Journal of Multidisciplinary Engineering Science and Technology (JMEST)
ISSN: 2458-9403
Vol. 9 Issue 3, March - 2022

Implementation of Electric Aircraft:
Aviation Operators' Perspectives

Dongyang Li
School of Electrical and Computer Engineering
Purdue University
West Lafayette, IN, USA 47907
lidongyang@purdue.edu

Chien-tsung Lu
School of Aviation & Transportation Technology
Purdue University
West Lafayette, IN, USA 47907
ctlu@purdue.edu

Joshua Guzek
School of Aviation & Transportation Technology
Purdue University
West Lafayette, IN, USA 47907
jguzek@purdue.edu

Kenneth Smith
Breeze Airways
Cottonwood, UT, USA 84047
smit3509@purdue.edu

***Abstract*— The aviation industry is set to see another significant leap in new technology, namely electric aircraft. As of the time of this research, both 9-seat and 19-seat aircraft would be ready to be launched by air service providers under the Essential Air Service (EAS) program. While electric aircraft manufacturers are hoping to incorporate electric aircraft into the national airspace system, challenges are salient. This study explored existing research and literature by using Qualitative Narrative Analysis in conjunction with the application of VOSviewer to visualize research themes and interconnected clusters followed by interviewing practitioners to reflect on theoretical basis and collect the first-hand data. VOSviewer showed regulations (U.S.A. and Canada), engine design, continued airworthiness, military standards, and maximum transient were primarily discussed and studied. Second-level analysis discovered that Federal Aviation Administration (FAA) has focused on aircraft specification, service and maintenance, and project management perspectives. Regardless of the ongoing technical and regulatory challenges, selected aviation practitioners were recruited and interviewed. Practitioners indicated that although airports and airlines possessed different means of benchmarking success, there was a market niche and tangible benefits that smaller electric aircraft would bring to the needed communities.**

Keywords—Electric aircraft, aviation batteries, EAS, SCASD

I. INTRODUCTION

Electric aircraft have been developing in the form of Unmanned Aerial Systems (UAS) for an extended period of time. In recent years innovations in structure design, materials, payload, and battery technologies have allowed engineers to develop manned electric aircraft for passenger and cargo transportation. Besides the small-sized electric aircraft developed as prototypes, large manufacturers have been investing in high-payload zero-emission aircraft such as Airbus ZEROe [1]. Other sectors of air transportation including general aviation also saw the convenient mobility of using e-aircraft, for example the vertical takeoff and landing (VTOL) aircraft, for inner/inter transportation between urban cities and remote townships. While most of the ongoing electric aircraft projects are aiming to service before 2030, it is worth of noting that the Federal Aviation Administration (FAA) had approved USD 100 Million into developing the next generation of sustainable aircraft [2]. This investment awarded to industry leaders like GE Aviation, Honeywell Aerospace, Boeing, and Pratt & Whitney to work on comprehensive and reliable systems that will support the operation of the future electric aircraft.

A study by Prapotnik Brdnik et al. [3] confirmed that the most feasible electric aircraft to be electrified is the regional turboprop regarding investment, payload, distance, infrastructure and operational cost. Correspondingly, in order to enable fully electric or hybrid aircraft operations, airports need to make substantial additions and upgrades to their infrastructure. According to a study conducted by Salucci, Trainelli, Faranda, & Longo [4], battery charging stations (which aircraft could directly plug into) and battery swapping stations (where batteries are removed and charged separately) were two key pieces of infrastructure necessary to be conducive to host electric aircraft operations. To test the aforementioned theory, Salucci and research associates used an airport in Athens, Greece, which served a large number of regional jet operations per day, as an example in their analysis. They discovered that even for the smaller regional jets, direct charging stations would not be suitable due to the size of the batteries. Before approaching to the determined goal, there are a series of complex decisions made including the selection of proper aircraft.

The foundation of this study stemmed from the concerns of technical achievements, government's standards, preparedness of practitioners (airlines and airports), potential market and cost-benefit, just to name a few. Research areas to be discovered of this study were:

1. The key innovative fields related to electric aircraft that had been investigated.
2. Existing governmental standards and supports for the R&D and operations of electric aircraft.
3. Needed infrastructures investment for airports or airlines to facilitate electric aircraft operations.

4. Governmental subsidies for air service providers and airports for the usage of electric aircraft.

II. LITERATURE REVIEWES

A. The basics of Essential Air Service (EAS)

In response to the Airline Deregulation Act (ADA), Congress added section 419 to the Federal Aviation Act where the Essential Air Service (EAS) program was put into place to guarantee that small cities maintain a "minimum level" of scheduled air service [5]. Through this program, the DoT determines the minimum service level required at eligible EAS communities including the ability of connection to the national network, a minimum number of weekly round trips and available seats, aircraft characteristics, and the number of stops that are permitted to the designated hub.

This legislation requires all candidate communities to see at least 10 enplanements per day excluding Alaska, Hawaii, or communities that sit 175 miles or more from the nearest medium or large hub airport or otherwise waived by the Secretary of Transportation. In order to decide which cities to serve, the DoT has five factors to consider:

(1) the demonstrated reliability of the applicant in providing scheduled air service; (2) the contractual and marking arrangements the applicant has made with a large carrier to ensure service beyond the hub airport; (3) the interline agreements that the applicant has made with larger carriers to allow passengers and cargo of the applicant at the hub airport to be transported by the larger carrier(s) through one reservation, ticket, and baggage check in; (4) the preferences of the actual and potential users of air transportation at the eligible place, giving substantial weight to the views of the elected officials representing the users of the service; and (5) whether the air carrier has included a plan in its proposal to market its service to the community. [5]

In communities where EAS is utilized, the benefits the program brings to an area can boost significant economic growth [6]. As a business entity, profit is the lifeblood to remain perpetually sustainable. While some airports are served by turbo-propped 9-seat Cessna 402 or Tecnam P2012, some currently served with 50-seat aircraft such as Bombardier CRJ-200 under EAS program. For instance, Billings, Montana, can be considered a hub in relation to Lewiston, Montana. Conditions taken into consideration including flight frequency and location of service based upon the history of service and geographic location [7].

