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Contemporary aspects and Prospects of Pollution-Free Aviation: Concept of Green Skies with Data Analysis

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Abstract

This research paper aims to examine the current state and future of sustainable aviation, electric aviation, and pollution-free aviation. The paper will explore the various technologies and innovations that have been developed to reduce the environmental impact of aviation, including fuel-efficient airplane designs, lightweight materials, and cleaner engines. It will also discuss the potential of electric aviation, which offers a promising alternative to traditional fossil-fueled airplanes. The paper will evaluate the benefits and challenges of these sustainable aviation solutions, and offer recommendations for how the aviation industry can continue to reduce its carbon footprint and minimize its impact on the environment. The findings of this research paper will be of interest to anyone who is invested in

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creating a more sustainable and environmentally friendly aviation sector. .

Keywords: Data Analysis, Sustainable Aviation, Electric Aircraft, Pollution free aviation.

I. INTRODUCTION

Air travel has a significant impact on the modern life, involving people and businesses around the world. However, the environmental impact of air transportation has also become increasingly apparent, as it contributes significantly to global greenhouse gas emissions and other forms of pollution. In response to this challenge, the aviation industry has been working to develop more sustainable and environmentally friendly solutions, including pollution-less airway transportation. This new approach to air transportation involves the use of technologies and innovations that minimize or eliminate the environmental impact of air travel, such as electric aviation and biofuels.

This paper will explore the current state and future of pollution-less airway transportation, including the benefits, challenges, and opportunities associated with this emerging field. It will also examine the various technologies and innovations that are driving this transformation and discuss the implications for the aviation industry and society at large. Ultimately, the goal of this article is to provide a comprehensive view of pollution-less airway transportation and its potential to create a more sustainable and environmentally friendly future for air travel.

The next section provides an exhaustive interpretation of literature study in the area of Contemporary aspects and Prospects of Pollution-Free Aviation. This is followed by results and discussion explaining the various data analysis along with correlation and regression aspects of a considered dataset and appropriate conclusions.

II. LITERATURE REVIEW

A. Electric Propulsion System

The propulsion systems for aircraft can be classified into three main types: fully electric, turboelectric, and hybrid electric. A fully electric system relies solely on electrical energy from a battery or another source to power the aircraft. This configuration has the possibility for zero emissions and is much simpler than other types, but it is typically limited to smaller aircraft. Examples of fully electric aircraft include SCEPTOR X-57 by NASA, VoltAir by Bauhaus Luftfahrt, and Ce-Liner by Bauhaus Luftfahrt [1].

In contrast, a turboelectric system still relies primarily on fuel as the energy source, but it converts some or all of the chemical energy into electrical power to drive the propulsor. This setup exhibits reduced efficiency owing to extra losses in the electrical propulsion system, yet it enables distributed propulsion and facilitates the exploration of innovative concepts. Partially turboelectric systems use a combination of gas generators and turbofans for thrust. Examples of turboelectric aircraft include NASA’s N3-X, the STARC-ABL, Boeing’s SUGAR Freeze, and ESAero’s ECO-150.

Hybrid electric systems use both fuel and electrical energy sources, and can be further classified as series or parallel. In parallel configurations, both the electrical and gas turbine systems are mechanically linked to power the propulsion units. This configuration is less complex and lighter, but has operational limitations and requires careful control. Although fully electric aircraft are the ultimate goal, hybrid electric/ turboelectric systems are a more pragmatic solution in the near term due to limitations in electrical component technology. They offer higher efficiency than traditional systems while still using fuel to achieve longer range. However, they cannot match the efficiency of fully electric systems.

Moreover, electric propulsion offers a range of operational and control benefits, including diminished noise, zero emissions, enhanced thrust responsiveness, and reduced component count, among others. Implementing battery-powered propulsion systems in both manned and unmanned aircraft necessitates the development of more advanced methods for estimating available battery charge during flight. Determining the remaining charge during operation proves to be a challenging task, and furthermore, the charge storage capacity of each battery degrades over its operational lifespan [2].

