Evaluation Research on Green Operation Development of International Aviation

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Abstract

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At present, with the rapid development of the global economy, the aviation industry, as a key part of the modern transportation system, is playing an increasingly important role. However, with the intensification of global warming and the continuous improvement of people's environmental protection awareness, the aviation industry is facing huge pressure for green transformation. Against this background, this paper conducts a study on the development of international aviation green operations. This paper first elaborates on the research background, the impact of greenhouse gas emissions from the aviation industry on the environment while promoting global economic development and communication, as well as the urgent global demand for the green transformation of the aviation industry. Then it explains the theoretical and practical significance of studying the green operation and development of international aviation, and introduces the research methods and ideas. Secondly, in the literature review section, The research status of green aviation operation at home and abroad was sorted out. The definition, connotation and related technical standards of green aviation operation were analyzed. The existing research was summarized and generalized. Then this paper selects two typical cases, Emirates Airlines and Southwest Airlines, and quantitatively evaluates their green operation levels by using AHP (Analytic Hierarchy Process). It analyzes the advantages and disadvantages of the two airlines in terms of environmental performance, energy efficiency and operation management, and puts forward corresponding improvement measures and development suggestions. Meanwhile, combined with SWOT analysis, The internal disadvantages and external threats of the two airlines were further explored, providing more targeted strategic guidance for their green transformation. Finally, in the conclusion and outlook section of this paper, the research results are summarized, the importance of the green transformation of the aviation industry is emphasized, and some constructive opinions and suggestions are put forward, hoping to contribute to the sustainable development of airlines of the same type.

Key words
International Airlines Green operation SWOT analysis Analytic Hierarchy Process

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1 Introduction

1.1 Research Background

In today's world, the global economy is developing rapidly. As a key component of the modern transportation system, the aviation industry is playing an increasingly important role. It has significantly reduced the distance between various places, facilitated the rapid flow of people, materials and information, and provided strong support for international trade, the tourism industry and the process of globalization. However, as the problem of global warming becomes increasingly serious and people's environmental protection awareness continues to strengthen, the aviation industry, as one of the main sources of greenhouse gas emissions, is facing unprecedented pressure for green transformation.

Although the volume of aviation emissions is not large, it is estimated that the impact of the aviation industry on global warming caused by human activities is approximately 3.5%, while the cement industry accounts for about 6%, and road transportation reaches 17% (liguiju, 2020). However, most aircraft suitable for air transportation rely on the combustion of aviation fuel to obtain power. The greenhouse gases produced by the combustion of aviation fuel, as well as the fuel that sublimates without combustion due to high temperatures, are directly discharged into the stratosphere. But here, there are neither exhaust gas absorption devices nor green belts on the ground that can absorb some of the exhaust gases, so it will cause direct pollution to the environment. Its harm can be two to four times that of ground emissions from similar sources, which has a significant impact on the climate. For this reason, all countries attach great importance to the development of green aviation, and the global aviation industry has proposed to achieve net zero emissions by 2050 (Liu Yanhua,2023; Wang Yibo, Shang Meng, Liu Yu, Wang Yuping,2021.

The aviation industry not only has to deal with the difficult problem of carbon emissions, but also has to confront many environmental issues. For instance, the wastewater, waste gas and solid waste generated during the operation of airports, if not properly disposed of, may cause pollution to the soil, water areas and air, as well as the noise pollution emitted during aircraft takeoff, landing and flight. It will also affect the quality of life and physical health of the residents around the airport. Moreover, the aviation industry has a huge demand for energy, so it has encountered many difficulties in energy security and sustainable development.

Against this backdrop, the concept of "green air logistics" was proposed and gradually became the focus of industry attention. "Green air logistics" first appeared in government documents in the UK Energy White Paper in 2003. Its meaning is to achieve an economic development trend with low greenhouse gas emissions. Especially for a key greenhouse gas like carbon dioxide, it is essential to effectively control its emissions. This is not only an inevitable move by the aviation industry in response to the global climate change situation, but also an important measure to meet consumers' constantly rising environmental protection demands and improve its own corporate image and competitive strength.

To promote the green transformation of the aviation industry, the international community and governments of various countries have taken active actions. The European Union has implemented the Carbon Emissions Trading System (ETS) and included the aviation industry, imposing strict regulations on the carbon emissions of airlines. The Federal Aviation Administration (FAA) of the United States has introduced numerous plans to support the creation of sustainable airports, formulating relevant policies and guidelines. The Civil Aviation Administration of China proposed in the "Action Outline for Building a Strong Civil Aviation Country in the New Era" to create "four types of airports", with green airports being one of them. It attaches great importance to implementing the concepts of sustainable development and green low-carbon throughout the entire process of airport construction and operation.

However, even though the international aviation industry has shown some trends in green operation, it still encounters many difficulties. The policies, technologies and standards related to green aviation vary among different countries and regions, and the speed of the global aviation industry's green transformation is uneven. The research and development and adoption of green aviation technologies require huge financial and technological support. This is a great test for some airlines. Moreover, how to maintain the economic benefits and service levels of the aviation industry while achieving green operation is also an urgent problem to be addressed. Therefore, a detailed exploration of the development of green operation in international aviation has significant practical value.

1.2 Research significance

1.2.1 Theoretical significance

This study has achieved theoretical breakthroughs in the field of green aviation research by creating an innovative comprehensive evaluation system of AHP and SWOT. It has updated and presented a comprehensive evaluation framework covering three aspects: environmental performance, energy efficiency, and operation and management. This framework can more accurately consider the emission reduction potential under different business models and identify the ideal emission reduction approaches for each airline. This three-dimensional consideration method can optimize the accuracy of the evaluation results by more than 30%, providing new research perspectives and methods to support the completeness of the green aviation theoretical system (Wang, Z., Wang, Q., & Yang, Z. 2023).

1.2.2 Practical significance

From the perspective of practical operation, this study provides targeted classified guidance plans for the green transformation of the aviation industry. It selects Emirates and Southwest Airlines as research examples, which are typical of the industry. For long-haul airlines like Emirates, this study shows that Sustainable aviation fuel (SAF) is the most crucial means for them to achieve their emission reduction goals. Research conducted by ICAO (2023) shows that the contribution rate of SAF to emission reduction in the long-haul aviation sector can reach up to 70%, which highlights the extremely significant strategic importance of first planning the supply chain of sustainable aviation fuel. As for low-cost airlines like Southwest Airlines, this study shows that they can achieve their emission reduction goals through a more cost-effective approach of fleet renewal. The technical report released by Boeing (2022) points out that replacing the old NG models with the 737MAX can achieve a 15% energy-saving increase within a five-year period, while maintaining a relatively low investment amount. Such cognition has endowed low-cost airlines with practical and feasible emission reduction methods. From the perspective of the entire industry, green operation has become an inevitable path for the future development of the aviation industry. With increasingly strict environmental regulations and the continuous strengthening of consumers' environmental awareness, airlines' vigorous promotion of green operation can not only optimize their own social image, Build an excellent brand reputation and be able to attract more customers who are concerned about environmental protection affairs, thereby seizing the initiative in the highly competitive market environment. Green operation will prompt airlines to cut operating costs, improve energy utilization efficiency and enhance the sustainable development capabilities of enterprises.

The aviation industry is a key component of the global economy. Its green transformation has a strong industrial driving effect. The green development of the aviation industry will prompt aviation manufacturing enterprises to intensify efforts in the research and development and production of environmentally friendly aircraft, and also promote the transformation of airport operations towards green and intelligent directions. It will also drive energy supply enterprises to develop and provide more clean energy. This will enable the entire industrial chain to undergo upgrading and transformation in the direction of a green economy, thereby promoting the continuous development of the social economy. After the green aviation industry develops, it can also bring new job opportunities and economic growth poles, making positive contributions to social development.

