

Social and Environmental Impacts of Commercial Aviation

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Social and Environmental Impacts of Commercial Aviation

Introduction

The perpetuation of the commercial aviation industry in its present form is at odds with the societal imperative of mitigating anthropogenic climate change. With U.S. commercial airlines alone consuming about 1.3 million barrels of jet fuel a day in January 2020 (Barnett, 2020) and 5% of warming attributable to commercial aviation (Lee et al., 2010), the industry has significant environmental implications. Meanwhile, commercial aviation is vital for connecting people and enabling the globalized economy. In the U.S., commercial aviation facilitates \$1.9 trillion dollars in economic activity annually and supports about eleven million jobs (FAA, 2022). The industry is an essential component of the modern economy, but, as with many other essential industries, is problematic environmentally.

Major technological breakthroughs will be necessary to decouple the growth of the industry from the growth of its greenhouse gas emissions. Research and development to this end has begun in the form of more efficient gas turbine engines, sustainable aviation fuels (SAFs), and electric propulsion systems. No single solution will be adequate on its own, at least in the short term. Focusing on one segment of the industry, in this case, fifty passenger regional aircraft, will allow a focused technological solution to the issue. For these aircraft, pure battery electric propulsion would be inadequate, however, a hybrid-electric architecture shows promise. Therefore, as my technical project, I will work with my team to create a conceptual design for a fifty-seat hybrid-electric regional turboprop.

The societal consequences of how the industry balances economic benefits with environmental sustainability will be significant. To assess this issue and its ethical ramifications, one must understand the interconnection between various actors with different incentives and

values. The literature review will develop the necessary context of the industry and its consequences. Analysis will be done using the framework of actor-network theory (ANT). This will allow the history and future of the industry to be understood by examining how actors, such as manufacturers, airlines, governments, and the general public, interact. Given each actor's interests and power, their willingness and ability to address the industry's environmental impact. With this analysis, it will also be possible to evaluate the ethical responsibility of different actors.

Literature Review

Background of the Commercial Aviation Industry

The commercial aviation industry plays a significant role in our modern, globalized society. In 2019, airlines transported 4.5 billion passengers and 57.6 million tonnes of cargo (ICAO, 2020). This impressive logistical feat is enabled by several companies, government institutions, and individuals. To understand how the industry reached this point, it is necessary to consider the history of its development.

On 17 December 1903, the first aircraft, designed and built by Orville and Wilbur Wright, flew in Kitty Hawk, North Carolina. Initially, the opportunities to commercialize the invention were limited to some military use and as toys for the wealthy (Roach, 2014). Further development of the technology, which would ultimately allow for a wider range of use cases, was brought about by WWI. This is a common theme in the aerospace industry, where military and national security concerns drive innovation that trickles down to the commercial sector. The main commercial use for aircraft in their infancy was to transport air mail. In the United States, following the advice of the newly formed National Advisory Committee for Aeronautics (NACA), the government took an active role in the development and regulation of the industry. As air-mail routes became profitable and safer, passenger air travel became practical. By 1938,

the industry had become relatively mature, with a wide range of domestic passenger routes available in the U.S. (Johnson, 2019). While this progress, from the first flight to a developed passenger and air mail system, was certainly impressive, it falls far short of the extensive, international network that exists today.

For aviation to develop into the global industry that exists today, both technological and international institutional innovation were necessary. One example of the required technological innovation is the Boeing 747, which helped make air travel more accessible. It was developed by Boeing using designs and technologies developed for a military contract that they ultimately lost. However, with its wide-body design and high bypass ratio engines, it could transport more passengers more cheaply than previous jet-age aircraft (Boeing, n.d.). To make full use of such technologies, it was necessary for countries to ensure that international air routes are open and accessible to airlines. This has been achieved through multilateral agreements, such as the Chicago Conference that defined the Five Freedoms of the air, and more recently bilateral Open-skies treaties (Dobson, 2017). One conclusion that can be drawn from this history is that the advancement of commercial aviation has largely been enabled and driven by government actions.

Economic and Connectivity Benefits

The economic benefits of the commercial aviation industry can be split into direct and indirect benefits. The direct benefits would include the jobs provided by airlines and aircraft manufacturers as well as the profits made by these companies. The indirect benefits would include benefits to industries that support or are supported by commercial aviation as well as spending by the industry's employees. Together, these benefits can have an enormous impact on a country's economy. For 2019, the FAA estimated that the direct economic impact is worth

\$852.3 billion, and the indirect impact is worth \$1.066 trillion. This represents almost 5% of U.S. gross domestic product. Additionally, in 2019, about 3.7 million people were directly employed by the industry and another 6.7 million jobs were supported by the industry (FAA, 2022).