B. Aircraft Requirements for Sustainable Regional Aviation

As per the European Commission's vision for Horizon 2020, a hybrid-electric 50-seat regional aircraft could potentially enter the Environmental Impact Statement (EIS) by 2035/2040, despite the challenge. Electric powertrain offers several advantages over traditional designs, such as zero local emissions and the scalability of electric motors with respect to power and mass.

This could pave the way for innovative propulsion ideas, such as distributed electric propulsion, which has the potential to boost efficiency by harnessing the synergistic interaction between the aircraft's wings and propulsion systems. Although a fully electric aircraft provides the least emissions during operation, the limited precise energy of present battery technology constrains its range. However, a hybrid-electric design can combine the advantages of both conventional fuel and electrified powertrain with higher efficiency, resulting in reduced emissions during the most polluting phases of the flight. The design cruise speed of the aircraft is crucial for its productivity, as it affects the number of dispatches in a day. To achieve maximum efficiency, the speed range of 450 to 550 km/h was chosen, which is similar to current-gen turboprops. Dropping this speed would result in reduced aircraft productivity, whereas increasing it would necessitate additional surplus thrust or power for accelerating the aircraft, potentially resulting in an increase in the aircraft's overall weight.

The overall climb performance of the aircraft is gauged by the time required to ascend to FL 170, allowing for comparisons with other aircraft, such as the ATR 42-600, which accomplishes this in 12.7 minutes [3-5]. In air-breathing propulsion systems, power and, consequently, the rate of climb are contingent on altitude, leading to potential performance losses. However, in hybrid-electric aircraft, these losses could potentially be mitigated with the assistance of the battery system. The choice of setting the aircraft's maximum operational altitude at FL 250 or 7620 meters is grounded in several considerations. Firstly, in accordance with regulations (CS 25.841), it becomes imperative to incorporate an additional redundant air management system for altitudes surpassing this threshold. This requirement, while essential for safety, inevitably introduces heightened system intricacy and contributes to an overall increase in the aircraft's mass.

Secondly, it's worth noting that the typical duration of turboprop missions spans approximately one hour. Consequently, opting for a higher cruise altitude often proves superfluous, potentially elongating the climb phase, which, in turn, demands a greater allocation of power and fuel resources. Furthermore, operating at a lower cruising altitude augments passenger comfort, a vital consideration given that the cruise phase encompasses a substantial portion of the entire flight experience.

Lastly, a noteworthy environmental perspective comes into play. Anticipations indicate that the creation of aviation-induced clouds and contrails at the specified altitude would yield a markedly reduced climate impact when juxtaposed with their formation at higher altitudes. This conscientious choice aligns with sustainability goals and emphasizes the aircraft's contribution to environmental preservation.

Presented below are graphical representations illustrating the implementation of the EIS 2035-2040 plan and its corresponding effects in comparison to current-generation aircraft, further elucidating the rationale behind these altitude determinations.

C. Sustainability in Aviation Industry: Improving scenario

One effective approach to attaining fuel efficiency involves the incorporation of lightweight materials like Ti, carbon fiber, and advanced carbon plastics. The utilization of these materials has already contributed to a noteworthy 20% reduction in fuel consumption in numerous new aircraft models.

Boeing, a prominent global aircraft manufacturer, recently introduced its B787 Dreamliner aircraft model, representing a remarkable leap in fuel efficiency and reduced emissions. Notably, it outperforms any other aircraft of its size in these respects. Furthermore, the B787 Dreamliner registers an impressive 28% reduction below the 2008 manufacturing limits for nitrogen-dioxide emissions, underscoring Boeing's commitment to environmental responsibility and sustainability in aviation. The Boeing 787 achieves significant reductions in carbon emissions due to its innovative wing design, more efficient GE and Rolls-Royce engines and nacelles, a lighter composite primary structure, and a smaller flight deck. This new model of airplane also produces a 90% smaller noise footprint compared to earlier models, making it more environmentally friendly.

