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Integrated Environmental Assessment of Aviation Activities in the Kingdom of Bahrain

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ABSTRACT

The growing air transport industry is under pressure to identify strategies for greenhouse gas (GHGs) emission reduction, specifically CO_2, by incorporating sustainable and carbon-neutral operations. This study follows an Integrated Environmental Assessment (IEA) methodology through the Driver-Pressure-State-Impact-Response (DPSIR) framework and policy analysis to evaluate the relationship between aviation-related activities and carbon emissions. It also suggests future policy pathways to achieve a sustainable scenario. The study area is the Kingdom of Bahrain, a Small Island Developing State (SIDS) in the Arabian Gulf region. The findings reveal that aviation activities and related ground operations have increased in recent years, resulting in a 7% annual increase in emissions since 2013 and a 4.88% projected increase for the coming years by 2030. In addition, Bahrain's location and its economic developments have been the main factors influencing aviation emissions. The average growing population rate of 2.7% has put an additional demand on the air transport system to expand its infrastructure, increase aircraft fleets, and upgrade facilities. The study uniquely identified a lack of distinct institutional mechanisms and a requirement for legislative standardization at both national and industrial levels. Through policy analysis, Bahrain's national policies and industry-level policies are mostly regulatory instruments, with varying degrees of effectiveness. It also recommends that research gaps in local aviation impacts be technically filled to assist Bahrain in achieving its 2060 goal of Net Zero emissions.

1. INTRODUCTION

Climate change issues have prompted increased demands in the aviation sector to cut its carbon footprint. The aviation sector emits around 5% of overall emissions, a number likely to grow over the next few decades [1]. While there have been numerous studies on global aviation emissions, there have been limited integrated environmental studies for Small Island Developing States (SIDS) such as those in the Arabian Gulf region of Bahrain. This paper fills this vacuum by assessing Bahrain's aviation-associated emissions through the DPSIR approach, determining primary drivers, pressures, and policy responses that have an impact on emissions in the peculiar socio-economic environment.

Concerns over climate change and global warming have intensively pressurized industries to find ways to considerably reduce GHGs emissions, such as adopting sustainable, and carbon-neutral development practices [2]. The growth in the air transport industry has resulted in a parallel increase in emissions. The industry currently accounts for 5% of the world's GHGs emissions, a figure expected to increase significantly in the near future [1, 3]. As the complexities and challenges of lowering emissions increase, there becomes a pressing need to use tools and frameworks to effectively understand and mitigate emissions. Currently, there is a requirement for interdisciplinary research that incorporates policy evaluation in environmental assessments, using frameworks such as the Integrated Environmental Assessments (IEA), based on the Global Environment Outlook (GEO) process of the United Nations Environment Program [4, 5].

Despite attempts to reduce GHG emissions in recent years, emission values are expected to increase due to airline and airport operational expansions that are normally continuous processes [6]. Aviation has brought economic progress through better connectivity and the use of cleaner energies to achieve Net Zero emissions by 2050. However, the industry still requires a clear roadmap to tackle its carbon footprint. There is a need for greater clarity on how airports and airlines record sources of emissions and subsequently mitigate them.

Some might cover only emissions resulting from their direct activities, whereas others include emissions across their value chains and the life cycle of their aircraft and equipment [2, 7]. Global aviation has been, for many years, an efficient mode of transport, witnessing more dynamic changes than any other mode of transport. It has supported the trade and connectivity of Bahrain, being an island strategically positioned between the East and West. With a population exceeding 1.7 million with an annual population growth rate of 2.7%, the country saw great reliance on air transport [8]. The industry is currently contributing considerably to economic growth, which evolved and expanded to cater to a growing demand for its services [9]. Advancements in aircraft and equipment technology have also been a driving force, where noticeable positive contributions towards greener and more sustainable aviation were seen. Gulf Air, the national carrier of Bahrain, has invested in new aircraft technologies that are 75% more fuel-efficient, noise-reducing, and soot-eliminating. Similarly, airport ground operators have also invested in electric GSE, reducing ground-level emissions and noise [10].

