McNair Research Journal SJSU

Volume 14 *Spring 2018* Article 12

2018

Electric Aircraft and the Environment: A Literature Review

Uyen T. Sou

Recommended Citation

Sou, Uyen T. (2018) "Electric Aircraft and the Environment: A Literature Review," *McNair Research Journal SJSU*: Vol. 14 , Article 12.
https://doi.org/10.31979/mrj.2018.1412 https://scholarworks.sjsu.edu/mcnair/vol14/iss1/12

Cover Page Footnote

[1] Baumgardner,W., Bruzzone, A., Coffin, R., Eddy, J., Huey, B., Iswalt, M., Pattinson, T., Vaquer, S., "Bay Bridge Corridor Congestion Study," Arup Corporation, San Francisco, CA, October 2010. [5] Osman, T., Thomas, T., Mondschein, A., Taylor, B.D., "Not so fast: A study of traffic delays, access, and economic activity in the San Francisco Bay Area". UCLA Institution of Transportation Studies. Los Angeles, California. March 2016.

Uyen T. Sou

Major:
Aerospace Engineering

Mentor: **Dr. Nikos J. Mourtos and Dr. Maria Cruz**

Electric Aircraft and the Environment: A Literature Review

Biography

Uyen aspires to integrate her passion for learning, aerospace, and art to impact the world around her in a positive way. She is inspired by her family, advisors, and friends around her that give her the confidence to pursue her goals. She is also inspired by the professors and mentors who have helped and continue to help broaden her mind every day. Being a first-generation student has proven to be a challenge as well as a driving force that motivates her to give it her all and try out things she thought she never could. She hopes to make an impact in industry and become a professor in her field in the future. She was involved with Rocket Club earning a level 1 certification from Tripoli Rocketry Association and is a member of the American Institute of Aeronautics and Astronautics. She is also involved with community outreach programs that encourage the next generation of engineers such as the Engineering Ambassadors Program as well as Project Lead the Way here at San Jose State University.

Electric Aircraft and the Environment: A Literature Review

Abstract

Historically, the integration of social need, environmental impact, and technological advancement has been a challenging balancing act for growing cities and metropoles. If the balance between social need and environmental sustainability is reached, the increasing advancements and improvements made to electric aircrafts have the potential to steer society towards a new mode of sustainable air. One reason why electric aircraft technology has not grown as fast as other technologies is because there lacked a need for fast advancements. With that said, electric aircraft technologies are improving today due to the demand in heavily populated cities to relieve traffic [5]. Some issues growing cities face are inadequate housing, inefficient infrastructure, and high traffic congestion. According to the Metropolitan Transportation Commission (MTC), traffic congestion within the Bay Area has increased 9% in the past two years [5]. The gridlock in the Bay Area increased as approximately 13,000 cars cross the Bay Bridge daily. A report produced by Arup Corporation reports that the Bay Area is second only to Los Angeles in the intensity of traffic congestion [1]. A study by UCLA determined that the economic boom in the Bay Area in the previous decade had driven the influx of inhabitants to the area [5]. These are two examples of metropolitan cities that are impacted by traffic congestion. To mitigate the negative consequences associated with high traffic congestion, it is beneficial to explore redesigning the infrastructure of metropolitan cities in tandem with residual effects of the economic boom. [5]. This literature review analyzes electric aircraft as a viable solution to high congestion and explores the possible effects of it on the environment.

Introduction

The development of a taxi-like system with small electric aircraft could potentially help alleviate the issue of bumper-to-bumper traffic and mobility in highly congested metropolitan areas. With that said, this increase in use raises a concern about how this would affect the environment. Prior to examining the use of electric aircraft as a taxi-like transportation system, a brief understanding of the general environmental

https://scholarworks.sjsu.edu/mcnair/vol14/iss1/12
DOI: 10.31979/mrj.2018.1412

impact of air travel needs to be addressed. The general concerns surrounding conventional air travel on the environment are the level noise, emissions, and the state of air [9]. Conventional air travel meaning using aircraft operated by combustion engines.

