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Abdulkadir ALICI[1]

FINANCIAL SUSTAINABILITY PERFORMANCE OF AIRLINES

Summary. The aim of the study is to analyze the financial sustainability of airline companies. In this study, ESG (Environmental, Social, and Governance) scores, financial failure, and financial rating scores were analyzed using Multi-Criteria Decision Making (MCDM) methods to analyze the financial sustainability performance of airlines. The study measures financial sustainability performance using data obtained from 30 airlines in 2023. The Altman Z model used in the study has been adopted as an optimal method for measuring the risk of financial failure in the airline industry. Additionally, the TAA financial rating method was used to evaluate the financial efficiency and risk levels of airlines, presenting a unique approach as the first application in the literature in this field. The TAA financial rating method and MCDM methods used in the study enable the evaluation of not only the current financial status of companies but also their future financial risks and opportunities. The study provides strategic guidance to the industry on integrating ESG scores with financial failure analysis and financial rating methods. These findings will serve as an important reference point for both academic research and airline policies and practices.

Keywords: financial sustainability, ESG, sustainability, LOPCOW and CRADIS, aviation management

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[1] Civil Aviation School-Aviation Management, Kastamonu University. Türkiye. Email: aalici@kastamonu.edu.tr. ORCID: https://orcid.org/0000-0002-4796-6385

1. INTRODUCTION

Financial sustainability has become increasingly important for companies when making strategic decisions. Besides focusing on their long-term financial performance growth and improvement, as Bennett and James [2] highlighted, companies are now also expected to fulfill their social and environmental responsibilities. This means that businesses need to consider economic success and integrate social and environmental factors into their strategic decision-making processes. Maintaining stability is especially crucial in industries such as aviation due to their reputation for consuming large amounts of energy and emitting carbon [28].

The financial stability of airlines is influenced by a mix of conditions and societal and environmental factors that shape their performance over time. Evaluating companies based on ESG (Environmental, Social, and Governance) scores provides a framework for assessing their environmental consciousness, social responsibility, and governance practices. These scores impact companies' long-term financial health beyond market value [11]. Therefore, it is crucial to consider ESG scores alongside traditional financial metrics to get a holistic view of the on the financial sustainability of the airlines.

The importance of ESG in ensuring sustainability and shaping the future is highlighted by its defining qualities. Taking part in ESG and sustainability efforts enables airlines to enhance their responsibility concerning results and social influence. The airline industry stands out as a sector where ESG principles are becoming progressively important due to its significant emissions and influence over temperature patterns. The aviation sector is making efforts to reduce carbon emissions and noise pollution as well as address environmental concerns while also prioritizing social responsibility and governance [21, 35]. Despite its contribution to the global economy, the aviation industry faces sustainability challenges. The International Civil Aviation Organization (ICAO) is trying to reduce emissions on a scale as detailed in their latest reports from 2021 to 2022. This includes promoting energy sources and implementing initiatives to reduce carbon emissions [15, 16].

This includes promoting energy sources and implementing initiatives to reduce carbon emissions. Environmental, Social, and Governance (ESG) practices in the aviation industry impact financial performance. Studies suggest that ESG policies improve long-term financial performance. Companies that emphasize ESG characteristics and standards get more attention, improving their financial sustainability. Research on Norwegian firms demonstrates that ESG disclosures benefit financial performance [13]. Thus, it signifies that ESG must be recorded inside firms in the aviation sector. ESG policies empower governments to alleviate financial risks and bolster their resilience to calamities. Thus, ESG reporting in the aviation sector is crucial for sustainability efforts [13].

This study assesses how well airlines are doing financially by looking at ESG ratings and financial performance metrics using Multi-Criteria Decision Making (MCDM). MCDMs help to give a comprehensive evaluation by considering various factors in complex decision-making processes [25]. Since airline companies operate in a competitive market and are vulnerable to external economic changes, this method provides a good way to evaluate the industry's financial sustainability.

This study is driven by the necessity to address the challenges faced by the aviation sector, such as high-energy consumption levels and environmental impact due to carbon emissions. Financial sustainability encompasses prosperity as well as meeting environmental and social responsibilities. Integrating ESG ratings into financial assessment systems allows for evaluating sector sustainability. The study explores ways airlines can strengthen their resilience against instability and global crises, like pandemics, while addressing increasing environmental pressures. This approach aims to contribute insights to academic studies and shed light on practical ways to address industry challenges uniquely and innovatively by leveraging ESG criteria to gauge financial viability and gain a competitive advantage.

2. CONCEPTUAL FRAMEWORK AND LITERATURE

Achieving development involves looking at the economic impact as well as environmental and social aspects in a holistic manner. That is what the United Nations Sustainable Development Goals (SDGs) introduced in 2015, which urged companies to do as well by focusing on profits and their responsibilities towards the environment and society [37]. To reach these objectives successfully and gauge companies' sustainability efforts effectively, ESG (Environmental Social Governance) scores are used to assess their performance in these areas. As sustainable finance is relatively new and evolving worldwide, no universal framework or widely accepted standards and procedures are currently in place. A taxonomy has been established to outline investment's requirements to qualify as green finance. Additionally, the United Nations has taken steps to categorize finance and define its structure accordingly.

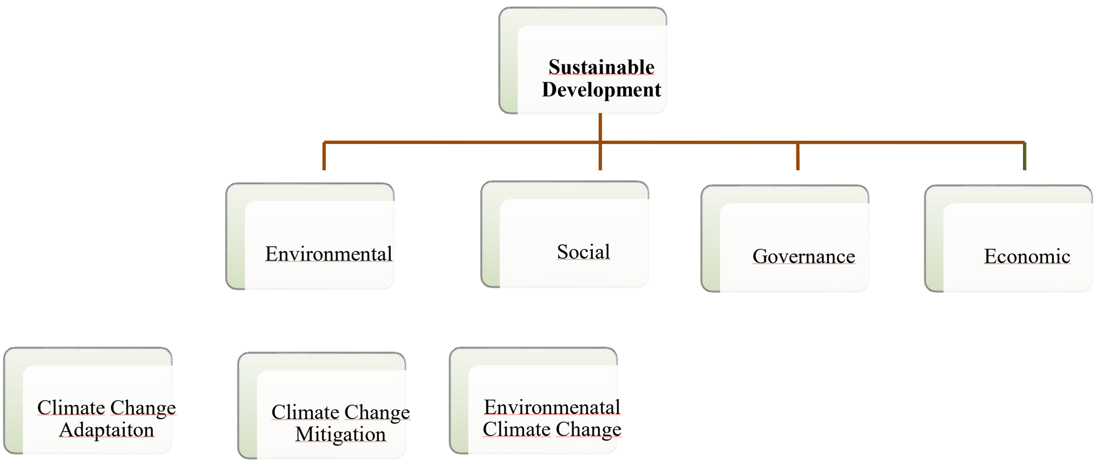

Fig. 1. UN Financial Sustainability Framework
Source: [37]

