviation industry, particularly in the region. This conflict, marking the second major crisis affecting aviation, led to a decrease in air travel due to safety concerns and a shift in the use of airpower by both countries (Bergquist, 1988).

The Gulf War of the early 1990s, which is regarded as another significant event in modern history, resulted in industry losses amounting to $10 billion (Rosen, 1995). This crisis significantly impacted the demand for air services, necessitating airlines to implement cost-cutting measures (Abeyratne, 2017; Ferguson et al., 1993; Mason, 2005; Mbemap, 2005).

The Asian Crisis of 1997-1998 influenced the patterns of air traffic in Southeast Asia and between this area and other global regions (Rimmer, 2000). The economic downturn in Asia had a detrimental impact on the growth prospects of numerous airlines in the region, prompting a shift in air transport policies towards greater openness (Chin, Hooper, & Oum, 1999). As with other crises, this event had a significant economic impact on the industry, leading to the implementation of cost-cutting measures (Oum & Yu, 2019; Sadi & Henderson, 2000).

The 9/11 terrorist attacks had a more immediate impact on the aviation sector in 2001 than other crises. There was an immediate 50% decline in airline passenger loads (Goodrich, 2002). Furthermore, the attack resulted in a temporary decline in air traffic, a reduction in airline revenue by over one-third, and the grounding of more than 10% of the U.S. commercial fleet (Karber, 2002). The 9/11 terrorist attacks directly resulted in a decline in demand for air transportation services and total losses to the U.S. economy ranging between $214.3 billion and $420.5 billion (Gordon et al., 2007).

The severe acute respiratory syndrome (SARS) virus caused a severe outbreak across the globe in 2003, resulting in a significant decrease in air travel (Karpinska, 2022). The outbreak resulted in a 2.6% reduction in global air travel, with a 68% decline in travel to Asia (Liu, Moss, & Zhang, 2011). The SARS epidemic had adverse effects on air passenger demand in both the short and long term (Chi & Baek, 2013). Additionally, it contributed to multiple airline bankruptcies and record losses in the aviation industry (Berry et al., 2004).

The 2008-2009 financial crisis had a significant impact on the aviation industry. This period was characterized by job losses, the collapse of financial institutions, and the loss of billions in savings, resulting in a global decline in production volumes alongside rising unemployment and inflation (Somchenko & Sulieimanova, 2020). In particular, the financial performance of companies in the aviation sector declined significantly as a result of the crisis, as evidenced by research studies (Chang, 2023; Dzikowska & Jankowska, 2012).

The 2020 global pandemic, caused by the SARS-CoV-2 virus, had a profound and far-reaching impact on the aviation sector (Sun, Wandelt, & Zhang, 2020). It stands as one of the most significant crises to affect the

industry throughout its historical trajectory. The pandemic resulted in a dramatic decline in air passenger traffic due to travel restrictions and limitations (Nizetic, 2020; Rupani et al., 2020). World passenger traffic collapsed with an unprecedented decline in history, as illustrated in Figure 1. In the first year of the pandemic, there was a 60% decrease in traffic volume compared to the previous year. Airlines incurred an approximate loss of USD 372 billion in gross passenger operating revenues (International Civil Aviation Organization [ICAO], 2024). In the subsequent years, a gradual recovery was observed. However, this led to significant revenue decreases and operational challenges for airline companies (Rahman et al., 2020). In response, airlines took urgent measures such as flight cancellations, fleet reductions, and staff layoffs. During this challenging period, the industry was confronted with the imminent bankruptcy of several airlines, which in turn necessitated the restructuring of others. This resulted in an extended recovery period (Akhter et al., 2022).

