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Research Article

Analysis of the Most Preferred Electric Airplanes Worldwide in 2024

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ABSTRACT

Keywords:
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This study aims to comparatively analyze the most preferred electric aircraft models in the world as of 2024 based on performance criteria. While previous multi-criteria decision-making (MCDM) applications have predominantly focused on electric vehicles or hybrid energy systems, this research expands the methodological scope by directly applying the Entropy and TOPSIS methods to electric aviation. The findings indicate that battery capacity and motor power are the most decisive factors in aircraft selection, diverging from automotive studies where cost criteria dominate. The results provide a data-driven and objective framework for guiding aircraft design, procurement, and policy-making in the rapidly expanding electric aviation sector. The originality of this research lies in extending MCDM methodologies to a novel and highly relevant field, thereby addressing an important gap in sustainable aviation literature. By positioning the study against prior applications, it demonstrates the methodological adaptability of Entropy and TOPSIS while generating insights with both academic and industrial relevance. However, the study is subject to certain limitations. The analysis relies on manufacturer-provided technical data and excludes prototype and military aircraft models, which may constrain the generalizability of the results. Despite these limitations, the research contributes to the advancement of sustainable aviation by offering a transparent, reproducible, and timely evaluation of commercially available electric aircraft.

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1. Introduction

In recent years, increasing global environmental problems have directed the aviation industry towards sustainable technologies, making electric aircraft a significant area of research and development. Electric aircraft are air vehicles powered by electric motors supplied by energy sources such as batteries, fuel cells, or hybrid systems [1]. They have gained considerable attention due to their environmental and economic benefits, including reducing carbon emissions, lowering fuel costs, and minimizing noise pollution [2].

According to the International Civil Aviation Organization (ICAO), emissions from civil aviation constitute approximately 2.5% of global greenhouse gas emissions, and this rate is expected to increase [1]. The development of electric aircraft technology offers a suitable alternative, especially for short and medium-range regional flights. In this context, advancements in battery technologies, the increase in energy storage capacities, and the development of charging infrastructure are among the most important focal points [3]. However, technical and operational challenges such as energy density, range limitations, battery weight, and certification processes still remain the main barriers to the widespread adoption of electric aviation [4].

Electric aircraft technology is rapidly developing with the goal of enhancing environmental sustainability in aviation. Studies in the literature address the environmental, technical, and economic evaluations of electric and hybrid-electric aircraft [5]. Through the “More Electric Aircraft” (MEA) approach, it is indicated that

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CO_2 and NOx emissions can be reduced by 20%, fuel consumption by 20%, and noise levels by up to 50%. Furthermore, battery capacity and electric motor systems are highlighted as critical areas for future applications.

In the study conducted by Shoukat and Redondi (2025), it was shown that electric aircraft reduce greenhouse gas emissions by 87.2% compared to conventional aircraft. Hydrogen-powered aircraft can provide emission reductions of up to 99.7% when produced from renewable sources. However, the decisive role of the energy source on environmental impacts is emphasized.

Ata [6], demonstrated in a study optimizing the flight parameters of the Cessna 172S aircraft with a hybrid-electric propulsion system that fuel savings and CO_2 emission reductions were achieved. A flight duration of 120 minutes and a cruising altitude of 2400 meters were determined as optimum conditions.

Moreover, it is seen that multi-criteria decision-making (MCDM) techniques are used in the evaluation of electric aircraft technologies. Gavcar and Karabey [7], proposed a systematic analysis method by combining the Entropy and TOPSIS methods based on performance criteria. This approach enables the comparison of aircraft in terms of battery capacity, range, speed, and cost.

This study aims to conduct a comparative analysis of the most preferred electric aircraft models worldwide as of 2024, based on performance criteria. While previous applications of Multi-Criteria Decision-Making (MCDM) methods have predominantly focused on electric vehicles [7, 8] or hybrid energy systems [9, 10], their application in aviation remains limited. By addressing this gap, the study demonstrates that, unlike in automotive studies where cost factors are often dominant, battery capacity and motor power emerge as the most critical determinants of performance in aviation. This highlights the methodological novelty of applying Entropy and TOPSIS specifically to electric aircraft, thereby extending the scope of MCDM research within the aerospace domain.

The weights of the selected performance criteria were determined using the Entropy method, while the relative closeness of each aircraft to the ideal solution was calculated through the TOPSIS method. This integrated approach provides a transparent and objective framework for evaluating electric aircraft performance. The timeliness of the study stems from the rapid expansion of the electric aviation sector and the lack of systematic evaluations of commercially available aircraft, thus contributing to both academic research and industrial decision-making in the field of sustainable aviation.