The study's theoretical framework is based on the UN's "Financial Sustainability Framework". This direction aims to measure the financial sustainability of airline companies. The financial sustainability analysis of airline companies was carried out by measuring the Environmental, Social, and Governance headings with ESG scores and the Economy headings with financial failure and financial rating scores using the MCDM (Multi-Criteria Decision Making) method. Studies that reveal the relationship between sustainability and financial performance are presented to support the theoretical background of the study systematically designed within the scope of the financial sustainability framework.

2.1. Sustainability and Financial Performance

A literature review was conducted, considering studies examining the relationship between financial sustainability and financial performance. The reviewed literature is presented in Table 1.

Tab. 1

Sustainability and Financial Performance Literature

Author Name Surname/Date	Method	Variables	Findings
Canikli (2022) [5]	Content analysis	Climate Change, Sustainable Development, Sustainable Finance Covid-19	While interest in sustainable finance is increasing worldwide, more incentives and investments are required. In Turkey, there are some efforts in this regard, although they are not sufficient.
Satioglu (2021) [29]	Content analysis	Sustainable finance, Green bonds, Social and sustainable bonds, equity and index funds	The most important requirement for the development of sustainable finance is the development of standards.
Senbayram (2022) [33]	Systematic literature review	Sustainability, Sustainable Development, Green Transformation	It is emphasized that it is necessary to be sensitive in taking the steps planned for sustainability, and in developing countries such as Turkey, it is necessary to go with the sensitivity of economic growth. It was concluded that Turkey should increase the speed of its efforts for the sustainable development target among the 2030 targets.
Simsek et al. (2022) [34]	Content analysis, Report Analysis	Green Bonds, Green Financing, Sustainable Development	It has been achieved that green bonds are expected to grow in developing countries and will play an important role in sustainable development.
Zairis et al (2024) [42]	Literature analysis of 80 studies on sustainable finance and ESG criteria obtained from the Scopus	Sustainable finance, ESG criteria, ESG and Finance	Between 2011 and 2017, the number of publications varied between one and three per year, reaching 31 in 2021. In the early part of the decade analyzed, the research was more comprehensive, and as we enter the last period, more specific factors of ESG were investigated

	research database		in the articles. Most of the research has been conducted in Europe.
Munteanu, et al. (2024) [20]	Bibliometric analysis	Circular economy, financial performance, financial strategies	At the end of the study, 4 approaches were identified. 1. that the relationship between circular economy and green financial performance is quite high, 2. that the environmental impact of the circular economy depends on the economic integration of recycling and bioenergy production, 3. that the development of detailed measurements on circular economy provides a competitive advantage when using circular economy practices, and 4. that circular economy relationships are closely linked to government support.
Hooda and Yadav (2023)	In the study, literature was analyzed using the SLR method	ESG, sustainability performance, green finance, aviation sector, sustainable aviation fuel, low carbon use	ESG criteria in aviation need to be integrated into financing functions. Various economic incentives are needed to support sustainability. More investment, incentives, and support are needed to realize sustainable development in the aviation sector.
Daube et al (2024) [8]	An approach based on literature review and sectoral data analysis was used	Sustainable economy, innovation, pure fuel, carbon emissions, greenhouse gas absorption, global climate change	Adopting the Circular Economy in aviation can significantly reduce waste, optimize resource use and contribute to the global fight against climate change by reducing greenhouse gas emissions. Circular economy principles not only increase sustainability, but also contribute to cost savings and operational efficiency. There are economic barriers to utilizing the circular economy in the aviation sector. The focus should be on developing cost-effective, safe and durable materials, advancing technological innovation, and

			establishing supportive policies and regulations.
Sai (2024) [26]	Two research methods, literature review and semi-structured interview, were used	Eco-efficiency, sustainability assessment, sustainable aviation, sustainable development, sustainability indicator, sustainable transport	Among the sustainable aviation issues, carbon emission and environmental dimension have been emphasized the most. The importance of the social and economic dimension has not yet been realized. It is concluded that the definition of sustainable aviation is understood differently by everyone. On behalf of the aviation sector, 14 basic sustainability indicators were identified.
Mercan (2022) [19]	ARCH, GARCH, TARCH, EGARCH and GARCH-M models using the series	Company stock returns	If airports publish their sustainability reports, investors are affected by negative shocks through their shares, while negative shocks cause volatility clustering for the shares of non-publishing airports.
Fullwier (2016) [12]	Financial analysis method was used	The impact of traditional finance theories of risk, time and diversification on sustainable finance	Sustainable finance is generally defined as more value and return, ESG, sustainability-supported financial developments, social environment of sustainability, return risks and the importance of time. It is stated that the creation of a more general sustainability environment depends on understanding the importance of sustainability and penalizing its pollution.
Wahyudi et al. (2023) [39]	Data analysis method and systematic review approach were used	Green finance and sustainability development in economic and environmental dimensions	According to the studies conducted in 2022 and 2023; it has been observed that green finance is concentrated on studies aimed at reducing carbon emissions, and fewer studies have been conducted on issues such as green finance, ecological footprint, and renewable energy.
Basoglu (2024) [1]	Source scanning method and qualitative	Green finance in terms of sustainability, investment areas and	As a result of the research, it was observed that the studies in the field of sustainability were