1.3 Research ideas

This research focuses on the green operation and development of international aviation. Southwest Airlines and Emirates Airlines are regarded as typical airline representatives. The Analytic Hierarchy Process (AHP) and Situation Analysis (SWOT) are adopted. First, the index weights are calculated through the Analytic Hierarchy Process (AHP), and then data such as enterprise annual reports and industry reports are integrated. Analyze these two airlines using the SWOT analysis method and finally provide targeted development strategies. The following figure is my overlay matrix.

Research question	Theoretical Framework (Chapter)	Results(Chapter)
What are the specific impacts of the aviation industry on global warming and the necessity of its emission reduction?	2.1, 2.2.1, 2.2.2	1.1
How to build a scientific evaluation system to quantify the green operation level of airlines?	3.1, 3.3, 3.4	3.2
What are the differences and optimization strategies between low-cost airlines and long-haul airlines in green operations?	4.1, 4.2, 3.3, 3.4	5
What is the theoretical basis of green aviation operation and its guiding significance in practice?	1.2, 2.1	2.3
What are the limitations of the current green aviation evaluation methods and what are the future improvement directions?	2.2.3, 3.1, 3.2	6

Tab 1 overlay matrix

2 Literature review and theoretical basis

2.1 The definition and connotation of green aviation operation

The conceptual definitions of green aviation operations mostly come from the official documents of authoritative institutions such as the International Civil Aviation Organization (ICAO) and the International Air Transport Association (IATA). The relevant expressions were clearly made for the first time in the "Environmental Report" published by ICAO in 2021: "An operational approach of reducing carbon emissions, noise pollution and resource consumption throughout the entire cycle of air transportation through a series of measures and ensuring its safety and economic feasibility" (ICAO,2021), this definition highlights the perspective of the entire life cycle, expanding the operation of the aviation environment from the traditional flight stage to cover fuel production. The entire value chain, including airport operations and aircraft maintenance, this report indicates that this systematic thinking is crucial for achieving the aviation industry's net zero emissions target by 2050 (ICAO,2021).

In 2022, as a representative of the industry, the IATA the sustainable aviation fuel map (SustainableAviationFuelRoadmap) gives a more detailed strategy of "three pillars" in the framework, the green aviation business into technology improvement, The three aspects of operational improvement and market initiatives (IATA,2022), in terms of technological improvement, the key includes the design of new aircraft (such as models like the Boeing 787 and Airbus A350NX) and the application of sustainable aviation fuel (SAF); Operational improvement emphasizes the renewal of air traffic management and the improvement of the route network. Market initiatives focus on carbon pricing and emissions trading mechanisms. The IATA specifically stated that these three pillars need to be promoted in coordination, and it is difficult to achieve climate goals relying solely on one measure (IATA,2022).

On the technical standard, ICAO air environment protection committee (CAEP) work out specific quantitative indicators, according to the 2022 "aircraft carbon dioxide emission standard" (AircraftCO2EmissionsStandards), research and development of new aircraft emissions intensity 20% lower than in 2014, The number of aircraft in production needs to be reduced by 8% (ICAO,2022). These standards have been included in Annex 16, Volume III of the Convention on International Civil Aviation and have become legally binding international norms. It should be emphasized that this document is the first to regard the proportion of SAF usage as a qualified option. Allow airlines to use sustainable fuels to meet some of the emission reduction requirements (ICAO,2022).

In the updated "AviationClimateSolutions" of IATA in 2023, the significance of green aviation was further elaborated, presenting five main features: Fuel efficiency (fuel consumption per passenger per kilometer is less than 3.5 liters), carbon emissions (less than 90 grams of carbon dioxide per person-kilometer), noise control (noise during takeoff is less than 85 decibels), garbage disposal (recycling rate exceeds 50%), and water usage (water consumption per unit passenger flow is reduced by 20%) These measurable standards provide a clear technical roadmap for airlines' green transformation. The report highlights the need to take regional differences into account, such as the specific difficulties that airlines in developing countries face in accessing technology and obtaining financial support (IATA,2023).

2.2 Research Status at Home and Abroad

2.2.1 Domestic research on green aviation

Research on the green operation of aviation in China has gradually gained attention. In light of the current situation of China's aviation industry, active explorations have been carried out from a wide range of perspectives, including the analysis of the current situation of green development in the aviation industry, the application of technology, policy support, and sustainable development strategies, etc.

Sun Ying (2021) indicated that the situation of global warming is extremely severe, which has created a macro environment for the research on the green operation of the aviation industry. The aviation industry is one of the sources of greenhouse gas emissions, and the green operation of this industry is very crucial for solving the problem of global warming. Relevant studies have narrowed the range of climate sensitivity indicators to between 2.6 and 3.9°C. This makes it essential for the aviation industry to actively carry out emission reduction efforts and accelerate the pace of its transformation towards a green direction. This can be achieved by improving flight routes, enhancing fuel efficiency, and developing new types of aviation fuels, thereby reducing its contribution to global warming and achieving sustainable development (Sun Ying, 2021).

Wang Yibo et al. (2021) meticulously analyzed many problems encountered in the green development of China's air logistics industry, among which air transportation pollution was involved, such as greenhouse gas emissions and noise pollution. Airport pollution, such as excessive particulate matter, chemical substance pollution, emissions from ground transportation facilities, etc. There is also pollution from ground logistics operations, including ground transportation pollution, pollution from other logistics operations, and packaging pollution, etc. Some improvement suggestions have also been given. For example, in terms of air transportation, it should be green, that is, aircraft emissions need to be green, and noise should also be properly treated. In terms of airports, green development should be achieved, that is, ground emissions should be reduced. Transportation vehicles should also be green, and snow and ice melting operations need to be improved. Ground logistics operations should also be made green, including the greening of ground transportation, other logistics operations, and packaging, among other measures. These provide practical guidance for the green operation of the aviation industry and are beneficial for airlines to comprehensively enhance their green operation level starting from the logistics link (Wang Yibo et al., 2021).

Qi Jianan (2020) explored the application of Internet of Things (iot) technology in airport energy operation and its real improvement achievements. Through the update of the energy operation system of Hangzhou Xiaoshan Airport (adding a sensor network, implementing energy consumption hierarchical operation, alarm notification, adopting embedded technology and making safety planning), and the improvement and transformation of pipeline networks (adding an intelligent pipeline network detection system), The analysis of energy conservation in air conditioning systems (by applying the energy operation control system of central air conditioning) and other aspects demonstrates that the Internet of Things technology has great potential in enhancing the energy utilization rate of airports and reducing energy consumption, providing valuable practical experience and technical references for the intelligent development of energy operation in the green operation process of the aviation industry (Qi Jianan, 2020).

Wang Jijie (2021) sorted out the development process and application status of green airports at home and abroad, and described the important technologies and operational experiences of large hub airports in terms of energy conservation and emission reduction, environmental improvement, efficient operation, and humanistic services. For instance, Los Angeles International Airport has made requirements for the design and planning of sustainable airports from aspects such as overall planning, energy efficiency, and renewable energy. The Heathrow Airport in the UK prioritizes sustainability and passenger experience in its architectural design and utilizes biomass energy. China's airports have made green attempts in energy conservation, indoor environment creation, and site water conservation. The appropriate contents and characteristics of green technologies in the field of civil buildings in airports have been analyzed, providing comprehensive technical and experience references for the creation of green airports, which is beneficial to promoting the transformation of green aviation operations from concepts to reality (Wang Jijie, 2021).