The noise generated by aircraft stems primarily from airframe noise and engine noise during take-off and landing at major airports [9]. Airframe noise is defined as the noise produced when the turbulent flow encounters the aircraft's surfaces, landing gears, slats, and flaps [10]. There has been some success in reducing the amount of airframe noise by redesigning wings that produce lift more efficiently. These designs help in getting the aircraft from take-off to level flight in less time when compared to previous designs [10]. However, the noise level of busy airports remains a big issue with its surrounding neighborhoods. The relationship around noise level and how much it annoys does not have a linear relationship [11]. This means having higher frequency of noise does not follow a linear increase in annoyance. The level of annoyance increases at a faster rate than the rate of increase of frequency level of noise [11]. Electric aircraft motors can help with noise pollution because its motors are quieter during flight than an airplane that uses a combustion engine [16]. During a comparison flight with two airplanes, one with an electric motor and one with a combustion engine, the results showed a 14 decibel decrease in noise production from the electric aircraft [16].

Another environmental concern pertaining to air travel are the effects engine emissions have on the climate. The amount of emissions put into the air is not the only concern. It is the combination of the amount as well as the content of the emissions that is worth investigating. The substances that make up the emissions are hydrocarbon (HC), carbon monoxide (CO), nitrogen oxides (NO_x), sulfur dioxide (SO_2), carbon dioxide (CO_2), and dinitrogen monoxide (N_2O) [11]. The main contributor to the climate change is the combination of carbon dioxide, nitrogen oxides, and methane gas mixing with the surrounding water vapors [11]. When these gases mix in the atmosphere behind the engines, a contrail is created [11,12,13]. Contrails are the cloud-like trails formed aft of the aircraft engines [13]. These contrails eventually contribute formation of cirrus clouds which is a factor in climate change [11]. These emissions also contribute to the visibility in the air. Some of these gases contribute to allergies from the air [11]. This leads to the next concern of air quality.

The air quality in metropolitan areas is an increasing concern when it comes to modes of transportation because in the past these effects were not known or regulated. Air quality is under regulation [2]. This means governmental agencies have laws and regulations in place for airlines and aircraft designers and manufacturers to abide by. The guidelines help designers choose which aspects of an aircraft is priority when brainstorming designs. Although the gases are harmful to human health in high amounts, there are measures in place to keep levels at an acceptable amount [2]. With the environmental concerns introduced and defined, the idea of using electric aircraft as a means of an air taxi-like system can be explored.

With the main concerns surrounding air travel briefly explained, the concept of having electric aircraft become a common mode of transportation will be explored next. The idea for air taxis is not a new concept. The concept of air taxis required battery technology to reach a level of efficient to carry the weight of passengers and be compact and lightweight [6]. In the past decade, advancement in batteries is projected to meet the necessary power to make this concept a reality. It is a concept of interest in recent years because today's technology has been advancing towards what the concept needs. Electric aircraft would have less noise production and could lessen the amount of emissions contributing to the climate. The success of electric aircraft as a common mode of transportation can herald in a new form of travel that potentially reforms how transportation effects the environment.

Methodology

The methods commonly used to evaluate how much effect air travel has on the environment are based on mathematical models. First, data needs to be collected from airports and the type of flights that are taking place. Such data can be found in the Official Airline Guide database [12]. For example, are the flights short-, medium-, or long-range flights ranging from less than 500 km to over 5000km [12]. It was found that medium-range flights ranging from 1750km to 5000km flights are

https://scholarworks.sjsu.edu/mcnair/vol14/iss1/12
DOI: 10.31979/mrj.2018.1412

least wasteful per kilometer of travel [12]. Table 1 has the connection between emissions and distance traveled.

Table 1: Connection between distance to emissions during various range of flight [12].

Distance flown (km)	Distance correction factor
<500	1.86
750	1.39
1250	1.18
1750	1.09
2000–5000	1.00
>5000	1.05

The composition of the fuel that goes into engines are also broken down into each type of gas and evaluated. Once the type of gases was determined, the next thing to do is to determine the amount of each gas emitting into the atmosphere. The data for flight distance, fuel used, load weight during lift off and landing, and other flight performance date is used in the following mathematical model to calculate the amount of emissions is emitted [12]. For this model, it calculates carbon dioxide emissions.

$$E_{X_{pax}} = E_X \frac{V_{pax}}{V_{pax} + \dfrac{1000 \times V_{fr}}{\overline{C_{W_{pax}}}}}$$

This mathematical model depicts emissions relative to passenger weight [12].