A critical aspect of understanding aviation emissions and mitigating their impacts is to fully identify the pressures from human activities and their implications on the environment. Through the DPSIR framework, it is possible to analyze the state of the environment as it is affected by natural forces, human activities, and policies [11]. This study focuses on the interaction between aviation activities and emissions, being assessed through the DPSIR framework, as part of a holistic IEA that helps link environmental issues to social and economic goals of the country. It focuses on the driving forces and pressures of aviation activities and the resulting impacts to analyze the responses and propose avenues for future scenarios and policies.

Although various studies on aviation emissions in the world exist, there is a clear shortage of combined environmental studies for SIDS such as Bahrain, which experience special geographical, economic, and policy circumstances. The management of emissions in SIDS remains under-researched, particularly in area such as the Arabian Gulf, where it experiences fast economic development and infrastructural growth [1, 2].

In Bahrain, poor air quality associated with airport activities has been identified as a cause of respiratory diseases, impacting both residents and employees around the airport, highlighting the necessity to conduct a comprehensive environmental study of aviation activities [12, 13]. Furthermore, local studies have indicated that aviation industry growth is a major contributor to the country's CO_2 emissions, impacting both urban and rural residents [8, 14].

2. MATERIALS AND METHODS

2.1 Study area

Bahrain is SIDS strategically located in the Arabian Gulf and, for many years, has positioned itself on the map of global aviation [15]. With almost 9.5 million passengers using Bahrain International Airport (BIA) annually, the demand for aviation is continually growing, especially after the recent terminal expansion in January 2021 [16]. With the increased demand for air travel and the need to diversify its economy, Bahrain has grown the industry to accommodate this growth and promote its strategic position as a regional hub. The airport, a Leadership in Energy & Environmental Design (LEED) Gold certified building, is operated by Bahrain Airport Company (BAC), supported by air navigation and meteorology services, and encouraged to attract investment and employment opportunities, aimed at increasing the contribution of the aviation sector to the economy [9].

2.2 IEA methodology and data

The study follows the IEA methodology [17], based on Global Environment Outlook (GEO) processes of the United Nations Environment Program (UNEP), specifically GEO-6 [4] and GEO-7 [5] It has been used to assess environmental impacts of aviation activities in Bahrain using:

- DPSIR framework
- Policy analysis of existing laws, strategies, programs, initiatives, etc.
- Scenario development and analysis
- Policy option for sustainable aviation activities

Although secondary data provided by the World Bank [18] International Civil Aviation Organization (ICAO) [19] and Bahrain's Ministry of Transport [20] were utilized, inaccuracies are possible due to reporting inconsistency or over time. These sources of data, especially the aviation datasets, may not reflect fluctuations in the aviation sector, such as abrupt changes in air traffic or improvements in operational efficiency that might influence estimates of emissions. There could also be biases in the data, such as non-reporting from smaller aviation operators or variable data on emissions for ground operations. This brings into focus.

The secondary data employed in this study came from credible databases, including the ICAO reports, the World Bank, and national databases offered by Bahrain's Ministry of Transport [20]. The data used spanned the period between 2013 and 2021, aligning with historical trends and forecasts. Emission datasets were cross-checked using global emission standards offered by the Intergovernmental Panel on Climate Change (IPCC). Policy choice relied on a consideration of national and regional reports with a focus on prominent aviation policies from Bahrain, the UAE, and other GCC states.

Although secondary sources of data were utilized to corroborate the analysis, there are intrinsic limitations, such as biases within grey literature and missing links in the emission data sets, especially for ground operations and small operators. Some of the sources lack comprehensive data regarding GSE emissions or may include incomplete data from small aviation companies. To lower such challenges, statistics from credible sources like ICAO and environmental national reports were given preference. Data was also cross-checked wherever possible with other global emission databases to guarantee a better and more representative analysis.

The Driver-Pressure-State-Impact-Response (DPSIR) framework is also best for this study in that it offers a structured approach to connecting the environmental effects of aviation operations to socio-economic drivers. The DPSIR framework is good at capturing the interactions between environmental pressures like air traffic growth, energy demand, and emissions and the response measures available. Unlike other approaches like the Pressure-State-Response (PSR), which addresses mainly pressures and environmental states, the DPSIR framework also captures policy responses, which is an important consideration when analyzing Bahrain's emission reduction strategy. The DPSIR model makes it easier to take a more comprehensive approach in that it can identify crucial drivers as economic growth and increases in population that affect aviation emissions. In addition, it enables the integration of policy analysis to suggest appropriate interventions to reduce aviation's environmental footprint. Considering Bahrain's special status as a small island developing state with high economic growth, the DPSIR framework is particularly apt to examine both the pressures and responses that influence the development of aviation emissions.