Qi Jianan (2020) explored the application of Internet of Things technology in airport energy management and its actual improvement effects. Through the practical analysis of aspects such as the upgrade of the energy management system of Hangzhou Xiaoshan Airport (adding sensor networks, hierarchical energy consumption management, early warning and alarm, application of embedded technology and safety design), the optimization and transformation of pipeline networks (adding an intelligent pipeline network monitoring system), and energy conservation of the air conditioning system (introducing a central air conditioning energy management control system), It demonstrates the great potential of Internet of Things technology in improving the energy utilization rate of airports and reducing energy consumption, providing valuable case experience and technical references for the intelligent development of energy management in the green operation of aviation (Qi Jianan, 2020).

Wang Jijie (2021) sorted out the development history and practical situation of green airports at home and abroad, and introduced the key technologies and operational experiences of large hub airports in terms of energy conservation and emission reduction, environmental improvement, efficient operation, and humanistic services. For instance, Los Angeles International Airport put forward requirements for the design and planning of sustainable airports from aspects such as overall planning, energy efficiency, and renewable energy. In the architectural design of Heathrow Airport in the UK, sustainability and passenger experience are given priority, and biomass energy is utilized. China's airports have carried out green practices in energy conservation, indoor environment creation and site water conservation. Meanwhile, the applicable contents and characteristics of green technologies in the field of civil buildings in airports have been analyzed, providing comprehensive technical and experience references for the construction of green airports and helping to promote the implementation of green aviation operations from concept to practice (Wang Jijie, 2021).

Yu Ye et al. (2019) attached great importance to the significance of energy management for the creation of green airports. They took Urumqi Diwopu International Airport, Qingdao Jiaodong International Airport and Beijing Daxing International Airport as examples to discuss the efforts made by airports in energy management, such as utilizing clean energy, improving building shapes, and adopting energy management systems, etc. These practices have provided a variety of ideas and methods for improving energy management in the green operation process of the aviation industry, which is beneficial for airports to achieve efficient energy utilization and sustainable supply, reduce operating costs and minimize environmental damage (Yu Ye et al., 2019).

Feng Leijie (2022) mentioned many advanced examples of energy operation systems in domestic airports. Beijing Capital International Airport has implemented meticulous operation, such as dividing the lighting into different areas and improving the operation planning of the baggage system. Beijing Daxing International Airport has established an integrated energy operation platform, which includes many functions such as data collection, analysis, prediction and auxiliary decision-making. Shanghai Hongqiao International Airport has achieved meticulous operation of electrical metering and accomplished energy-saving goals through sub-item metering and error analysis. Nanjing Lukou International Airport implements real-time energy detection and adopts energy-saving measures. Hangzhou Xiaoshan International Airport has updated its Internet of Things (iot) energy operation system. Chengdu Tianfu International Airport has adopted an intelligent building control system and so on. These examples provide specific operational references for energy management in the green operation of aviation, demonstrating the innovative means and achievements of various airports in energy management. This is beneficial for other airports to follow suit and improve their own energy management standards (Feng Leijie, 2022).

Huang Wenbo et al. (2021) analyzed the development status of China's air logistics, covering aspects such as market size, infrastructure, and service quality. They also put forward corresponding suggestions for the existing problems, such as intensifying the creation of infrastructure, improving the level of informatization, and enhancing operation and management. These studies have certain reference significance for the development of the logistics part in the green operation of aviation, which can prompt airlines to improve logistics steps, enhance operational efficiency, and reduce energy consumption and environmental pollution (Huang Wenbo et al., 2021).

He Xia (2016) explored the trend of low-carbonization in air logistics. She proposed measures such as adopting new types of aviation fuel, improving the transportation organization, and enhancing energy utilization efficiency to reduce the carbon emissions of air logistics. This provides ideas for the low-carbon development of green operation in the logistics industry. Aviation enterprises can refer to these methods to promote the low-carbon development of air logistics. Change in the green direction (He Xia, 2016).

Shang Meng et al. (2019) established an evaluation index system for the development level of the aviation logistics industry in the airport economic zone. This system assesses from many aspects such as economic development, logistics operation, infrastructure, and service quality. This way of creating an index system has certain inspiring significance for improving the evaluation index system of green aviation operation. It can prompt researchers to evaluate the development level of green aviation operations more comprehensively (Shang Meng et al., 2019).

Zhou Yang (2021) conducted a review on domestic research related to low-carbon logistics systems. This research covers aspects such as the calculation of carbon emissions in logistics activities, methods for reducing emissions, and the application of technologies. Although the research object is within the general logistics category, the low-carbon concepts and research methods therein can be learned by the aviation industry. It is beneficial for airlines to implement more effective green operation measures in the logistics process and reduce carbon emissions (Zhou Yang, 2021).

Luo Runsan (2021) has conducted research on the impact of the emission reduction market mechanism on carbon reduction in China's air cargo industry, and has also explored the application results and principles of policy measures such as carbon emissions trading and carbon taxes in air cargo. These works have provided theoretical support for the adoption of policy tools in the green operation of aviation (Luo Runsan, 2021).

2.2.2 Research on green aviation abroad

Research on green operation of aviation abroad began relatively early. Its research scope is broad and in-depth, covering many aspects such as the impact of the aviation industry on the environment, technological updates in green operation, policies and regulations, and sustainable development strategies.

AntonioFicca et al. (2023) stated that green and environmentally sustainable aviation can be achieved through continuous improvement through multiple parallel approaches. Relying on the increase in the production of sustainable aviation fuel (SAF) and combining it with the application of breakthrough technologies, the aviation industry needs to shift from short-term improvement of aircraft fuel efficiency to long-term transition to zero-carbon fuel for decarbonization. This requires interdisciplinary research covering technology, operation and economic aspects. New aircraft technologies such as electric and hydrogen fuel cell commuter aircraft may gradually be put into use in the coming decades, while aircraft using carbon-neutral fuels will require huge infrastructure investment (Ficcaetal.,2023).

SteveGriffiths et al. (2024) discussed the green flight path to achieve the goal of net zero aviation emissions by 2050, covering aspects such as the extensive use of sustainable aviation fuel (SAF), the research and development of new aircraft technologies, the improvement of operational processes, and policy support. They particularly emphasized the necessity of collaborative efforts among various departments. It is believed that organizations such as airlines, airports, aviation authorities, manufacturers, and the government all need to work together to formulate and implement strategic plans that can ensure sustainable development, thereby reducing the extent of damage caused by the aviation industry to the ecological environment (Griffith etal.,2024).

CandelariaBerger et al. (2023) analyzed the various approaches for the aviation industry to achieve net zero emissions, including enhancing fuel efficiency, utilizing sustainable aviation fuels, developing electric aircraft, hydrogen fuel cell aircraft, and other technical routes, as well as the role of policy measures, market strategies, and international collaboration. This study provides a reference for technological updates and policy-making in the green operation of aviation. Aviation enterprises can follow these approaches to explore green operation forms suitable for themselves, and it can also provide policymakers with a basis for formulating relevant policies, thereby leading the aviation industry towards net-zero emissions (Delbecq et al.,2023).

LynnetteDray et al. (2022) explored the costs and emission pathways necessary for the aviation industry to achieve net-zero climate impact, considering the feasibility and effectiveness of various technologies and strategies such as biofuels, synthetic fuels, electric aircraft, and operational improvement initiatives. They also explored how to promote the adoption of these technologies and strategies with the help of policies and market systems, thereby reducing costs and achieving the goal of emission reduction. This is of great reference significance for aviation enterprises to select green operation technologies and strategies, and can help enterprises make a balance between economic feasibility and environmental benefits. Select the most appropriate scheme (Delbecq et al.,2022).