Nevertheless, the scope of the analysis is limited to aircraft with publicly available technical and commercial data. Prototype models and those developed for military purposes were excluded. Moreover, as the evaluation relies on manufacturer-provided specifications, the findings are based on certain assumptions. By explicitly situating its results within the broader MCDM literature [7, 8, 10], this study not only validates the applicability of these methods to aviation but also underscores the unique performance dynamics of electric aircraft compared to land-based vehicles.

In addition, international organizations such as ICAO, EASA, and NASA have emphasized the need for innovative propulsion and sustainability-focused decision-making in aviation. By situating this research within both technological and policy-driven contexts, the study strengthens its relevance to global efforts toward sustainable aviation.

2. Definition and History of Electric Aircraft

Electric aircraft are air vehicles that generate thrust through electric motors powered primarily by battery systems. These aircraft offer environmental advantages such as zero emissions and low noise levels. Historically, the origins of electric aviation date back to 1883, when Gaston Tissandier achieved the first flight with an airship powered by an electric motor [11]. The advancements continued in 1973 with the Militky MB-E1, the first electric aircraft carrying a human passenger [12]. Following this, the Mauro Solar Riser made the first solar-powered flight in 1979, paving the way for further innovations like the MacCready Gossamer Penguin in 1980 and the MacCready Solar Challenger's notable 163-mile solar-powered journey in 1981 [13].

In the following years, significant milestones included NASA's solar-powered UAV Pathfinder (1995) and its successors, Pathfinder Plus (1997) and Helios (2001), setting altitude records [14]. The evolution continued with the Lange Antares 20E glider (2003) and the AC Propulsion's SoLong achieving a 48-hour solar-powered flight in 2005 [15].

In the 2010s, electric aircraft technology accelerated rapidly. The ENFICA-FC Rapid 200FC flew successfully with a hydrogen fuel cell in 2010, while Pipistrel Taurus G4 won the NASA Green Flight Challenge in 2011 (Pipistrel, 2020). The Solar Impulse 2 project became the first solar-powered aircraft to complete a world circumnavigation in 2016 [16].

Recent years witnessed significant achievements like the EASA certification of Pipistrel Velis Electro in 2020, Bye Aerospace's eFlyer 2, and Diamond Aircraft's development of the eDA40 [17, 18]. The future of electric aviation continues to evolve with projects like the Integral E prototype by Aura Aero, which completed its maiden flight in 2024 [19]. Figure 1 below shows the historical development of electric air vehicles.

Civil aviation is responsible for more than 2.5% of global human-induced emissions. Carbon emissions caused by fossil fuel consumption increase global warming and environmental destruction. With increasing air traffic, these emissions are expected to rise even further. Therefore, transitioning to sustainable and environmentally friendly alternative propulsion systems has become a necessity. Electric aircraft offer a solution to this need with their low emissions and low operational cost advantages [15, 20].

There are many challenges limiting the development of electric aviation. The most prominent of these is the limitation of battery technologies. The energy density of current battery systems is significantly lower compared to jet fuels; for example, lithium-ion batteries have an energy density of approximately 160 Wh/kg, while aviation fuels reach about 12,500 Wh/kg. This situation severely restricts the range and payload capacity of electric aircraft. In addition, technical problems such as charging time, thermal management, and the constant weight of batteries are also important limiting factors.