E_X denotes total emissions from the flight. V_{pax} denotes the number of passengers. V_{fr} denotes the amount of freight. $C_{W\,pax}$ denotes the average weight of passengers [12]. The variables can change depending on what data is available. Further explanation can be found in Chapter 3 of the *Aviation and Climate Change* book [12]. The volume of emissions would undergo a comparison with the radiative forcing index (RFI). This index is defined as a unique value that is calculated for each year. This calculation consists of taking the total radiative forcing (RF) in aviation in a given year divided by the radiative forcing that is caused by the buildup of carbon dioxide emissions of that same year [12]. Since this ratio is changing every year, it has been skeptical to use this as a sole metric to the trends of emission increase or decrease [12]. With this said, the RFI is used as a minimum value of emissions and is used with the recommendation of renewing the RFI every year [12]. It is important to take data for the volume of emissions in relation to per passenger because it can give a scope of how electric aircraft can reduce emissions per passenger. Another area that would benefit from taking data for is traffic patterns and areas of high congestion.

To clarify, this data collection for traffic is referring to ground traffic such as cars and other motor vehicles. It is necessary to track the traffic trends in large cities so high traffic zones can be identified [5]. Identifying these heavily traveled areas allow for strategic positioning of hubs where small electric aircraft can board passengers and land [4]. These areas are where these air taxis would be most effective [6]. It is also beneficial to understand the traffic patterns of any large airports surrounding the area of interest as well. One company that has taken the initiative in investing and implementing this idea of transportation is A-cubed by Airbus Group [4]. They have taken the next step to understanding the impact that electric aircraft can have. They also had considered different configurations to the aircraft designs. One example was combining the hovering ability of helicopters with the size of a small personal aircraft [14]. This method is knowing as multidisciplinary design optimization [3]. This method of multidisciplinary design optimization takes into consideration different types of disciplines and combines the best method from each discipline to design the optimal solution to a given problem [15].

Literature Review

The concept of a transitioning from traditional aircraft to electric aircraft was conceived many decades ago. The reason why this concept is getting picked up in recent years is due to the advancement of batteries for electric motor vehicles [8].

For an aircraft to be commercially successful, the efficiency of operation needs to be considered. Efficiency is generally defined as getting the most out of something with the least amount of waste. In aviation, efficiency means getting the maximum amount of thrust to

https://scholarworks.sjsu.edu/mcnair/vol14/iss1/12
DOI: 10.31979/mrj.2018.1412

produce enough lift to counteract the effects of gravity and drag. In electrical aircraft, the weight of the fuel cell in relation to the power it produces is a major concern [8]. The fuel cell is set at a specific weight that would only take up a fraction of the weight allowable for an aircraft of a given size [6]. By reducing the weight of the battery, the more passenger weight the aircraft would be able to carry. This is important because one of the factors to consider in designing the vehicle is the weight to lift ratio [6].

Another way to affect the efficiency of an aircraft is to determine whether to use engines or propellers and how they are arranged on your aircraft. The designs that have mostly been explored are propellers with the capabilities for vertical take-off and landing. Vertical take-off and landing refers to the integration of two ideas; the vertical lift of a helicopter and the stability of an aircraft flight [4]. With this capability, the design of pocket airports would resemble helicopter landing pads. These pocket airports would potentially be on high platforms, possibly from converted parking structures [4]. The top level of the parking structure can be converted for the aircraft to land as well as receive passengers. This concept has been explored by the Airbus cubed group.

Figure 1: (left) Demonstration of the Vahana about to land at a hub above a tall building. (Right) The aircraft landing to pick up a passenger [17].

This is conceptualized through having each landing pad arranged like how parking spaces for cars are arranged, only with more space in between each one for safety measures [4]. The aircraft would land on the platform and then a ramp nestled in the landing pad will raise from the ground and snap itself into place with the aircraft [4]. The passenger would then load or unload from the aircraft. With the vertical take-off and landing ability of this aircraft, there would be no need to have large land plots for long runways [8]. Due to this feature, the aircraft can operate in more populated areas as well as operate in fleets of higher concentration [3].

Another way the use of electrical aircraft is beneficial is it produces a lower noise level. The motors in electrical aircraft would produce less noise than conventional aircraft engines [3].With lower noise levels, public acceptance of these aircrafts and this mode of transportation could increase. These aircrafts can be placed in high populated areas where the accessibility to companies and business occurs. As previously mentioned, one concern when designing electrical aircraft is the availability of batteries that can meet the requirements needed to produce cost efficient air taxis [3].