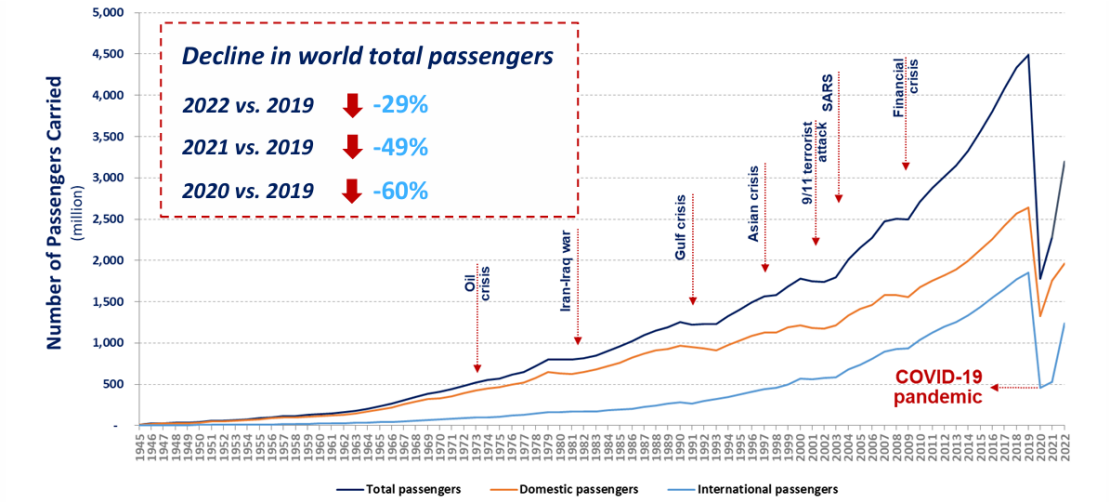

Figure 1: World passenger traffic evolution 1945 – 2022

Source: ICAO, 2024, p.5

2.2.TOPSIS method in financial performance analysis

Financial performance assessment is a process of decision-making among multiple choices (Wang, 2008, 2009). The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), a multi-criteria decision-making (MCDM) method that has gained considerable traction in various fields (Hwang & Yoon, 1981), represents a well-established approach for addressing decision-making with multiple alternatives (Zavadskas et al., 2010). Its applicability extends to the assessment of financial performance (Hsu, 2013; Söylemez, 2020).

Ertuğrul and Karakaşoğlu (2009) conducted an examination of 15 Turkish cement firms listed on the Istanbul Stock Exchange. Yılmaz and Konyar (2013) evaluated the financial performance of nine hospitality businesses from 2008 to 2011 using the TOPSIS method. Bulgurcu (2012) evaluated the financial performance of 13 technology firms listed on the Istanbul Stock Exchange between 2009 and 2011. Hsu (2013) employed a TOPSIS approach combined with factor analysis and entropy weighting to analyze the financial performance of Taiwan's 50 opto-electronic companies. In a further example, Çam et al. (2015) conducted a TOPSIS analysis on publicly traded textile companies in Borsa Istanbul from 2010 to 2013. Oral (2016) employed the TOPSIS to assess the financial performance of privately owned banks in Türkiye between 2012 and 2014. Temizel, Doğan, and Bayçelebi (2016) employed the TOPSIS to rank 34 companies according to their performance on 10 financial ratios as represented in the Corporate Governance Index. Balcı (2017) undertook an examination of the financial performance of 27 state university hospitals between the years 2014 and 2015. Orçun and Eren (2017) conducted an analysis of the financial performance of technology companies listed on the Borsa Istanbul from 2010 to 2015. Temür, İşer, and Temür (2017) conducted a study on the financial statements of ten retail trade businesses on the Borsa Istanbul from 2011 to 2016. Ouenniche, Pérez-Gladish, and Bouslah (2017) evaluated the financial performance of bankrupt and non-bankrupt firms on the London Stock Exchange from 2010 to 2014. Rahim et al. (2020) employed

the TOPSIS to rank Malaysian construction companies based on seven financial ratios. Ova (2021) analyzed the financial performance of Turkish deposit banks from 2012 to 2019 using the TOPSIS method. Müftüoğlu and Gerekan (2022) conducted a financial performance analysis of eight energy companies in the public sector between 2016 and 2020. Liew et al. (2024) developed a TOPSIS model to assess the financial performance of Malaysia's listed construction companies. Rana (2024) conducted a TOPSIS analysis on the financial data of top ESG-ranked firms from March 2020 to March 2023, utilizing seven key financial ratios.

Assessing financial performance using TOPSIS methods has been conducted in the aviation sector, similar to other industries. Wang (2008) assessed the financial performance of three leading Taiwanese airlines from 2001 to 2005 using 12 indicators with TOPSIS. Ömürbek and Kınay (2013) analyzed the financial data of two airlines for the year 2012 using TOPSIS. Avcı and Çınaroğlu (2018) ranked five European airlines (Turkish Airlines, Lufthansa, EasyJet, Air France-KLM, and Ryanair) based on their financial performance from 2012 to 2016 using TOPSIS. Dağlı (2021) considered the financial performance of seven airlines that ranked in the top 10 in Europe in terms of passenger numbers in the second quarter of 2019, the fourth quarter of 2019, and the second quarter of 2020 using TOPSIS. Teker, Teker, and Polat (2022) analyzed and ranked the financial performance of the top 11 global airlines for the periods of 2019-2021 (Covid era), categorizing them as US Airlines, European Airlines, and Chinese Airlines.