Kanafani and Abbas [8], who looked at three California cities (Bakersfield, Redding, and Monterey) and how they were affected by the Airline Deregulation Act (ADA). Cities lacking air services would encounter slow economic growth compared to those with air service. For instance, City of Monterey's geographical isolation that prohibited commercial aviation service encountered slow or no economic growth. An article written by Blonigen and Cristea [9] had discovered that a region's additional income has been correlated to the increased amount of air service. In their study, they revealed that the "quasi-natural policy experiment" of the ADA, in most cases, worked. Their findings suggested that externally stimulating demand increased regional growth rate when passenger traffic increased by 50% would lead to a 1.55% (conservatively) increase in population size. By linear regression analysis, over a 20-year period, ADA could stimulate hundreds of millions of dollars into the local economy.

B. Small Community Air Service Development Grant (SCASD)

In a study by Wittman [10], who explored the other large type of grant besides EAS, namely Small Community Air Service Development (SCASD) grants. Unlike the EAS program, SCASD grants provide funding to airports to complete specific incentive packages to either attract new air service or promote existing services. With the average amount of SCASD grants given per year totaling between 6 million and 20 million USD, it is relatively small compared to EAS. Wittman proposed viewpoints for SCASD grants to become more successful. The first point was to attract new air services. If the airport was able to attract and maintain air service in the first 28 months after grant was awarded. it showed a higher likelihood of staying long term. Wittman's provided an example to explain that between 2006 and 2011, 89 total grants given to attract new services and 25.9% of these grants were overall successful within 28-month timeframe. The second point, related to marketing existing services, was that if the airport could improve its level of service by greater than 10% in 28 months, it was more likely to succeed with 73.1% of the 26 grants succeeding.

C. Electrical AircraftPolicies and Certification

Federal Aviation Administration (FAA) type certification processes mandate safety and reliability measurement for future electric or hybrid-electric aircraft. As of a recent FAA ruling regarding magniX electric engines, electric propulsion systems as an aircraft design feature were still considered to be novel and unusual, which required a more stringent certification process [11]. When the original 14 CFR Part 33, which covers airworthiness standards for aircraft engines, was developed, the FAA only considered internal combustion systems and the potential hazards that they specifically may present. Obviously, since electric engines behave quite differently and possess unique sets of potential flaws related to mechanical, thermal, chemical, and high-voltage operating conditions, 14 CFR Part 33 or even Part 21.47 may contain inadequate certification standards against innovative engines and associated propellers. Therefore, the development of special conditions has been required by the engine developing community.

The FAA's response to electric engines was shown in the Notice of Proposed Rulemaking (NPRM) in 2020 [11] that proposed to collect public voice to help certify new aircraft with innovative or unusual propulsion engine systems. Comments were submitted by interested organizations and individuals, suggesting that this particular certification process should be more smooth as new electric propulsion technology emerged. On September 27, 2021, the FAA released the "*Special Conditions: magniX USA, Inc., magni350 and magni650 Model Engines; Electric Engine Airworthiness Standards*" via Federal Register to certify magni350 and magni650 electric engines [12] Federal guidelines have been set to streamline and speed up the process for electric propulsion aircraft to become feasible and commonplace.

D. Infrastructural considerations

Electric propulsion systems. Electric propulsion systems for aircraft have been seriously investigated to fulfill emissions-reduction goals and green-energy policies such as pure-electric (PE) engines, which use a battery to store energy, and hybrid-electric (HE) engines, which combine battery technology with a more conventional fuel system [13]. The introduction of both aircraft types was expected to impose a substantial effect on a part of airport facilities and call for a renovation or even a new infrastructural installation.

Recharging facilities. The most essential need is the facilities for battery recharging, which can be categorized into two basic types: battery plug-in chargers (BPCs) or battery swapping stations (BSSs). Using a BPC is similar to current fuel-refilling systems like automotive counterparts. BPCs seem less complicated in terms of operations than BSSs but have the major shortcoming of taking more time, especially sensitive to size and weight increase. Trainelli et al. used an international airport as the case that incorporated considerable daily turboprop regional operations, discovered that both BPC and BSS systems alone would not be able to sufficiently provide power supply to the smaller regional planes at the speeds required to support the current operational use.

Cost. Another challenge is the cost. Battery swapping stations would make it possible to take advantage of relatively reasonable and stable electricity prices by allowing for recharging at any time, regardless of the presence of an aircraft. However, battery procurement and inventory cost would be a financial burden [14].

E. Efficiencies of batteries

Passenger air transportation has been expected to be gradually restored in the post-pandemic era [15]. However, increasing emission restrictions are being considered in key markets such as European nations. The 2050 target set by the Advisory Council for Aeronautical Research in Europe to reduce emissions in air transport by 90%. Electrification of aircraft propulsion will become more necessary but is currently limited by battery capacity which can provide only a fraction of the energy per kilowatt per hour per kilogram (kWh/kg) [3] Batteries currently have a specific energy of up to 0.25 kWh/kg, while that of kerosene is 4 kWh/kg when used in an internal combustion process. Significant improvements of light-weight high-capacity batteries for large aircraft remain challenging kilogram. Remarkably, Heart Aerospace's development of the ES-19 aircraft, which could seat up to 19 people, had proven that larger electric aircraft were possible [16] yielded two hundred pre-orders.

