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Adoption Readiness and Feasibility of Electric Aircraft for Regional Mobility: A TOE–DOI Model Study in the Philippine Aviation Sector

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Abstract: The global push for aviation decarbonization has elevated electric aircraft (EA) as a promising solution for short-haul and regional routes. However, adoption readiness in emerging markets, particularly the Philippines, remains insufficiently examined. This study assesses the feasibility of integrating EA into the Philippine regional aviation landscape through an integrated Technology Organization Environment (TOE) framework and Diffusion of Innovations (DOI) theory. A mixed-methods multi-case approach was employed, combining survey responses (n = 150) with qualitative insights from interviews with airline operators, regulators, and industry experts. Findings reveal strong organizational readiness (M = 4.02) and moderate confidence in technological maturity (M = 3.75), contrasted by limited infrastructure and regulatory preparedness (M = 3.52). DOI analysis highlights high perceived relative advantage (M = 4.20) and operational compatibility (M = 4.05), yet adoption is tempered by concerns over system complexity (M = 3.35) and limited trialability (M = 3.60). Lifecycle cost analysis suggests that electric aircraft offer approximately 20% lower total ownership costs and up to 50% lower emissions compared to conventional turboprops, despite higher acquisition and infrastructure requirements. This research advances theoretical understanding by applying the TOE-DOI integration to an underexplored domain, offering a strategic decision-support framework for managing adoption risks and infrastructure planning. It underscores the urgency of pilot demonstration programs and policy roadmaps to accelerate EA integration in developing aviation markets. Future studies should track longitudinal adoption trajectories as enabling technologies and regulatory ecosystems evolve.

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1. Introduction

The aviation industry is under increasing pressure to decarbonize as part of the global response to climate change and sustainability targets. Globally, aviation accounts for approximately 2.5% of CO_2 emissions, with regional air transport playing a significant role in the carbon footprint of short-haul flights (International Air Transport Association [IATA], 2023). Electric aircraft (EA) technology has emerged as a potential alternative to conventional jet-powered aviation, promising significant reductions in greenhouse gas emissions and enhanced energy efficiency (Tian, 2024; Li, 2023). However, the realization of fully electric flight faces critical challenges, including the current limitations of battery energy density, thermal management complexities at high altitudes, and the need for greater thrust (Sun, 2023; Wheeler, 2016). Researchers are actively working to advance battery technologies, propulsion system designs, aerodynamics, and power electronics to address these constraints (Liang et al., 2024; Dorn-Gomba et al., 2020; Sun, 2023). While the transition from multi-electric systems to fully electric regional aircraft is underway, substantial technological, regulatory, and infrastructure advancements are still necessary before widespread commercial adoption can occur (Tian, 2024; Sahoo et al., 2020).

The Philippine aviation sector presents both challenges and opportunities for the future of regional electric aviation. The country's archipelagic geography, comprising over 7,600 islands, makes air connectivity vital for economic development and regional integration (Dela Peña, 2024). The growth of low-cost carriers has contributed significantly to regional development and tourism, yet concerns regarding environmental impacts persist (Andriesse, 2017). Furthermore, the COVID-19 pandemic exposed the vulnerabilities of the national air transport system and highlighted the urgent need for resilience and sustainability measures (Gonzales, 2024). The ASEAN

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region, including the Philippines, is expected to be a key contributor to global aviation growth (Joyce et al., 2021). However, the country's infrastructure constraints and technological gaps may hinder this potential (Tan & Norońa, 2021; Boquet, 2017). Recent initiatives have focused on improving aviation safety through data-driven analytics and forecasting (Abesamis et al., 2020). However, the introduction of disruptive technologies such as electric aircraft will require equally robust regulatory, economic, and technological adaptations (Artajo et al., 2023).

Despite promising international developments, research on the feasibility of adopting electric aircraft in emerging aviation markets remains limited. Previous studies have primarily focused on technical feasibility and operational challenges (Ludowicy et al., 2023; Washington State Department of Transportation [WSDOT], 2021; National Renewable Energy Laboratory [NREL], 2022), but few have addressed systemic readiness and multidimensional adoption barriers at the organizational and environmental levels, particularly within Southeast Asia. Studies have also shown that while the environmental benefits of electric aircraft could be considerable (Sismanidou et al., 2024), regulatory standards and certification frameworks must be established to ensure safe and effective market introduction (European Union Aviation Safety Agency [EASA], 2023).

To bridge this research gap, the present study applies the integrated Technology Organization Environment (TOE) framework and Diffusion of Innovations (DOI) theory to investigate the factors influencing adoption readiness of electric aircraft for regional air transport in the Philippine archipelago. The TOE framework (Tornatzky & Fleischer, 1990) has been widely validated for studying the organizational adoption of technological innovations across various sectors, including green initiatives (Angeles, 2014), cloud computing (Micheni, 2015), and IT integration (Madaki et al., 2023). It offers a structured approach to examining technological attributes, organizational capacity, and external environmental factors that influence adoption decisions (Baker, 2012; Arpaci et al., 2012; Ramdani et al., 2013; Hoti, 2015; Thomas & Yao, 2023). The DOI theory complements this by explaining how innovations diffuse within social systems and highlighting adopter categories and key innovation attributes such as relative advantage, compatibility, complexity, trialability, and observability (Green & Senge, 2011; Stephenson et al., 2018; Minishi-Majanja, 2013; Kapoor et al., 2011; Bhattacharya et al., 2019).

The purpose of this study is to assess the technological, organizational, and environmental factors that affect the feasibility and adoption readiness of electric aircraft in the Philippine regional aviation sector. Specifically, the study seeks to: (1) evaluate how TOE factors influence organizational decision-making, (2) examine the role of DOI innovation attributes in adoption intention, and (3) assess the overall economic and operational feasibility of electric aircraft integration using sustainability and lifecycle cost perspectives (Wang & Yu, 2024; Köse; Duarte et al., 2023; Khujamberdiev & Cho, 2024; Kossarev et al., 2022; Agarwal, 2009).