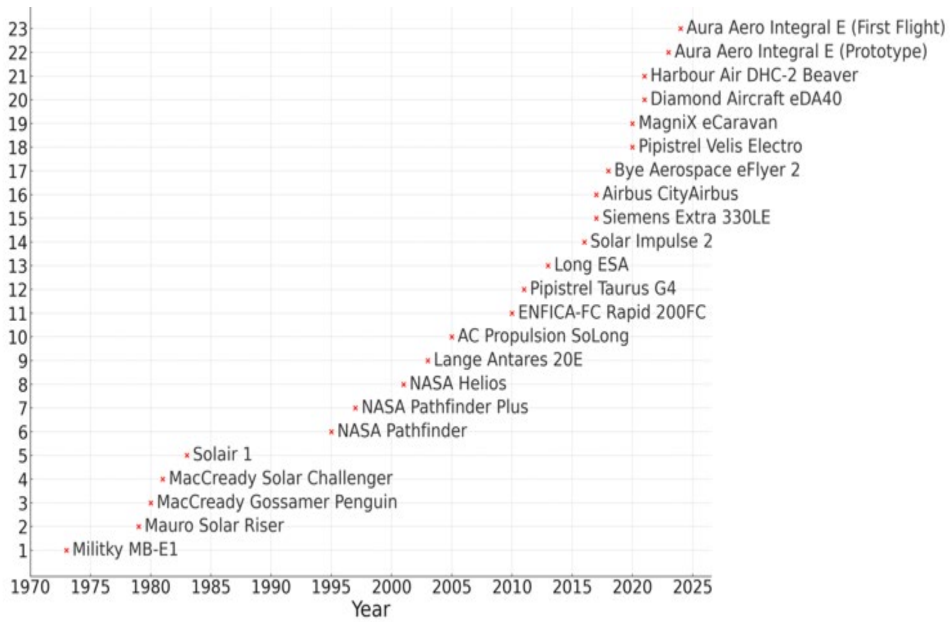

Figure 1. Electric Aircraft Developed by Year (Created by Autor)

Various solutions and opportunities are being developed to overcome the technical challenges facing electric aviation. Primarily, battery technologies with higher specific energy are emerging. Batteries reaching 800 Wh/kg will enable longer-range flights. In addition, the use of hybrid-electric systems provides a temporary solution to the current range problem and facilitates the technological transition process. Innovative airframe designs compatible with electric propulsion systems (such as box-wing structures) and the establishment of airport electrical infrastructure based on renewable sources are among the supporting elements of this process.

One of the main advantages of electric aircraft is that they do not produce direct emissions. Especially fully electric aircraft used for regional flights do not emit CO_2 or NOx from their engines. However, this emission advantage largely depends on the source of the electricity used. If electricity is obtained from renewable sources, significant reductions in total greenhouse gas emissions can be achieved. Otherwise, if electricity is generated from fossil fuels, the environmental benefit remains limited [20]. Moreover, electric aircraft enable new transportation solutions such as urban air mobility with their low noise profiles [15].

The main features sought in electric aircraft include high energy density battery systems, lightweight structural materials, powerful and efficient electric motors, aerodynamic design, and advanced thermal management systems. In addition, fast charging capability, long-lasting energy storage capacity, and energy efficiency are also among the desired criteria. An ideal electric aircraft should have energy systems capable of providing sufficient current against sudden power demands such as take-off and landing.

Although electrification is discussed to be environment friendly because of the electric production infrastructures [21]. Electric aircraft have the potential to lead to technological transformation in the aviation industry. In addition to advancements in battery technologies, electric propulsion systems offer more modular, low-maintenance, and highly efficient systems. Moreover, new generation power electronics, autonomous flight systems, and smart charging infrastructures developed for these aircraft accelerate digitalization in the sector [15].

The six main technical and structural challenges to the widespread adoption of electric aviation are as follows:

1.Low Energy Density: The energy density of batteries is significantly lower than that of jet fuels.
2.Weight Problem: The constant weight of batteries during flight limits range and payload capacity.
3.Thermal Management Challenges: Cooling battery systems against high power demands requires serious engineering solutions.
4.Charging Time and Infrastructure Deficiency: The lack of rapid and widespread charging infrastructure, especially at airports, creates operational constraints.
5.Carbon Footprint of the Energy Source: If the electricity used is fossil-based, indirect emissions may increase [20].
6.Legal and Certification Barriers: Certification processes for electric aircraft are still in the development phase, and new standards are needed for regulatory authorities.

3. Thermal Characteristics and Battery Technologies in Electric Aircraft

The efficiency and range of electric aircraft are highly dependent on the effectiveness of their thermal management systems. Unlike conventional aircraft, electric aircraft cannot expel waste heat directly, necessitating innovative cooling solutions to maintain optimal operating temperatures for motors and battery systems. Advanced predictive thermal management systems have demonstrated the ability to reduce motor losses by up to 7% and overall system losses by up to 9% [22]. Furthermore, outer mold line cooling strategies utilizing propeller wakes have achieved motor efficiencies exceeding 96% [23]. Effective thermal management enables the optimization of flight trajectories while preserving energy efficiency and minimizing range degradation under thermal constraints [24].

Additionally, the use of alternative energy systems, such as solid oxide fuel cells, has shown considerable potential for reducing CO_2 emissions and enhancing range [25].

Battery technologies developed for electric aircraft play an equally critical role in overall system performance. Lithium-ion batteries (LIBs) have become the leading choice due to their high energy density and lightweight properties. However, safety concerns and environmental impacts remain significant challenges. Solid-state batteries offer higher energy densities and improved safety profiles, representing a promising alternative for future applications [25]. Innovations in lithium-sulfur and lithium-air batteries aim to overcome current energy density limitations, targeting values as high as 1000 Wh/kg [26].