	analysis method were used	the relationship of investments	generally carried out in the field of livable world. In order to increase green finance practices, various financial supports should be provided, trainings should be provided, and awareness-raising activities should be carried out.
Schoenmaker (2017) [30]	Content analysis, Method development	Sustainable development, framework for sustainable finance, traditional shareholder model, equities	It is recognized that sustainable finance has the potential to move from finance as a goal to finance as an objective. A new framework for sustainable finance is presented.
Kamara et al. (2008) [17]	Content analysis, report analysis	Financial sustainability strategies	It is concluded that countries' mobilization of additional resources, improving the security of their existing banks and funding sources is an efficiency enhancer in financial sustainability.
Zetzsche and Anker-Sørensen (2022) [43]	Literature and activity analysis	Setting a sustainability strategy, adopting sustainable financial management in the context of the EU Sustainable Finance Strategy 2021 and the EU Green Deal	The study concludes that sustainability and finance-related investments are still in the development stage, financial sustainability is used for policy purposes in the EU market, and specialization in financial sustainability is needed.
Schumacher et al. (2020) [31]	Comprehensive examination and scenario analysis method	Transition to sustainable economy in Japan, sustainable finance strategies, and ESG relationship	The Japanese economy faces climate risks from both internal and external causes. Japanese sustainable finance needs more time for ESG integration. In order to realize sustainable finance, Japan needs to create a roadmap that includes a set of rules and ESG policies.
Dede (2023) [9]	Sustainability and green financing analysis of data in annual reports	The relationship between the concepts of green growth, green economy, and green energy with sustainability and with each other	Today, the increasing use of fossil fuels has caused many ecological, biological and economic problems. It is stated within the scope of the study that with the application of sustainable finance in today's conditions, we can leave a world

			to live in for future generations and that utilizing green finance practices while doing so will enable us to create a sustainable system in environmental, economic and social terms.
Gülener (2023) [14]	Panel data analysis method	Impact of sustainable growth rate on sales and income level	Financial decisions and the variables of these decisions are found to have a significant and positive effect on sustainable growth. In addition, the capital ratio and return on assets ratio are also found to have a significant and positive effect on sustainable growth.
Yılmaz (2024) [41]	Bibliometric analysis method	National and international status of the concept of green finance	Green finance is conceptually a component of sustainable finance. With the establishment of the Green Climate Fund, the concept of green finance has started to be mentioned more frequently. As a result of the research, it was determined that green bonds and renewable energy are among the most searched concepts.
Çevirgen et al. (2024) [7]	Bibliometric analysis method	Identifying the studies on green finance by bibliometric analysis and determining the missing points	Reasons such as misuse of resources cause global climate problems. The UN has taken various measures to cope with these climate problems. As a result of the analyses, it has been determined under various headings such as when the first study was carried out under the concept of green finance, in which year the most frequent study was carried out, who carried out the most studies and which country did the most studies.
Sarigul (2024) [24]	Bibliometric analysis method	Impact of green finance and green growth on sustainable development rate	The emergence of the concept of sustainable development started with the increase in environmental problems. Countries that only consider sustainable development from an economic perspective have

			realized the importance of social and environmental disciplines, albeit late. The hypothesis that green finance has an impact on sustainable finance has been confirmed to be positive and significant as a result of the research.

Literature studies conducted in the aviation sector and in the field of financial sustainability provide valuable contributions by addressing different dimensions of sustainability. These studies generally focus on issues such as green finance, circular economy, ESG (Environmental, Social and Governance) criteria, sustainable development, and operational efficiency in the aviation sector. A detailed review of the literature shows that various strategies have been developed to achieve sustainability goals.

This research linked ESG (Environmental, Social, and Governance) scores with financial failure and rating methodologies to examine financial sustainability, using a Multi-Criteria Decision Making (MCDM) methodology. The paper seeks to enhance current analytical methods pertaining to sustainable finance and ESG criteria, often found in the literature, while offering a novel viewpoint on financial failure and rating systems within this framework.

The impact of ESG ratings on financial performance has been analyzed in several studies within the literature. Zairis et al. said that ESG criteria have been extensively examined, especially in Europe, and that several aspects of ESG have begun to be clarified. Nonetheless, this study has mostly concentrated on explicitly examining the relationship between financial sustainability and ESG ratings, excluding considerations of financial failure or financial grading systems. This highlights the unsolved issue of using ESG ratings in financial risk management and failure forecasting. This study aims to fill this gap and show that ESG ratings may function both as a performance indicator and as a forecast tool for financial collapse risk [42].

In contrast, current research on sustainable finance has been focused on traditional financial performance measurements, but the potential of Multi-Criteria Decision Making (MCDM) approaches in this field is largely underexploited. Özmen et al. used multi-criteria decision-making procedures to evaluate the financial performance of companies included in the BIST Sustainability Index, although they could not establish a correlation between ESG ratings and these methodologies. In our study we introduce an approach in this field by combining MCDN methods with ESG ratings and evaluations of financial instability and credit ratings. The effectiveness of ESG scores in assessing social impacts, alongside financial risk evaluations was investigated within this framework.

This research will use financial rating methods to completely examine the problem of financial sustainability. In the literature, financial rating has generally been considered as an independent assessment method, and studies in which it has been integrated with ESG scores have been limited. Our study aims to analyze financial sustainability in both performance and risk dimensions by integrating these two approaches, thus providing an alternative to the one-dimensional approaches in literature.

As a result, the originality of this study lies in filling the gaps in the literature by providing a framework that relates ESG scores to financial failure and financial rating, and proposing an innovative method in the field of sustainable finance with Multi-Criteria Decision-Making methods. The findings to be obtained in this context will provide significant contributions to both the literature and practice.

3. METHODOLOGY

The aim of the study is to analyze the financial sustainability of airline companies. In this direction, calculations and analyses were carried out on the data of 30 airlines in 2023. Environmental, social, governance, financial failure score, and financial performance score variables are used to measure financial sustainability. Altman Z" for financial failure score, and TAA financial rating score calculations for financial performance. In the study, environmental, social and governance variables were taken from the Thomson Reuters (Eikon Datastream) database to measure financial sustainability. All variables were analyzed using the LOPCOW-CRADIS method, one of the multi-criteria decision-making methods. Altman Z" score and TAA financial rating scores and Lopcow-Cradis calculations were performed with Excel (Microsoft 365) program.

3.1. LOPCOW and CRADIS Multi-Criteria Decision-Making Methods

The LOPCOW methodology is an impartial method that determines criteria weights without reliance on the decision maker's convictions. Employing the negative performance values of alternatives helps in determining criterion weights and enhances the administration of many criteria and alternatives [2]. The LOPCOW methodology was created to mitigate substantial variations in the performance metrics of alternatives due to criteria influence, the large scale of the decision matrix, and the presence of negative values inside the decision matrix [3]. The LOPCOW method, developed by Ecer & Pamucar, calculates the standard deviation for each criterion and percentage values through a logarithmic function relative to the number of alternatives, thereby demonstrating the variance between the most and least significant criteria in a more rational manner. The solution phases of the LOPCOW methodology used in the study may be categorized into three stages [10].