This research contributes to advancing the theoretical understanding of the drivers of adoption for emerging technologies in aviation. It offers practical insights for regulators, airlines, and industry stakeholders in the Philippines and other developing aviation markets. It is expected to provide a decision-support framework to guide strategic investments, policy formulation, and infrastructure planning necessary for the successful transition toward electric regional air mobility.

2. Review of Related Literature

2.1 Electric Aircraft: Trends and Challenges

Electric aircraft technology has emerged as a promising solution to reduce the environmental footprint of aviation, driven by global concerns over emissions and fuel efficiency (Tian, 2024; Li, 2023). The transition from multi-electric to fully electric aircraft is accelerating, with light regional electric aircraft approaching deployment (Tian, 2024; Li, 2023). Despite these advances, several critical technical challenges remain, including limited battery energy density, thermal management issues at high altitudes, and insufficient thrust output (Sun, 2023; Wheeler, 2016). Researchers are intensifying efforts to improve battery technologies, aerodynamic designs, and propulsion systems to overcome these barriers (Sun, 2023; Wheeler, 2016).

Power electronics also play a vital role in the development of electric aircraft, with ongoing investigations into efficient converter topologies and charging infrastructure (Liang et al., 2024; Dorn-Gomba et al., 2020). Sahoo et al. (2020) highlighted that, beyond technological advancements, regulatory frameworks and infrastructure development are necessary to enable widespread adoption of electric aviation. Additionally, solar electric aircraft are being explored as a future pathway for emission-free flight, though this remains in early experimental phases (Mohammadi, 2018).

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2.2 Regional Aviation in the Philippines

The Philippine aviation sector faces unique challenges and opportunities. As an archipelagic nation, regional air transport plays a critical role in economic integration and tourism development (Dela Peña, 2024). The emergence of low-cost carriers has significantly boosted accessibility and market growth; however, environmental concerns persist (Andriesse, 2017). The COVID-19 pandemic further exposed vulnerabilities in the Philippine aviation system and underscored the urgent need for strategic resilience and sustainable innovation (Gonzales, 2024).

ASEAN, including the Philippines, is projected to experience substantial growth in global aviation demand (Joyce et al., 2021). However, infrastructure limitations, technological constraints, and regulatory barriers continue to challenge the sector's long-term viability (Tan & Noroña, 2021; Boquet, 2017). Efforts to enhance aviation safety through data analytics and forecasting are underway (Abesamis et al., 2020). Meanwhile, Artajo et al. (2023) emphasize that addressing regulatory, competitive, and macroeconomic factors will be crucial for the sector's future sustainability.

2.3 Exploring the Technology Organization Environment (TOE) Framework

The Technology Organization Environment (TOE) framework, introduced by Tornatzky and Fleischer (1990), remains a widely recognized model for analyzing organizational adoption of new technologies. It categorizes the factors influencing adoption into three key contexts: technological, organizational, and environmental (Baker, 2012; Arpaci et al., 2012; Madaki et al., 2023). The framework has been applied in various fields, including IT adoption in public organizations (Madaki et al., 2023), green innovation initiatives (Angeles, 2014), and cloud computing in higher education (Micheni, 2015).

Particularly relevant to small and medium-sized enterprises (SMEs), the TOE model provides a robust structure for predicting technology adoption (Ramdani et al., 2013; Hoti, 2015). Recent studies have proposed further refinement of the framework by adding sub-categories and addressing measurement challenges (Thomas & Yao, 2023). The TOE framework offers actionable insights for researchers and policymakers seeking to understand and promote adoption readiness (Ramdani et al., 2013).

2.4 Diffusion of Innovations (DOI) Theory

The Diffusion of Innovations (DOI) theory, developed by Everett Rogers, provides a complementary lens for understanding how technologies spread across social systems (Green & Senge, 2011). The model identifies five key attributes influencing adoption: relative advantage, compatibility, complexity, trialability, and observability (Stephenson et al., 2018). The DOI model has been applied in education, healthcare, and research on information and communication technology (ICT) adoption (Minishi-Majanja, 2013; Alonso & Calderón, 2014; Kapoor et al., 2011; Bhattacharya et al., 2019; Aronson & Beckett, 2007). Although the theory offers strong descriptive insights, it has been criticized for limited predictive power and potential cultural biases (Minishi-Majanja, 2013). Nonetheless, DOI remains a valuable complement to the TOE framework when exploring adoption pathways of electric aircraft.

2.5 Sustainable Aviation and Lifecycle Cost Analysis

Sustainable aviation fuels (SAFs) have received considerable attention to reduce greenhouse gas emissions compared to conventional jet fuels (Wang & Yu, 2024). Several SAF production pathways, such as HEFA, Fischer–Tropsch synthesis, and alcohol-to-jet processes, are being explored (Khujamberdiev & Cho, 2024). Despite their potential, cost, scalability, and feedstock sustainability present ongoing barriers (Duarte et al., 2023). While alternative technologies, such as hydrogen and biofuels, offer long-term promise, they currently face higher environmental impacts and operational costs compared to traditional aviation fuels (Kossarev et al., 2022). Agarwal (2009) emphasizes the importance of a holistic approach to sustainable aviation, including aircraft design, air traffic management, airport infrastructure, and regulatory policies to address environmental, economic, and technological challenges effectively.

2.6 Key Findings from Recent Feasibility Studies

Ludowicy et al. (2023) conducted a feasibility study on retrofitting the ATR 42-500 regional aircraft with battery-electric propulsion, identifying key barriers such as battery energy density and structural modifications. A study by WSDOT (2021) further evaluated the feasibility of electric aircraft for regional air mobility, finding that economic viability depends heavily on energy costs, infrastructure investment, and operational factors.