Secondary data, including CO_2 emission datasets, annual aircraft movement numbers, fuel uplift, country's GDP figures, and population growth rate, were gathered from official and grey literature sources [18, 21].

The selection of this methodology is based on its documented effectiveness in several studies over the past years. It has excelled over other frameworks in the level of its comprehensiveness, wide applicability, and systemization. The DPSIR framework is easy to follow and has proved to be a strong indexing model for a wide range of sustainability assessments [22-24].

3. RESULTS AND DISCUSSIONS

3.1 Situating aviation emissions in context

Aviation emissions in Bahrain are recorded primarily from international civil aviation activities, including aircraft operations, relevant ground support equipment operations, runway, and taxiway lighting. The current state of aviation emission i.e., the Baseline, is the historic level of fuel consumption, Revenue Ton Kilometers (RTK), CO_2 emissions, and fuel efficiency (in miles per gallon). The Baseline also represents expected future evolution without effective mitigative policy actions. Historical data for the Baseline are shown in Figure 1.

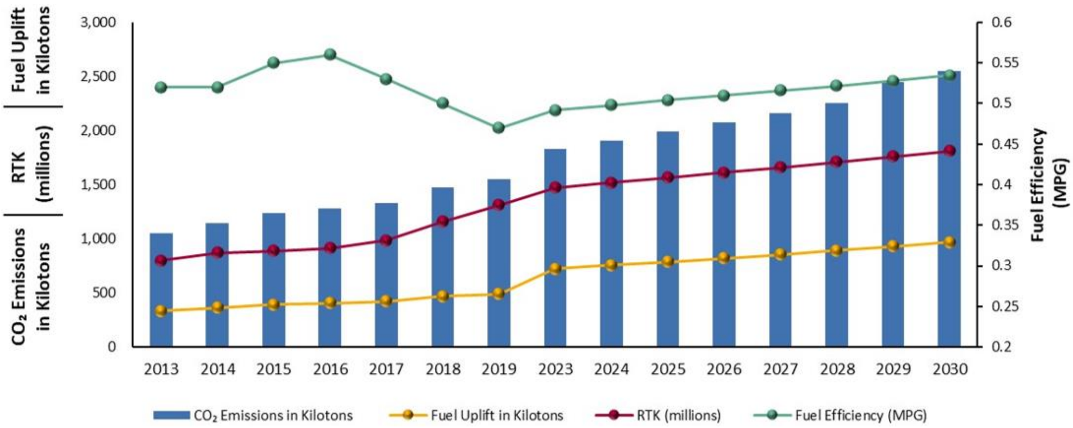

Figure 1. Baseline and projected data for the period 2013-2030 [20]