In order to compare ANSPs, a comprehensive dataset of both operational and financial parameters is required for each ANSP included in the benchmarking process; financial parameters may be used for comparative analysis in addition to operational metrics (Standfuss & Schultz, 2018; Standfuss et al., 2022). Data Envelopment Analysis (DEA) serves as an effective method in operational comparisons, with the recommendation that not all ANSPs should be included in the analysis and that financial inputs and outputs should be excluded from the model (Standfuss et al., 2024). Building on the need for a structured approach to financial performance assessment, the use of TOPSIS in the study to assess the financial performance of ANSPs is based on its capability to handle multiple criteria and provide a clear comparative framework. Since financial performance involves various complex factors, TOPSIS enables the systematic ranking of ANSPs by comparing their financial outcomes.

3.DATA AND METHODOLOGY

Due to the nature of the study, informed consent or ethics committee approval was not required.

3.1.ANSPs included in the scope of the study

In the study, ANSPs shown in Table 1, which are EUROCONTROL members and have accessible financial data in EURO-based financial reports from the Performance Review Unit (PRU) for the years 2018-2022, were examined to ensure comparability. These ANSPs collectively served 54.94% of the air traffic in the EUROCONTROL region in 2022 (EUROCONTROL's Aviation Intelligence Unit [EUROCONTROL-AIU], 2024).

Table 1: ANSPs & Organizational/Corporate Arrangements

ANSP	State	Organizational & Corporate Arrangements
AirNav Ireland	Ireland	Joint-stock company (State-owned)
Austro Control	Austria	Limited liability company (State-owned)
DFS	Germany	Limited liability company (State-owned)
DSNA	France	State body (autonomous budget)
EANS	Estonia	Joint-stock company (State-owned)
ENAIRE	Spain	State-owned enterprise
ENAV	Italy	Joint-stock company (State-owned)
Fintraffic	Finland	State-owned enterprise
LGS	Latvia	Joint-stock company (State-owned)
LPS	Slovakia	State-owned enterprise

LVNL	Netherlands	Independent administrative body
MATS	Malta	Joint-stock company (State-owned)
NATS	United Kingdom	Joint-stock company (part-private)
NAV Portugal	Portugal	State-owned enterprise
Oro Navigacija	Lithuania	State-owned enterprise
skeyes	Belgium	State-owned enterprise
Slovenia Control	Slovenia	State-owned enterprise

3.2.Financial ratios used in the study

Nine financial ratios were used under the main topic of Income Statement, Balance Sheet, and Cash Flow Statement in the study.

Income statement:

Income statements show a company's earnings and spending for a year (EUROCONTROL-AIU, 2024). Revenue, EBITDA, and EBIT are the financial ratios used as income statements in the study.

Revenue: Revenue refers to income generated from regular business operations, encompassing items such as operating income, other operating income, and grants (EUROCONTROL-AIU, 2024). Revenue is an important indicator for evaluating financial performance using the TOPSIS method (Feng & Wang, 2000; İşseveroğlu & Sezer, 2015).

EBITDA (Earnings Before Interest, Taxes, Depreciation, and Amortization): EBITDA is a measure of how much profit a company makes from its regular activities, without including interest, taxes, depreciation, and other non-cash expenses (EUROCONTROL-AIU, 2024). It is a popular financial performance metric in companies (Todorovic, Kalicanin, & Nojkovic, 2015).

EBIT (Operating income): EBIT measures how much profit a company makes from its operations before deducting interest and taxes (EUROCONTROL-AIU, 2024). It is a financial ratio used in TOPSIS performance assessment (Feng & Wang, 2000; Hasanloo et al., 2013; Wang & Hsu, 2004).

Balance sheet:

Balance sheets show a company's assets, debts, and shareholders' ownership at the end of the year. While the format of balance sheets is generally standardized in financial statements, there may still be some differences in how certain items are presented (EUROCONTROL-AIU, 2024). The study utilized the equity ratio, cash-on-hand days, and current ratio.