NREL (2022) emphasized that regional airport infrastructure must be upgraded to meet the high energy demands of electric aircraft fleets. Additionally, a ScienceDirect study (2024) confirmed the potential for emissions reduction with fully electric regional aircraft, especially on short-haul routes, while underscoring the need for continued improvements in battery technology. The European Union Aviation Safety Agency (EASA) has also initiated the development of certification standards for electric and hybrid-electric aircraft, which will be crucial for market integration (EASA, 2023).

2.7 Conceptual Framework

This study employed an integrated conceptual framework that combines the Technology Organization Environment (TOE) framework (Tornatzky & Fleischer, 1990) and the Diffusion of Innovations (DOI) theory (Rogers, 2003) to examine the adoption readiness and feasibility of electric aircraft for regional air transport in the Philippine archipelago. The TOE framework structures the analysis into three contexts: technological (e.g., aircraft performance, battery systems, infrastructure readiness) (Li, 2023; Tian, 2024), organizational (e.g., airline capacity, workforce competence, financial resources) (Madaki et al., 2023; Ramdani et al., 2013), and environmental (e.g., regulatory policies, market demand, infrastructure development) (EASA, 2023; Artajo et al., 2023).

To illustrate the fundamental design and components of electric aircraft being considered in this study, a conceptual schematic of a generic electric regional transport aircraft is presented (Figure 1). This schematic serves as a reference for academics to highlight key features, such as electric propulsion units, high-energy battery modules, and potential solar array integration for auxiliary power.

Complementing the Technology Organization Environment (TOE) and the Diffusion of Innovations (DOI) theory, the Innovation Adoption Model (IAM) focuses on five innovation attributes, relative advantage, compatibility, complexity, trialability, and observability, that influence stakeholders' adoption decisions (Green & Senge, 2011; Stephenson et al., 2018). These attributes capture perceptions of the operational, strategic, and economic impacts of transitioning to electric aviation (Minishi-Majanja, 2013; Kapoor et al., 2011).

The proposed conceptual framework for this study (Figure 2) illustrates the hypothesized relationships between TOE contextual factors and DOI innovation attributes leading to adoption readiness and feasibility outcomes. The framework posits that TOE factors create the structural conditions for adoption, while DOI attributes shape individual and organizational attitudes toward innovation. Furthermore, sustainability considerations and lifecycle cost analysis are incorporated as moderating variables, reflecting the crucial role of cost-efficiency and environmental performance in shaping adoption decisions (Wang & Yu, 2024).

By integrating TOE and DOI, this study offers a comprehensive lens to assess both systemic and perceptual factors influencing the readiness and feasibility of electric aircraft adoption in Philippine regional aviation.

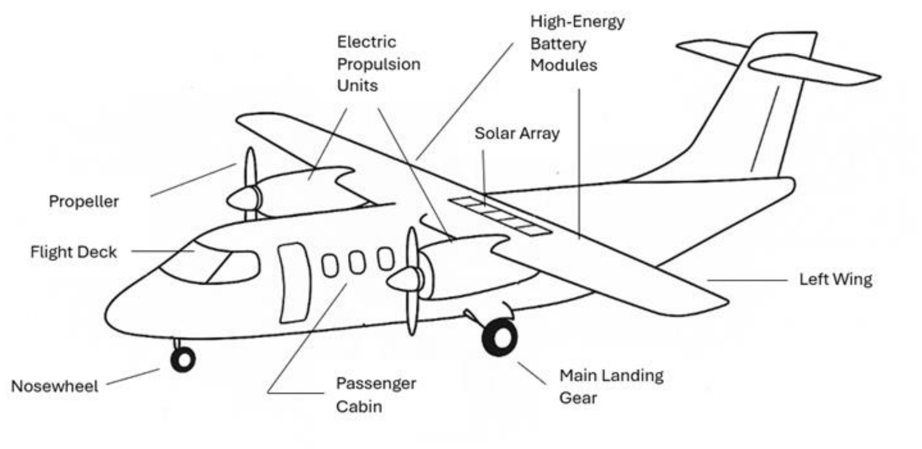

Figure 1. Conceptual schematic of a generic electric regional transport aircraft. Note: Illustration is for academic purposes only and does not represent any specific manufacturer design.

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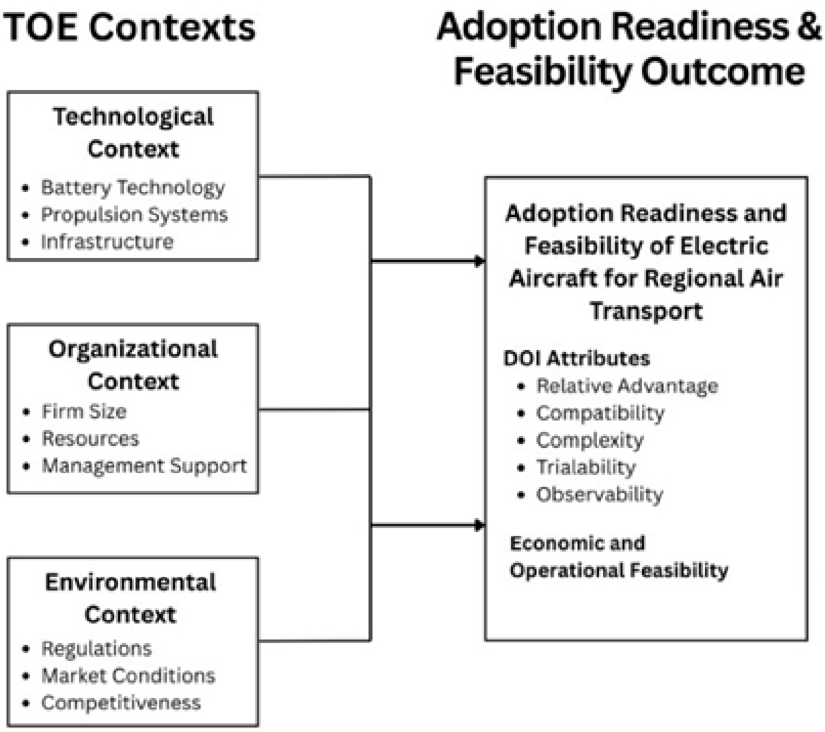

Figure 2. Conceptual framework for assessing adoption readiness and feasibility of electric aircraft in regional air transport. The framework integrates the Technology Organization Environment (TOE) model with the Diffusion of Innovations (DOI) theory.