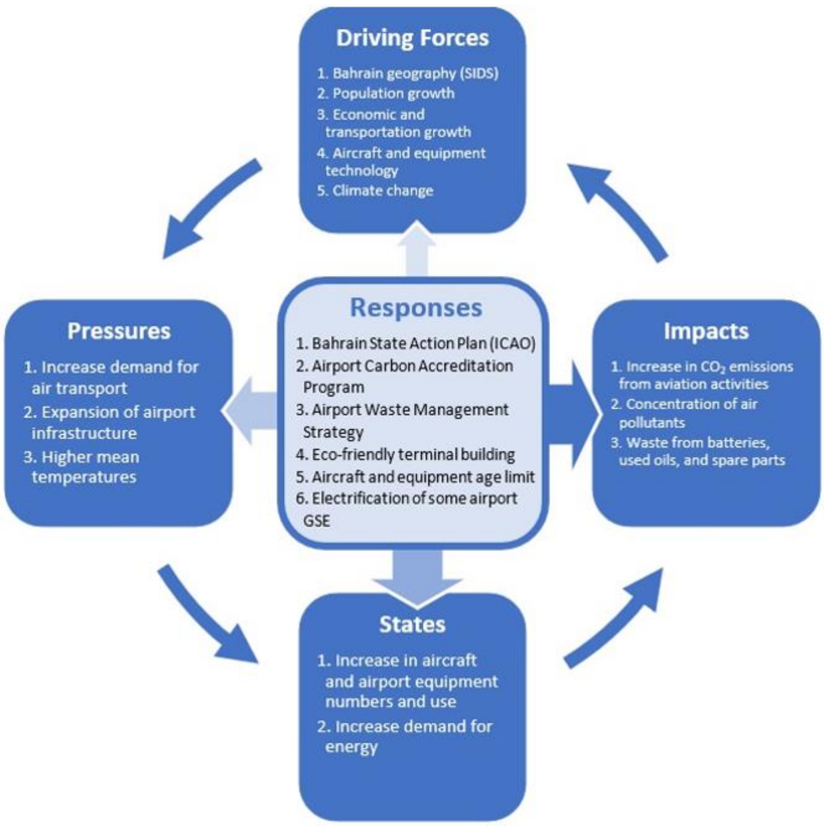

Figure 2. Analysis of aviation emissions in Bahrain using DPSIR framework

As revealed by the figure, Bahrain recorded a growth in emissions over the past years, where total CO_2 emitted from aircraft movement has increased by ~7% annually. This is due to the increased number of flight movements, reflected in the growing need for more fuel, by approximately 6% annually, and the larger capacity to carry revenue generating weight on the aircraft. This is also linked to a steady increase in passenger movements in the past decade, reaching a record pre-COVID-19 level of 9,578,797 passengers in 2019. Despite the sustained growth reflected through the increase in fuel uplift over the years, this issue necessitates real analysis and effective mitigation measures. In a report submitted to the ICAO in 2021, Bahrain has put forward its action plans for reducing aviation emissions and improving fuel efficiency. It has so far achieved an average of 1.2% improvement in fuel efficiency, a relatively close target to the ICAO's ambitious 2% by 2050.

The State Action Plan 2021 therefore aims to provide Bahrain with the ability to encourage cooperation, establish partnerships, and accelerate technology transfer [20].

3.2 The DPSIR approach

A DPSIR analysis was used to organize key information on aviation emissions and review current knowledge on the driving forces, pressures, state, and impacts. A comprehensive literature review has been performed on the responses to the emissions. Several factors influence CO_2 emissions, including the development of technology, demand for aviation, energy structure, Bahrain's economic structure, and population growth [25]. Figure 2 summarizes the DPSIR analysis results and can be used as a supporting scheme for the following discussion.

3.3 Assessment findings

The IPCC has reported the present state of global aviation in the Special Report on Aviation and the Global Atmosphere, where aviation emissions of CO_2 are approximately 2.1% of total anthropogenic GHGs, a figure expected to grow annually within the range of 3-4% [26]. The industry is responsible for 12% of CO_2 emissions from all transport sources, compared to 74% of road transport [27]. In Bahrain, where an increase in energy consumption has occurred, a similar trend is reflected in the local operation of aircraft and airport equipment. Currently, an upward trend in CO_2 emissions is parallel to the current increase in air traffic movements. This is reflected in the 2017-2019 aircraft movement data, which remained at approximately 95,000 total aircraft movements in Bahrain, increasing ~5% since 2013 [20].

The increase in population growth has led to a parallel increase in demand for air travel, coupled with steady economic growth that supported the expansion of the industry through airline subsidies and terminal expansions. In January 2021, BIA began operations in its new terminal and increased the airport's capacity by 50%, with an annual intake of 14 million passengers. It is an integral element of the socioeconomic development of Bahrain and a main contributor to its economy [28]. Therefore, the aviation industry is growing rapidly to meet the requirements of an increased population as pressures on the environment mount. With climate change having increasing effects on the atmosphere, aviation emissions are, among other factors, contributing to sea level rise, higher average global temperatures, and recurring heatwaves of high intensity in Bahrain [13].

The impact of the aviation industry in Bahrain encompasses not only aircraft, but other aviation-related activities such as GSE operations, airport facilities, and ground movement of vehicles within the airport perimeter. The total contribution of CO_2 is recorded to be 1,549,560 tons in 2019, up from 1,476,960 tons in 2018, a 4.9% increase [20]. Currently, CO_2 emissions from air travel range from 24 kg CO_2 per passenger mile for short flights down to 18 kg CO_2 per passenger mile for long flights [29]. The impacts on air quality from various sources, including airport activities, have been presented in a literature report [12]. Dust storms, industrial activities, power plants, vehicular emissions, airport activities and filling stations are major air polluters; with $PM_{2.5}$ being the most significant source of air pollution throughout the country. The Civil Aviation Affairs (CAA) of Bahrain presented to the ICAO, projected CO_2 emissions through the year 2030, using a traffic growth rate (RTK) forecast of 3% for the Middle East Region. This baseline represents the fuel burn that will occur if no mitigation measures are applied. As shown in Figure 1, an upward projection in emissions is therefore estimated where an average annual growth in CO_2 emissions is calculated. A 4.88% increase is projected for the coming years till 2030.