Equity ratio: The equity ratio compares shareholders' equity to total liabilities & equity, showing how much of a company's assets are funded by equity rather than debt, indicating its financial leverage (EUROCONTROL-AIU, 2024). The TOPSIS method analyzes equity ratio to determine company financial performance unique points (Fahami et al., 2019; Feng & Wang, 2000; İşseveroğlu & Sezer, 2015).

Cash-on-hand days: Cash-on-hand days measure how many days a company's operating expenses can be covered using its cash and equivalent reserves, indicating its liquidity and ability to cover expenses without relying on revenue (EUROCONTROL-AIU, 2024). Cash-on-hand days are used as criteria in the TOPSIS algorithm to evaluate financial performance (Feng & Wang, 2000; Hasanloo et al., 2013).

Current ratio: The current ratio compares a company's current assets to its current liabilities, showing its ability to meet short-term debts and obligations, serving as a liquidity measure (EUROCONTROL-AIU, 2024). The current ratio is a financial ratio utilized in the TOPSIS approach for evaluating financial performance (Fahami et al., 2019; Feng & Wang, 2000; Hasanloo et al., 2013).

Cash flow statement:

Cash flow statements show the movement of cash in and out of a company during the year. While the format of these statements is generally standardized in financial reports, there can still be differences in how specific items are presented (EUROCONTROL-AIU, 2024). The study utilized net cash flow, investing activities, and CAPEX ratio.

Net cash flow: Net cash flow from operating activities is the overall result of cash coming in and going out from regular business operations (EUROCONTROL-AIU, 2024). Net cash flow can be considered in evaluating financial performance, making the assessment more comprehensive in the TOPSIS (Deng, Yeh, & Willis, 2000; Feng & Wang, 2000).

Investing activities: Investing activities mean the money that comes in and goes out from buying and selling things like equipment, property, or investments (EUROCONTROL-AIU, 2024). Net cash flow from investing activities can contribute to performance assessment (Feng & Wang, 2001).

CAPEX (Capital Expenditure): Capex refers to the money spent on buying non-current assets, which is part of the cash flow from investing activities (EUROCONTROL-AIU, 2024). Capex is a financial metric used to measure financial performance (Abdel-Basset et al., 2020; Feng & Wang, 2000, 2021).

The sum of the coefficients of financial ratios should typically equal 1 to determine the overall effectiveness of each criterion (Bulgurcu, 2012). The criteria's weight values in the study shown in Table 2 were established according to input from two aviation finance experts. Given that revenue reflects the ability of a company to enhance its competitive strength and market share (Damodaran, 2012), is a crucial indicator of the financial performance of a company (Brealey, Myers, & Allen, 2014), and forms the basis of other financial ratios (Penman, 2013), the study assigned a higher coefficient to revenue compared to other financial ratios.

Table 2: Financial ratios, Codes and Weights for each section

Sections	Codes	Weights	Financial ratios
Income Statement (IS)	IS1	0.20	Revenue
	IS2	0.10	EBITDA
	IS3	0.10	Operating income (EBIT)
Balance Sheet (BS)	BS1	0.10	Equity ratio
	BS2	0.10	Cash-on-hand days
	BS3	0.10	Current ratio
Cash Flow Statement (CF)	CF1	0.10	Net cash flow
	CF2	0.10	Investing activities
	CF3	0.10	CAPEX

3.3.TOPSIS steps

This paper uses the following steps of the TOPSIS method, which is an accepted variation of multi-criteria analysis methods (Hwang & Yoon, 1981; Opricovic & Tzeng, 2004; Rahim et al., 2018). TOPSIS alternatives should be close to the best solution and far from the worst solution, using Euclidean distance to measure how close an alternative is to the optimal solution geometrically.

TOPSIS uses the best possible values for each attribute as the positive ideal solution and the worst possible values as the negative ideal solution. It calculates how far each alternative is from these ideal points. The chosen solution in TOPSIS should be the shortest distance from the positive ideal solution and the longest distance from the negative ideal solution. By comparing these distances, TOPSIS determines the priority order of alternatives (Chamodrakas, Leftheriotis, & Martakos, 2011; Dutta et al., 2019; Lai, Liu, & Hwang, 1994; Mahmudova, 2019). Before proceeding with the TOPSIS steps, a decision matrix is formed as shown below. The matrix provides the number of decision points (m) and the number of assessment criteria (n).

$$A_{ij} = \begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ldots & \vdots \\ a_{m1} & \cdots & a_{mn} \end{bmatrix} \quad (1)$$

Step 1: Normalizing the decision matrix

The normalized decision matrix (R_{ij}) is obtained using the elements of matrix A_{ij} and the following formula.