Airbus, another prominent aircraft manufacturer, has also made significant advancements in the realm of environmental sustainability with its cutting-edge A380 aircraft. The A380 boasts the lowest fuel consumption per passenger seat, emitting just 75g of CO2/passenger km. On a round trip flight from Paris to Tokyo, it saves a substantial 105 kilograms of fuel per passenger when compared to less fuel-efficient aircraft models.

These impressive fuel efficiency and emissions reductions are achieved through several innovative strategies. Airbus employs composite materials, are lighter than the aluminum alternatives, contributing to the aircraft's enhanced performance. Additionally, the A380 incorporates a lighter and more compact dual hydraulic/electric flight control architecture. To further bolster fuel efficiency, the aircraft features the Engine Alliance GP7200 engine.These measures collectively underscore Airbus's commitment to environmental stewardship and sustainability within the aviation industry.

Furthermore, alongside its impressive fuel efficiency, the A380 also boasts a notable reduction in noise pollution compared to older aircraft models. During takeoff, it generates only half the noise energy and, during landing, emits 3-4 times less sound energy than the 747 models. These advancements in aircraft technology underscore a steadfast commitment to environmental sustainability within the aviation industry.

The potential environmental impact of reducing fuel consumption in aircraft is substantial. A direct reduction in carbon emissions in the atmosphere holds the promise of mitigating the dramatic climate changes currently underway. By curbing the release of carbon emissions that contribute to the rising temperatures of the Earth's surface, we can potentially slow down the degradation of ecosystems. This, in turn, would aid in preserving the diverse range of ecosystem services that human society depends upon, encompassing essentials such as food, clean water, unpolluted air, and the aesthetic and recreational values that enhance our overall well-being and quality of life [6].

D. Sustainable Aviation – Hydrogen as fuel

Sustainable aviation has become the primary goal of the industry, with a growing emphasis on achieving zero-carbon flights to counter global warming. Hydrogen has emerged as a promising alternative fuel due to its abundance, environmental cleanliness, and its ability to produce only water as emissions, which could potentially have a cooling effect on the atmosphere. Hydrogen holds the potential to meet the energy needs of various aviation services. However, before hydrogen tech can stay effectively adopted besides put into practice, several other concerns, including government policies, education, and employment opportunities, need to be addressed.

The establishment of alternative renewable-energy and H2 roadmaps by the international community can serve as a long-term strategy for the development of the alternative energy industry. In a case study conducted on a diesel engine at the Automotive Lab in Pahang, it was observed that the use of hydrogen at flow rates ranging from 21.4 L/min to 42.8 L/min had a significant impact on the engine's performance and coefficient of variation (COV). The engine was found to be more responsive to enrichment and exhibited improved knock resistance and thermal break efficiency at difficult loads with higher hydrogen flow rates. The study also revealed reductions in NOx and CO2 emissions as the amount of hydrogen increased. Additionally, cylinder pressures decreased while the rate of pressure decrease and the rate of heat released decreased with higher hydrogen levels. Traditionally, the aviation industry has relied on conventional petroleum-based fuels to power aircraft.

Hydrogen is considered an environmentally friendly fuel, as it does not produce any pollutants when consumed [7]. However, uncontaminated hydrogen is not readily accessible and must be either mass-produced or extracted. Various processes exist for generating hydrogen fuel, but these methods may not be entirely free of pollutants, despite reducing carbon emissions. Only green hydrogen is completely zero-carbon, as there is zero-carbon generated during its production and use. Grey hydrogen generates carbon during the extraction/manufacturing process, while blue hydrogen captures and stores the carbon produced during manufacturing. Green Hydrogen is generated using renewable energy sources. The below table categorizes hydrogen into three colors: grey, blue, and green, based on the amount of carbon production.