Aviation activities also result in other impacts, such as in aircraft maintenance and ground handling operations. Hazardous waste like oils, electrical and electronic wastes, batteries, etc. have potentially large impacts that are currently being addressed through developing more sustainable environmental practices, waste management, and safe disposal of these wastes by the airport operator [30, 31].

3.4 In-depth analysis of policy effectiveness

3.4.1 Challenges of policies with adverse or non-essential impacts

Bahrain's poor aviation policies efficacy is traceable to several challenges such as poor enforcement, insufficiency in financing, and stakeholder opposition with a vested interest in ensuring continuity in status. As identified by Cosgrove [10], lack of regulatory coverage hampers the environmental implications of the intended policies. Moreover, there is limited regulation of ground operations, e.g., taxiing and maintenance of aircraft that can lead to increased emissions resulting from non-flight activities. For instance, Mizrak and Kızılcan [31] identify the fact that ground support equipment and taxiing routines are mainly disregarded in the emission regulations, thus leading to unnecessary emissions during the non-flight stages. In addition, opposition from aviation stakeholders like airlines and ground operators tends to limit the implementation of stricter emissions regulations, as it is noted by Gössling and Lyle [32], who point out the economic resistance of the stakeholders in implementing low-emission technologies owing to financial considerations.

3.4.2 Comparison to other nations' policies

UAE and Qatar have stronger policy standards on fuel-efficient flying and emissions restrictions. According to Huang et al. [33], the UAE has instituted policies that are centered on increasing the fuel efficiency of airlines and ground operations in airports, such as the implementation of electrically powered ground support equipment and more efficient taxiing protocols. In a similar vein, Qatar's aviation strategies have required the use of more energy-efficient airframes and alternative fuels, which have helped reduce emissions in aviation [34]. Bahrain may learn from these strategies by embracing similar tactics, such as improving fuel efficiency standards and undertaking more investments in sustainable aviation technologies. By comparing itself with these regional powers, Bahrain might be able to enhance its aviation emissions controls and make a better contribution to regional and global sustainability goals.

To put Bahrain's efforts into perspective, it is worth comparing the aviation policies of Bahrain with other GCC nations. The UAE's Aviation Climate Policy and Saudi Arabia's Green Initiative tackle analogous challenges through a similar approach of setting high emissions reduction levels and using clean energy technologies in aviation. The UAE plans to cut carbon emissions through the optimization of fuel efficiency, and Saudi Arabia's Green Initiative has a goal to diversify the sources of energy and minimize the carbon footprint of the aviation industry. The GCC nations have reported a 3% annual rise in aviation emissions, as seen in Bahrain, although some, such as the UAE, have taken more radical policies to curtail carbon output.

3.5 Policy analysis

Policies in Bahrain relating to transport emissions, target the drivers and pressures of the issue that causing an increase in emissions, are summarized in Table 1. Most of these policies are regulatory with varying degrees of effectiveness. Specifically, positive impacts from the Bahrain National Energy Efficiency Action Plan (NEEAP) are noted in articles pertaining to “Vehicle Efficiency Standards and Labelling”, “Transport Subsidy Reform”, and “Institutional Infrastructure”. Other policies, such as Bahrain Law No. 7 related to the 2022 Environment Law, Articles 37, 38, and 99 have yet to achieve similar impacts as they do not include transportation-specific laws targeting the aviation industry [15].

3.6 Stakeholders barrier

Bahrain's aviation stakeholders, such as airlines, airport operators, and government agencies, can resist strict emission reduction policies because of economic reasons. Airlines, for instance, might be reluctant to implement fuel-efficient technologies or carbon taxes if they raise operational expenses. According to Gössling and Lyle [32], resistance can be addressed through public-private partnerships and incentives that align the interests of environmental and economic stakeholders. Behavioral economics predicts that stakeholders will be more inclined to implement sustainable practices if the financial gains, such as reduced fuel expenses and government incentives, are greater than the initial investment expenses.