Another benefit of the industry that has both economic and social implications is improved connectivity, especially for remote communities. Initially, the benefits in this area were limited as flying was expensive. This limited the increased mobility allowed by aviation to business travelers and the wealthy. As aviation developed and flying became cheaper, more people gained access to air travel including middle class tourists, immigrants, and migrant workers (Baer, 2020). Wider access to air travel has enabled the world to become smaller, allowing for more international personal and business connections. However, as with many aspects of globalization, there are also segments of the population that have not benefited as much or who have been harmed. One such group is people living in rural areas. In the U.S., there has been a decrease in both the number of airports served and the number of flights to smaller airports as airlines focus on more profitably connecting major cities instead (Marien et al., 2018). The government has attempted to address this issue since the deregulation of the airline industry through the Essential Air Service (EAS). This program provides subsidies to airlines serving rural airports that could not economically support airline service. The program received \$288 million in funding in 2018 (Yang, 2018). Overall, the connectivity provided by commercial aviation is one of the industry's biggest contributions to society.

Given these significant benefits, it is unsurprising that many governments put significant resources into developing and supporting their commercial aviation industries. However, as with anything, there are trade-offs and risks that must be taken into consideration. In the case of aviation, many issues are environmental in nature.

Global Impacts and Climate Change

Climate change is an existential threat to society. Therefore, any activity, such as aviation, must have its impact on climate change evaluated. Commercial aircraft are, at this point, universally powered by the combustion of fossil fuels due to the fuels' superior specific energy (energy per unit mass). As such, the industry certainly plays a role in the continuation of climate change. Through emissions of greenhouse gasses such as CO₂ and the emission of water vapor, which can form cirrus clouds, aviation is estimated to contribute about 5% of global anthropogenic warming (Lee et al., 2010). The increase in average global temperatures is expected to result in various negative impacts such as drought and more extreme weather. Because commercial aviation is playing a considerable role in this potential human tragedy, it is necessary to consider its ethical implications.

Local Impacts and Health

Airports, especially large hubs, concentrate global connectivity allowing for convenient travel. However, they also concentrate aircraft emissions and noise, which is detrimental to the health of people living nearby.

Aircraft emit various substances, such as CO, NO_x, and SO_x that negatively impact people's health. These emissions increase the rates of respiratory diseases, increasing the morbidity and mortality of people living near airports. In 2013, the damage from these emissions was estimated to be approximately \$1.9 billion (Nahlik, Chester, Ryerson, & Fraser, 2016).

Exposure to the elevated levels of noise near airports has been associated with worse health outcomes. In particular, it has been shown in multiple studies to increase the rate of hypertension, cardiovascular disease, and stress (Meister & Donatelle, 2000). In addition, the noise also negatively impacts children's cognitive development and increases the rate of

hyperactivity. A study of children attending schools near London Heathrow airport found that for every 5 dB increase in average aircraft noise at a school, was associated with a two-month delay in reading age (Clark et al., 2021). This harm that is caused by airports to their local communities certainly raises ethical questions about their operation.

Environmental Justice and the Aviation Industry

The impacts of climate change are unevenly distributed around the world. While wealthy countries, including the U.S., have disproportionately contributed to the issue, poor countries are expected to be more significantly affected (Farbotko, 2019). This is an issue of justice as a group is being harmed by the actions of another. At the moment, it does not seem that wealthy countries are taking enough responsibility for mitigating climate change and addressing the harm already done in developing countries.

Locally, within countries with developed aviation industries, the negative impacts of aircraft operations are often concentrated in neighborhoods inhabited by typically socioeconomically disadvantaged groups. This has, in many cases, been the result of intentionally locating airports in these areas. A good example is Washington Dulles International Airport in Loudoun, VA. At the dawn of the jet age, the U.S. government was looking for a site for a new international airport to serve Washington D.C. They initially settled on a location in Fairfax County. This was met by fierce opposition from the residents of the surrounding, predominantly white suburbs. Consequently, the government backed down and changed course to a site in Loudoun County: Willard, VA, which was a predominantly Black town. The residents of Willard were evicted while the land the government had bought in Fairfax County became Burke Lake Park (Scheel, 2002).

Airport operations result in noise that can be harmful to nearby residents. A study looking at the decision of an Arizona city regarding the adjusting of flight plans to address noise resulted in the location of a disamenity (in this case noise) in a predominantly Hispanic neighborhood. The option they chose resulted in more people being affected by the noise but was considered easier and cheaper to implement (Sobotta, Campbell, & Owens, 2007). This highlights an issue with justice in that a group of people seems to have been harmed unnecessarily.