Tab. 2

LOPCOW Method Solution Steps

STEP	CALCULATİON	EXPLANATİON
1	$r_{ij} = \frac{x_{ij} - x_j^{min}}{x_j^{max} - x_j^{min}}\ Fayda$ $r_{ij} = \frac{x_j^{max} - x_{ij}}{x_j^{max} - x_j^{min}}\ Maliyet$	The decision matrix is normalized according to the cost-benefit characteristics.
2	$PV_{ij} = \left\lvert \ln\left(\frac{\sqrt{\frac{\sum_{i=1}^{m} r_{ij}^2}{m}}}{\sigma}\right) 100 \right\rvert$	The percentage values (PV) of the individual criteria are found.

3	$w_j = \frac{PV_{ij}}{\sum_{i=1}^{n} PV_{ij}}$	The final objective weight of each criterion is calculated.

In a decision problem where criterion weights are determined, various CRADIS methods can be used to evaluate alternatives. In this study, the CRADIS method is used as a distance-based measurement method, which, like the LOPCOW method, has only recently been introduced to the literature, has very few applications, and has no application in the Turkish literature. The CRADIS method is a very new CRCDM method introduced to the literature by [24] evaluating the utility function and the distance of certain alternatives from ideal and anti-ideal solutions, the basic idea of which is to rank alternatives according to ideal and anti-ideal solutions and deviation from optimal solutions [23]. It should be noted that the CRADIS method represents a new approach in the scientific world, using existing and modified steps of existing methods when ranking different alternatives, with an approach to creating new methods [24]. The steps of the CRADIS method can be expressed in 7 stages [24, 32].

Tab. 3

CRADIS Method Solution Steps

STEP	CALCULATİON	EXPLANATİON
1	$n_{ij} = \frac{x_{ij}}{x_{jmax}} \quad if\ j \in B$ $n_{ij} = \frac{x_{jmin}}{x_{ij}} \quad if\ j \in C$	The decision matrix is normalized according to (B)enefit and (C)ost characteristics.
2	$v_{ij} = n_{ij} * w_j$	A weighted normalized decision matrix is obtained by multiplying the normalized matrix values by the criteria weights.
3	$t_i = maxv_{ij}, t_{ai} = minv_{ij}$	For the ideal solution, the largest 'v_{ij}' value in the weighted decision matrix is found, for the anti-ideal solution, the smallest 'v_{ij}' value in the weighted decision matrix is found.
4	$d^+ = t_i - v_{ij}, d^- = v_{ij} - t_{ai}$	Deviations from ideal and anti-ideal solutions are calculated.
5	$s_i^+ = \sum_{j=1}^{n} d^+, s_i^- = \sum_{j=1}^{n} d^-$	The degree of deviation of individual alternatives from the ideal and anti-ideal solutions is calculated.
6	$K_i^+ = \frac{s_0^+}{s_i^+}, K_i^- = \frac{s_i^-}{s_0^-}$	The utility function for each alternative is calculated for deviations from the optimal alternatives. s_0^+ is the optimal alternative with the smallest distance from the ideal solution, s_0^- is the optimal alternative with the largest distance from the anti-ideal solution.

7	$Q_i = \frac{K_i^+ + K_i^-}{2}$	The final rank is found by looking at the average deviation of the alternatives from the utility. The best alternative is the one with the highest Q_i.

The CRADIS method uses ideal solutions representing the maximum value of alternatives and ideal solutions representing the minimum value of alternatives by observing alternatives through all criteria, and it is worth noting that the CRADIS method was introduced to the literature as a combination of ARAS, MARCOS and TOPSIS methods [24].

4. FINDINGS

Financial sustainability performance of airline companies is calculated using the LOPCOW-CRADIS multi-criteria decision-making method. The criteria will be weighted with the LOPCOW method and the weights of the airlines will be calculated and ranked with the CRADIS method.

Tab. 4

Financial Sustainability Criteria

Criteria	Methodology	Description
Environmental Variable	Thomson Reuters (Eikon Datastream)	E
Social Variable	Thomson Reuters (Eikon Datastream)	S
Governance Variable	Thomson Reuters (Eikon Datastream)	G
ESG Variable	Thomson Reuters (Eikon Datastream)	ESG
Financial Failure	Altman Z'' Score	FF
Financial Performance	TAA Financial Rating Score	FR

4.1. Results of the LOPCOW

In the study, the Altman Z score and TAA financial rating score were calculated by the author. The ESG score was obtained from the Thomson Reuters datastream. In order to calculate the importance weights of the criteria in the study, the LOPCOW method was used within the criteria weighting method group. The decision matrix related to ESG data and financial data used in the study for 2023 is shown in Table 5.

Tab. 5

Decision Matrix

Airline	E	S	G	ESG	FF	FR
Aeroflot	53,66	59,06	32,05	49,84	0,77	5,23
Air Canada	77,03	72,51	89,05	78,53	0,73	3,62
Air China	71,96	67,13	51,09	64,13	-1,03	1,78
Air France-KLM	77,54	82,62	54,39	73,15	0,25	4,23
American Airlines	67,02	77,60	66,97	71,37	-0,91	2,85
All Nippon Airlines	78,71	69,09	31,26	61,47	2,17	6,15
Capital A Berhad	50,05	61,39	83,07	63,97	-4,79	1,55