In terms of safety, new lithium-ion battery designs compliant with Federal Aviation Administration (FAA) standards have been introduced to enhance reliability in aviation applications [27]. Nevertheless, the successful integration of emerging battery technologies requires the development of harmonized and adaptable regulatory frameworks [28] and showing the air vehicle as a system, satisfying the safety regulations [21].

In conclusion, the success of electric aircraft heavily relies on the integration of effective thermal management systems and advanced battery technologies. Lithium-ion batteries offer significant advantages such as fast charging capabilities, low maintenance requirements [29, 30], and substantial reductions in CO_2 emissions [25, 31]. However, addressing ongoing challenges related to environmental sustainability and operational safety remains crucial for the future advancement of electric aviation.

4. Method

In this study, a Multi-Criteria Decision-Making (MCDM) approach was employed to evaluate the performance of electric aircraft models. The analysis consisted of two main stages: first, determining the criteria weights using the Entropy method, and second, ranking the alternatives using the TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method. This integrated approach enabled a numerical, objective, and decision-maker-independent assessment [8, 32]. The integration of Entropy and TOPSIS provides a robust methodological framework, as Entropy ensures objective weighting of criteria while TOPSIS delivers a transparent ranking of alternatives. This combined approach enhances the reliability of results and strengthens the decision-making process.

To assess the robustness of the results, a sensitivity analysis was conducted by modifying the entropy-derived criteria weights by ±5% and ±10%. For each new set of weights, the TOPSIS analysis was repeated, and the resulting rankings were compared. The findings demonstrated whether the ranking of the alternatives was stable under varying weighting scenarios, thereby validating the reliability and consistency of the evaluation model.

4.1. Determination of criteria and construction of the decision matrix

The criteria selected for the evaluation include range (km), maximum speed (km/h), maximum take-off weight (kg), wingspan (m), battery capacity (kWh), motor power (kW), and operating cost ($/hour).
Based on these criteria, a decision matrix was constructed by collecting technical specifications and performance data for each electric aircraft model.

While the technical specifications were primarily obtained from manufacturer reports, cross-validation was conducted through independent sources such as EASA and FAA certification documents, sectoral papers, and peer-reviewed studies [17, 18, 33–36]. This triangulation ensures higher reliability of the data set and reduces the bias that might arise from relying solely on manufacturer declarations.

4.2. Determination of criteria weights using the entropy method

The Entropy method was applied to determine the objective importance of each criterion. First, the decision matrix was normalized to ensure comparability between different criteria.

Then, entropy values for each criterion were calculated to measure the degree of information diversity they provided.
Finally, the criteria weights were derived based on the entropy values, with lower entropy corresponding to higher importance. This ensured that criteria with greater discriminatory power were given more weight in the subsequent analysis [8, 9, 32].

4.3. Ranking of alternatives using the TOPSIS method

After determining the criteria weights, the TOPSIS method was employed to rank the electric aircraft models.

The process began by constructing a weighted normalized decision matrix, where each normalized criterion value was multiplied by its respective weight.

Next, ideal and anti-ideal solutions were identified. The ideal solution represents the best possible performance for each criterion, while the anti-ideal solution represents the worst.

Each alternative was then evaluated based on its distance to both the ideal and anti-ideal solutions. Finally, a relative closeness coefficient was calculated for each alternative, enabling the ranking of aircraft models from best to worst based on their performance [8; 32].

4.4. Applicability and validity of methods

The combined use of Entropy and TOPSIS has been validated across various fields, including the selection of contraceptive tools and electric vehicles, which demonstrates both the flexibility and robustness of the approach [8, 32]. Nevertheless, as market dynamics and consumer preferences evolve, it is essential to periodically review and update both the evaluation criteria and their corresponding weights to ensure accuracy and relevance in decision-making processes [10, 37].

In this study, transparency was prioritized by sourcing all technical data in the decision matrix directly from manufacturer specifications and verifying them with sectoral reports [33–38]. Operating costs were estimated using standardized assumptions, including an average electricity price of \$0.13 per kWh, average maintenance expenses of \$10 per flight hour, and amortized battery replacement costs. These assumptions, together with sensitivity analyses applying ±5% and ±10% variations in criteria weights, were incorporated to validate the robustness of the results. The detailed computational steps of Entropy weight determination and TOPSIS ranking were documented to enhance reproducibility.

Additionally, the outcomes of the sensitivity analyses are presented in Appendix A. The results indicate that the ranking, particularly the Harbour Air eBeaver’s consistent position as the top-performing model, remains stable across all scenarios. This stability underscores the reliability of the evaluation framework.