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

$$R_{ij} = \begin{bmatrix} r_{11} & \cdots & r_{1n} \\ \vdots & \ldots & \vdots \\ r_{m1} & \cdots & r_{mn} \end{bmatrix} \quad (3)$$

Step 2: Calculating the weighted normalized decision matrix

First, weight values (w_j) related to assessment criteria are determined ($\sum_{j=1}^{n} w_j = 1$). Then, the elements in each column of matrix R_{ij} are multiplied by the corresponding w_j value to create the weighted normalized decision matrix (V_{ij}) as shown below.

$$V_{ij} = \begin{bmatrix} w_1 r_{11} & \cdots & w_n r_{1n} \\ \vdots & \ldots & \vdots \\ w_1 r_{m1} & \cdots & w_n r_{mn} \end{bmatrix} \quad (4)$$

Step 3: Determining the positive ideal *(A^+)* and negative ideal *(A^-)* solutions

The positive ideal solution (A^+) set is constructed by selecting the maximum weighted column value in the V_{ij} matrix. Conversely, the negative ideal solution (A^-) set is formed by selecting the minimum weighted column value in the V_{ij} matrix.

$$A^+ = \{(max_i v_{ij} \,|j \in J), (min_i v_{ij} \,|j \in J')\} \quad (5)$$

$$A^- = \{(min_i v_{ij} \,|j \in J), (max_i v_{ij} \,|j \in J')\} \quad (6)$$

Step 4: Calculating the separation measures

The distance of each decision point from both the positive ideal solution (S_i^+) and the negative ideal solution (S_i^-) is calculated using the Euclidean Distance Approach to measure these distances accurately. These distances are then utilized to assess how much each decision point deviates from the ideal and negative ideal solution sets. The calculation of Ideal Separation (S_i^+) and Negative Ideal Separation (S_i^-) values is based on below formulas, allowing for an effective assessment of these deviations.

$$S_i^+ = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^+)^2} \quad (7)$$

$$(S_i^-) = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^-)^2} \quad (8)$$

Step 5: Calculating the relative closeness to the ideal solution

The relative closeness of each alternative to the ideal solution (C_i^+) is calculated using the ideal and negative ideal separation measures. The criterion used here indicates the proportion of the negative ideal separation measure within the total separation measure. The calculation of the relative closeness value to the ideal solution is shown in the following formula.

$$C_i^+ = \frac{s_i^-}{s_i^- + s_i^+} \quad (9)$$

Step 6: Ranking the alternatives

The final step of TOPSIS involves ranking the alternatives. The best alternative has the highest C_i^+ value, which is closest to 1. Conversely, the worst alternative has the lowest C_i^+ value. The solution is the top alternative on the list with the highest C_i^+ value.

4.RESULTS

A decision matrix (17x9) was created using the financial ratios of 17 ANSPs for each year from 2018 to 2022 at the beginning of the analyses, including Revenue (IS1), EBITDA (IS2), EBIT (IS3), Equity ratio (BS1), Cash-on-hand days (BS2), Current ratio (BS3), Net cash flow (CF1), Investing activities (CF2), and CAPEX (CF3). From this decision matrix, a normalized matrix was derived. Then, using the weights of each financial ratio, a Weighted Normalized Decision Matrix was computed. Next, the positive ideal (A^+) and negative ideal (A^-) solution sets were determined based on the Weighted Normalized Decision Matrix. The closest Euclidean distance values of each decision criterion to the positive (S_i^+) ideal solution and the farthest distance to the negative (S_i^-) ideal solution were identified, and the relative proximity (C_i^+) of each alternative to the ideal solution was calculated. Finally, the values obtained in the previous step were arranged in order to facilitate performance assessments.

Decision matrix in Table 3, normalized decision matrix in Table 4, weighted normalized decision matrix in Table 5, ideal and negative ideal solution in Table 6, and distances between the valuation subjects and ideal and negative ideal solution in Table 7 are shown for the year 2022.