The airport has adopted several policies to reduce the sector’s emissions. In this regard BIA has installed 13 fixed electrical Ground Power Units (GPU), and pre-conditioned air, allowing aircraft Auxiliary Power Units (APU) to be switched off during turnaround operations, and giving an approximate fuel saving of 2,120 tons/year. The airport has also installed the Advanced Surface Movement Guidance and Control System (A-SMGCS) that helps reduce aircraft idle time [20]. The system provides routing, guidance, and surveillance for the control of aircraft and vehicles, to maintain the declared surface movement rate under all weather conditions within the aerodrome visibility operational level (AVOL) [19].

The airport has also improved its aircraft taxi procedures, as these operations are a significant source of energy consumption and emissions. Moving on the ground (taxiing) is a short segment of a flight, but jet engines are not at their optimal use. One mitigative solution adopted is to taxi with one (or several) engines shut down since one engine provides enough power to move the aircraft on the ground. Currently, BIA has 50% of its arrivals and 10% of departures following this policy [20].

Much like national policies, industry-level policies are mostly regulatory instruments, with varying degrees of effectiveness. This is partly due to individual airline policies namely, at times, limit the implementation of national policies because of conflict of interest. For example, some international airlines flying into BIA do not allow single-engine taxi operations, therefore, restricting full implementation of this policy.

3.7 Mitigation technologies and strategies

Adoption of renewable energy in the aviation sector is becoming an important strategy for cutting emissions. Airports like Cochin International Airport in India and Adelaide Airport in Australia have effectively installed solar power systems, producing a significant level of renewable energy to drive airport operations. For instance, Cochin International Airport has become the first completely solar-powered airport, generating more energy than it uses, substantially lowering its carbon emissions [35]. For Bahrain, the installation of solar energy at BIA has the potential to lower CO_2 emissions by an estimated 15-20%, in comparison with the same rate of adoption across airports around the world [20]. This can be achieved through the installation of solar panels on airport rooftops and the integration of solar energy into terminal operations.

3.8 Outlook

Scenario 1: At current policy and technology levels, aviation emissions will increase by 4.88% each year.

Scenario 2: If Bahrain becomes more stringent on fuel efficiency and converts to biofuels, emissions might stabilize.

Scenario 3: If advanced technologies such as electric or hydrogen-powered planes are used, emissions might decrease by as much as 20% by 2040.

Major stakeholders in the aviation industry of Bahrain are the Ministry of Transport, BIA, Gulf Air, and local communities. The government's concern is mainly achieving economic growth and environmental objectives, while airlines and airports care about profitability. Local communities, particularly those living adjacent to the airport, might agree on tighter emissions controls because they are concerned about their health.

The DPSIR framework has been used to show casual linkages between various factors impacting GHGs emissions from aviation in Bahrain. The airport has invested in infrastructural improvements, and policy adoption, and is committed to sustainability targets to reduce its environmental impacts. Two strategies can be followed to tackle the issue of emissions from aviation: mitigation of CO_2 and adaptation to impacts, both strategies are addressed hereunder.

Mitigation efforts at national and international levels play a crucial role in managing and reducing overall emissions from the aviation sector. The long-term aspirational goal of the ICAO is to continue the improvement rate of 2% in global fuel efficiency between 2021 and 2050 [36]. Moving into the future, ICAO is continuing its efforts in supporting fuel-efficient technologies, cleaner engine technologies, aircraft production using lightweight materials, efficient infrastructure facilities, and promotion of bio- and alternative fuels [34]. So far, the industry has focused on reducing aircraft weight, improving aerodynamics, optimizing aircraft systems, and improving engine fuel efficiency [36]. Research and development are being carried out on further improvements in the design of engines and aircraft aerodynamics through the introduction of innovative wing designs that could potentially reduce GHGs emissions [37].

Locally, Bahrain has presented its mitigation efforts to the ICAO through two pathways, further improvements on existing infrastructure and air traffic management [20].

Infrastructure improvements have been achieved through the new terminal building, whereas the other facilities at the airport will undergo major changes in the coming years. The cargo equipment and maintenance facilities will require upgradation as the airport moves towards greener operations.