Cathay Pacific	69,79	60,29	17,21	51,24	2,69	2,24
China Airlines	87,39	88,17	45,17	75,89	0,97	4,77
China Eastern	39,96	56,49	22,58	41,91	-1,83	2,7
China Southern	56,73	53,65	63,78	57,43	-1,67	2,7
Delta Airlines	63,24	74,83	60,85	67,34	-0,21	3,69
Easyjet	35,52	54,05	72,80	53,59	1,27	5,92
Gol Airlines	43,03	41,42	77,88	52,12	-7,95	2,7
Interglobe	65,23	61,10	76,09	66,63	1,74	4,24
International Group	71,60	51,91	91,82	69,15	-0,52	5,23
Japan Airlines	76,90	59,15	58,60	64,46	2,41	6,61
Jetblue	28,56	53,68	90,21	56,17	0,42	2,39
Korean Air	72,63	70,83	67,23	70,38	1,36	3,85
Latam	52,58	72,75	69,64	65,67	0,44	3,62
Lufthansa	69,27	88,60	54,29	73,04	0,77	5,38
Norwegian	13,92	70,73	28,99	41,55	-0,12	5,46
Pegasus Airlines	73,13	79,12	86,92	79,46	2,08	4,7
Qantas	61,11	64,07	81,62	68,07	-1,03	4,46
Ryanair	32,34	46,31	68,19	48,13	2,96	6,46
Singapore	75,37	67,50	69,93	70,60	1,85	6,23
Southwest	76,49	82,69	71,94	77,77	2,53	4,77
Turkish Airlines	90,09	95,52	65,20	85,36	1,57	3,55
United Airlines	43,39	51,76	77,63	56,43	0,73	5,3
Wizzair	35,91	52,60	79,28	54,93	0,63	4,7
Max	90,085	95,522	91,821	85,359	2,964	6,610
Min	13,924	41,419	17,215	41,554	-7,948	1,550

Source: ESG data is obtained from the Thomson Reuters database. FF indicator by Altman Z Score calculation, and the FR indicator was created as a result of the TAA financial rating calculation

Table 5 provides the basic (raw) data to be used for weighting the different criteria (LOPCOW method) and for the final ranking (CRADIS method). Turkish Airlines (85.36), Pegasus Airlines (79.46) and Southwest Airlines (77.77) scored the highest ESG scores, demonstrating strong environmental, social, and governance performance. Norwegian (41.55) and Ryanair (48.13) were among the companies with low ESG scores. Gol Airlines (-7.95) had the highest risk of financial failure, while Cathay Pacific (2.69) and All Nippon Airlines (2.17) showed more solid financial performance. Japan Airlines (6.61) and Ryanair (6.46) received the highest financial rating scores.

In the second part of the method, the normalized decision matrices containing the information of airline companies for the year 2023 and the decision matrix where the weightings are calculated are given in Tables 6 and 7.

Tab. 6

LOPCOW Normalized Decision Matrix

Airlines	**E**	**S**	**G**	**ESG**	**FF**	**FR**
Aeroflot	0,478	0,674	0,801	0,189	0,798	0,273
Air Canada	0,171	0,425	0,037	0,844	0,796	0,591

Air China	0,238	0,525	0,546	0,515	0,634	0,955
Air France-KLM	0,165	0,239	0,502	0,721	0,752	0,470
American Airlines	0,303	0,331	0,333	0,681	0,645	0,743
All Nippon Airlines	0,149	0,488	0,812	0,455	0,927	0,091
Capital A Berhad	0,526	0,631	0,117	0,512	0,289	1,000
Cathay Pacific	0,266	0,651	1,000	0,221	0,975	0,864
China Airlines	0,035	0,136	0,625	0,784	0,817	0,364
China Eastern	0,658	0,721	0,928	0,008	0,561	0,773
China Southern	0,438	0,774	0,376	0,363	0,575	0,773
Delta Airlines	0,353	0,382	0,415	0,589	0,710	0,577
Easyjet	0,716	0,767	0,255	0,275	0,845	0,136
Gol Airlines	0,618	1,000	0,187	0,241	0,000	0,773
Interglobe	0,326	0,636	0,211	0,572	0,888	0,468
International Group	0,243	0,806	0,000	0,630	0,681	0,273
Japan Airlines	0,173	0,672	0,445	0,523	0,949	0,000
Jetblue	0,808	0,773	0,022	0,334	0,767	0,834
Korean Air	0,229	0,456	0,330	0,658	0,853	0,545
Latam	0,492	0,421	0,297	0,551	0,769	0,591
Lufthansa	0,273	0,128	0,503	0,719	0,799	0,243
Norwegian	1,000	0,458	0,842	0,000	0,717	0,227
Pegasus Airlines	0,223	0,303	0,066	0,865	0,919	0,377
Qantas	0,381	0,581	0,137	0,605	0,634	0,425
Ryanair	0,758	0,910	0,317	0,150	1,000	0,030
Singapore	0,193	0,518	0,293	0,663	0,898	0,075
Southwest	0,178	0,237	0,266	0,827	0,960	0,364
Turkish Airlines	0,000	0,000	0,357	1,000	0,872	0,605
United Airlines	0,613	0,809	0,190	0,340	0,795	0,259
Wizzair	0,711	0,793	0,168	0,305	0,786	0,377
Standard Deviation	0,250	0,249	0,276	0,258	0,206	0,283

Tab. 7

LOPCOW Decision Matrix and Weights

Airlines	**E**	**S**	**G**	**ESG**	**FF**	**FR**
Aeroflot	0,229	0,454	0,642	0,036	0,638	0,074
Air Canada	0,029	0,181	0,001	0,713	0,633	0,349
Air China	0,057	0,275	0,298	0,266	0,402	0,911
Air France-KLM	0,027	0,057	0,252	0,520	0,565	0,221
American Airlines	0,092	0,110	0,111	0,463	0,417	0,552
All Nippon Airlines	0,022	0,239	0,659	0,207	0,860	0,008
Capital A Berhad	0,276	0,398	0,014	0,262	0,084	1,000
Cathay Pacific	0,071	0,424	1,000	0,049	0,950	0,746
China Airlines	0,001	0,018	0,391	0,615	0,668	0,132
China Eastern	0,433	0,520	0,861	0,000	0,314	0,597
China Southern	0,192	0,599	0,141	0,131	0,331	0,597
Delta Airlines	0,124	0,146	0,172	0,347	0,503	0,333
Easyjet	0,513	0,588	0,065	0,076	0,713	0,019