F. Research Questions

While electric aircraft possesses green-energy related benefits such as zero CO_2 emission, what are the research areas or themes that the industry or academia have studied? What were the specific research areas that have been important to make electric aircraft successful? While revenue or cash flow is the major driving force for practitioners to continuously improve their services and to be sustainable, what are perceptions of aviation practitioners regarding using or hosting electric aircraft? The authors defined two research questions as the following:

Research Question 1: What research areas had been studied in relations to electric aircraft?
Research Question 2: What were the major concerns affecting aviation practitioners when considering the usage of electric aircraft?

III. METHODOLOGY

Case Study. For stage-1 of the methodology, the authors proceeded Case Study to collect qualitative data from existing body of knowledge. According to Naumes and Naumes [17], case studies could use one unique set of research projects to comprehensively extract useful information for a special research purpose. To answer Research Question 1 based on meta data, the authors applied VOSviewer to generate available themes and interconnected clusters for further analysis. To answer Question 2, the stage-2 of the study applied in-person interviews. Interview questions in the questionnaire are provided in the Appendix, which stemmed from literature reviews and focused on collecting the perception of electric aircraft from aviation practitioners.

VOSviewer. The VOSviewer software uses a smart local moving algorithm that identifies nodes and edges efficiently. And this smart locally moving algorithm constructs networks at different levels breaks down the complexity and continues to process the sub-network. This algorithm reiterates itself until a maximum level of optimization has been achieved when processing a large number of iterations on larger-sized networks [18][19]. VOSviewer mechanism enables researchers to download and categorize documents for a quick data visualization and as a foundation for questionnaire to answer Research Question 2. *Web of Science* was used to download publications in the full-record format. These downloaded documents were then converted into .txt format for VOSviewer mapping process. VOSviewer is a program that uses Artificial Intelligence (AI) to review, analyze and extract qualitative themes, highlights or clusters available to researchers for a further interpretation [20] Using artificial intelligence, VOSviewe also enables a researcher to visually discover themes or clusters from a large number of qualitative documentations providing a general landscape of interconnection among significant clusters/themes based on frequencies of appearances [21][22][23].

Reliability & Validity. While one of the purposes of this study was to examine consistency, authenticity, and truthfulness of the findings [23][24], the authors identified and finalized themes and interconnected clusters by testing

VOSviewer 30 times. VOSviewer findings were incorporated in the questionnaire and delivered to practitioners for the validation, namely Delphi Technique [26]. The interview questionnaire of Research Question 2 was designed intentionally to capture a wide range of feedback, using open-ended questions and compared with the literature reviews after the process of data triangulation [27].

IV. FINDINGS

A. *What research areas had been studied in relations to electric aircraft?*

Running the VOSviewer algorithm on the reference list, this research gathered revealed about 100000 words, and VOSviewer identified about 6000 terms from the data. Running the full counting of the terms generated Figure 1, which showed around 12 clusters such as "*FAA*", *"TCCA", "aircraft", "battery", "case", "airport", "city"* just to name a few, with the biggest cluster being the "*FAA*" a.k.a. Federal Aviation Administration and "*TCCA*" a.k.a. Transport Canada, together, they can be referred to as the regulators. The VOSviewer network visualization based on full counting is comprehensive, involving many sub-clusters that contain important information for the research.

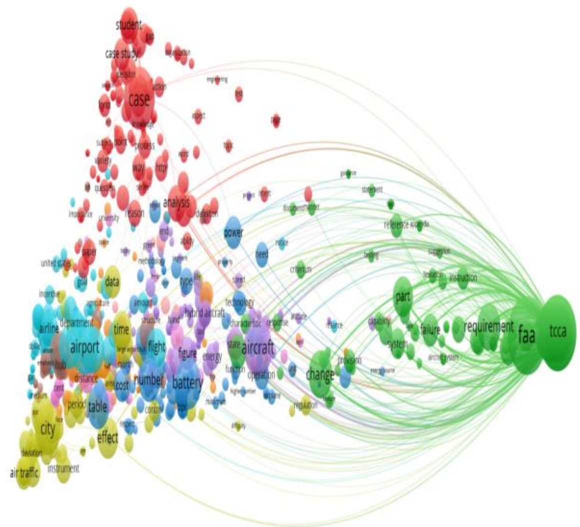

Fig. 1. *Regulatory Bodies of Electric Aircraft Studies*

The highlighted connection of "*FAA*" cluster with other sub-clusters in the network visualization is shown in Figure 2. Although the full counting of terms generated a rather big diagram, it can be observed that there were *"case analysis", "aircraft specification", "service and maintenance", "project management"* perspectives connected to the "*FAA*" cluster. Those connections identified by the natural language processing software taking the connections of key concepts across dimensions, expressed in clusters as parallel, could enable policy makers to make more practical analysis and decisions on the emerging technologies.