The analysis of the performance ranks for the years 2022-2021-2020-2019-2018 of the seventeen listed ANSPs, as shown in Tables 8 and Table 9, indicates that DSNA exhibited the most favorable financial performance in 2022, maintaining a comparable performance in previous years. Similarly, NATS, ENAV, and DFS have exhibited robust financial performance among the current ANSPs from 2018 to 2022. Conversely, ENAIRE demonstrated a decline in financial performance in 2022.

Table 3: Decision Matrix (for 2022)

	IS1	IS2	IS3	BS1	BS2	BS3	CF1	CF2	CF3
AirNav Ireland	185.0	27.0	15.0	0.78	137	6.3	-1.0	18.0	11.0
Austro Control	303.0	75.0	45.0	0.01	14	2.9	-14.0	24.0	24.0
DFS	1355.0	181.0	70.0	0.43	44	2.2	-307.0	87.0	89.0
DSNA	1730.0	202.0	38.0	0.23	35	8.8	-100.0	216.0	224.0
EANS	16.1	0.9	4.7	0.43	79	0.7	-6.9	5.1	5.1
ENAIRE	739.0	132.0	216.0	0.52	12	1.3	-87.0	-374.0	169.0
ENAV	934.0	254.0	133.0	0.48	132	0.8	52.0	70.0	97.0
Fintraffic	72.2	1.7	0.6	0.46	42	0.6	-0.3	3.6	3.7
LGS	19.9	0.1	4.5	0.78	11	0.9	-2.3	2.6	2.6
LPS	75.0	18.4	10.1	0.76	180	3.5	4.3	10.4	10.4
LVNL	235.0	1.0	23.0	-0.32	0	0.0	-8.0	41.0	41.0
MATS	28.5	7.9	6.0	0.31	199	2.8	9.5	-3.0	0.7
NATS	934.0	281.0	174.0	0.31	90	1.4	131.0	112.0	119.0
NAV Portugal	211.0	25.0	7.0	0.24	152	1.6	62.0	16.0	17.0
Oro Navigacija	27.7	6.0	2.0	0.80	87	2.8	-1.8	3.3	3.3
skeyes	310.0	35.0	19.0	0.52	142	4.4	0.0	0.0	0.0
Slovenia Control	41.4	6.7	3.2	0.33	24	1.0	1.4	2.4	2.4

Table 4: Normalized Decision Matrix (for 2022)

	IS1	IS2	IS3	BS1	BS2	BS3	CF1	CF2	CF3
AirNav Ireland	0,0678	0,0548	0,0464	0,3541	0,3240	0,4593	-0,0027	0,0389	0,0327
Austro Control	0,1110	0,1521	0,1393	0,0045	0,0331	0,2114	-0,0380	0,0518	0,0714
DFS	0,4963	0,3671	0,2167	0,1952	0,1041	0,1604	-0,8326	0,1878	0,2647
DSNA	0,6336	0,4097	0,1176	0,1044	0,0828	0,6415	-0,2712	0,4663	0,6662
EANS	0,0059	0,0018	0,0145	0,1952	0,1868	0,0510	-0,0187	0,0110	0,0152
ENAIRE	0,2707	0,2677	0,6687	0,2361	0,0284	0,0948	-0,2360	-0,8074	0,5026
ENAV	0,3421	0,5151	0,4117	0,2179	0,3122	0,0583	0,1410	0,1511	0,2885
Fintraffic	0,0264	0,0034	0,0019	0,2088	0,0993	0,0437	-0,0008	0,0078	0,0110
LGS	0,0073	0,0002	0,0139	0,3541	0,0260	0,0656	-0,0062	0,0056	0,0077
LPS	0,0275	0,0373	0,0313	0,3450	0,4257	0,2551	0,0117	0,0225	0,0309
LVNL	0,0861	0,0020	0,0712	-0,1453	0,0000	0,0000	-0,0217	0,0885	0,1219
MATS	0,0104	0,0160	0,0186	0,1407	0,4706	0,2041	0,0258	-0,0065	0,0021
NATS	0,3421	0,5699	0,5387	0,1407	0,2128	0,1021	0,3553	0,2418	0,3539
NAV Portugal	0,0773	0,0507	0,0217	0,1090	0,3595	0,1166	0,1681	0,0345	0,0506
Oro Navigacija	0,0101	0,0122	0,0062	0,3632	0,2057	0,2041	-0,0049	0,0071	0,0098
skeyes	0,1135	0,0710	0,0588	0,2361	0,3358	0,3207	0,0000	0,0000	0,0000
Slovenia Control	0,0152	0,0136	0,0099	0,1498	0,0568	0,0729	0,0038	0,0052	0,0071