Storing hydrogen as aviation fuel requires reinforced storage tanks due to the high-pressure nature of the gas. However, placing these tanks on an aircraft poses challenges in terms of safety and maintaining the aircraft's balance. Hydrogen as aviation fuel would require modifications to both aircraft and engine designs. One possible placement for the tanks is behind the passenger cabin, although this would shift the center of gravity of the plane. Another option is to place one tank in front of the passenger cabin and one behind it, with medium-range aircraft potentially benefiting from a tank placed on top. It is also possible to store the other two at the top of the cabin and one in the fuselage tail. Storing liquid hydrogen at optimal energy density requires low temperatures, and selecting an appropriate storage technology depends on factors such as hydrogen quantity, storage footprint, and energy use. Some options include compression, liquefaction, and chemical storage using substances such as ammonia and metal hydrides under ambient conditions. Storing hydrogen onboard aircraft presents challenges due to its low energy density compared to kerosene. Liquid hydrogen, obtained by dropping the temperature to negative 253°C, is a more efficient option.

Cryogenic liquid hydrogen storage tanks are currently used in various industries, including aerospace. However, commercial aircraft storage tanks must be more durable and retain hydrogen liquid for longer periods. Developing clean-burning fuels derived from renewable sources is necessary for long-term safety and visibility of combustion engines. Hydrogen has a high ignition temperature and is lighter than air, making it a safe fuel option. Specialized training for aviation maintenance engineers will be necessary [8].

E. Efficient and sustainable fuel in aviation (SAF)

SAF stands for sustainable aviation fuel, which is a type of fuel made from non-fossil sources. These fuels are produced in a way that reduces emissions compared to traditional jet fuel, which helps to reduce CO2 emissions throughout its life cycle. SAF is designed to meet sustainability criteria beyond just reducing CO2 emissions, such as avoiding the use of feedstock that competes with food production, conserving water, and avoiding harmful. Unlike fossil fuels, which add to CO2 emissions by releasing carbon that was previously stored underground, SAF recycles CO2 that has been absorbed by the biomass used in its production

The aviation industry aims to achieve net-zero carbon emissions by reducing emissions at the source through various means, such as using SAF, pioneering force technologies, and improving efficiency in air traffic navigation. SAF is expected to contribute approximately 65% of the required emissions reduction to reach net- zero by 2050. However, meeting the demand for SAF will require a significant increase in production. The largest acceleration in SAF adoption is anticipated in the 2030s when global policy support is expected, SAF becomes competitive with fossil kerosene, and credible offsets become scarcer.

In 2016, the United Nations passed a plan called the Sustainable Development Goal, which included 17 different goals, one of which was climate action. Aviation is a huge industry for transporting people and goods around the world, with over 6 million people traveling by plane and 6 trillion dollars' worth of cargo exported and imported each year. More than 65 percent of sustainable aviation fuel is now being used for commercial flights, and over 50 airlines have experience with it. In 2022, over 300 million litres of sustainable aviation fuel were produced. If more planes switch to using SAF, it could decrease CO2 emissions by three-fourths compared to jet fuel [10].

III. RESULTS AND DISCUSSION

A. Data visualization

Fig 1. is the bar chart of frequency (time elapsed since the start of the experiment) vs temperature of the battery during the short cruise of air-craft using electric power. Fig 2 depicts another bar chart of frequency (time elapsed since the start of the experiment) vs temperature of the battery during the long cruise of an aircraft using an electric powertrain. Fig 3 gives pie chart representation of the values considered from the data set.