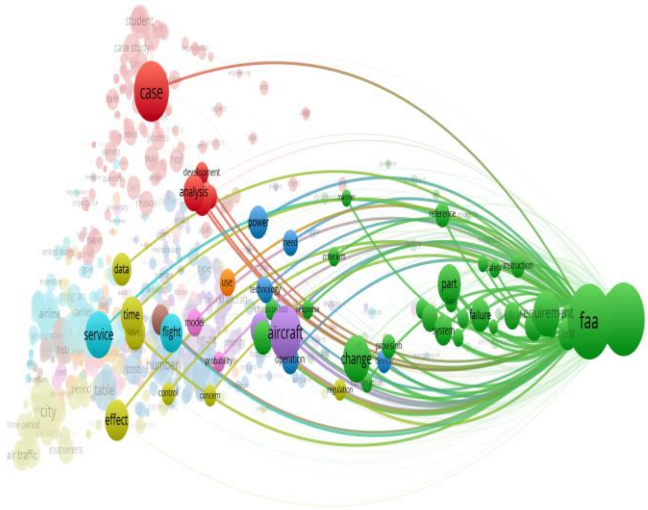

Fig. 2. *FAA & Related Clusters of Electric Aircraft Studies*

To further analyze, the "*special conditions*" of the electric aircraft were linked to the "*FAA*" cluster as electric aircraft is new to the FAA approval procedure via "*special condition*" (see Figure 3). This observation reflected on the importance of the specific Federal Register published in June 2021 for electric engines. To analyze further, there were enormous sub-clusters of "*special conditions*" for the electric aircraft development research. The links to the sub-cluster such as magniX engine design, continued airworthiness, mil-std (military standard), maximum transient, etc. These technical terms provided an informative outlook for the study to discover key areas in the development of electric aircraft.

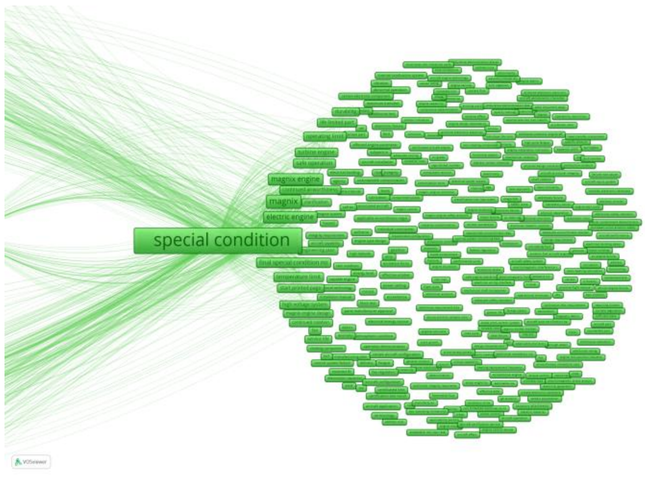

Fig. 3. *FAA "Special Conditions" of Electric Aircraft Studies*

In figure 4, a more concise natural language processing procedure was done. The result yielded eight (8) color-coded themes, with some sub-clusters of *"battery", "case", "mass/weight", "airports", "technical tables", "city", "Bakersfield",* and *"certification"*. A further analysis on "*battery*", which was one of the keys to develop of electric aircraft, connected to a series of key terms that provided researchers with insights into what needed to look for when developing and testing new battery technologies, such as the *"acquisition cost", "battery charging schedule", "charge time evolution", "procurement cost", "BPC" (battery plug-in chargers), and "battery swapping"* (see Figure 5). This has been a functional way for the battery researchers to identify key areas for their future development.

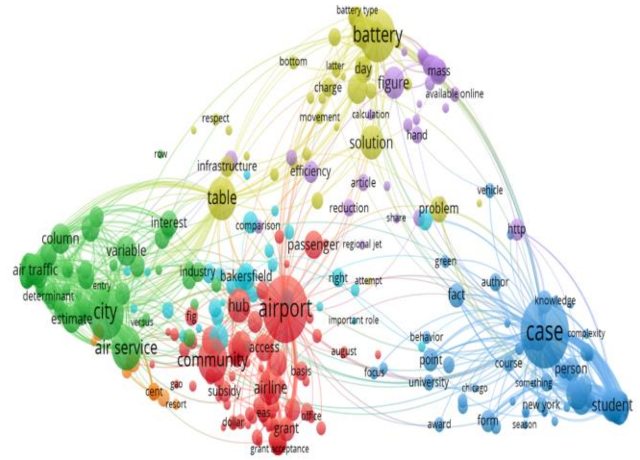

Fig. 4. *Clusters of Related Studies of Electric Aircraft Studies*

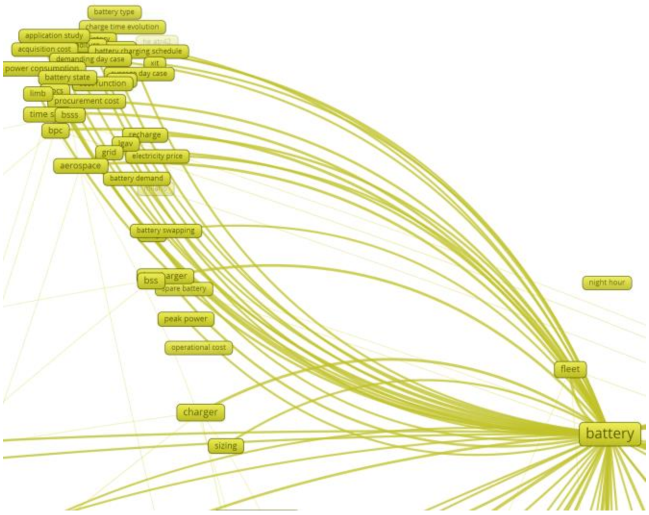

Fig. 5. *Related Studies of Battery for Electric Aircraft Studies*

Another observation the *"battery"* cluster was connected to was technical concepts (see Figure 6) including current energy-output methodologies of the electric aircraft industry including *"electric aircraft", "hybrid aircraft", "hydrogen", "energy consumption", and "regional aircraft"*. Besides battery studies, another alternative green energy like hydrogen was also studies by scientists to reduce CO_2 emission. There is no surprise that energy consumption or efficiency played an influential variable of the study.