Table 5: Weighted Normalized Decision Matrix (for 2022)

	IS1	IS2	IS3	BS1	BS2	BS3	CF1	CF2	CF3
AirNav Ireland	0,0136	0,0055	0,0046	0,0354	0,0324	0,0459	-0,0003	0,0039	0,0033
Austro Control	0,0222	0,0152	0,0139	0,0005	0,0033	0,0211	-0,0038	0,0052	0,0071
DFS	0,0993	0,0367	0,0217	0,0195	0,0104	0,0160	-0,0833	0,0188	0,0265
DSNA	0,1267	0,0410	0,0118	0,0104	0,0083	0,0641	-0,0271	0,0466	0,0666
EANS	0,0012	0,0002	0,0015	0,0195	0,0187	0,0051	-0,0019	0,0011	0,0015
ENAIRE	0,0541	0,0268	0,0669	0,0236	0,0028	0,0095	-0,0236	-0,0807	0,0503
ENAV	0,0684	0,0515	0,0412	0,0218	0,0312	0,0058	0,0141	0,0151	0,0288
Fintraffic	0,0053	0,0003	0,0002	0,0209	0,0099	0,0044	-0,0001	0,0008	0,0011
LGS	0,0015	0,0000	0,0014	0,0354	0,0026	0,0066	-0,0006	0,0006	0,0008
LPS	0,0055	0,0037	0,0031	0,0345	0,0426	0,0255	0,0012	0,0022	0,0031
LVNL	0,0172	0,0002	0,0071	-0,0145	0,0000	0,0000	-0,0022	0,0089	0,0122
MATS	0,0021	0,0016	0,0019	0,0141	0,0471	0,0204	0,0026	-0,0006	0,0002
NATS	0,0684	0,0570	0,0539	0,0141	0,0213	0,0102	0,0355	0,0242	0,0354
NAV Portugal	0,0155	0,0051	0,0022	0,0109	0,0359	0,0117	0,0168	0,0035	0,0051
Oro Navigacija	0,0020	0,0012	0,0006	0,0363	0,0206	0,0204	-0,0005	0,0007	0,0010
skeyes	0,0227	0,0071	0,0059	0,0236	0,0336	0,0321	0,0000	0,0000	0,0000
Slovenia Control	0,0030	0,0014	0,0010	0,0150	0,0057	0,0073	0,0004	0,0005	0,0007

Table 6: Ideal and negative ideal solution (for 2022)

	IS1	IS2	IS3	BS1	BS2	BS3	CF1	CF2	CF3
A^+	0,1267	0,0570	0,0669	0,0363	0,0471	0,0641	0,0355	0,0466	0,0666
A^-	0,0012	0,0000	0,0002	-0,0145	0,0000	0,0000	-0,0833	-0,0807	0,0000

Table 7: Distances between the valuation subjects and ideal and negative ideal solution (for 2022)

	S_i^+	S_i^-	C_i^+
AirNav Ireland	0,1643	0,1411	0,4620
Austro Control	0,1653	0,1237	0,4279
DFS	0,1538	0,1535	0,4995
DSNA	0,0969	0,2149	0,6892
EANS	0,1885	0,1219	0,3927
ENAIRE	0,1769	0,1249	0,4140
ENAV	0,1041	0,1752	0,6273
Fintraffic	0,1878	0,1223	0,3944
LGS	0,1905	0,1264	0,3989
LPS	0,1741	0,1376	0,4415
LVNL	0,1831	0,1227	0,4013
MATS	0,1816	0,1313	0,4197
NATS	0,0955	0,1959	0,6724
NAV Portugal	0,1697	0,1394	0,4510
Oro Navigacija	0,1827	0,1301	0,4158
skeyes	0,1621	0,1327	0,4501
Slovenia Control	0,1893	0,1207	0,3893

Table 8: Performance indexes of the seventeen listing ANSPs for 2022-2021-2020-2019-2018