The battery in consideration are lithium polymer batteries. The current power that is outputted from the lithium polymer batteries is around 200 Wh/kg, but it is estimated that 2400 Wh/kg is necessary for electric aircraft [4]. Another issue arises when electric aircraft flies at high altitudes. The wires and batteries would need insulation to prevent electricity from jumping around from conductor to conductor. With the added insulation to fix this, the issue of weight is counteracted [8]. The attention to this issue is being addressed due to the rise in demand for industry to produce high efficient batteries with less weight.

Conclusion

The main concern surrounding the increase of air traffic is still being investigated and analyzed. Although the addition of taxi aircraft arises concerns for some, through investigation the benefits outweigh any potential challenges of integrating taxis into our current air travel. The concerns of noise level, aircraft emissions, and the quality of air is something to keep in mind during the development of electric aircraft as an option for public transportation. However, electric aircraft would help to minimize noise and emissions through its use of electric motors to power the propellers. It can take years to see results, but electric aircraft can potentially help the environment and move society into new heights.

https://scholarworks.sjsu.edu/mcnair/vol14/iss1/12
DOI: 10.31979/mrj.2018.1412

References

[1] Baumgardner,W., Bruzzone, A., Coffin, R., Eddy, J., Huey, B., Iswalt, M., Pattinson, T., Vaquer, S., "Bay Bridge Corridor Congestion Study," Arup Corporation, San Francisco, CA, October 2010.

[2] Dellingham, G., Martin, B., "Airport Operations and Future Growth Present Environmental Challenges," GOA, gov., GAO/RCED-00-153, Washington D.C., VA, 2000.

[3] Brooks, C.T., Salgueiro, S., "Design space investigation of a small electric general aviation airplane". 55th AIAA Aerospace Sciences Meeting Journal. 2017. 14 pp. Print.

[4] Lovering, Z., "Vahana Configuration Trade Study--Part 1," *Vahana.aero*, December 2016, https://vahana.aero/vahana-configuration-trade-study-part-i-47729eed1cdf.

[5] Osman, T., Thomas, T., Mondschein, A., Taylor, B.D., "Not so fast: A study of traffic delays, access, and economic activity in the San Francisco Bay Area". UCLA Institution of Transportation Studies. Los Angeles, California. March 2016.

[6] Raymer, D., Zhang, M., Rizzi, A., Raymer, E., "Sparky Flapjack: Electric Aircraft Design Inspirations from the Vought V-173," *55th AIAA Aerospace Sciences Meeting Journal*, 17 pp, AIAA, 2017.

[7] Schultz, TJ., "Synthesis of Social Surveys on Noise Annoyance," *Journal of the Acoustical Society of America*, V64: 377–405, August 1978.

[8] Weber, Austin. "Electrical Power Will Transform Aviation," Assembly, January 2017, https://www.assemblymag.com/articles/93676-electric-power-will-transform-aviation.

[9] Waitz, I., "Lecture: Aviation and the Environment," 2003.

[10] Dobrzynski, W., "Almost 40 Years of Airframe Noise Research- What Did We Achieve?", *14th Aeroacoustics Conference*, Duetsches Zentrum fur Luft-und Raumfahrt Institute of Aerodynamics and Flow Technology, AIAA/CEAS-2008-AFN, Vancouver, 2008.

[12] Gossling, S., Upham, P., "Chapter 3: Calculating Emissions and Radiative Forcing," *Climate Change and Aviation: Issues, Challenges, and Solutions,* London: Earthscan, 2009.

[13] Wuebbles, D., "Evaluating the Impacts of Aviation," EOS, Transactions, American Geophysical Union, V88 No14 157-168pp. 2007 on Climate Change

[14] Bower, G., Droandi, G., Syal, M., "Vahana Design Process Part II: Preparing for Lift-Off," Vahana.aero, March 2018, https://vahana.aero/vahana-design-process-part-ii-preparing-for-lift-off-a75b7ef6d583

[15] Wikipedia, "Multidisciplinary design optimization," Available: https://en.wikipedia.org/wiki/Multidisciplinary_design_optimization.

[16] "The Sound of Silence- Reduced Noise with Electric Propulsion," *Siemens PLM*, 2017, https://www.youtube.com/watch?v=kcZCwSe3qZI.

[17] Grundry, K., "Vahana: Passenger Experience," *Vahana.Aero,* June 2017, https://vahana.aero/vahana-passenger-experience-3290120070b.

DOI: 10.31979/mrj.2018.1412