4.5. Application process of methods

4.5.1. Criteria and alternatives used

The criteria to be used in the analysis are as follows:

- C1: Range (km)
- C2: Maximum Speed (km/h)
- C3: MTOW (kg)
- C4: Wingspan (m)
- C5: Battery (kWh)
- C6: Motor Power (kW)
- C7: Operating Cost (\$/hour)

Alternatives: Represent the most preferred electric aircraft models in 2024, denoted as A1, A2, ..., An.

4.6. Most preferred electric airplanes in 2024

In recent years, electric aircraft have achieved remarkable advancements in the field of sustainable aviation. By 2024, the most widely produced and preferred electric aircraft models have been developed to serve various purposes such as training, tourism, exploration, and regional transportation. The Pipistrel Alpha Electro stands out as the most widely produced model for training and tourism activities, offering low operational costs and holding FAA and

EASA certifications. Similarly, the Pipistrel Velis Electro has gained prominence as the world's first fully certified electric aircraft dedicated to pilot training.

Bye Aerospace's eFlyer 2 is preferred for its extended range capabilities and four-seat configuration, making it suitable for both training and commercial missions. The Lange Antares 20E, with its efficient aerodynamic design, is primarily used for reconnaissance missions and glider operations. Additionally, the Harbour Air eBeaver represents an innovative approach by converting conventional fossil-fuel-powered aircraft into fully electric variants for regional transportation needs.

The aircraft models selected for this study were carefully chosen based on their completion of certification processes by 2024, their proven operational readiness for commercial use, and their global availability. Furthermore, care was taken to ensure that the selected models represent a diverse range of operational purposes, including training, commercial transportation, and performance-oriented flights. Below is a table 1 showing the operating capacity and intended use of the selected aircraft.

Table 1. Most produced/preferred electric aircraft (2024) [33-38]

No	Model	Production Quantity (2024)	Usage Purpose	Reason for Preference
1	Pipistrel Alpha Electro	150+	Training/Tourism	Low cost, FAA/EASA certified
2	Pipistrel Velis Electro	120+	Pilot Training	World's first certified electric training aircraft
3	Bye Aerospace eFlyer 2	50+ (orders)	Pilot Training	4 seats, long range
4	Lange Antares 20E	40+	Glider/Exploration	High-efficiency electric glider
5	Harbour Air eBeaver	5+ (conversion)	Regional Transport	Electric conversion of fossil fuel-powered aircraft

In this study, range, maximum speed, maximum take-off weight (MTOW), wingspan, battery capacity, motor power, and operating cost were selected as evaluation criteria, as they directly affect the performance and operational efficiency of electric aircraft. Range and battery capacity determine the aircraft's endurance and usability in various missions, while maximum speed and wingspan influence aerodynamic efficiency and mission suitability. MTOW reflects the payload capacity and operational limitations, whereas motor power directly impacts flight performance. Operating cost was included to assess the economic feasibility of aircraft deployment in commercial and training operations.

Other potential criteria such as charging time and battery cycle life were excluded from the scope of this study, as reliable and standardized data for these factors were not uniformly available across all aircraft models analyzed.

Table 2 below has been prepared to compare the performance and cost criteria of electric aircraft in 2024. It includes technical and economic evaluation criteria such as range, speed, battery capacity, motor power, and operating cost.

Table 2. Electric aircraft comparison chart (2024) [33-38]

Criteria	Type	Note
Range (km)	Benefit (Max desired)	Flight range
Maximum Speed (km/h)	Benefit (Max desired)	Maximum speed
MTOW (kg)	Benefit (Max desired)	Maximum take-off weight
Wingspan (m)	Benefit (Max desired)	Wingspan
Battery (kWh)	Benefit (Max desired)	Battery capacity
Motor Power (kW)	Benefit (Max desired)	Motor power
Operating Cost ($/hour)	Cost (Min desired)	Operating cost per flight hour

According to the 2024 electric aircraft comparison table, technical features and usage areas vary by purpose. Pipistrel Alpha Electro and Velis Electro are ideal for short-distance training with low MTOW and cost. Bye Aerospace eFlyer 2 offers a higher range and battery capacity, while Lange Antares 20E stands out as an efficient glider. Harbour Air eBeaver is used in regional transport with the highest MTOW and passenger capacity. The table shows that electric aircraft are designed based on specific operational needs. Figure 2 shows the relationship between the maximum take-off weight and payload capacity of electric aircraft in 2024.