Methodology

Actor-network theory (ANT) will be used to develop a framework that will allow the industry and its impacts to be understood. This analysis will focus on how interactions between different individuals, firms, and governments are involved in this issue. The actors that will be analyzed include government policy makers who set regulations on the issues of aircraft noise and emissions, aircraft manufacturers who determine how the aircraft are built and therefore how much research and development spending is directed towards emission and noise reduction, airlines who operate the aircraft, and the public who are affected by the industry and, through demanding air travel, oblige its continued existence.

Prior literature, such as that discussed above, helps quantify the economic and environmental impacts of aviation. Many past studies involve surveys and interviews of people affected by aviation noise and emissions, which will help to understand the human impact of the industry. Additionally, a better understanding of the industry and its participants will be developed. Together, this will allow for an ANT framework to be used to analyze the issue. Looking at the continued development of the aviation industry and the push for new, cleaner technologies will allow the role of different actors to be examined. To do this systematically, first, each major actor in the industry will be analyzed. Their interests and characteristics will be

individually defined and examined. Next, the interplay between the actors will be analyzed. Finally, the developed understanding of the actors and networks will be used to consider ethical responsibility for issues caused by the industry.

Analysis

Actors

Aircraft Manufacturers. Given the high cost and necessary technical experience required to develop and manufacture commercial aircraft, the industry is extremely consolidated. The industry is effectively a duopoly with Airbus and Boeing together having a market share of over 90% (Duddu, 2020). Boeing was founded in Seattle, Washington in 1916. Much of its initial business was producing military aircraft for the U.S. during WWI. Through much of the remaining 20th century, Boeing was the largest producer of commercial aircraft, with McDonnell Douglas being their most significant competitor. However, the two companies merged in 1997, leaving the U.S. with one dominant commercial aircraft manufacturer (Wilburn & Nowlin, 2016). Airbus, founded as a joint venture between various European state-owned aerospace companies in 1970, faced a daunting challenge in becoming a legitimate contender in the industry. Over time, the companies involved in Airbus were all privatized and merged into a single corporation. Airbus has experienced significant growth and is now neck and neck with Boeing (Airbus, n.d.).

Both Airbus and Boeing are private sector, publicly traded corporations whose primary goal is to maximize returns for shareholders. To maximize their profits, they must make their products appealing to their customers. Obviously, the upfront cost is important to this, but so is the operating cost. Fuel is one of the biggest contributors to aircraft operating costs. Therefore, aircraft manufacturers have invested heavily in making their aircraft more fuel efficient. The

resulting incremental improvements to aircraft and engines have decreased block fuel intensity (fuel use per tonne kilometer) by 40% between 1970 and 2019 (Zheng & Rutherford, 2020).

Both Airbus and Boeing have been pursuing zero-emission aircraft technologies, including battery and hydrogen-powered aircraft. Whether they devote enough investment to bring these technologies to market will depend on how they perceive the potential market for such technologies.

Airlines. As with aircraft manufacturers, most are private corporations which seek to maximize returns for shareholders. Therefore, airlines are incentivized to minimize costs and attract as many passengers as possible. As previously mentioned, one way to reduce costs is to operate more fuel-efficient aircraft. However, this requires some trade-offs as newer, more efficient aircraft are generally more expensive. Additionally, the growth of passenger numbers, which is in airlines' interests, necessitates increased emissions as it requires more planes to fly.

There is some concern in the industry that more passengers may become less willing to fly due to its environmental impact. To address this, most major airlines from around the world have committed to have net-zero emissions by 2050 (IATA, 2021). To achieve this, most airlines will rely heavily on carbon offsetting. Some offer voluntary offsetting programs to try to cater to environmentally conscious consumers. Critics of this system claim that offsetting does not work and gives companies an excuse to not change their behavior (Aviation Environment Federation, 2022). However, by doing this, airlines are internalizing some of the costs, which provides an incentive to reduce emissions. Overall, airlines are the most visible contributor to climate change within the aerospace industry and have a role in addressing it.

Governments. Within the commercial aviation industry, the government plays both the roles of a promoter and a regulator. It provides subsidies and other assistance to both aircraft

manufacturers and airlines as the industry is often seen as strategically and economically important. In addition, governments generally tightly regulate the safety and security practices of the industry and have the power to regulate other aspects, such as the environmental impact.