Airbus (2024) publicly disclosed the results of the first flight inspection of a commercial aircraft using 100% sustainable aviation fuel, demonstrating outstanding non-carbon dioxide emission reduction effects. This inspection provided empirical support for the application of sustainable aviation fuel, prompting aviation enterprises to enhance their research and development and application intensity of sustainable aviation fuel, and helping the aviation industry reduce greenhouse gas emissions. Achieve green operation (Airbus,2024).

M.j. Watson et al. (2024) conducted a comprehensive review of the technology, cost, emissions, policies and market of sustainable aviation fuel, analyzing the advantages and disadvantages, production costs, emission reduction potential and corresponding policies and market conditions of various sustainable aviation fuels. This review provides a key reference for aviation enterprises to understand the field of sustainable aviation fuel. It is beneficial for enterprises to comprehensively weigh various factors and make appropriate choices when considering whether to adopt and how to use sustainable aviation fuel, and it can also provide policy makers with a basis for formulating policies and guiding the market (Watsonetal.,2024).

S. Delbecq et al. (2023) reviewed the future of sustainable aviation and technological mitigation measures against the backdrop of the Paris Agreement, exploring how the aviation industry can contribute to the global efforts to address climate change, which involves technological innovation, policy measures, international collaboration, and more. This provides guidance for aviation enterprises to formulate green operation strategies under the framework of international climate agreements, prompting them to link their own development with the global sustainable development goals and take the initiative to do something to reduce the damage caused to the environment. Moreover, it can also provide some references for policymakers when planning domestic policies in line with international agreements (Delbecq et al.,2023).

2.2.3 The evolution and limitations of green aviation evaluation methods

The development process of green aviation evaluation methods shows a gradual improvement trend from simplicity to completeness and from single to systematic. In the early stage, the evaluation focused on individual indicators such as aircraft fuel efficiency. For example, the "Fuel Efficiency Improvement Target" launched by the International Air Transport Association (IATA) in 2009 only took fuel consumption per passenger kilometer as the consideration scale (IATA,2009). With the continuous strengthening of environmental protection concepts, the evaluation system has gradually covered many environmental elements. In the "Aviation Environment Report" issued by the International Civil Aviation Organization (ICAO) in 2016, carbon emissions, noise pollution and air quality were included in the comprehensive evaluation category first (ICAO,2016).

In the mid-2010s, the Life Cycle Assessment (LCA) method was applied in the aviation field. The European Aviation Safety Agency (EASA) conducted a study in 2018, in which the LCA method was utilized. This method assesses the environmental impact of an aircraft throughout its entire life cycle, from fuel manufacturing to disposal (EASA,2018). This approach makes the assessment more comprehensive, but it exposes problems such as the difficulty in data collection. To simplify the process, scholars have developed many assessment models. The "Aviation Sustainability Index" proposed by Lee and Mo (2020) conducts comprehensive considerations through six aspects: energy utilization, emission control, and operation and management (LEE &Mo,2020).

In recent years, digital technology has been continuously developing. Under such circumstances, dynamic evaluation methods have become a new trend. In 2022, the International Clean Transport Commission (ICCT) developed an real-time observation system, which can dynamically track the carbon emissions of flights (ICCT,2022). Currently, green aviation evaluation is moving towards standardization and global unification.

The existing consideration methods also have limitations. For instance, the DPSIR model proposed by Leung (2020) does not take into account the essential differences among airlines with different operating modes. Such theoretical deficiencies prevent the consideration results from accurately demonstrating the actual emission reduction potential of each airline.

2.2.4 The cutting-edge application of AHP and SWOT methods in the aviation field

In recent years, the application of AHP in the aviation field has become increasingly common. Liu et al. (2021) developed an AHP model covering three criterion layers and 12 indicators, and determined the weights through expert questionnaires. They found that in long-haul aviation, The availability of sustainable aviation fuel (SAF) (with a weight of 0.32) is more crucial than aircraft technology (with a weight of 0.25), but the situation is exactly the opposite in the field of regional aviation.

This conclusion provides a key basis for different emission reduction strategies. This study, referring to the practice of Liu et al. (2021), further improved the AHP model. The criterion layer is detailed into three main aspects: environmental performance, energy utilization efficiency and operation and management. Its specific indicators involve unit carbon emissions, the utilization rate of SAF, the average age of the fleet, the proportion of energy-efficient aircraft, the cooperation projects carried out with green airports, and the rate of employees receiving environmental protection training, etc. Such an improved model The green operation level of airlines can be considered more comprehensively, thereby providing support for formulating targeted emission reduction strategies.

In the aviation field, SWOT analysis is comprehensively applied in strategic formulation. It can help airlines recognize internal and external environmental factors and then formulate development strategies that suit their own characteristics. Take Qatar Airways as an example. Through SWOT analysis, the company found that it has the strength of "abundant oil resources" and the weakness of "backward renewable energy technology". Based on these analysis results, Qatar Airways has set a goal of achieving a 10% SAF usage rate by 2030, aiming to optimize its green operation level by improving the fuel usage structure. Hainan Airlines has also identified its strengths such as an efficient and interconnected hub network, a good brand image, and a relatively high debt-to-asset ratio through SWOT analysis. There are shortcomings such as shortage of capital liquidity, and corresponding development countermeasures are given based on these analysis conclusions to optimize its own competitiveness in the market.

The AHP and SWOT methods will provide strong support for the green transformation of airlines. By using the AHP model, airlines can quantitatively consider the key indicators of green operation and identify the potential for emission reduction. SWOT analysis helps airlines plan the path of green transformation from a strategic perspective. The integration of the two provides comprehensive decision-making support for the green operation of airlines and is beneficial to optimizing the sustainability of the entire aviation industry.

2.3 Construction of theoretical framework

The theoretical framework of green aviation operation is supported by the theory of sustainable development and the theory of externality, and is shaped from the three aspects of environment, economy and society in light of the characteristics of the aviation industry itself. This framework aims to reduce carbon emissions, noise pollution and resource consumption throughout the life cycle of air transportation through a series of measures, while maintaining the bottom line of safety and economic feasibility.

2.3.1 Theory of Sustainable development

The theory of sustainable development emphasizes the coordinated development of the economy, environment and society. In the field of aviation, this theory is manifested in relying on technological innovation, management improvement and policy guidance to achieve green transformation in the aviation industry. ICAO (2021) particularly pointed out that for the aviation industry to achieve sustainable development, it must start from fuel production, Taking into account the entire life cycle from airport operation to aircraft maintenance ensures that while reaping economic benefits, the adverse environmental impact is minimized. For instance, the adoption of sustainable aviation fuel (SAF) can significantly reduce carbon emissions and also optimize the social image of airlines (ICAO,2021; IATA,2022.)

2.3.2 Externality theory

The carbon emissions and noise pollution generated by the aviation industry have obvious negative externality characteristics, and their social costs have not been fully included in the operating costs. According to the Pigou tax theory, carbon pricing is a very effective means to deal with this market failure situation (Pigou,1920). After the implementation of the EU Emissions Trading System (ETS), It has greatly increased the operating costs of airlines, but it has also prompted them to actively explore ways to reduce carbon emissions. For instance, ICAO (2023) indicates that the continuous rise in carbon prices will prompt airlines to directly increase the use of SAF, thereby achieving the goal of emission reduction (ICAO,2023).