3. Methodology

3.1 Research Design

This study employed a mixed-methods research design, utilizing a multi-case study approach, to investigate the adoption readiness and feasibility of electric aircraft for regional air transport in the Philippine archipelago. The mixed-methods design was chosen to enable a comprehensive exploration of the complex, multi-dimensional factors involved by integrating both qualitative and quantitative strands of inquiry (Creswell & Plano Clark, 2018).

The research was grounded in a multi-case study strategy involving selected airline operators, regulatory bodies, and industry stakeholders. This approach was deemed appropriate given the exploratory nature of the topic and the intention to examine similarities and differences across organizational contexts. The multi-case design enhanced the depth and credibility of the findings by allowing for cross-case comparisons and pattern identification (Yin, 2018).

Cases were selected using purposive sampling, targeting organizations relevant to the future deployment of electric aircraft in regional aviation. The design aligned closely with the study's conceptual framework, providing a structured yet flexible approach to examine how technological, organizational, and environmental factors, combined with perceptions of innovation attributes, influence adoption readiness.

The mixed-methods, multi-case research design provided a robust foundation for capturing both the contextual dynamics of the Philippine regional aviation sector and the systemic factors critical to the adoption of electric aircraft.

3.2 Population and Sampling Technique

The population for this study consisted of key stakeholders within the Philippine regional aviation sector who were considered knowledgeable and influential in decisions related to the potential adoption of electric aircraft. The targeted population included senior management and operational staff of regional airline operators, representatives from aviation regulatory agencies, and industry experts involved in aircraft maintenance, infrastructure development, and sustainable aviation initiatives.

A purposive sampling technique was applied to select the cases and participants. This non-probability sampling method was considered appropriate given the exploratory nature of the study and the need to focus on information-rich participants capable of providing deep insights into the research phenomenon (Creswell & Plano Clark, 2018). Selection criteria included organizational relevance to domestic regional air transport operations, active engagement in sustainable aviation discussions or initiatives, and participants' professional experience and decision-making roles in aviation operations or regulatory affairs.

The qualitative sample size was guided by the principle of thematic saturation, whereby data collection was concluded once no new themes emerged (Creswell & Poth, 2018). Consistent with Yin's (2018) guidelines for multi-case study designs, a minimum of three to five organizational cases were targeted, with three to five key informants per case to ensure adequate cross-case comparison and transferability of findings.

For the quantitative phase, sample size requirements followed the recommendations of Hair et al. (2017) for exploratory research and structural equation modeling (SEM). A ratio of five to ten respondents per observed variable was applied to ensure reliable model estimates. Based on the expected number of variables in the survey instrument, a minimum of 125 to 200 completed responses was deemed sufficient to provide adequate statistical power and robust analysis.

This dual sampling approach provided the necessary methodological rigor to meet the study objectives while maintaining flexibility suitable to the emerging nature of electric aircraft research in the Philippine regional aviation context.

3.3 Data Collection

Data for this study were collected through a combination of quantitative and qualitative methods consistent with the mixed-methods, multi-case study design. Multiple data sources were used to ensure triangulation and enhance the validity and reliability of the findings (Creswell & Plano Clark, 2018). Quantitative data were primarily gathered through structured surveys administered to management and operational personnel of selected regional airline operators and regulatory agencies. The survey instrument was designed to capture participants' assessments of technological readiness, organizational capability, environmental factors, and perceptions of the innovation attributes of electric aircraft. The survey items were developed based on existing validated scales and were adapted to reflect the specific context of regional aviation in the Philippines.

Qualitative data were collected through semi-structured interviews with purposively selected participants representing key stakeholder groups, including airline executives, aviation regulators, maintenance professionals, and infrastructure planners. The interview protocol was designed to elicit rich, contextual information regarding perceived barriers, enablers, and strategic considerations for the adoption of electric aircraft in regional air transport. Interview sessions were conducted either face-to-face or via virtual platforms, depending on participant availability and logistical considerations. In addition, document analysis was conducted by reviewing organizational reports, policy documents, regulatory guidelines, and sustainability strategies relevant to Philippine domestic aviation and emerging electric aircraft technologies. This provided contextual background and corroborated insights obtained through surveys and interviews.

Finally, secondary data were collected from publicly available sources, including manufacturer specifications, published technical reports, regulatory frameworks, and market analysis reports to support the cost analysis and feasibility assessment of electric aircraft operations. These data were used to estimate operational costs, infrastructure requirements, and lifecycle sustainability impacts associated with the transition to electric regional air transport. This multi-source data collection approach provided a robust and holistic foundation for addressing the study's objectives, ensuring that both quantitative metrics and qualitative stakeholder perspectives were comprehensively captured.

3.4 Instrument Development

The primary data collection tool for the quantitative phase was a structured questionnaire designed to assess factors influencing adoption readiness and feasibility of electric aircraft for regional air transport in the Philippines. Instrument development was based on an integrated conceptual framework combining the Technology Organization Environment (TOE) framework (Tornatzky & Fleischer, 1990) and Diffusion of Innovations (DOI) theory (Rogers, 2003). Items were measured on a five-point Likert scale (1 = strongly disagree to 5 = strongly agree), grouped according to the Technology-Organization-Environment (TOE) and Degree of Innovation (DOI) dimensions. The Technology section assessed perceptions of aircraft performance, battery system maturity, maintenance requirements, and infrastructure availability (Li, 2023; Tian, 2024). The Organization section captured internal readiness factors, including management support, employee competence, organizational resources, and sustainability alignment (Madaki et al., 2023; Ramdani et al., 2013). The Environment section addressed regulatory policies, customer demand, competitive pressures, and airport infrastructure (EASA, 2023; Artajo et al., 2023). The DOI component measured relative advantage, compatibility, complexity, trialability, and observability (Green & Senge, 2011; Stephenson et al., 2018). Content validity was established through expert panel review from aviation management, regulatory compliance, and sustainable aviation fields. A pilot test with airline and regulatory personnel refined item clarity and usability. Internal consistency reliability was subsequently evaluated using Cronbach's Alpha, with all constructs achieving values ≥ 0.70, indicating acceptable scale reliability for further analysis.