Gol Airlines	0,382	1,000	0,035	0,058	0,000	0,597
Interglobe	0,107	0,405	0,044	0,328	0,789	0,219
International Group	0,059	0,650	0,000	0,397	0,463	0,074
Japan Airlines	0,030	0,452	0,198	0,274	0,901	0,000
Jetblue	0,653	0,598	0,000	0,111	0,588	0,696
Korean Air	0,053	0,208	0,109	0,433	0,727	0,298
Latam	0,242	0,177	0,088	0,303	0,591	0,349
Lufthansa	0,075	0,016	0,253	0,517	0,638	0,059
Norwegian	1,000	0,210	0,709	0,000	0,515	0,052
Pegasus Airlines	0,050	0,092	0,004	0,749	0,845	0,142
Qantas	0,145	0,338	0,019	0,366	0,402	0,181
Ryanair	0,575	0,827	0,100	0,023	1,000	0,001
Singapore	0,037	0,268	0,086	0,440	0,806	0,006
Southwest	0,032	0,056	0,071	0,684	0,922	0,132
Turkish Airlines	0,000	0,000	0,127	1,000	0,760	0,366
United Airlines	0,376	0,654	0,036	0,115	0,633	0,067
Wizzair	0,506	0,629	0,028	0,093	0,618	0,142
Total	6,387	10,592	6,517	9,573	18,274	8,921
Total/m	0,213	0,353	0,217	0,319	0,609	0,297
Square root	0,461	0,594	0,466	0,565	0,780	0,545
square root/std.dev.	1,847	2,390	1,692	2,188	3,784	1,929
Pvij	61,344	87,141	52,564	78,299	133,089	65,701
Wj	0,128	0,182	0,110	0,164	0,278	0,137
Rank	5	2	6	3	1	4

According to the calculation of the weighting of the criteria, the FF (Financial Failure) criterion has the highest importance with 0.278. This indicates that the risk of financial failure has a decisive impact on the sustainability performance of airlines. The G (Governance) criterion has the lowest weight, with 0.110. Governance performance is considered to be less determinant compared to other criteria. This table provides a basic structure for a detailed analysis of sustainability performance, guiding decision makers on which areas need improvement and which areas are strong. CRADIS method assessment based on weightings by the LOPCOW method.

4.2. Results of the CRADIS

In the problem whose criteria and criteria weights were determined, the CRADIS method was used to evaluate the alternatives. According to the decision matrix in Table 5, normalization values were first calculated. The calculated normalized decision matrix is presented in Table 8.

Tab. 8

CRADIS Normalized Decision Matrix

	max	max	max	Max	max	max
Airlines	**E**	**S**	**G**	**ESG**	**FF**	**FR**
Aeroflot	0,596	0,618	0,349	0,584	0,258	0,791
Air Canada	0,855	0,759	0,970	0,920	0,248	0,548

Air China	0,799	0,703	0,556	0,751	-0,348	0,269
Air France-KLM	0,861	0,865	0,592	0,857	0,086	0,640
American Airlines	0,744	0,812	0,729	0,836	-0,305	0,431
All Nippon Airlines	0,874	0,723	0,340	0,720	0,733	0,930
Capital A Berhad	0,556	0,643	0,905	0,749	-1,616	0,234
Cathay Pacific	0,775	0,631	0,187	0,600	0,906	0,339
China Airlines	0,970	0,923	0,492	0,889	0,328	0,722
China Eastern	0,444	0,591	0,246	0,491	-0,618	0,408
China Southern	0,630	0,562	0,695	0,673	-0,565	0,408
Delta Airlines	0,702	0,783	0,663	0,789	-0,069	0,558
Easyjet	0,394	0,566	0,793	0,628	0,428	0,896
Gol Airlines	0,478	0,434	0,848	0,611	-2,681	0,408
Interglobe	0,724	0,640	0,829	0,781	0,588	0,641
International Group	0,795	0,543	1,000	0,810	-0,176	0,791
Japan Airlines	0,854	0,619	0,638	0,755	0,813	1,000
Jetblue	0,317	0,562	0,982	0,658	0,142	0,362
Korean Air	0,806	0,741	0,732	0,824	0,458	0,582
Latam	0,584	0,762	0,758	0,769	0,149	0,548
Lufthansa	0,769	0,928	0,591	0,856	0,260	0,814
Norwegian	0,155	0,740	0,316	0,487	-0,040	0,826
Pegasus Airlines	0,812	0,828	0,947	0,931	0,702	0,711
Qantas	0,678	0,671	0,889	0,797	-0,347	0,675
Ryanair	0,359	0,485	0,743	0,564	1,000	0,977
Singapore	0,837	0,707	0,762	0,827	0,623	0,943
Southwest	0,849	0,866	0,784	0,911	0,854	0,722
Turkish Airlines	1,000	1,000	0,710	1,000	0,528	0,537
United Airlines	0,482	0,542	0,846	0,661	0,247	0,802
Wizzair	0,399	0,551	0,863	0,644	0,212	0,711

After the decision matrix is normalized, a weighted normalized decision matrix is obtained according to the solution stages of the CRADIS method. All criteria are inherently maximized.

Tab. 9

CRADIS Weighted Normalized Decision Matrix

Airlines	**E**	**S**	**G**	**ESG**	**FF**	**FR**
Aeroflot	0,076	0,113	0,038	0,096	0,072	0,109
Air Canada	0,110	0,138	0,107	0,151	0,069	0,075
Air China	0,102	0,128	0,061	0,123	-0,097	0,037
Air France-KLM	0,110	0,158	0,065	0,140	0,024	0,088
American Airlines	0,095	0,148	0,080	0,137	-0,085	0,059
All Nippon Airlines	0,112	0,132	0,037	0,118	0,204	0,128
Capital A Berhad	0,071	0,117	0,099	0,123	-0,450	0,032
Cathay Pacific	0,099	0,115	0,021	0,098	0,252	0,047
China Airlines	0,124	0,168	0,054	0,146	0,091	0,099
China Eastern	0,057	0,108	0,027	0,080	-0,172	0,056
China Southern	0,081	0,102	0,076	0,110	-0,157	0,056