The airlines' implementation of best practices in fuel savings and improvement in aircraft-related technologies is expected to reduce environmental impacts [10]. Bahrain expects a significant reduction of aviation emissions by minimizing the projected baseline fuel burn from 1010.85 million liters by 2031 (business-as-usual scenario) to 916.75 million liters by 2031 (with mitigation).

With new standards emerging globally for the emission of CO_2, airports, and airlines are obliged to meet these standards to address issues associated with local air quality. At the same time, within the given political structure, airports, and airlines may have limited interest in policies seeking to curb emissions, as changes in cost will have implications on profitability. This is also true for the aviation sector in Bahrain, as profit margins are small, and the economy is vulnerable to changes in demand. Therefore, policies must be designed with an understanding of the economic and social sensitivities of the country [32]. A transformational approach to policies, technologies, and innovation is required to navigate current challenges and meet goals that enhance and support the aviation industry. It requires a fundamental transformation in both its technology and energy sources to achieve a smooth phase-out in the consumption of fossil fuels. The more ambitious aviation emission reduction targets are, the more rapid the transformation must occur in terms of the targets set. Transformation pathways are governed by choices that dictate to level emissions. These options include, among long-term stabilization objectives, emissions strategy to accomplish the objective, and the technologies to be used to reduce emissions [38]. Therefore, green industrial policies are required to target real transformation of industries such as aviation, with a focus on economic and social issues incumbent to real shifts towards Net Zero [39].

Currently, carbon emission reduction policies, such as carbon tax, cap policy, and cap-and-trade policy, have attracted much attention. The cap policy provides an overall limited cap on carbon emissions, whereas the cap-and-trade policy allows companies to trade a portion of the cap to other companies with high GHGs emissions [40]. Numerous research has analyzed the effectiveness and effect of adopting such policies on various transport systems [41, 42]. The main concerns associated with these policies are their impact on decision-making and companies' economic performance if adopted. Therefore, when formulating national-level policies, the interlink between economic, social, and environmental objectives should be understood and realized to ensure that positive synergies between the three pillars of sustainability are achieved [43, 44].

In the case of Bahrain, various plans and policies are proposed to assist in reducing the impact of aviation activities. An integrated mitigative approach based on the successful existing measures taken by the government, combined with other processes, can pave the way to a sustainable path of green aviation. In its Nationally Determined Contribution (NDC) report, submitted to the United Nations Framework Convention on Climate Change (UNFCCC) in 2021, the country has put forth its mitigation and adaptation plans through various economic diversification strategies with sustainability being the pillar of its growth [45, 46].

Table 1. Bahrain policy instrument scan mix and policy gaps

Instruments	Drivers	Pressures	State	Impact
Description of DPSI	-Population growth -Economic development -Technology -Climate change	-Increase demand for air transport -Consequent airport expansion	-Increase in airport equipment number and use -Energy/fuel use	Increase in CO_2 emissions from aviation fuel use and waste
Increase in CO_2 emissions from aviation activities	ICAO Doc 9889 (Airport Air Quality Manual)-(DE) Bahrain Civil Aviation Law No. 14 (2013) Environmental Protection (In accordance with Annex 16)-(R)	Bahrain National Energy Efficiency Action Plan (NEEAP 2017-2015) Vehicle Efficiency Standards and Labelling+(R) Bahrain National Energy Efficiency Action Plan (NEEAP 2017-2015) Transport Subsidy Reform++(E) Bahrain National Energy Efficiency Action Plan (NEEAP 2017-2015)–Institutional Infrastructure+(I)	Bahrain Law No. 7 related to the 2022 Environment Law (Chapter 17 Article 99)-(R)	Bahrain Law No. 7 related to the 2022 Environment Law (Chapter 2 Article 37 and 38)-(R)

Policy instruments: R = Regulatory, I = Institutional, E = Expenditure, DE = Direct Expenditure
Effectiveness of policy: + = positive, - = negative, 0 = neutral

Policy formulation for Bahrain's aviation industry specifically should aim at achieving low carbon growth of international air transport, for both aircraft and related ground-level operations. This is fundamental and in line with ICAO's Market-Based Measures (MBMs) that avoid hindering aviation operations. It is expected that a global offset of 2.5 billion tons of CO_2 between 2021 and 2035 could be achieved [47]. A combination of policies that include aggressive levels of technological and operations efficiency improvements, use of biofuels along with moderate levels of carbon pricing and short-haul demand shifts achieve a 140% increase in capacity while only increasing emissions by 20% [48].