3.5 Data Analysis

Data analysis for this study employed a two-pronged approach, aligning with the mixed-methods design, which combined both statistical and cost-based evaluation techniques. For the quantitative data collected through structured surveys, descriptive statistical analysis was first conducted to summarize the demographic characteristics of the respondents and to provide an overview of the responses related to technological, organizational, environmental, and innovation adoption factors. Measures of central tendency (mean, median, and mode) and dispersion (standard deviation and variance) were used to describe the distribution of responses across the TOE and DOI constructs.

To examine the relationships among the study variables and to test the hypothesized influence of TOE and DOI factors on adoption readiness, inferential statistical analysis was performed. Depending on the data characteristics and sample size adequacy, multiple regression analysis or Structural Equation Modeling (SEM) was employed. Multiple regression was utilized to assess the predictive power of independent variables (technology, organization, environment, and innovation attributes) on the dependent variable (adoption readiness and feasibility). Where the data met the necessary assumptions (e.g., normality, sample size, model fit indices), SEM was applied to model the latent relationships between constructs, offering a more comprehensive understanding of the direct and indirect effects among variables (Kline, 2016). SEM analysis was conducted using software such as AMOS or SmartPLS.

In parallel, to evaluate the operational and economic feasibility of integrating electric aircraft into regional air transport, a Lifecycle Cost Analysis (LCCA) was conducted. Secondary data from manufacturer specifications, operational benchmarks, and industry reports were used to estimate key cost components, including acquisition, maintenance, energy consumption, and infrastructure investments over the aircraft's projected operational lifespan. The LCCA compared the total ownership costs of electric aircraft with those of conventional regional aircraft, enabling an assessment of the long-term financial viability of electric aviation adoption in the Philippine context. This integrated data analysis strategy ensured a robust examination of both the organizational adoption dynamics and the economic feasibility dimensions, providing comprehensive evidence to support the study's conclusions and recommendations.

3.6 Ethical Considerations

This study adhered to established ethical research standards throughout its design and implementation. Prior to data collection, the research protocol was submitted for review and received approval from the Institutional Ethics Committee of the affiliated academic institution. The approval ensured that the study complied with relevant ethical guidelines for research involving human participants. All participants were provided with a detailed informed consent form explaining the purpose of the study, the voluntary nature of participation, and the measures taken to ensure confidentiality and anonymity. Participants were informed of their right to withdraw from the study at any point without any consequences. Data collected was securely stored and used exclusively for research purposes. No personal identifiers were linked to survey or interview responses to protect participant privacy. These procedures ensured that the study maintained the highest standards of ethical integrity and respected the rights and well-being of all participants.

4. Results

4.1 Respondent Profile

A total of 150 valid responses were collected for the survey. As shown in Figure 3, respondents represented a diverse cross-section of the Philippine regional aviation sector. The majority were affiliated with airline operators (43.3%), followed by regulatory agencies (23.3%), maintenance providers (16.7%), and airport and infrastructure managers (16.7%). In terms of gender, male respondents accounted for 70% of the sample, while female respondents represented 30%. The distribution by position level indicated that 50% of participants held middle management positions, 26.7% were in senior management, and 23.3% were in technical or operational staff roles. The professional experience of respondents was broadly distributed, with 43.3% having between five and ten years of experience, 36.7% possessing more than ten years, and 20% reporting less than five years of experience. This distribution ensured that the data captured informed insights from highly experienced stakeholders across the industry spectrum.

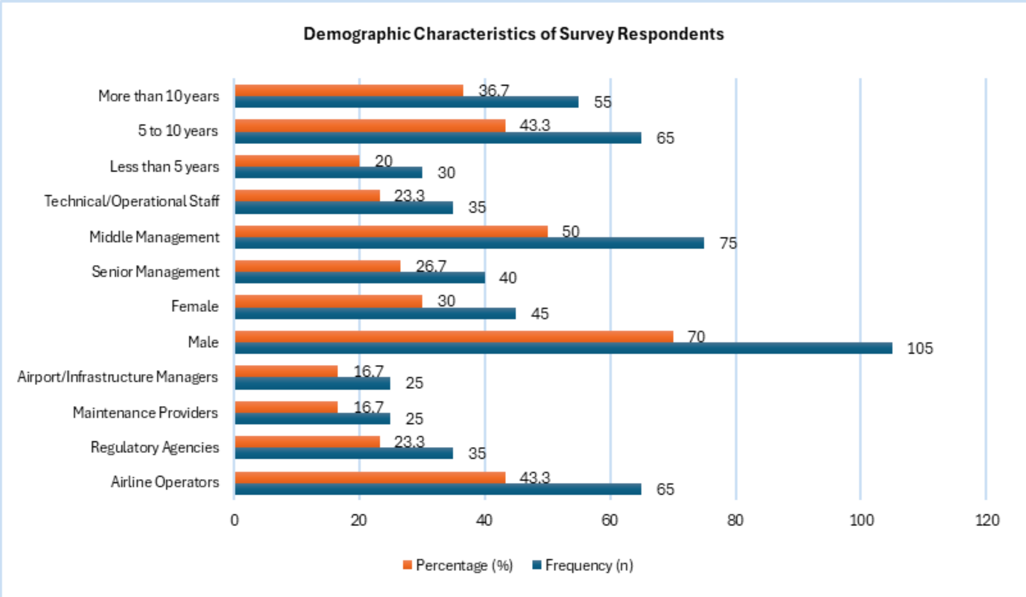

Figure 3. Demographic profile of survey respondents (n = 150). The figure presents the distribution of participants by organization type, gender, position level, and years of professional experience in the Philippine regional aviation sector.