The next cluster of interest was the policy sub-themes, as shown in Figure 7. These themes were under the main connection node of the "*city*", which referred to *"airports", "traffic management", "income"*, and *"Airline Deregulation Act (ADA)"* involving governmental subsidies. There were significant terms related to the benefits of implementing the ADA's Essential Air Service (EAS) program on electric aircraft, including *"correlation", "economic growth", "employment", "urban growth", "robustness",* etc. When considering electric aircraft, "ADA" and "air traffic change" reflecting on the "income" that connected to "city." While "income" stood out, it showed that revenue is critical to cities when considering air services.

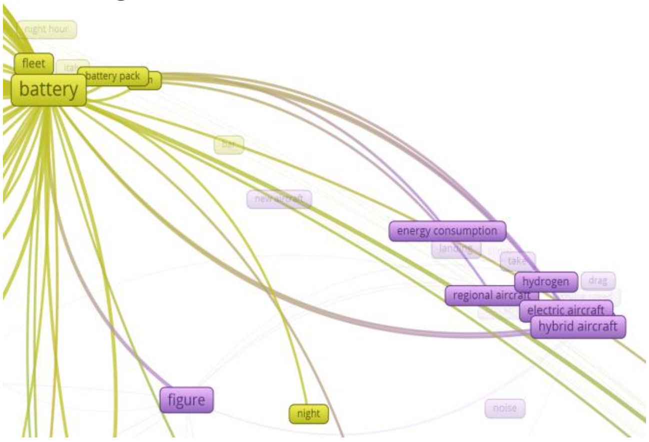

Fig. 6. *Related Technologies of Battery*

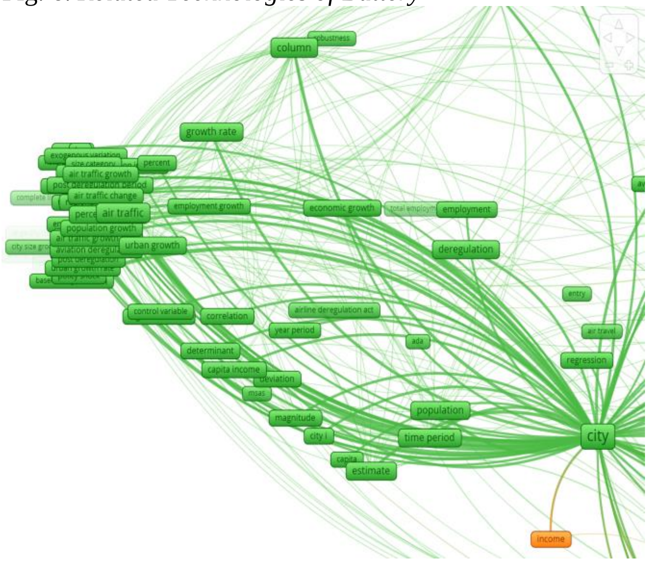

Fig. 7. *Related Studies of "City" cluster*

The last cluster of interest was the Essential Air Service. Notice that there were robust connections with the other clusters and terms of the "*SCASD Grant*" prevailed. Small Community Air Service Development Program (SCASD) Grant has been a program designed to assist smaller communities with their air transportation needs. The algorithm was able to pick up that co-occurrence in the data, that connected this program with terms such as *"incentive package", "grant application", "X seats regional jet", "small community air service", "grant acceptance", and "grantee*." This finding partially help build up the foundation of the open-ended questionnaire (see Appendix) for interviewing voluntary aviation practitioners.

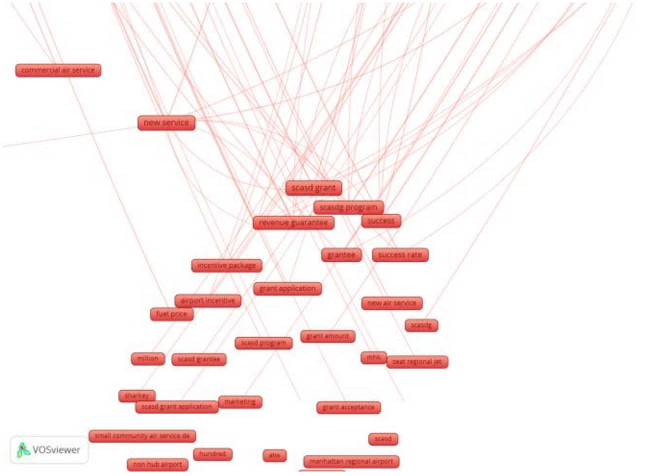

Fig. 8. *"SCASD" Sub-clusters*

B. What were the major concerns affecting aviation practitioners when considering the usage of electric aircraft?

The stage-2 of this study aimed to validate the findings from VOSviewer meta-analysis. Voluntary aviation practitioners were purposively selected, and in-person interviews were conducted virtually. One SCASD-subsidized regional air carrier was recruited to shed light on the concerns of the similar air service providers (see Table 1).