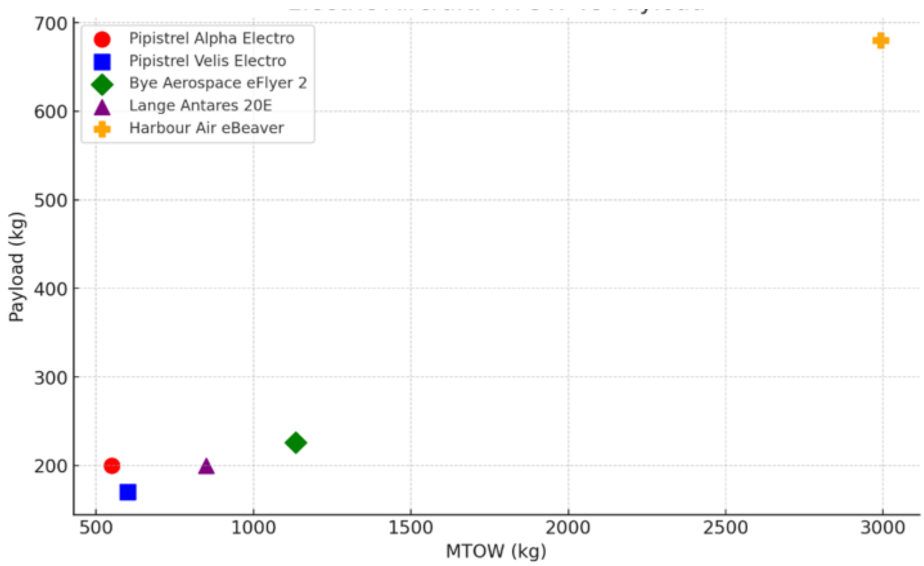

Figure 2. Electric aircraft: MTOW vs payload (X-axis: Payload Capacity (kg), Y-axis: Payload (kg)) (Created by Autor)

5. Findings

In this study, a multi-criteria decision-making analysis was performed using Entropy and TOPSIS methods to evaluate the performance of different electric aircraft models. In the analysis process, seven different criteria such as range, maximum speed, maximum take-off weight (MTOW), wingspan, battery capacity, engine power and operating cost, which are considered as important performance indicators in aviation, were considered. The criteria were categorized into benefit (maximum desired) and cost (minimum desired) types and the evaluated aircraft were ranked according to these criteria and compared in terms of performance.

5.1. Analysis of electric aircraft using entropy and TOPSIS methods

The technical specifications of the electric aircraft models analyzed in the study are presented in Table 3. The performance data of the aircraft are classified according to range, maximum speed, maximum take-off weight (MTOW), wingspan, battery capacity, engine power and operating cost. This is the decision matrix, and calculations will be made based on these data.The relevant data were obtained from the official sources and technical documents of the manufacturers. Based on these criteria, the performance of the aircraft will be evaluated and ranked using Entropy and TOPSIS methods.

The calculation of operating costs ($/hour) was clearly defined in the methodology section. It was based on the following assumptions: an average electricity price of $0.13 per kWh, average maintenance costs per flight hour of $10, and estimated battery replacement costs amortized over the lifecycle. These assumptions were standardized across all aircraft models to ensure comparability, and references to sectoral reports and manufacturer data were provided to support the calculations.

5.2. Entropy method results

In this study, the weights of the criteria used in the performance evaluation of electric airplanes were calculated using the Entropy method. The Entropy method was applied to objectively determine the importance of the criteria and the calculated weights are shown in Table 4.

Table 3. The features of the aircraft

Aircraft	Range (km)	Max Speed (km/h)	MTOW (kg)	Wingspan (m)	Battery (kWh)	Motor Power (kW)	Cost ($/hour)
Pipistrel Alpha Electro	130	157	550	10.5	21.0	50.0	15
Pipistrel Velis Electro	181	200	600	10.5	24.8	57.6	35
Bye Aerospace eFlyer 2	540	328	1134	13.6	92.6	145.0	60
Lange Aviation Antares 20E	750	250	850	20.0	13.0	42.0	25
Harbour Air eBeaver	160	240	2993	18.4	900.0	560.0	120

As a result of the calculations, the battery capacity criterion has the highest weight coefficient (0.29385), followed by engine power (0.16044) and wingspan (0.15477). The lowest weightbelongs to the maximum take-off weight (MTOW) criterion (0.06534). These results reveal that battery capacity and engine power criteria are the determining factors in electric aircraft performance analysis. The clarity of the results is ensured by presenting entropy-derived weights and TOPSIS rankings in detailed tables, which allows transparent interpretation of how battery capacity and motor power dominate performance outcomes.