4.1.1 Instrument Reliability

To assess the internal consistency of the survey instrument, Cronbach's Alpha coefficients were computed for each construct. As presented in Table 1, all constructs demonstrated values ranging from 0.75 to 0.85, exceeding the commonly accepted threshold of 0.70 (Hair et al., 2017). This confirms that the survey items were reliable indicators of the intended Technology Organization Environment (TOE) and Diffusion of Innovations (DOI) dimensions, providing a sound basis for further statistical analysis.

Table 1. Cronbach's Alpha values indicating internal consistency reliability of the TOE and DOI constructs (n = 150).

Construct	Number of Items	Cronbach's Alpha
Technology Readiness	4	0.81
Organizational Readiness	4	0.85
Environmental Readiness	4	0.78
Relative Advantage	3	0.84
Compatibility	3	0.8
Complexity	3	0.77
Trialability	3	0.75
Observability	3	0.79

Note. A Cronbach's Alpha value of ≥ 0.70 indicates acceptable internal consistency reliability (Hair et al., 2017).

4.2 TOE Factors Analysis

The survey instrument assessed stakeholders perceived readiness across the Technology Organization Environment (TOE) dimensions using a five-point Likert scale (1 = strongly disagree; 5 = strongly agree). Descriptive statistics were calculated to summarize the mean and standard deviation for each item under the three domains, as shown in Table 2. To ensure scale reliability, Cronbach's Alpha values were computed for each domain, all of which exceeded the 0.70 threshold, confirming acceptable internal consistency (Table 1).

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Organizational readiness emerged as the most potent enabler for electric aircraft adoption, with an overall mean score of 4.02 (SD = 0.67). The highest-rated item was top management's commitment to sustainability and innovation (M = 4.35, SD = 0.55), followed by organizational willingness to invest in emerging technologies (M = 4.10, SD = 0.65). In contrast, the availability of a skilled workforce for electric aircraft maintenance and operations received a lower rating (M = 3.60, SD = 0.81), indicating a potential implementation barrier.

Technological readiness reflected moderate optimism, with a domain mean of 3.75 (SD = 0.77). Respondents viewed future improvements in battery technology (M = 4.10, SD = 0.68) and reduced maintenance complexity of electric propulsion systems (M = 3.95, SD = 0.75) as significant enablers. However, the lack of charging infrastructure at regional airports (M = 3.20, SD = 0.88) was perceived as a key technological constraint.

Environmental readiness received the lowest mean score of 3.52 (SD = 0.78), revealing notable external barriers. While regulatory support for decarbonization (M = 3.80, SD = 0.70) and anticipated market demand for low-emission flights (M = 3.65, SD = 0.73) were viewed favorably, concerns were raised over the inadequacy of airport infrastructure (M = 3.10, SD = 0.92) for electric aircraft operations. These comparative readiness levels are illustrated in Figure 4, which presents a radar chart summarizing mean scores across the three TOE domains. The visual highlights a strong organizational foundation but underscores a readiness gap in technological and environmental infrastructure that must be addressed to facilitate successful adoption. In summary, while internal readiness is high, especially in terms of leadership support and investment willingness, external infrastructure and policy limitations remain significant hurdles for regional electric aircraft deployment.

Table 2. Mean and standard deviation scores of TOE factors influencing adoption readiness of electric aircraft in Philippine regional aviation (n = 150). Data reflect stakeholders' perceptions across technological, organizational, and environmental dimensions.

TOE Dimension	Item	Mean (M)	Standard Deviation (SD)
Technological	Anticipated battery technology improvements	4.10	0.68
	Expected reduction in propulsion maintenance	3.95	0.75
	Availability of charging infrastructure	3.20	0.88
	Overall Technological Mean	3.75	0.77
Organizational	Management's commitment to sustainability	4.35	0.55
	Willingness to invest in new technologies	4.10	0.65
	Availability of specialized workforce	3.60	0.81
	Overall Organizational Mean	4.02	0.67
Environmental	Regulatory momentum toward decarbonization	3.80	0.70
	Market demand for low-emission flights	3.65	0.73
	Infrastructure readiness for electric aircraft	3.10	0.92
	Overall Environmental Mean	3.52	0.78

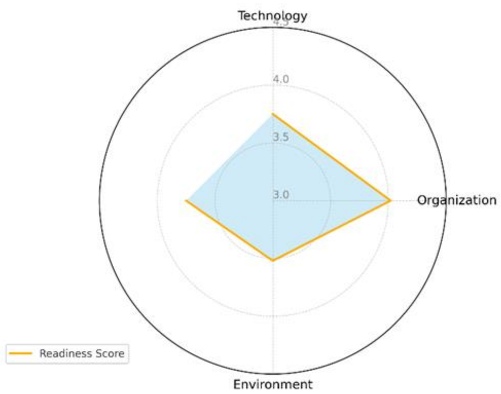

Figure 4. Radar chart showing perceived readiness scores across technological, organizational, and environmental domains in the Philippine context.

4.3 DOI Factors Influence

The study also evaluated stakeholders' perceptions of the innovation attributes of electric aircraft using Rogers' Diffusion of Innovations (DOI) theory. Five core attributes were assessed, relative advantage, compatibility, complexity, trialability, and observability, through a five-point Likert scale (1 = strongly disagree; 5 = strongly agree). Descriptive statistics for each attribute are presented in Table 3**.**

Among the innovation attributes, relative advantage received the highest rating (M = 4.20, SD = 0.60), reflecting a strong belief that electric aircraft offer substantial operational and environmental benefits over conventional turboprops. Compatibility was also rated favorably (M = 4.05, SD = 0.65), suggesting alignment with existing aviation systems and practices.