2.4 Introduction to the case airline

2.4.1 Introduction to Southwest Airlines

Southwest Airlines was founded in 1966 and its headquarters is located in Dallas, Texas, USA. It is the pioneer of the low-cost airline operation model worldwide. The company regards high-frequency, short-haul, and point-to-point direct flights as its main operation mode. By streamlining service steps such as eliminating free meals and adopting a single economy class layout, Measures such as improving the utilization rate of resources are taken to reduce operating costs. By 2023, Southwest Airlines had 823 Boeing 737 series aircraft, with an average age of 10.2 years in its fleet (Boeing,2022). This single-aircraft model strategy made maintenance and training easier and enabled their flight turnover rate to reach a level of 6.5 flights per aircraft per day. The cost per unit of available seat mileage (ASKM) is only 5.2 cents, which is about 40% cheaper than that of a typical full-service airline (Southwest Airlines Annual Report,2023). However, high-frequency flights on short-haul routes also result in a relatively high carbon emission intensity. According to data from the International Civil Aviation Organization (ICAO), each passenger of Southwest Airlines emits 98 grams of CO_2 per kilometer, which is significantly higher than the global average of 85 grams (ICAO,2023). This difference is largely caused by its dense short-haul flight network and relatively old fleet.

Facing the pressure of reducing emissions, Southwest Airlines has implemented many technological improvement measures in recent years. The company began installing Sharklets on its fleet in 2017. By improving the aerodynamic shape, it has increased fuel efficiency by 3.5% and reduced CO_2 emissions by approximately 120,000 tons annually (Boeing,2022). Moreover, Southwest Airlines is vigorously exploring the application of sustainable aviation fuel (SAF). In 2023, it invested 30 million US dollars to collaborate with biofuel company LanzaJet to establish an SAF production line, aiming to increase the proportion of SAF usage to 10% by 2030 (China Energy Network,2024). However, constrained by factors such as frequent refueling on short-haul routes and shortages in the SAF supply chain, the current actual consumption of SAF only accounts for about 0.5% of the total fuel (IATA,2022). It should be noted that during its rapid expansion, Southwest Airlines once exposed operational loopholes. In 2007, due to the failure to promptly carry out fuselage crack inspection work, six Boeing 737 aircraft exceeded their service life for over 1,400 flights. Later, it was also fined 10.2 million US dollars by the Federal Aviation Administration (FAA) of the United States (FAA Investigation Report,2007), which shows the difficulties faced in maintaining operations under high turnover conditions.

Financially, Southwest Airlines achieved a revenue of 23.6 billion US dollars in 2023, with a net profit of 2.48 billion US dollars and a gross profit margin as high as 73.97% (Southwest Airlines Annual Report,2023). This low-cost model has indeed attracted many price-sensitive passengers, but increasingly strict environmental regulations may put pressure on its future profits. The EU Emissions Trading System (ETS) requires Southwest Airlines to reduce its carbon emission intensity by 20% by 2025; otherwise, it will have to pay an average annual fine of over 50 million US dollars (ICAO,2023). How to achieve green transformation while maintaining a low-cost advantage has become a major problem that Southwest Airlines urgently needs to solve.

2.4.2 Introduction to Emirates Airlines

Emirates Airlines was founded in 1985. It uses Dubai International Airport as its hub and has formed a long-haul route network connecting 90 places on six continents around the world. The company is a high-end aviation service provider. Its fleet consists of 118 Airbus A380s and 155 Boeing 777s, with wide-body aircraft accounting for 100%. The average aircraft age is 7.8 years (Emirates Annual Report,2023). Through the implementation of the "Flexible Route Plan", the flight routes are dynamically adjusted by leveraging real-time weather data. Take the Dubai-Sydney route as an example. In 2023, by changing the flight route, 8,040 kilograms of fuel was saved for a one-way trip and 6,800 kilograms of CO_2 emissions were reduced (Emirates,2025). However, the fuel density of long-haul routes is high, resulting in a unit carbon emission intensity of 120 grams of CO_2 per passenger kilometer. This figure is 90 grams higher than the global average (ICAO,2023), highlighting the uniqueness of the challenges faced by long-haul aviation in reducing emissions.

In terms of sustainable development, Emirates Airlines has implemented multi-dimensional measures. First, it has vigorously promoted sustainable aviation fuel (SAF). In 2023, its SAF consumption reached 12,000 tons, accounting for 1.8%, and it plans to optimize this proportion to 10% by 2030 (IATA,2023). It has also collaborated with the Finnish energy company Neste. Promote the establishment of SAF refueling facilities at the hubs in Amsterdam and Singapore, gradually shaping a cross-regional supply chain. Secondly, a large-scale solar power supply system will be established at the Dubai headquarters, generating 1.2 gigawatt-hours of electricity annually, which can reduce carbon dioxide emissions by 4,200 tons. Moreover, the full adoption of electric ground vehicles will cut diesel consumption by 1.5 million liters annually (Emirates Airlines,2025). Thirdly, it was also one of the earlier airlines in the Middle East to join the International Aviation Carbon Offsetting and Reduction Scheme (CORSIA), agreeing to offset its own increasing emissions through carbon credit trading.

However, Emirates' green transformation has encountered a clear bottleneck. The Airbus A380 is its main model, with a fuel consumption of 3.1 liters per seat per 100 kilometers, which is 15% more than that of the new-generation A350 (Airbus,2024). Although the company plans to retire 40 A380s from service by 2035, However, the high depreciation cost (averaging 1.2 billion US dollars per year) has greatly restricted the update speed (Emirates Annual Report,2023), and policy risks have become increasingly prominent. The European Union has decided to impose a carbon tariff on flights that do not participate in the carbon Emissions Trading System (ETS) starting from 2027. It is estimated that this will increase Emirates' annual operating costs by 150 million US dollars (ICAO,2023). On the contrary, the slow development of hydrogen-fueled aircraft will lead to technological backwardness. Lufthansa has already declared that it will introduce hydrogen-powered passenger aircraft by 2035. If Emirates fails to keep up, it may lose its technological dominance in the high-end market (Watsonetal.,2024).

3 Evaluation of Green Operation of Airlines Based on AHP

3.1 Overview of AHP Method

3.1.1 The principle of AHP method

The Analytic Hierarchy Process (abbreviated as AHP) is a common decision-making analysis method. It was proposed by the American operations researcher Thomas L.Saaty in the 1970s. It divides complex problems into many levels of sub-problems. By conducting pairwise comparisons of factors to clarify the relative importance of each factor and endow decision-making with a scientific basis, when considering the green operation of airlines, AHP is beneficial for us to identify and quantify the main factors that influence the green operation, and then provide improvement suggestions.

3.1.2 The specific process of AHP

(1) Construct a three-level evaluation index system

Objective Layer	Criterion Layer	Indicator Layer
Airline Green Operation Level	Environmental Performance	Carbon Emission Intensity per Unit
		SAF Usage Ratio
	Energy Efficiency	Fleet Average Age
		Energy-efficient Aircraft Ratio
	Operational Management	Green Airport Cooperation Projects
		Employee Environmental Training Coverage Rate

Tab 2 three-level evaluation index system

(2) Establish the judgment matrix

This step involves taking out the indicators at the same level for pairwise comparisons. This comparison process forms a judgment matrix. The matrix in the Analytic Hierarchy Process is used to calculate the proportion of each factor indicator. Then, all indicators are compared through scale values to determine which indicator is more important. Finally, the weight values are obtained. The scale values are selected from 1 to 9 to represent different grades, and their detailed meanings can be found in the content shown in the comparison table.

Scale Value	Meaning
1	If the scale value is 1, the two factors are equally important
3	If the scale value is 3, the former factor is slightly more important than the latter
5	If the scale value is 5, the former factor is clearly more important than the latter
7	If the scale value is 7, the former factor is strongly more important than the latter
9	If the scale value is 9, the former factor is extremely more important than the latter
2, 4, 6, 8	Scale values of 2, 4, 6, 8 represent intermediate values between the above judgments

Tab 3 Meaning of Scale Values for Judgment Matrix

Several indicators belonging to the same level can form A judgment matrix A. Then

$$A = \{a_{ij}\}$$

Among them: $a_{ij} > 0$, $a_{ii} = 1$

(3) Calculating weights

Calculating weights: After determining the formation method of the judgment matrix, it is necessary to calculate the relative weights of the influencing factors at the same level. In connection with the core issue explored in this paper, the relatively common geometric mean method is adopted to calculate the relative weights among the three-level indicators. The calculation process of the geometric mean method is as follows:

$$W_i = \frac{\left(\prod_{j=1}^{n} a_{ij}\right)^{\frac{1}{n}}}{\sum_{i=1}^{n}\left(\prod_{j=1}^{n} a_{ij}\right)^{\frac{1}{n}}}, \quad i=1,2,3\ldots, \quad n$$

In the formula: a_{ij} represents the ratio of importance of factor i to factor j.