TABLE 1. VOLUNTARY INTERVIEWEES - AVIATION PRACTITIONERS

Interviewee A	Airport Manager, restoring commercial air service
Interviewee B	Airport Manager, EAS contractor
Interviewee C	Airport Manager, EAS contractor
Interviewee D	Airport Manager, EAS contractor
Interviewee E	Airline Executive, EAS contractor
Interviewee F	Airport Manager, EAS contractor

From an airport perspective, any services are important as long as operational scope and services meet community's needs underpinning development and economic growth. In the same vein, airlines need to be financially sustainable to serve specific areas, either a route that could generate sufficient profit on its own or receive subsidies to continuously survive. From feedbacks of aviation practitioners, some challenges and concerns are listed as the following:

B.1 Cost, Subsidy and Green Energy

Interviewee F brought a supportive perspective and was the only interviewee who was actively looking towards electric aircraft. As a city that was looking towards carbon neutrality and emission reduction, the airport had existing solar facilities, and was looking forward to adding more panels onto hangars and parking facilities. Interviewee F explained that as a major maintenance base of a regional air carriers using turboprop aircraft, it was likely that eventually the airport would be servicing electric aircraft. Like Interviewee D, this airport has been using AIP money for runway development projects and would likely use the SCASD grant in the future to study demand in the catchment area. When asked about future services, Interviewee F specifically supported 19-seaters such as Heart Aerospace ES-19, as 19-30 seat aircraft had worked sufficiently for this community throughout history.

Interviewee E, an airline manager, explained that aircraft were chosen based on the cost per available seat mile (CASM) and aeronautical capabilities. This made sense from a cost-benefit analytical perspective. While the airline had a deal with Eviation for 9-seat electric airplanes, interviewee E explained that there seemed to still be a cost disadvantage, even when accounting for fuel savings. Cost would need to be offset with additional subsidies, hoping that the Department of Transportation or other entities come to increase financial support for "green" technology adoption at the airport. Of course, electric aircraft had been recognized due to the advantage in speed performance over its current fleet of conventional, thus allowing for farther flights in the same amount of time. This observation was important for the operational scope of this airline, whose main competitor was ground transportation. Due to the confined space and weight of the aircraft, lavatories were infeasible. Thus, flight range and time should be carefully concerned or restricted for the sake of passenger comfort. By utilizing faster aircraft like electric aircraft, longer routes could be achieved and made the carrier more competitive against ground vehicles. The seat number at nine (9) was also crucial as this was the maximum allowable passengers to fly under 14 CFR Part 135, which permitted one ATP certified pilot to operate. As Interviewee D explained, EAS supported up to 36 trips/week for nine (9) seaters or fewer, or up to eighteen (18) trips/week at 30 seats or more. Aircraft with less than nine (9) seats or more than 30 seats were not eligible to be subsidized under EAS at this airport. However, this condition varies due to different cases or local community service needs.

Interviewee E also mentioned that the process of singing an EAS contract needed a high level of public involvement. Since electric aircraft were such a new technology, there may be apprehension to choose the eco-friendly aircraft. In this case, Interviewee E suggested that air carriers should still offer traditional air services to increase the chance when electric aircraft were not supportive by passengers within certain markets.

B.2 Fitness of Operation for Local Community

Interviewee D, like airport managers (interviewees A and C), was open to different services, but wanted to make sure it would appropriately fit the community's demands. Not too long ago, the airport switched from Cape Air (Cessna 402 9-seaters, Tecnam P2012 11-seaters) to

SkyWest (CRJ200 50 seaters) under EAS, which was a significant shift. While the public input strongly indicated supports for the change to CRJs due to perception of lower risk, after it was implemented, issues became noticeable. Firstly, the larger jets offered less frequency or flexibility. Secondly, larger jets caused significant onsite flight delays due to problems (weather, schedule, manpower, mechanical issues) happened at the large hub airport. Often, the night "flight in" would become so delayed as the crews might not be rested adequately to operate the next "flight out" in the morning. Ultimately, when time came for the next contract, the public decided to forgo lucrative jet service in favor of returning to 9 or 11-seaters. With this in mind, Interviewee D noted that if an airline could provide reliable services with electric aircraft that fits the community's needs, it would be supportive and successful. In addition, effectively accommodating electric aircraft would require significant political support from the local citizens and could take a long time to initiate and come to fruition.

Conversely, Interviewee B's airport had SkyWest CRJ service under EAS contract which was just renewed for another three years. For this community, the larger jet service had been a better fit. Interviewee B indicated that it was because that local people tended to feel safer in jets over turboprops. Thus, Interviewee B would be hesitant to invite electric turbo-prop aircraft that offered far fewer seats than a regional jet, which could potentially jeopardize the airport's enplanements and airline revenue. However, Interviewee B did see the potential market of electric aircraft for other smaller communities.

B.3 Facility Renovation, Return on Investment and EAS

Interviewee A, who has been seeking to regain scheduled air services, was hoping for airlines to schedule flights to serve the adjunct communities. While Interviewee A was confident that sufficient demand did exist in the area for successful sustainability, airlines were reportedly hesitant to start service due to the lack of adequate terminal facilities per FAA FAR Part 139. This put the airport in a challenging situation because even if it was ready to invest in terminal faculties and install security measures, there was no guaranteed airline services.

Interviewee C, which had EAS service in place, was considering business expansion due to the subsidized enplanements stagnating at around 10,000 per year. While the demand was significant, this airport opted to expand service with a non-EAS airline in the early 2000s. After a $200K investment to renovate its infrastructure, including a baggage claim area and added holding space in the terminal, however, incumbent airlines cancelled flight frequency at the airport due to the unforeseen recession of 2008. As smaller airports have been extremely sensitive to expenditures while hoping to expand service, flight reduction caused substantial financial burden at this airport. They were hesitant to spend large amounts of money on upgrades if there were no guaranty to attract airlines. As a result, when considering housing electric aircraft, none of the above two interviewees were intending to revamp infrastructure to support electric aircraft.