Conversely, complexity emerged as a potential barrier (M = 3.35, SD = 0.80), signaling apprehension over technical integration, maintenance complexity, and unfamiliar procedures. Trialability, or the perceived ability to test and evaluate electric aircraft on a limited scale, received a moderate score (M = 3.60, SD = 0.75), indicating limited exposure to pilot programs. Observability was rated moderately high (M = 3.85, SD = 0.70), suggesting that the benefits of electric aircraft, such as reduced emissions and lower operating costs, are increasingly recognized but not yet broadly visible.

The aggregated interpretation of these innovation attributes is visually summarized in Figure 5, showing a concentration of stakeholder perceptions within the "moderate to high" influence range, but with pockets of "moderate-low" responses related primarily to complexity and trialability.

The internal consistency of the DOI constructs was confirmed through Cronbach's Alpha analysis, with all constructs exceeding the 0.70 benchmark (see Table 1), supporting the validity of the instrument used. In summary, while stakeholders acknowledge the clear strategic advantages and compatibility of electric aircraft, their concerns about operational complexity and lack of trial exposure present tangible barriers to adoption. Addressing these issues through demonstration projects and clearer operational standards will be key to accelerating diffusion within the Philippine regional aviation sector.

Table 3. Mean and standard deviation scores of DOI innovation attributes influencing the perceived adoption of electric aircraft in Philippine regional aviation (n = 150).

DOI Attribute	Item Description	Mean (M)	Standard Deviation (SD)
Relative Advantage	Electric aircraft offer environmental and operational benefits over conventional aircraft.	4.2	0.6
Compatibility	Electric aircraft can be integrated into existing operations and infrastructure.	4.05	0.65
Complexity	Perceived difficulty in operating, maintaining, or integrating electric aircraft.	3.35	0.8
Trialability	Opportunity to test electric aircraft on a limited scale prior to full adoption.	3.6	0.75
Observability	Visibility of measurable benefits (e.g., cost savings, emissions reduction).	3.85	0.7

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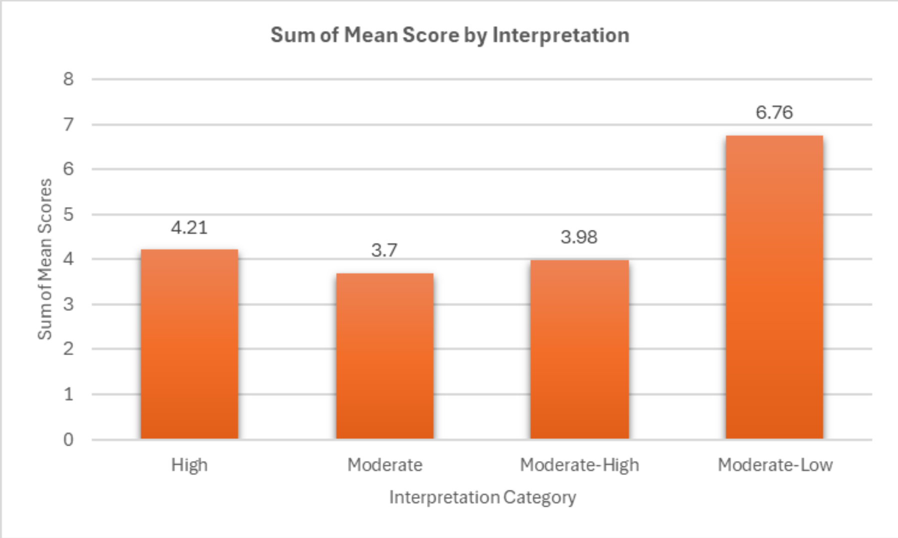

Figure 5. Aggregated Perception of Innovation Attributes Based on Mean Score Interpretations

4.4 Feasibility Results: Cost and Sustainability Assessment

To complement the analysis of adoption readiness factors, the study conducted a supplementary assessment of the feasibility of adopting electric aircraft for regional air transport in the Philippines. The analysis included a comparison of estimated lifecycle costs and sustainability impacts between emerging electric aircraft designs and conventional turboprop regional aircraft. Secondary data were sourced from manufacturer specifications, industry technical reports, and published lifecycle cost studies to develop baseline comparisons (Table 4).

Results indicated that electric aircraft are expected to incur higher initial acquisition costs (USD 7 million vs. USD 5 million for conventional turboprop aircraft) and significant upfront infrastructure investments for charging and maintenance facilities (USD 2 million vs. USD 0.5 million). However, the long-term operational costs of electric aircraft were notably lower due to substantially reduced energy and maintenance expenses. Energy consumption costs per flight hour were estimated at USD 200 for electric aircraft compared to USD 500 for conventional alternatives. Maintenance costs per flight hour were similarly lower for electric aircraft (USD 100 vs. USD 300). As a result, the total lifecycle cost of ownership for electric aircraft was projected to be approximately 20% lower than that of conventional regional turboprops.

In terms of environmental performance, electric aircraft offered significant emissions reduction potential. Estimated lifecycle carbon emissions were 40–50% lower than those of conventional aircraft when applied to short-haul regional routes. Industry stakeholders and previous research consistently identified the decarbonization benefits of electric propulsion as a primary incentive for future adoption. Despite the current financial and infrastructure barriers, the findings suggest that electric aircraft offer a promising long-term alternative for sustainable regional aviation. As battery technology, infrastructure readiness, and regulatory support continue to evolve, electric aircraft may become increasingly viable within the Philippine aviation sector.

Table 4. Comparative analysis of lifecycle costs and emissions between electric and conventional turboprop regional aircraft. Estimates based on secondary data from manufacturer reports and technical publications.