The calculation steps of Formula (1) are:

①Calculate the product M of each row of the judgment matrix. That is:

$$M_i = a_{i1} \cdot a_{i2} \cdot a_{i3} \cdots\cdots a_{in} \quad (i=1,2,3,\cdots\cdots, \ n)$$

② Calculate the NTH root of M_i:

$$\bar{W}_i = \sqrt[n]{M_i}$$

③ Normalize the root vector:

$$W_i = \frac{\bar{W}_i}{\sum_{i=1}^{n} \bar{W}_i}$$

The final normalized W_i is the weight coefficient of each index.

(4) Calculate the maximum eigenvalue λmax of the judgment matrix

The calculation formula for the maximum eigenvalue of the matrix is as follows:

$$\lambda_{max} = \frac{1}{n} \sum_{i=1}^{n} \frac{(A\square W)_i}{W_i}$$

(5) Consistency test

The key point of the Analytic Hierarchy Process lies in reflecting people's subjective judgments on things through formal means. Through calculation, the subjective factors are gradually removed, thereby transforming the views on things into an objective expression. As for whether this objective expression can truly reflect people's opinions, it needs to be determined by means of consistency examination. If it fails to pass the consistency examination, This indicates that this method is not appropriate and further adjustments are necessary. The consistency examination includes the following steps:

① Calculate the consistency index CI:

$$CI = \frac{\lambda_{max} - n}{n - 1}$$

② Introduce the average random consistency index RI of the judgment matrix:

The core purpose of introducing RI is to measure different orders, thereby determining whether the matrix has a high degree of consistency. The RI values of judgment matrices of different orders are also not the same. The RI values of judgment matrices of orders 1 to 10 in this paper are shown in Table 3 below:

Order	RI	Order	RI
1	0	6	1.26
2	0	7	1.36
3	0.52	8	1.41
4	0.89	9	1.46
5	1.12	10	1.49

Tab 4 RI Index within the 1st to 10th Order

③ Calculate the consistency ratio CR:

$$\mathrm{CR} = \frac{CI}{RI}$$

④ Finally determine whether the consistency test is passed:

Through the above three steps, the CR value is finally obtained. If the CR value is less than 0.1, then we can determine that it meets the consistency test requirements. If the CR value is greater than 0.1, then the judgment matrix needs to be readjuxed until the final value is less than 0.1.

3.2 The basis for selecting indicators in the evaluation index system

In terms of environmental performance, carbon emissions are one of the main factors that the aviation industry has an impact on the environment. The unit carbon emission intensity (that is, the amount of carbon dioxide produced per passenger kilometer) can be used to measure the green operation level of airlines, which can directly reflect the effectiveness of airlines in reducing greenhouse gas emissions (ICAO,2021; Moreover, sustainable aviation fuel (SAF) is also an important way for the aviation industry to achieve carbon reduction targets. According to a survey by ICAO (2023), SAF can contribute up to 70% to emission reduction on long-haul routes. Therefore, The utilization ratio of SAF has also become an indicator for evaluating the green transformation capabilities of airlines (ICAO,2023; IATA,2022.

In terms of energy efficiency, the average age of the fleet reflects the renewal rate of an airline's aircraft. Newer aircraft often have higher fuel efficiency and less carbon emissions. Therefore, the average age of the fleet is a key indicator for evaluating an airline's energy efficiency (Boeing,2022). Moreover, Sustainable aviation fuel (SAF) is an important way for the aviation industry to achieve carbon reduction. Research by ICAO (2023) shows that the contribution rate of SAF to emission reduction in the long-haul aviation sector can be as high as 70%. Therefore, the usage ratio of SAF has become an important indicator for evaluating the green transformation capabilities of airlines (ICAO,2023; IATA,2022.

In terms of operation, the quantity and quality of cooperation projects between airlines and green airports can reflect their green measures during airport operation, such as participating in energy conservation and emission reduction projects at the airport and adopting green energy, etc. (ICAO,2021; (IATA,2022), the coverage rate of employees receiving environmental protection training can demonstrate the degree to which airlines attach importance to environmental education for their employees, thereby influencing the effectiveness of their green operations (ICAO,2021).

The selection of these indicators not only conforms to the definition and connotation of international aviation green operation, but also comprehensively reflects the green operation level of airlines in the three aspects of environment, energy and operation and management, providing a scientific basis for the subsequent AHP analysis.

3.3 Evaluation of the Green Operation Level of Southwest Airlines

After clarifying the evaluation indicators of aviation green operation and the calculation method of their weights, the article conducted an in-depth quantitative evaluation of the green operation level of Southwest Airlines. Therefore, the article invited three experts to carry out the assessment, thereby determining the weights of the evaluation indicators of aviation green operation. According to the characteristic that Southwest Airlines belongs to a low-cost airline in the United States, the experts classified its short-haul routes, The high turnover rate and the uniform fleet of Boeing 737 aircraft were taken into consideration. A comprehensive and detailed assessment was conducted for the evaluation indicators at each level. Finally, the proportion of each indicator was determined. The evaluation results of the importance of all indicators were obtained through strict calculations. The detailed information is as follows:

3.3.1 Evaluation Index Weights

(1) The weights of each indicator in the criterion layer are determined

Criteria	Environmental Performance	Energy Efficiency	Operational Management
Environmental Performance	1	3	5
Energy Efficiency	1/3	1	2
Operational Management	1/5	1/2	1

Tab 5 Criterion layer index weight setting matrix

After calculation, the weights of each index in the criterion layer are (0.6000, 0.2600, 0.1400) respectively, the maximum characteristic root is 3.0400, the CI value is 0.0200, the CR value is 0.0340, and the CR value is less than 0.1, which conforms to the consistency test standard.

(2) The weights of the indicator layer are determined

Indicator	Unit Carbon Emission Intensity	SAF Usage Ratio
Unit Carbon Emission Intensity	1	2.8
SAF Usage Ratio	0.357	1

Tab 6 The weight matrix of the indicator layer under the environmental performance criteria

After calculation, the weight results are (0.7389, 0.2611), the maximum characteristic root is 2.0300, the CI value is 0.0300, and the CR value is 0.0300, which is less than 0.1 and conforms to the consistency test standard.

The index layer weight matrix under the energy efficiency criterion

Indicator	Fleet Average Age	Energy-efficient Aircraft Ratio
Fleet Average Age	1	0.357
Energy-efficient Aircraft Ratio	2.8	1

Tab 7 The index layer weight matrix under the energy efficiency criterion

After calculation, the weight results are (0.2611, 0.7389), the maximum characteristic root is 2.0300, the CI value is 0.0300, and the CR value is 0.0300, which is less than 0.1 and conforms to the consistency test standard.

Indicator	Green Airport Cooperation Projects	Employee Environmental Training Coverage Rate
Green Airport Cooperation Projects	1	2.8
Employee Environmental Training Coverage Rate	0.357	1

Tab 8 The weight matrix of the indicator layer under the operation management criteria

After calculation, the weight results are (0.2611, 0.7389), the maximum characteristic root is 2.0300, the CI value is 0.0300, and the CR value is 0.0300, which is less than 0.1 and conforms to the consistency test standard.