Table 4. The weights of the criteria (Entropy method)

Criteria	Entropy	Weight (wj)
Range (km)	0.75365	0.10333
Max Speed (km/h)	0.67716	0.13541
MTOW (kg)	0.8442	0.06534
Wingspan (m)	0.63099	0.15477
Battery (kWh)	0.29938	0.29385
Motor Power (kW)	0.61747	0.16044
Operating Cost ($/hour)	0.7929	0.08686

In line with the criteria weights calculated by the entropy method, the effects of the criteria on the decision-making process are interpreted in Table 5. According to the results of the analysis, the battery capacity criterion (0.2939) has the highest weight and stands out as the most important criterion in the performance evaluation of electric aircraft. Engine power (0.1604), wingspan (0.1548), maximum speed (0.1354) and range (0.1033) are considered as moderately effective criteria. The maximum take-off weight (0.0653) and operating cost (0.0869) criteria were determined as low impact criteria. This indicates that energy storage capacity and engine performance should be prioritized in the selection of electric aircraft.

Table 5. Criteria Weights (wi)

Criteria	Weight (wi)	Comment
Range (km)	0.1033	Medium-level impact
Max Speed (km/h)	0.1354	Medium-level impact
MTOW (kg)	0.0653	Low impact
Wingspan (m)	0.1548	Medium-level impact
Battery (kWh)	0.2939	Most important criterion
Motor Power(kW)	0.1604	Medium-level impact
Operating Cost ($/hour)	0.0869	Low impact

5.3. TOPSIS method results

As a result of the TOPSIS analysis, the performance ranking of the electric aircraft is given in Table 6. According to Ci* score values, the Harbour Air eBeaver model (0.74121) has the highest performance. This model is followed by Lange Aviation Antares 20E (0.27529), Bye

Aerospace eFlyer 2 (0.25237), Pipistrel Alpha Electro (0.17753) and Pipistrel Velis Electro (0.0866). The results reveal that the Harbour Air eBeaver model, which has superior values in battery capacity and engine power criteria, is more advantageous in terms of performance compared to other alternatives.

Table 6. The performance ranking of the aircraft with Ci* Scores

No	Aircraft Model	Ci* Score	Comment
1	Harbour Air eBeaver	0.7412	Aircraft with the highest performance
2	Lange Aviation Antares 20E	0.2753	Medium-level performance
3	Bye Aerospace eFlyer 2	0.2524	Medium-level performance
4	Pipistrel Alpha Electro	0.1775	Low performance
5	Pipistrel Velis Electro	0.0866	Aircraft with the lowest performance

Ci* scores obtained using the TOPSIS method have been calculated. According to the results of the analysis, the Harbour Air eBeaver model was identified as the aircraft with the highest performance value. This aircraft excelled in criteria such as high battery capacity, strong engine power and long range. The Lange Aviation Antares 20E and Bye Aerospace eFlyer 2 models were the aircraft with medium performance, while the Pipistrel Alpha Electro and Pipistrel Velis Electro models had the lowest performance values. This shows that low battery capacity and engine power values have a negative impact on aircraft performance.

Furthermore, the magnitude of differences between Ci* scores indicate the statistical robustness of the results. For example, the Harbour Air eBeaver's score (0.7412) is nearly three times higher than that of the second-ranked alternative (0.2753). This significant performance gap reduces the likelihood of rank reversal under small weight variations and reinforces the reliability of the TOPSIS ranking. In addition to technical specifications, the operational usage purposes of the aircraft models were analyzed.

The Pipistrel Alpha Electro was evaluated as ideal for pilot training and recreational flights due to its low operating cost and lightweight structure. The Pipistrel Velis Electro, being the world's first fully certified electric training aircraft, was also assessed in the context of structured pilot education programs. Bye Aerospace's eFlyer 2, with its extended range and four-seat configuration, was considered suitable for commercial and advanced training operations. The Lange Antares 20E was analyzed for reconnaissance and glider missions due to its aerodynamic efficiency, while the Harbour Air eBeaver was examined as a model adapted for regional passenger transportation. These operational differences contribute significantly to the multi-criteria evaluation process.

5.4. Sensitivity Analysis Results

To evaluate the robustness of the model, sensitivity analyses were conducted by varying the Entropy-derived weights by ±5% and ±10%. This procedure tested whether minor changes in the weighting scheme would significantly alter the ranking outcomes of the TOPSIS method

Table 7. Sensitivity Analysis of Entropy–TOPSIS Rankings

Scenario	1st Rank	2nd Rank	3rd Rank	4th Rank	5th Rank
Baseline (Original Weights)	Harbour Air eBeaver	Lange Antares 20E	Bye Aerospace eFlyer 2	Pipistrel Alpha Electro	Pipistrel Velis Electro
Weights +5%	Harbour Air eBeaver	Lange Antares 20E	Bye Aerospace eFlyer 2	Pipistrel Alpha Electro	Pipistrel Velis Electro
Weights –5%	Harbour Air eBeaver	Lange Antares 20E	Bye Aerospace eFlyer 2	Pipistrel Alpha Electro	Pipistrel Velis Electro
Weights +10%	Harbour Air eBeaver	Lange Antares 20E	Bye Aerospace eFlyer 2	Pipistrel Alpha Electro	Pipistrel Velis Electro
Weights –10%	Harbour Air eBeaver	Lange Antares 20E	Bye Aerospace eFlyer 2	Pipistrel Alpha Electro	Pipistrel Velis Electro