Delta Airlines	0,090	0,143	0,073	0,129	-0,019	0,077
Easyjet	0,051	0,103	0,087	0,103	0,119	0,123
Gol Airlines	0,061	0,079	0,093	0,100	**-0,746**	0,056
Interglobe	0,093	0,117	0,091	0,128	0,164	0,088
International Group	0,102	0,099	0,110	0,133	-0,049	0,109
Japan Airlines	0,110	0,113	0,070	0,124	0,226	0,137
Jetblue	0,041	0,102	0,108	0,108	0,040	0,050
Korean Air	0,103	0,135	0,080	0,135	0,127	0,080
Latam	0,075	0,139	0,083	0,126	0,041	0,075
Lufthansa	0,099	0,169	0,065	0,140	0,072	0,112
Norwegian	0,020	0,135	0,035	0,080	-0,011	0,114
Pegasus Airlines	0,104	0,151	0,104	0,152	0,195	0,098
Qantas	0,087	0,122	0,098	0,131	-0,097	0,093
Ryanair	0,046	0,088	0,082	0,092	**0,278**	0,134
Singapore	0,107	0,129	0,084	0,135	0,173	0,130
Southwest	0,109	0,158	0,086	0,149	0,238	0,099
Turkish Airlines	0,128	0,182	0,078	0,164	0,147	0,074
United Airlines	0,062	0,099	0,093	0,108	0,069	0,110
Wizzair	0,051	0,100	0,095	0,105	0,059	0,098
max-ti	0,128	0,182	0,110	0,164	**0,278**	0,137
min-tia	0,020	0,079	0,021	0,080	**-0,746**	0,032

From the weighted decision matrix according to the solution stages of the CRADIS method, the largest 'vij' value for the ideal solution is 0.278 and the smallest 'vij' value for the anti-ideal solution is -0.746. According to these values, deviations from the ideal and anti-ideal solutions specified in the 4th stage of the CRADIS method are calculated.

Tab. 10

CRADIS Deviations from the Ideal Solution

Airlines	E	S	G	ESG	FF	FR
Aeroflot	0,202	0,166	0,240	0,183	0,206	0,170
Air Canada	0,169	0,140	0,172	0,128	0,209	0,203
Air China	0,176	0,150	0,217	0,155	0,375	0,241
Air France-KLM	0,168	0,121	0,213	0,138	0,254	0,190
American Airlines	0,183	0,130	0,198	0,141	0,363	0,219
All Nippon Airlines	0,166	0,147	0,241	0,160	0,074	0,151
Capital A Berhad	0,207	0,161	0,179	0,156	0,728	0,246
Cathay Pacific	0,179	0,163	0,258	0,180	0,026	0,232
China Airlines	0,154	0,110	0,224	0,133	0,187	0,179
China Eastern	0,221	0,171	0,251	0,198	0,450	0,222
China Southern	0,198	0,176	0,202	0,168	0,436	0,222
Delta Airlines	0,188	0,136	0,205	0,149	0,298	0,202
Easyjet	0,228	0,175	0,191	0,176	0,159	0,155
Gol Airlines	0,217	0,199	0,185	0,178	1,025	0,222
Interglobe	0,185	0,162	0,187	0,151	0,115	0,190
International Group	0,176	0,179	0,168	0,146	0,327	0,170

Japan Airlines	0,169	0,165	0,208	0,155	0,052	0,141
Jetblue	0,238	0,176	0,170	0,171	0,239	0,229
Korean Air	0,175	0,143	0,198	0,143	0,151	0,198
Latam	0,203	0,140	0,195	0,152	0,237	0,203
Lufthansa	0,180	0,109	0,213	0,138	0,206	0,167
Norwegian	0,259	0,143	0,244	0,199	0,290	0,165
Pegasus Airlines	0,174	0,127	0,174	0,126	0,083	0,181
Qantas	0,191	0,156	0,181	0,148	0,375	0,186
Ryanair	0,232	0,190	0,197	0,186	0,000	0,144
Singapore	0,171	0,150	0,195	0,143	0,105	0,149
Southwest	0,169	0,121	0,192	0,129	0,041	0,179
Turkish Airlines	0,150	0,096	0,200	0,115	0,131	0,205
United Airlines	0,217	0,180	0,185	0,170	0,210	0,168
Wizzair	0,227	0,178	0,183	0,173	0,219	0,181
min	0,150	0,096	0,168	0,115	0,000	0,141

Deviations from the ideal solution (d+) are calculated by subtracting each criterion value from the largest 'vij' value of 0.278 found in the previous stage. On the other hand, deviations from the anti-ideal solution (d_) are calculated by subtracting each criterion value from the smallest 'vij' value for the anti-ideal solution found in the previous stage, which is -0.749.

Tab. 11

CRADIS Deviations from the Anti-Ideal Solution

Airlines	**E**	**S**	**G**	**ESG**	**FF**	**FR**
Aeroflot	0,823	0,859	0,785	0,842	0,818	0,855
Air Canada	0,856	0,885	0,853	0,897	0,815	0,822
Air China	0,849	0,874	0,807	0,869	0,650	0,783
Air France-KLM	0,857	0,904	0,811	0,887	0,770	0,834
American Airlines	0,842	0,894	0,826	0,883	0,661	0,806
All Nippon Airlines	0,858	0,878	0,784	0,864	0,950	0,874
Capital A Berhad	0,818	0,863	0,846	0,869	0,297	0,779
Cathay Pacific	0,846	0,861	0,767	0,845	0,999	0,793
China Airlines	0,871	0,915	0,800	0,892	0,838	0,845
China Eastern	0,803	0,854	0,773	0,827	0,574	0,802
China Southern	0,827	0,849	0,823	0,857	0,589	0,802
Delta Airlines	0,836	0,889	0,819	0,876	0,727	0,823
Easyjet	0,797	0,849	0,833	0,849	0,865	0,869
Gol Airlines	0,808	0,825	0,840	0,846	0,000	0,802
Interglobe	0,839	0,863	0,837	0,874	0,910	0,834
International Group	0,848	0,845	0,856	0,879	0,697	0,855
Japan Airlines	0,856	0,859	0,816	0,870	0,973	0,884
Jetblue	0,787	0,849	0,854	0,854	0,786	0,796
Korean Air	0,850	0,881	0,827	0,881	0,874	0,826
Latam	0,821	0,885	0,830	0,872	0,788	0,822
Lufthansa	0,845	0,915	0,811	0,886	0,819	0,858
Norwegian	0,766	0,881	0,781	0,826	0,735	0,860

Pegasus Airlines	0,850	0,897	0,850	0,899	0,942	0,844
Qantas	0,833	0,869	0,844	0,877	0,650	0,839
Ryanair	0,792	0,835	0,828	0,839	1,025	0,881
Singapore	0,854	0,875	0,830	0,882	0,920	0,876
Southwest	0,855	0,904	0,832	0,896	0,984	0,845
Turkish Airlines	0,875	0,929	0,824	0,910	0,893	0,820
United Airlines	0,808	0,845	0,839	0,855	0,815	0,856
Wizzair	0,797	0,847	0,841	0,852	0,805	0,844
max	0,871	0,915	0,853	0,897	0,999	0,874

Minimum and maximum column values are also given in the last row of the ideal and anti-ideal solution matrices. These row values are summed and included in the calculation in the same way when the values of the alternatives are summed in the next stage (stage 5).