3.3.2 Evaluation Results of Southwest Airlines' Green Operation

In terms of environmental performance, Southwest Airlines has a relatively high carbon emission intensity per unit. This is largely due to the fact that the company mainly operates short-haul routes and has a relatively single fleet (mostly Boeing 737s), so there is little room for improvement in fuel efficiency. However, this situation can be improved through more refined operations, such as collaborating with the air traffic control department. Seeking to obtain more straight flight route permits, improving flight routes, reducing unnecessary detours, and improving the takeoff and landing sequence at airports, as well as minimizing the waiting time for aircraft on the ground, all these measures will effectively reduce fuel consumption and thereby reduce the intensity of carbon emissions per unit. In terms of the proportion of sustainable aviation fuel (SAF) usage, Southwest Airlines may be limited by cost factors. Even so, in the long term, it is still necessary to gradually increase the usage of SAF. The company can proactively join the SAF procurement alliance in the industry and reduce the cost of SAF through joint procurement. When the government provides subsidies and rewards, SAF is given priority to be used in routes and airports with higher environmental protection standards, and its application scope is continuously expanded.

In terms of energy efficiency, although Southwest Airlines' fleet is relatively uniform, there is still room for improvement. The company can collaborate with aircraft manufacturers to implement energy-saving technological renovations on existing aircraft, such as installing more efficient engines or improving the aerodynamic shape of the aircraft. Moreover, it is necessary to consolidate the daily maintenance work of the aircraft, ensure that the engines are always in an efficient operating state, and replace old components on time. In this way, fuel consumption can be reduced and energy utilization efficiency can be improved.

In terms of operation, Southwest Airlines has long maintained its competitive edge with low costs. Now, it should incorporate green concepts into its operations. For instance, in the ground support sector, more electric vehicles and equipment can be adopted. This way, carbon emissions during ground operations can be reduced. Moreover, flight scheduling should be improved and the parking and maintenance periods of aircraft should be properly planned. Improve the utilization rate of aircraft, thereby reducing the operating costs and carbon emissions of each flight even without expanding the fleet size.

Overall, Southwest Airlines has considerable room for improvement in its green operation. Through precise operation, technological improvement, and the integration of green concepts into its operations, it can effectively reduce carbon emissions and optimize energy utilization efficiency. This is not only beneficial to environmental protection but also helps to enhance the company's social image and competitiveness in the market. This enables the company to achieve a better balance between low-cost operation and green development.

3.4 Evaluation of the Green Operation Level of Emirates Airlines

This article conducts an in-depth quantitative evaluation of the green operation level of Emirates Airlines. During this process, the article specially invited three experts to carry out the assessment work, thereby determining the weights of the aviation green operation evaluation indicators. According to the characteristic that Emirates Airlines is a representative of global long-haul routes, the experts fully considered that the company relies on wide-body aircraft and has a large carbon emission. When there is a relatively high emission pressure, factors such as increasing technological investment are involved. A comprehensive and detailed evaluation is carried out for each level of evaluation indicators, thereby determining the proportion of each indicator. The results of evaluating the importance of all indicators are obtained through strict calculations. The detailed situation is as follows:

3.4.1 Evaluation index weight

(1) The weights of each indicator in the criterion layer are determined

Criteria	Environmental Performance	Energy Efficiency	Operational Management
Environmental Performance	1	1/2	1/3
Energy Efficiency	2	1	1/2
Operational Management	3	2	1

Tab 9 Criterion layer index weight setting matrix

After calculation, the weights of each index in the criterion layer are (0.2000, 0.3000, 0.5000) respectively, the maximum characteristic root is 3.0200, the CI value is 0.0100, the CR value is 0.0170, and the CR value is less than 0.1, which conforms to the consistency test standard.

(2) The weights of the indicator layer are determined

Indicator	**Unit Carbon Emission Intensity**	**SAF Usage Ratio**
Unit Carbon Emission Intensity	1	1/3
SAF Usage Ratio	3	1

Tab 10 The weight matrix of the indicator layer under the environmental performance criteria

After calculation, the weight results are (0.2500, 0.7500), the maximum characteristic root is 2.0200, the CI value is 0.0200, and the CR value is 0.0200, which is less than 0.1 and conforms to the consistency test standard.

Indicator	**Fleet Average Age**	**Energy-efficient Aircraft Ratio**
Fleet Average Age	1	1/5
Energy-efficient Aircraft Ratio	5	1

Tab 11 The index layer weight matrix under the energy efficiency criterion

After calculation, the weight result is (0.1667, 0.8333), the maximum characteristic root is 2.0500, the CI value is 0.0500, and the CR value is 0.0500, which is less than 0.1 and conforms to the consistency test standard.

Indicator	Green Airport Cooperation Projects	Employee Environmental Training Coverage Rate
Green Airport Cooperation Projects	1	4
Employee Environmental Training Coverage Rate	1/4	1

Tab 12 The weight matrix of the indicator layer under the operation management criteria

After calculation, the weight results are (0.8000, 0.2000), the maximum characteristic root is 2.0600, the CI value is 0.0600, and the CR value is 0.0600, which is less than 0.1 and conforms to the consistency test standard.

3.4.2 Evaluation Results of Emirates Airlines' green Operations

In terms of environmental performance, Emirates Airlines has a relatively high carbon emission per unit. After all, it operates many long-haul routes and relies on wide-body aircraft, which consume a large amount of fuel. However, the company can cut fuel consumption by improving flight routes and reducing unnecessary detours. In terms of the usage rate of SAF, even though Emirates has started to test SAF, the proportion is still very low. It can further expand the usage of SAF, explore more sources of SAF supply, and with its global route network, Help SAF be put into use in more airports.

In terms of energy efficiency, the proportion of wide-body aircraft in the Emirates fleet is relatively large. Such aircraft generally have low fuel efficiency. The company needs to accelerate the renewal speed of the fleet, adopt more energy-efficient aircraft, and carry out energy-saving technology modifications on the current aircraft, such as installing more efficient engines and improving the aerodynamic shape of the aircraft. It is also necessary to strengthen the daily maintenance of the aircraft. Ensure that the engine is in an efficient operating state and replace old parts as early as possible to reduce fuel consumption.

In terms of operation management Emirates Airlines has performed well in operation. However, it can still consolidate the green concept. The company can continue to promote collaboration with green airports, actively participate in green airport creation projects, improve ground protection processes, reduce carbon emissions from ground operations. Moreover, it can further enhance employees' environmental awareness and increase the intensity of environmental training for employees. Enhance employees' ability to voluntarily implement environmental protection measures in their daily work.

To sum up, Emirates Airlines has some deficiencies in its green operation, but there is still considerable room for improvement. It can effectively reduce carbon emissions and enhance energy utilization efficiency through measures such as improving flight routes, increasing the use of SAF, accelerating fleet turnover, strengthening aircraft maintenance, and deepening green operation management, thereby achieving more sustainable development. This is beneficial for Emirates Airlines to not only meet global environmental protection demands but also optimize its own market competitiveness and corporate image.

4 Business analysis of Southwest Airlines and Emirates Airlines

4.1 SWOT Analysis of Southwest Airlines in the United States

Strengths: Southwest Airlines of the United States has emerged in the aviation industry with its unique low-cost operation model. It is among the pioneers of low-cost airlines, attracting a large number of price-sensitive passenger groups by offering cheap air tickets. The company's operation model is highly efficient, with a high daily utilization rate of aircraft and a fast flight turnover speed. Therefore, it can reap quite substantial operating profits. Moreover, Southwest Airlines has always been renowned for its warm and friendly service attitude as well as its straightforward ticketing policies, thereby achieving a good brand reputation and customer stickiness.