ANSP	2022		2021		2020		2019		2018	
	C_i^+	Rank	C_i^+	Rank	C_i^+	Rank	C_i^+	Rank	C_i^+	Rank
DSNA	**0,6892**	**1**	0.7652	1	0.7037	1	0.5788	3	0.6196	2
NATS	0,6723	2	0.5136	4	0.4509	4	0.6934	1	0.5698	3
ENAV	0,6273	3	0.5141	3	0.4925	3	0.6203	2	0.6373	1
DFS	0,4995	4	0.5477	2	0.4972	2	0.4851	4	0.4894	5
AirNav Ireland	0,4618	5	0.4535	5	0.3890	10	0.3760	7	0.4224	8
NAV Portugal	0,4510	6	0.4097	11	0.3647	15	0.3357	17	0.4327	6
skeyes	0,4501	7	0.4481	6	0.4051	6	0.3764	6	0.4195	9
LPS	0,4415	8	0.4308	8	0.4015	7	0.3580	10	0.3996	12
Austro Control	0,4279	9	0.4028	13	0.3810	11	0.3643	9	0.4252	7
MATS	0,4197	10	0.3827	15	0.3745	12	0.3482	13	0.3966	13
Oro Navigacija	0,4158	11	0.4161	10	0.3938	8	0.3656	8	0.4059	10
ENAIRE	0,4139	12	0.4415	7	0.4123	5	0.4237	5	0.5262	4
LVNL	0,4013	13	0.3742	17	0.3708	13	0.3557	12	0.3791	16
LGS	0,3989	14	0.4036	12	0.3922	9	0.3559	11	0.4034	11
Fintraffic	0,3944	15	0.3906	14	0.3644	16	0.3390	16	0.3878	14
EANS	0,3927	16	0.4234	9	0.3673	14	0.3448	14	0.3797	15
Slovenia Control	0,3893	17	0.3807	16	0.3639	17	0.3402	15	0.3779	17

Table 9: Performance ranks of the seventeen listing ANSPs for 2022-2021-2020-2019-2018

	2022	2021	2020	2019	2018
DSNA	1	1	1	3	2
NATS	2	4	4	1	3
ENAV	3	3	3	2	1
DFS	4	2	2	4	5
AirNav Ireland	5	5	10	7	8
NAV Portugal	6	11	15	17	6
skeyes	7	6	6	6	9
LPS	8	8	7	10	12
Austro Control	9	13	11	9	7
MATS	10	15	12	13	13
Oro Navigacija	11	10	8	8	10
ENAIRE	12	7	5	5	4
LVNL	13	17	13	12	16
LGS	14	12	9	11	11
Fintraffic	15	14	16	16	14
EANS	16	9	14	14	15
Slovenia Control	17	16	17	15	17

5.CONCLUSION

In the study, the financial performances of 17 ANSPs, which are members of EUROCONTROL and whose financial reports are disclosed in EURO currency between 2018 and 2022, consist of AirNav Ireland, Austro Control, DFS, DSNA, EANS, ENAIRE, ENAV, Fintraffic, LGS, LPS, LVNL, MATS, NATS, NAV Portugal, Oro Navigacija, skeyes, and Slovenia Control, and were evaluated using the TOPSIS method. The proposed method is utilized to rank ANSPs in the aviation sector based on predetermined criteria for each year. The comparison of ranking results across years provides insight into ANSPs with stable financial performances, even during the significant impact of the Covid-19 outbreak in 2020, which disrupted the sector. However, studies focusing on crisis periods in airline operations observed variations in financial performance assessments (Dağlı, 2021; Teker, Teker, & Polat, 2022). This is attributed to ANSPs' reliance on direct funding from user charges as well as indirect funding from governmental budgets or specific funds.

The financial performance assessment between 2018 and 2022 revealed no significant differences among ANSPs over the years. The leading ANSPs were DSNA, NATS, ENAV, and DFS. However, ENAIRE experienced a notable decline, dropping eight places from 2018 and ranking 12th among the 17 ANSPs. The use of TOPSIS alone may not be sufficient to assess the financial performance of ANSPs that are financially strong. The application of additional models in conjunction with TOPSIS can provide a more detailed analysis of this situation.

It is recommended that future studies undertake further analysis of ANSPs, which play a pivotal role in the continuity of the aviation sector. This analysis should encompass different periods and criteria. Additionally, financial management strategies and operational policies that enhance resilience to crises in the aviation sector represent an important area for future research. Furthermore, conducting a similar analysis among ANSPs in different geographical regions and understanding general trends in the global aviation sector could contribute to expanding the research field.

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