The deviation degrees of the individual alternatives from the ideal and anti-ideal solutions (si+, si-), the utility function (Ki+, Ki-) and the final rank (Qi) for each alternative calculated in the 5th, 6th and 7th stages of the method are calculated and presented together.

Tab. 12

CRADIS Ranking

2023						
Airlines	**S+**	**Ki+**	**S-**	**Ki-**	**Qi**	**Rank**
Aeroflot	1,166	0,574	4,982	0,921	0,748	19
Air Canada	1,021	0,657	5,127	0,948	0,802	12
Air China	1,315	0,510	4,833	0,894	0,702	26
Air France-KLM	1,085	0,618	5,063	0,936	0,777	15
American Airlines	1,235	0,542	4,913	0,908	0,725	23
All Nippon Airlines	0,939	0,714	5,209	0,963	0,838	6
Capital A Berhad	1,677	0,400	4,471	0,827	0,613	29
Cathay Pacific	1,038	0,646	5,110	0,945	0,795	13
China Airlines	0,987	0,679	5,161	0,954	0,817	8
China Eastern	1,514	0,443	4,634	0,857	0,650	28
China Southern	1,401	0,478	4,747	0,878	0,678	27
Delta Airlines	1,178	0,569	4,970	0,919	0,744	21
Easyjet	1,084	0,618	5,064	0,936	0,777	14
Gol Airlines	2,027	0,331	4,121	0,762	0,546	30
Interglobe	0,990	0,677	5,158	0,954	0,815	9
International Group	1,167	0,574	4,981	0,921	0,748	20
Japan Airlines	0,890	0,753	5,258	0,972	0,862	3
Jetblue	1,222	0,548	4,926	0,911	0,730	22
Korean Air	1,009	0,664	5,139	0,950	0,807	10
Latam	1,130	0,593	5,018	0,928	0,760	17
Lufthansa	1,013	0,661	5,135	0,950	0,805	11
Norwegian	1,299	0,516	4,849	0,897	0,706	25
Pegasus Airlines	0,865	0,774	5,283	0,977	0,876	2
Qantas	1,237	0,542	4,911	0,908	0,725	24
Ryanair	0,949	0,706	5,199	0,961	0,834	7

Singapore	0,912	0,735	5,236	0,968	0,852	5
Southwest	0,831	0,806	5,317	0,983	0,895	1
Turkish Airlines	0,897	0,747	5,251	0,971	0,859	4
United Airlines	1,129	0,593	5,019	0,928	0,761	16
Wizzair	1,161	0,577	4,987	0,922	0,749	18
S0+	0,670	S0-	5,408			

In the previous stage, the minimum values in the last row of deviations from the ideal solution are summed up and calculated as s0+=0.670 and the maximum values in the last row of deviations from the anti-ideal solution are summed up and calculated as s0-=5.480. According to the final Qi utility values based on the average of the utility ratings, the ones in green indicate the top 3 ranks, while the ones in red indicate the bottom 3 ranks. Southwest Airlines ranks first with a score of (0.895), followed by Pegasus Airlines (0.876) and Japan Airlines (0.862) in 3rd place. In the last ranks are Gol Airlines (0.546), Capital A Berhad (0.613) and China Eastern (0.650).

Southwest Airlines demonstrated strong leadership in both ESG performance and financial sustainability in 2023. This demonstrates the company's ability to effectively manage both its operational and environmental goals. Pegasus Airlines and Japan Airlines are notable for their exceptional performance. The minimal risk of financial collapse and balanced performance on ESG criteria of Pegasus Airlines facilitated this accomplishment. Gol Airlines and Capital A Berhad ranked worse primarily owing to their elevated risk of financial insolvency and shortcomings in ESG performance.

5. CONCLUSION

This research assessed the financial sustainability performance of airline firms by Multi-Criteria Decision Making (MCDM) approaches, merging ESG (Environmental, Social, and Governance) ratings with financial failure and financial rating methodologies. The results provide a comprehensive insight into the correlation between financial sustainability and ESG practices within the industry, indicating the need for the development of new methodologies in both domains. The study's conclusions highlight significant debate points for attaining sustainability objectives in the aviation industry.

The approach to ratings and multi-criteria decision-making (MCDM) analysis applied in the study brings a fresh perspective to assessing financial sustainability in the airline industry. Using the TAA method allows companies to gauge their performance across areas such as operational efficiency and management of liquidity and debt. This methodology empowers organizations to assess not only their current financial status but also to identify potential risks and opportunities in the future. For example, Japan Airlines and Ryanair have received ratings for their financial sustainability, highlighted as evidence of their ability to strengthen long-term competitiveness.

An in-depth analysis was carried out by merging ESG scores with information through the MCDM approach to gauge the industry’s financial sustainability comprehensively. Not just based on economic success but also considering environmental and social impacts. However, issues such as data accuracy, criteria weighting, and incorporating factors have posed challenges in executing this tactic. This situation highlights the importance of creating metrics and evaluation frameworks to improve the effectiveness of MCDM approaches.

The study discoveries suggest a variety of suggestions for crafting sustainability plans within the airline sector. To start with, there are the recommendations to enhance the incorporation of ESG policies into the planning of companies. ESG practices not only fulfill environmental and social responsibilities but also increase financial resilience during crisis periods. Second, companies need to take measures to increase their financial resilience to reduce the risk of financial failure. In particular, optimizing liquidity management and debt levels are critical for companies to survive during crisis periods.

Finally, wider adoption and standardization of methods used in ESG and financial performance analyses can increase the accuracy and comparability of sectoral analyses. The TAA financial rating method and MCDM analyses stand out as effective tools in this direction. However, more academic studies should be conducted to increase the applicability of these methods, and these methods should be disseminated throughout the sector.

As a result, this study has brought an innovative perspective to financial sustainability assessments in the airline sector. Integrating ESG scores with financial failure and financial rating methods provides a strong framework for achieving sustainability goals in the sector. The findings of the study will contribute to airline companies developing their sustainability strategies and creating a more resilient, responsible, and competitive structure in the sector.

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