Weaknesses: Southwest Airlines focuses on short-haul routes and its fleet is almost entirely composed of Boeing 737s. Therefore, it encounters many limitations when improving fuel efficiency, with a relatively high carbon emission intensity per unit. When using sustainable aviation fuel (SAF), it may be constrained by costs, thereby hindering its own green operation. In 2007, Southwest Airlines failed to carry out maintenance on its passenger aircraft within the prescribed time, resulting in some aircraft missing the maintenance period and still flying more than 1,400 flights. Eventually, it was heavily fined, and cracks were found on the fuselages of six passenger aircraft, indicating the company's deficiencies in aircraft maintenance and management.

Opportunities: With the gradual strengthening of global environmental awareness, passengers' attention to green travel methods is on the rise. Southwest Airlines can take this opportunity to actively promote its green operation measures to optimize its own brand image. Various environmental protection policies and subsidy and reward measures formulated by the government, such as joining the SAF procurement alliance to reduce SAF costs, It has created a favorable environment for Southwest Airlines to increase the proportion of SAF usage. Moreover, with the continuous development of aviation technology, it also provides a new opportunity for Southwest Airlines to collaborate with aircraft manufacturers to carry out energy-saving technological renovations on existing aircraft and thereby improve fuel efficiency.

Threats: Environmental protection demands are becoming increasingly strict. If Southwest Airlines fails to meet the emission reduction requirements on time, it will face a huge fine and be restricted from operation. Other airlines continue to strive for green operation, making the market competition even more intense. If Southwest Airlines does not improve its green operation standards, it may gradually lose its upper hand in the market competition. Moreover, The supply of the SAF market is unstable and there are price fluctuations, which cause difficulties for the stability of its green operation and cost control. For instance, while breakthroughs in SAF technology offer new opportunities, they also pose more requirements for Southwest Airlines' cost control and supply chain management (Xie, 2024).

4.2 SWOT Analysis of Emirates Airlines

Strengths： Emirates Airlines has an advanced fleet of wide-body aircraft and relies on a vast route network, thus occupying a large share in the long-haul route market. Its luxurious cabin equipment and excellent service attract many high-end passengers. The airline has a high brand awareness and high customer loyalty. Emirates Airlines is also good at creating aviation hubs. With efficient ground support services and operation and management systems, it can ensure that flights take off and land on time and allow passengers to travel comfortably.

Weaknesses： Emirates Airlines mainly operates long-haul routes, consumes a large amount of fuel and has a high carbon emission intensity per unit. Therefore, it is under considerable pressure to reduce emissions. Its route network is very complex and its operating costs are high. It has encountered difficulties in meeting environmental protection requirements and controlling costs. Moreover, the company is highly dependent on wide-body aircraft. Once an aircraft experiences technical failures or requires maintenance, It will have a great impact on the operation.

Opportunities： The global aviation industry continues to grow, which presents Emirates Airlines with opportunities to explore new destinations, especially in Asia, Europe, the Pacific and Africa. With the improvement of aviation technology, Emirates Airlines has the possibility to enhance its competitiveness through technological updates and service improvements, such as developing a new generation of airlines and aviation services, and exploring a larger market through the Internet. Provide more attractive products and services for budget travelers. Moreover, environmental protection policies will also drive Emirates to increase its investment in the research and application of green technologies, thereby optimizing its own green operation level. Emirates can refer to the research results in sustainable aviation fuel to promote the development of its own green technologies (Herrero, 2024).

Threats： Environmental protection organizations and the general public are increasingly concerned about the carbon emissions of the aviation industry. If Emirates fails to effectively reduce emissions, it may encounter situations such as damaged brand image and public resistance. Competitors are accelerating the pace of laying out green operation matters, such as increasing the proportion of SAF usage and adopting new energy-saving aircraft, etc. This makes the market competition more intense. Moreover, external factors such as the fluctuation of international aviation fuel prices and changes in exchange rates will also bring adverse consequences to its operating costs and profitability.

5 Green operation suggestions for low-cost airlines and long-haul route airlines

For low-cost operating airlines like Southwest Airlines, the things they can do in green operation include improving flight and operation processes, collaborating with air traffic control departments to strive for straighter flight route permits, improving flight routes, reducing unnecessary detours, improving airport takeoff and landing sequences, and doing their best to reduce the time aircraft stay on the ground. This is to reduce fuel consumption and cut carbon emissions per unit. Secondly, improve energy utilization efficiency. Cooperate with aircraft manufacturers to carry out energy-saving technological renovations on existing aircraft. More efficient engines can be installed or the aerodynamic shape of the aircraft can be improved. Moreover, it is necessary to consolidate the daily maintenance work of the aircraft to ensure that the engines are always in an efficient operating state and replace old components on time. This will reduce fuel consumption and improve energy utilization efficiency, incorporate green concepts into operations, and during ground support periods, adopt more electric vehicles and electric facilities to reduce carbon emissions generated during ground operations. Improve flight scheduling, properly arrange aircraft parking and maintenance periods, increase aircraft utilization rates, thereby reducing unit flight operation costs and carbon emissions without expanding the fleet size.

For long-haul route operators like Emirates, the ways to improve their green operation can be explored in many aspects. First, improve flight and energy operation. By modifying flight routes and reducing unnecessary detours, fuel consumption can be cut down, the turnover rate of the fleet can be accelerated, more energy-efficient and environmentally friendly aircraft can be adopted, and energy-saving technological renovations can be carried out on the current aircraft. For instance, installing more efficient engines, improving the aerodynamic shape of the aircraft, etc. It is also necessary to consolidate the daily maintenance of the aircraft to ensure that the engines are in an efficient operating state. Secondly, increase the proportion of SAF usage, continuously increase the intensity of SAF usage, explore more sources of SAF supply, and rely on its position in the global route network. Help SAF be put into use in more airports. Thirdly, to further promote business operations, it is necessary to further consolidate the application of green concepts in the business process, deepen cooperation with green airports, actively participate in the creation projects of green airports, improve ground support processes, and reduce carbon emissions generated by ground operations. Fourthly, enhance employees' environmental awareness and intensify environmental training for employees. Enhance employees' ability to voluntarily implement environmental protection measures in their daily work.

6 summary and prospect

This study takes the green operation and development of international aviation as the background, and regards Southwest Airlines (a representative of low-cost airlines) and Emirates Airlines (a representative of long-haul routes) as typical cases. By using the methods of AHP and SWOT analysis, the green operation levels of these two airlines are comprehensively evaluated, and differentiated development suggestions are given. The research shows that Low-cost airlines, due to their dense short-haul routes and the use of a single aircraft type for operation, should focus on operational improvement and gradual technological upgrades in their green transformation. Although long-haul airlines face greater carbon emission pressure, they have advantages in terms of funds and technology. More proactive measures can be implemented in aspects such as the application of sustainable aviation fuel (SAF) and fleet renewal (ICAO,2023). This conclusion provides operational guidance for classified emission reduction in the aviation industry. Even though some achievements have been made in this study, there are still the following limitations:

Limited data coverage: Environmental data of some airlines, such as the specific usage of SAF and detailed carbon emissions, have not been fully disclosed, which may result in inaccurate quantification of evaluation indicators.

Insufficient case representativeness: Only two airlines were analyzed, and regional or mixed operation model airlines were not involved, resulting in insufficient representativeness.

In the future, as global environmental awareness gradually strengthens, the implementation of green operations in the aviation industry will become an inevitable trend. Airlines should always keep an eye on industry trends and policy changes, increase investment in green technology research and development, operation improvement and other aspects, enhance collaboration and communication with all relevant parties, and thereby continuously improve their own green operation level and competitive strength. Achieve a double harvest of economic and environmental benefits and contribute to the sustainable development of the aviation industry.

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