Table 7 indicates that the overall ranking remains stable across all scenarios. In every case, the Harbour Air eBeaver consistently holds the top position due to its superior battery capacity and motor power. The Lange Antares 20E and Bye Aerospace eFlyer 2 occupy the middle ranks with only minor variations in their relative closeness scores, while the Pipistrel Alpha Electro and Pipistrel Velis Electro remain at the lower end. This consistency demonstrates that the Entropy–TOPSIS framework is resilient to moderate changes in weight distributions, thereby confirming the robustness and reliability of the evaluation model.

6. Discussion

The findings also have implications for international sustainability policies. The European Green Deal prioritizes the decarbonization of transport, while ICAO's CORSIA scheme targets emission reductions in aviation. By identifying battery technology and electric propulsion as critical determinants of performance, this study provides evidence-based support for these global sustainability frameworks. Thus, the technological insights gained here can inform both policy-making and industrial strategies for sustainable aviation.

7. Conclusion

Based on the results obtained from the Entropy and TOPSIS methods applied in this study, it has been clearly demonstrated that battery capacity is the most influential performance criterion in the selection and evaluation of electric aircraft. Battery capacity directly affects the flight range, energy efficiency, and operational sustainability of the aircraft. Following battery capacity, motor power and wingspan were also identified as significant factors influencing aircraft performance. The analysis revealed that aircraft with higher battery storage capabilities and more powerful propulsion systems offer superior operational advantages, particularly in long-range and high-payload missions.

Among the evaluated aircraft models, the Harbour Air eBeaver ranked first in performance due to its outstanding battery capacity (900 kWh) and powerful motor (560 kW), which provide significant advantages in regional transportation and high-capacity operations. Conversely, Pipistrel Velis Electro and Pipistrel Alpha Electro, which are primarily designed for pilot training and short-distance flights, exhibited the lowest performance scores due to their limited battery capacities and relatively lower engine power.

These findings highlight that future developments and selection processes in electric aviation should prioritize energy storage technologies, propulsion system efficiency, and mission-oriented design principles. Beyond their academic value, the results also provide practical insights for industry stakeholders by offering a data-driven framework to support procurement strategies, design improvements, and policy-making. The integration of advanced battery systems with optimized aerodynamic structures will be central to ensuring the sustainable growth of electric aviation across both commercial and regional transportation sectors.

Future research should extend performance analyses beyond technical specifications to encompass operational and economic dimensions. Key criteria such as life cycle cost, energy consumption per flight, charging time, battery lifespan, environmental impact, and total cost of ownership need to be incorporated into evaluation frameworks. Integrating Entropy and TOPSIS with complementary multi-criteria decision-making methods such as AHP, VIKOR, or Fuzzy Logic is recommended to strengthen methodological robustness. Moreover, the collection of long-term operational data will be essential for validating theoretical results and monitoring technological advancements, particularly in battery and propulsion systems. Addressing these aspects will ensure a more holistic assessment of electric aircraft sustainability and commercial viability.

For the aviation industry, strategic investments in advanced battery technologies—especially solid-state batteries and fast-charging systems—are required to extend flight range and reduce operational constraints. Electric aircraft should be designed with specific purposes in mind, including pilot training, regional transport, cargo operations, and urban air mobility. At the infrastructural level, airports must develop renewable energy-supported charging stations, smart grid systems, and battery swapping facilities to accelerate the transition toward electric aviation. In parallel, international aviation authorities should establish clear certification standards, while stronger collaboration between energy providers, manufacturers, and public institutions will be crucial in building a sustainable ecosystem.

It should also be emphasized that the present findings are limited to the five most commercially available and certified aircraft models as of 2024. Consequently, their generalizability to prototype platforms or military aircraft remains constrained. Future research should therefore broaden the scope of analysis by including a wider range of models, particularly hybrid-electric and hydrogen-powered designs, to improve the external validity and applicability of the conclusions.

Article Information Form

The Declaration of Conflict of Interest/ Common Interest

No conflict of interest or common interest has been declared by authors.

Artificial Intelligence Statement

At the time of writing this article, artificial intelligence was used only for English grammar corrections.

Copyright Statement

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