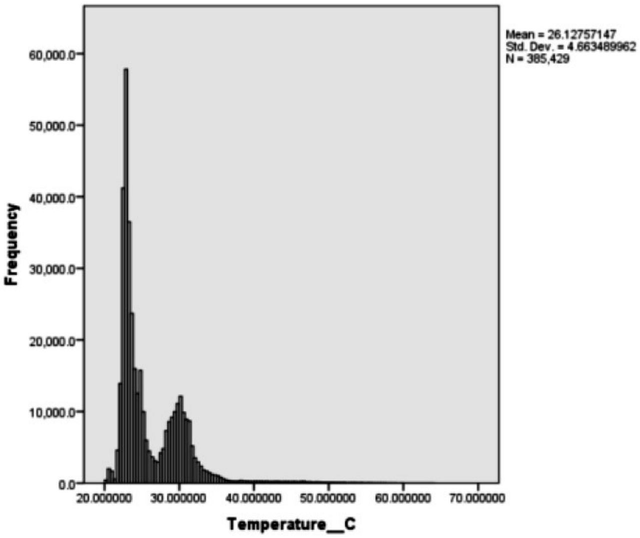

Fig .1. Bar chart of frequency (time elapsed since the start of the experiment) vs temperature of the battery during the short cruise of aircraft using electric power.

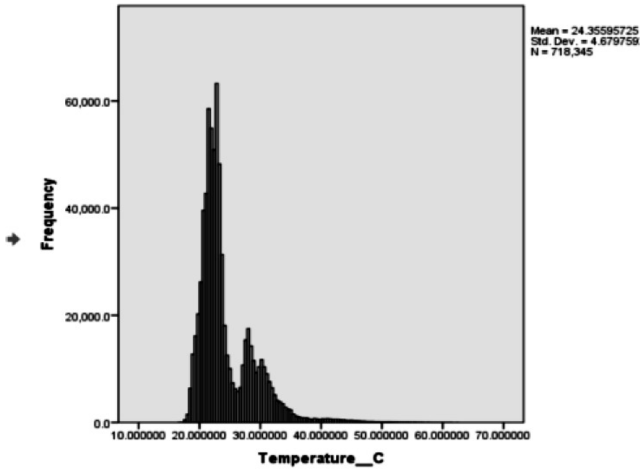

Fig .2.Bar chart of frequency (time elapsed since the start of the experiment) vs temperature of the battery during the long cruise of an aircraft using an electric powertrain.

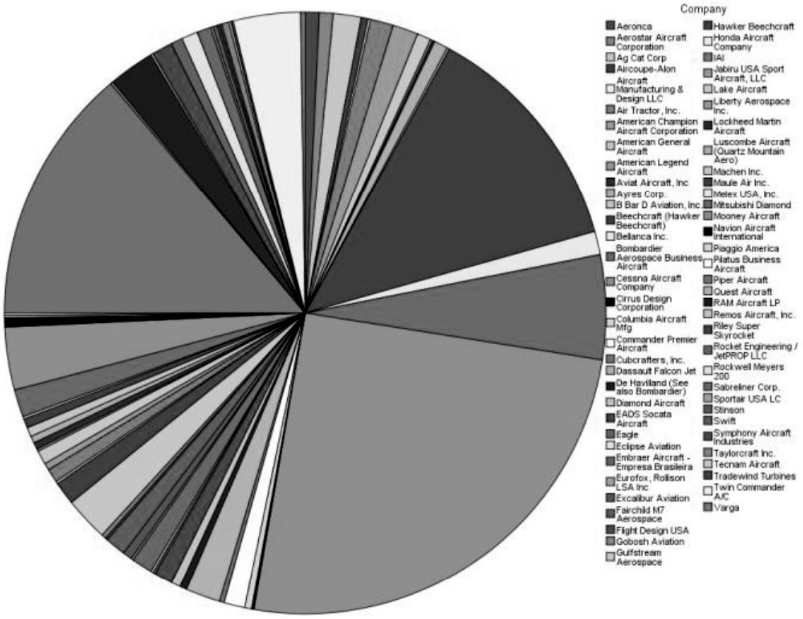

Fig .3. Pie chart of the composition of the aircraft companies of the dataset.