C. Discussion

The result of VOSviewer analysis showed interconnect among clusters. The finding also set a baseline for interview questions conducted with the six voluntary aviation practitioners. While battery technologies or certificate process of the electric aircraft were top priorities to manufacturers and the government, concerns on the practitioners' side were different. But each interviewee provided feedbacks that closely involved with technologies from the user's standpoint such as safety, frequency, cost, and range of flight. Airports and air carriers primarily focused on the demand of the communities embracing revenue-driven operations. Cost-benefit analysis has been critical while local public voice would be imperatively important. It has been another highlight that both EAS and SCACD grants could benefit small community who needed air services. Airport managers were intrinsically familiar with the needs of their community and understood how air service should operate. While some practitioners were looking for new, traditional services from air carriers without substantial investment to facilities, others preferred "round robin" style flight between cities in the state. An example was a flight operated from Phoenix Mesa with stops in Bloomington-Normal, and back to Phoenix-Mesa. While some practitioners were not interested in anything less than 50 seat services, others suggested virous options of air services.

Areas with more developed carbon neutrality programs or higher percentages of renewable resources would impact initial cost of program initiatives. While all interviewees mentioned about operational cost and governmental subsidy, Essential Air Service (EAS) program would be crucial to keep the remote air services alive. Due to the need for continuous technology upgrades and corresponding airfare, this could make EAS contractors using electric aircraft less competitive than EAS airlines using traditional fuel powered aircraft if a reasonable airfare, flight frequency, range and time, and safety could not be secure.

V. CONCLUSION

This study was performed to analyze how electric aircraft could fit the commercial air service system. A case study was created to collect research themes and clusters from existing body of knowledge followed by collecting practitioner's feedback and perception of incorporating electric aircraft under EAS or SCASD grant programs. Based upon first-step analysis and themes generated by VOSviewer, questions directed towards voluntary practitioners were developed.

Aviation practitioners focused on operational cost, market share and the local demands. While EAS subsidizes air carriers, airports would need a guaranteed service before investing in facility innovation to host electric aircraft. Facility investment is unrealistic by the time of this study due to market uncertainty as they indicated little to no benefits of investing in facilities to house electric aircraft soon.

While the current EAS grant covers various aircraft from Pilatus PC-12 (8 seaters), Cessna 208 Caravan (9 seaters) to Bombardier CRJ 200 (50 seats), there is certainly a market niche for electric aircraft. Interviewees mentioned that it would take significant push from the public and industry. They also believed that electric aircraft could be a part of the national airspace system (NAS), yet types of electric aircraft must be specified for different communities.

For cost-effective purpose, according to practitioners' perspectives, in order for electric aircraft to serve on a small but in-demand communities, aircraft must be reliable, safe, suitable for the specific operations and passengers. Besides, electric aircraft are expected to show equivalent cost per available seat mile (CASM) vis-à-vis that of traditionally powered aircraft including significant advantages in aeronautical capabilities such as flight time and range. With this in mind, if an airline is expected to use electric aircraft, EAS shall be awarded to offset the overall operational cost. An example of sustainable operation was one interviewee's operation of four (4) Britten-Norman Islander aircraft compared to 70 Cessna 402 and 24 Tecnam operations as Britten-Norman Islanders proved to have a significant advantage operating out of airports in the Caribbean. This air operator showed willingness to adopt electric aircraft provided all necessary conditions are met.

Yet it is also important to note that some aircraft do not fall under the umbrella of Essential Air Service and EAS is on a case-by-case situation. The rule of thumb is that air carriers under EAS providing services to remote communities would operate 50-seaters or smaller electric aircraft to maintain flight frequency, be cost-effective and reliable, and mitigate impact due to unforeseen delays at hub airports. This operational specification requires scientists and engineers to accomplish and continuously devote to improving electric aircraft.

A. *Future Study*

From the researchers' standpoint, even though the VOSviewer natural language processing software was able to guide through the massive amount of literature related to the technical research and development of electric aircraft such as battery and policy, it is important to note that many researchers or scientists were unfamiliar with operational nature of air carriers thus the best fit of their product market could be general aviation. A follow-up study should focus on the users of non-commercial general aviation industry including flight training institutes.

Appendix - *Open-ended Questions*

1. What is the history of commercial service at your airport/airline, and how has it been operated?
2. Per question 1, have the operation (pass or current) been subsidized? If so, what subsidy program(s) was/were used?
3. What is the 5-year plan to attract or expand Part 135 or Part 121commercial air services at your company?
4. Can provide your familiarity with electric aircraft?
5. What would be the pros and cons of accommodating/operating electric aircraft at your airport/airline?
6. Knowing Electric Aircraft are under development, what your airport/airline would expect to handle the change of operation?

REFERENCES

[1] Airbus. "*E-Fan X: a giant leap towards zero-emission flight*". Retrieve December 13th, 2021 from https://www.airbus.com/en/innovation/zero-emission/electric-flight/e-fan-x

[2] Federal Aviation Administration [FAA]. "FAA Awards $100M to Develop Next Generation of Sustainable Aircraft Technology". Retrieved September 17, 2021, from https://www.faa.gov/newsroom/faa-awards-100m-develop-next-generation-sustainable-aircraft-technology, 2021.

[3] Prapotnik Brdnik, A., Kamnik, R., Marksel, M., & Božičnik, S. "Market and Technological Perspectives for the New Generation of Regional Passenger Aircraft". *Energies (Basel)*, vol. *12*(10), pp. 1864–, 2019.

[4] Salucci, F., Trainelli, L., Faranda, R., & Longo, M. "An optimization Model for Airport Infrastructures in Support to Electric Aircraft". *2019 IEEE Milan PowerTech*, pp. 1–5. 2019.