Cost/Impact Category	Electric Aircraft	Conventional Turboprop Aircraft
Acquisition Cost	USD 7M	USD 5M
Energy/Fuel Cost (per flight hour)	USD 200	USD 500
Maintenance Cost (per flight hour)	USD 100	USD 300
Charging/Fueling Infrastructure	USD 2M	USD 0.5M
Estimated Lifecycle CO_2 Emissions	50% lower	Baseline
Estimated Total Cost of Ownership	20% lower	Baseline

5. Discussion

This study examined the adoption readiness and feasibility of electric aircraft for regional air transport in the Philippines using an integrated TOE-DOI framework. Organizational readiness emerged as the most significant driver of adoption, with aviation stakeholders demonstrating strong internal commitment, managerial support, and a willingness to invest in sustainable technologies. The internal consistency of the instrument used in the study was confirmed, as all constructs under the TOE and DOI frameworks met the required reliability threshold. This enhances confidence in the results and validates the relevance of these frameworks in emerging aviation contexts.

Technological readiness showed moderate optimism. Stakeholders acknowledged ongoing improvements in battery systems and propulsion technologies but expressed concern over limitations in charging infrastructure and overall system maturity. These concerns reinforce the importance of infrastructure development as a prerequisite for large-scale deployment.

Environmental readiness received the lowest overall scores. Many regional airports lack the infrastructure needed to support electric aircraft, and regulatory frameworks remain underdeveloped. This reflects the broader constraints faced by the Philippine aviation sector, which operates across geographically dispersed airports with limited public investment. Within the DOI framework, stakeholders perceived electric aircraft as offering relative operational advantages and being generally compatible with existing systems. However, high complexity and limited opportunities for trialability continue to hinder wider acceptance.

The lifecycle cost analysis revealed that although electric aircraft have higher upfront costs, they offer an estimated 20% total cost savings over their operational lifespan. This reinforces the long-term viability of electric propulsion, especially when paired with strategic investments and supportive regulation. To support these findings, a proposed adoption roadmap is presented in Figure 6, illustrating five key stages: Awareness, Preparation, Pilot Implementation, Scale-Up, and Integration. This staged approach provides a realistic pathway for gradual adoption and policy alignment in the Philippine context.

Overall, the study provides actionable guidance for both aviation operators and policymakers. Airlines can leverage organizational readiness by initiating pilot programs and capacity-building efforts. Meanwhile, regulators must prioritize infrastructure development and regulatory reform to enable the future integration of electric aviation.

Figure 6. Adoption roadmap for electric aircraft in the Philippine regional aviation sector. he roadmap illustrates sequential steps from awareness to full integration, emphasizing the roles of stakeholder engagement, pilot trials, and regulatory alignment.

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5.1 Recommendations

Considering the findings from this study, several targeted recommendations are proposed to support the strategic integration of electric aircraft into the Philippine regional aviation sector:

1. The Civil Aviation Authority of the Philippines (CAAP), in collaboration with the Department of Transportation and relevant stakeholders, should initiate the creation of a national roadmap that outlines regulatory, infrastructure, and certification pathways for electric aircraft. This roadmap should be aligned with ICAO and EASA guidelines and tailored to the unique needs of regional air mobility across the archipelagic landscape.
2. To mitigate perceived complexity and low trialability two key barriers identified in the study, government and private sector actors should co-fund pilot projects that test electric aircraft on select inter-island routes. These trials will generate empirical operational data, build stakeholder confidence, and serve as a foundation for scaled adoption.
3. Infrastructure gaps, particularly at secondary and remote airports, must be addressed. Priority investments should focus on scalable and modular electric aircraft charging systems, ideally powered by renewable sources to amplify sustainability outcomes. Public–private partnerships can be leveraged to de-risk capital outlays.
4. Educational and training institutions, especially those offering Aircraft Maintenance Technology programs, should integrate modules on electric propulsion systems, battery management, and high-voltage safety. Regulatory bodies should also prepare licensing protocols for electric aircraft maintenance personnel.
5. Given the novelty of electric aviation technologies, implementing regulatory sandboxes can facilitate controlled, real-world testing under provisional rules. This iterative approach enables learning, risk mitigation, and progressive rulemaking without hindering innovation.
6. Cross-agency coordination among aviation authorities, energy regulators, airport operators, and OEMs is essential to avoid fragmented efforts. Additionally, ASEAN-level collaboration could help harmonize technical standards and facilitate cross-border electric regional air services in the future.

Collectively, these recommendations address the key organizational enablers, technological opportunities, and environmental constraints identified in the study. By advancing policy coherence, infrastructure development, and workforce readiness, the Philippines can take early leadership in sustainable regional air mobility within Southeast Asia.

6. Conclusion

This study aimed to assess the adoption readiness and feasibility of electric aircraft for regional air transport in the Philippine archipelago by integrating the Technology Organization Environment (TOE) framework and Diffusion of Innovations (DOI) theory. The results showed that while organizational readiness emerged as the most potent enabler, moderate confidence was expressed regarding technological maturity, and substantial concerns remain regarding infrastructure and regulatory preparedness. DOI analysis confirmed strong perceptions of relative advantage and compatibility, but uncertainty about complexity and limited trial opportunities constrained enthusiasm for adoption. The study makes two key contributions. Theoretically, it extends the application of TOE-DOI models to the emerging field of electric aviation in a developing country context, providing new empirical insights from the Philippine market. The reliability of the survey instrument was also established, with all constructs demonstrating acceptable internal consistency as indicated by Cronbach's Alpha values above 0.70. Practically, it offers evidence-based guidance for regional airlines and regulators on the critical barriers and enablers that must be addressed to support the future integration of electric aircraft.

6.1 Limitations and Future Research

This study has limitations. It focused on a purposive sample within the Philippine domestic aviation sector, which may limit generalizability to other markets. Additionally, the feasibility assessment was based on secondary data projections and did not include operational field testing. Future research should explore longitudinal studies as technologies mature, and policies evolve. Pilot demonstration programs using experimental electric aircraft on actual regional routes in the Philippines are strongly recommended to validate assumptions, assess operational readiness, and provide more robust data to guide strategic decision-making in both industry and government sectors.

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8. Conflict of Interest

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