As a result of this assessment, several policy options to mitigate emissions from aviation are presented. Bahrain strives to achieve its 2060 mitigation targets of Net Zero, through reducing emissions in its economic development. With the support of the aviation sector, policy options are presented under three main pathways: operational efficiency, alternative energy sources, and carbon prices. A multi-level governance is required to determine an optimum policy mix that utilizes a variety of policy instruments. At the writing of this study, none of the few studies exploring Bahrain's CO_2 emission reduction potentials and policies [15, 49] have presented zero-carbon pathways for the aviation industry [50].

3.9 Policies on operational efficiency

Policies following an operational efficiency pathway aim at achieving improvements in airline and airport operations through the promotion of better route planning, reduced weight load on aircraft, and optimization of ground operations such as single-engine taxi operations or using tugs to tow aircraft instead of taxiing. Airport-level policies may promote operational efficiency through benchmarking and setting performance standards. One mechanism is to enhance the policy through airlines incentives for reducing fuel consumption and optimizing routing and fleet operations [33].

3.10 Policies on alternative energies

National-level renewable energy policies have limited adoption, where applications within the aviation industry are in their infancy. Currently, the airport terminal has worked in line with the objectives of the NEEAP but has not explored avenues of alternative and renewable energy sources. For Bahrain, policies directing the adoption of renewable energy generation technologies on-site at the airport can lower the carbon footprint with minimal impact on airport operations, such as the installation of solar panels on rooftops and road lighting [51].

3.11 Policies on carbon pricing

The adoption of carbon pricing policies has been regarded as an effective instrument in reducing demand for fossil fuels [52]. It is estimated that approximately 10% increase in price will reduce demand by 4.8%, allowing for a 12% emissions reduction by 2050 [35]. Carbon pricing through various instruments, such as carbon taxes and others favoring cap-and-trade mechanisms, is an essential element of any national policy that can achieve meaningful reduction of CO_2 emissions. Bahrain may design a policy that reduces complexity and administrative requirements, creates greater interactions with existing policies, and has limited effects on carbon price volatility [14, 53].

4. CONCLUSIONS

The aviation industry plays a pivotal role in facilitating nations' travel, trade, and economic growth. In the past few decades, the industry has witnessed tremendous growth in demand for air travel, causing a parallel increase in GHGs emission from aircraft and related airport operations. This has created a challenge for policymakers to effectively mitigate environmental impacts while striving to meet a profitable demand for such operations. In conducting an IEA on Bahrain, this study has therefore shown that aviation emissions are driven by the location of the country and the economic growth it has witnessed in the past years. With an increasing population, greater pressure is exerted on the air transport system to expand infrastructure and grow its aircraft fleet and airport equipment. National-level policies are currently not aligned with economic and environmental objectives and should therefore be enhanced to ensure positive synergies between the three pillars of sustainability. The assessment has also revealed the absence of different policy instruments and a need for policy streamlining between national and industry levels. Current policies are regulatory in nature, with limited direct expenditure and institutional instruments being used. As a result, a policy analysis is critical to present recommendations of new pathways to help Bahrain meet its 2060 target of Net Zero emissions.

To reach its target of Net Zero emissions by 2060, Bahrain ought to move ahead with carbon pricing policy introduction that incentivizes airlines to save emissions. Also, the government ought to finance renewable energy at airports like solar power to mitigate operational emissions. Future research is to aim for public acceptability of taxation for aviation and feasibility of novel emerging technologies like hydrogen-powered flights that can contribute towards further minimization of Bahrain's aviation industry emissions.

Future studies may investigate the long-term economic effects of carbon-pricing policies on Bahrain's aviation sector and investigate new technologies such as hydrogen-powered planes and their ability to lower emissions in Bahrain's special environment. To reach its Net Zero emissions goal by 2060, Bahrain can make policies with a focus on enhancing operational efficiency, investing in alternative energy, and implementing carbon pricing mechanisms. Furthermore, embracing international best practices and cooperation with regional aviation pioneers can speed up emissions reduction.

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