[5] Department of Transportation [DoT]. *Essential Air Service*. Retrieved September 17, 2021, from https://www.transportation.gov/policy/aviation-policy/small-community-rural-air-service/essential-air-service

[6] Goff, B. L. "Estimating Determinants of Passenger Air Service to Small Markets". *Urban Studies (Edinburgh, Scotland), vol. 42*(3), pp. 557–565, 2005. https://doi.org/10.1080/00420980500035782

[7] Matisziw, T. C., Lee, C.-L., & Grubesic, T. H. "*An analysis of essential air service structure and performance*". Journal of Air Transport Management, vol .18(1), 5–11, 2012, https://doi.org/10.1016/j.jairtraman.2011.05.002,

[8] Kanafani, A., & Abbas, M. S. "Local Air Service and Economic Impact of Small Airports". *Journal of Transportation Engineering*, vol. *113*(1), pp. 42–55., 1987. https://doi.org/10.1061/(ASCE)0733-947X(1987)113:1(42)

[9] Blonigen, B. A., & Cristea, A. D. "Air service and urban growth: Evidence from a quasi-natural policy experiment". *Journal of Urban Economics*, vol. 86, pp. 128–146, 2015, https://doi.org/10.1016/j.jue.2015.02.001

[10] Wittman, M. D. "Public funding of airport incentives in the United States: The efficacy of the Small Community Air Service Development Grant program". *Transport Policy*, vol. 35, pp. 220–228, 2014, https://doi.org/10.1016/j.tranpol.2014.06.001

[11] Federal Register. "*Special Conditions: magniX USA, Inc., magni250 and magni500 Model Engines*", vol. 85(224), pp. 73644 – 73655, November 19, 2020, from https://www.govinfo.gov/content/pkg/FR-2020-11-19/pdf/2020-23434.pdf

[12] Federal Register. "*Special Conditions: magniX USA, Inc., magni350 and magni650 Model Engines; Electric Engine Airworthiness Standards*", vol. 86(184), pp. 2021, 53508-58533.

https://www.govinfo.gov/content/pkg/FR-2021-09-27/pdf/2021-19926.pdf

[13] Trainelli, L., Salucci, F., Riboldi, C. E. D., Rolando, A., & Bigoni, F. "Optimal Sizing and Operation of Airport Infrastructures in Support of Electric-Powered Aviation". *Aerospace, vol. 8*(2), 40–., 2021, from https://doi.org/10.3390/aerospace8020040

[14] Justin, C.Y., Payan, A.P, Briceno, S.I. German, B.J., & Mavris, D.N. "Power optimized battery swap and recharge strategies for electric aircraft operations". *Transportation Research. Part C, Emerging Technologies*, vol. 115, pp. 1-17, June 2020.

[15] International Air Transportation Association [IATA]. "*Passenger demand recovery continued in 2021 but Omicron having impact"*. Retrieved Feb. 3rd. 2022 from https://www.iata.org/en/pressroom/2022-releases/2022-01-25-02/

[16] Kaminski-Morrow, D. "Nordic carriers give Heart to electric aircraft development". *Flight International, vol. 196*(5701), 21–21, 2019.

[17] Naumes, W., & Naumes, M.J. "*The art and craft of case writing"*. Thousand Oaks, CA: Sage, 1999.

[18] Waltman, L., van Eck, N. J., & Noyons, E. C. M. "A unified approach to mapping and clustering of bibliometric networks". *Journal of Informetrics, vol. 4*(4), pp. 629–635, 2010. https://doi.org/https://doi.org/10.1016/j.joi.2010.07.002

[19] Waltman, L., & van Eck, N. J. "A smart local moving algorithm for large-scale modularity-based community detection". *The European Journal of Psychical Journal B*, vol. 86:471, 2013. DOI: 10.1140/epjb/e2013-40829-0

[20] VOSviewer (n.d.). *Visualizing scientific landscapes*. https://www.vosviewer.com

[21] van Eck, N. J., & Waltman, L. "Software survey: VOSviewer, a computer program for bibliometric mapping". *Scientometrics*, vol .84(2), pp. 523–538, 2010. https://doi.org/10.1007/s11192-009-0146-3

[22] van Eck, N. J., & Waltman, L. "*Text mining and visualization using VOSviewer", 2011*. http://arxiv.org/abs/1109.2058

[23] van Eck, N. J., & Waltman, L. "Visualizing Bibliometric Networks". In Y. Ding, R. Rousseau, & D. Wolfram (Eds.), *Measuring Scholarly Impact: Methods and Practice*, pp. 285–320, 2014. Springer International Publishing. https://doi.org/10.1007/978-3-319-10377-8_13

[24] Babbie, E. "*The practices of social research"*. Belmont, CA: Wadsworth, 2010.

[25] Schwarz-Shea, P. & Yanow, D. (Eds.). "*Interpretive Research Design.* Routhledge". eBook, 2013, https://learning.oreilly.com/library/view/interpretive-research-design/9780415878081/

[26] Leib, S., & C-t. Lu. "A gap analysis of airport safety using ICAO SMS perspectives: A field study of Taiwan". *Journal of Aviation Technology and Engineering*, vol. 2(2), pp. 63-70, 2013https://doi.org/10.7771/2159-6670.1078

[27] Carter, N., Bryant-Lukosius, D., DiCenso, A., Blythe, J., & Neville, A. J. "The use of triangulation in qualitative research". *Oncology Nursing Forum*, vol. 41(5), pp. 545–547, 2014. https://doi.org/10.1188/14.ONF.545-547