Table 1. Statistical Parameters

Correlations

			Gross weight lbs	Fuel gal/lbs
Spearman's rho	Gross weight lbs	Correlation Coefficient	1.000	.957**
		Sig. (2-tailed)	.	.000
		N	792	775
	Fuel gal/lbs	Correlation Coefficient	.957**	1.000
		Sig. (2-tailed)	.000	.
		N	775	778

**. Correlation is significant at the 0.01 level (2-tailed).

The data from table 1 indicates an extremely substantial and robust positive correlation between the fuel consumption measured in gallons per pound and the gross weight in pounds. Fuel consumption tends to grow along with an increase in gross weight, according to the Spearman's rho correlation value of 0.957. With a sample size of 792 data points for the total weight and 775 data points for fuel usage, this association is strong. Given the strong statistical significance ($p < 0.001$), it is doubtful that this association is the result of chance. It also shows a strong and consistent relationship between an entity's weight and how efficiently it uses gasoline, suggesting that when weight grows, so does fuel consumption.

In table 2, a positive statistically significant link between "Fuel consumption per pound" (measured in gallons per pound) and the binary variable "Heavy or not" is demonstrated by the Spearman's rho correlation matrix displayed in the supplied data. As entities are categorized as "Heavy," their fuel consumption per pound appears to be increasing, according to the correlation value of 0.608. With a sample size of 778 data points for Fuel gal/lbs and 775 data points for the "Heavy or not" variable, this connection is strong. The statistical importance of this link is confirmed by the low p-value ($p < 0.01$), which suggests that it is unlikely to have happened by accident.

Table 2.Statistical Parameters

Correlations				
			Fuel gal/lbs	Heavy or not
Spearman's rho	Fuel gal/lbs	Correlation Coefficient	1.000	$.608^{**}$
		Sig. (2-tailed)	.	.000
		N	778	775
	Heavy or not	Correlation Coefficient	$.608^{**}$	1.000
		Sig. (2-tailed)	.000	.
		N	775	792
**. Correlation is significant at the 0.01 level (2-tailed).				

B. Regression analysis

The linear regression values for the data values of x (CO2 emissions) and y (fuel consumption city) are as follows which are outcome of results in SPSS tool.

Considering straight line equation in order to find the value of y (assume x=120)

Equation:

$y = bx+c$
Here $x = 12$
$b= 0.56$
$c = -1.24$
$y = 0.56 \times 120 + -1.24$
$= 67.2 - 1.24 = 65.96$

The correlation coefficient obtained $r = 0.928$(obtained from SPSS)

Table 3: Output of regression analysis

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-1.240	.385		-3.224	.001
	CO2 Emissions(g/km)	.056	.002	.928	36.834	.000

a. Dependent Variable: Fuel Consumption City (L/100 km)

C. Conclusion

To conclude, the aviation sector is making substantial headway in its shift towards electric and eco-friendly flight solutions. This transition is mainly motivated by the urge to counter harmful greenhouse gas emissions and address the consequences of climate change. Simultaneously, sustainable aviation fuels are gaining traction as a feasible substitute to conventional fuel.

Development of sustainable aviation fuels is anticipated to become a major global undertaking, particularly once a new policy framework is established through the forthcoming renewable energy directive. This endeavor will involve certification processes and substantial investments. At present, over 65% of sustainable aviation fuel is being employed for commercial flights, with more than 50 airlines gaining experience in its usage. In the year 2022 alone, production of sustainable aviation fuel exceeded 300 million liters. The advancement of alternative aviation fuels holds the potential to revolutionize sustainable air travel, potentially resulting in an 80% reduction in CO2 emissions compared to traditional fossil fuels.

Nonetheless, the path towards developing and widely adopting electric aircraft and sustainable fuels is fraught with formidable challenges, including high costs, limited infrastructure, and technological constraints. Effectively surmounting these challenges will necessitate concerted efforts from various stakeholders within the aviation industry, including governments, researchers, manufacturers, and investors. Despite these hurdles, the promising benefits of embracing electric and eco-friendly aviation technologies and sustainable fuels, including emissions reduction, enhanced air quality, and bolstered energy security, underscore the critical importance of continued research and development in this field for a more sustainable future.

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