The incentives of government decision-makers are dependent on the type of government. In the case of a democracy, public opinion and therefore the ability of elected representatives to get reelected drives government decisions. Of course, in many democracies, industry lobbyists also play a significant role in decisions. The Federal Aviation Administration (FAA), the primary aviation regulator in the U.S., has been the subject of multiple accusations of inadequately ensuring airline safety due to regulatory capture (Hoppe, 2019). When this leads to tragedy, such as in the case of the Boeing 737 Max, public opinion can be overwhelming and encourage meaningful change to the regulatory regime. Public pressure resulted in Congress passing new laws to require greater transparency as well as protections for whistleblowers (Shepardson, 2020). Despite these changes, it seems likely that the revolving door between regulatory agencies and the industry will continue.

The ability and willingness of the government to impose tighter environmental regulations on the commercial aviation industry depends on the balance between public opinion and special interests. As an alternative to regulations, subsidies could be used to encourage the development of cleaner technologies. This would likely be supported by the industry as well as environmentalists. Either way, the government will certainly have to play a leading role in making aviation less environmentally damaging.

General Public. General public is a somewhat vague and nebulous term, which is necessary as it represents a diverse group of individuals, many of whom wear multiple different hats. As employees of manufacturers and airlines, many have an interest in seeing the industry

thrive. As travelers, many want cheap and frequent flights to make their transportation as convenient as possible. As people who face the consequences of climate change and pollution, many would benefit from major changes to the industry. And, as voters, the general public has influence over how government policy impacts the industry. Ultimately, if any action is taken on the industry's environmental impact, it will likely be driven by citizens concerned about their health and the future of human life on Earth.

Network

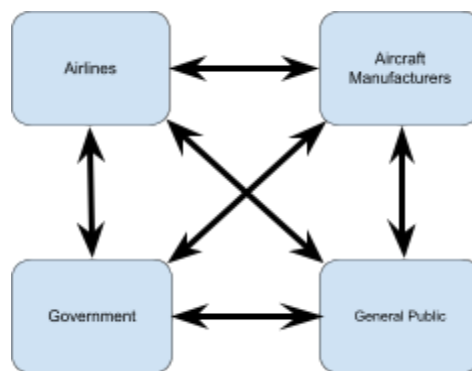


Fig. 1. Network Diagram.

As illustrated in Figure 1, the aforementioned actors all have some influence or impact on all the others. The structure of this network has ramifications on the manner that the environmental issues of the industry get addressed. Commercial aviation was developed and continues to thrive due to the demand for quick and convenient transportation by the public. Airlines, with aircraft from aircraft manufacturers, operate flights to satisfy consumer demand. All these transactions are beneficial to the people involved. However, these flights also produce negative externalities through noise and emissions. These affect the public, including those who do not benefit from the industry. The resulting flow of benefits and harms is illustrated in Figure 2. Without something to force airlines and aircraft manufacturers to internalize these costs, this cycle will be perpetuated.

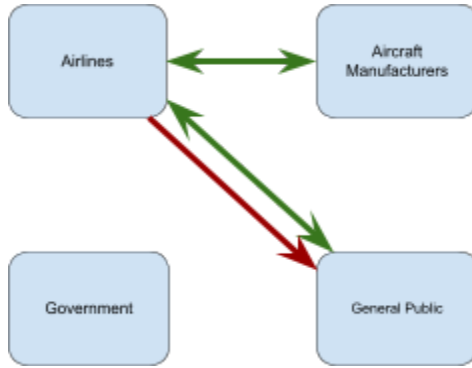


Fig. 2. Benefits and Harms.

Addressing the environmental issues of the industry will require systematic, expensive changes that airlines and aircraft manufacturers are unlikely to be willing to implement. The organization and power necessary to mandate such changes necessitate government action. For reasons discussed above, this must be preceded by public pressure. The resulting flow within the network is shown in Figure 3. Whether through taxes that force corporations to internalize costs or subsidies that encourage investment in environmentally friendly technologies, government intervention will be necessary to mitigate the environmental consequences of the industry.

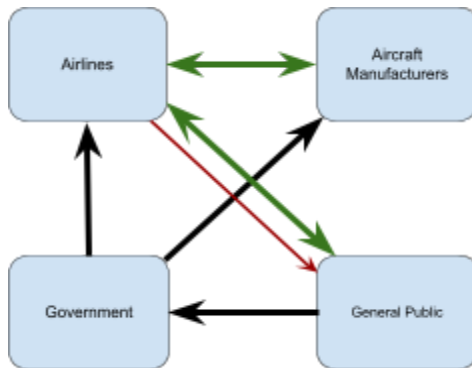


Fig. 3. Addressing Environmental Consequences.

Ethical Responsibility

As previously discussed, there are many negative consequences of commercial aviation related to the environment and human health. Although these consequences are global in their

impact, relatively few people benefit from the industry. Therefore, there are many people who are being harmed without a say or compensation. Under a utilitarian ethical framework, this would not necessarily be unethical if the benefits outweigh the harms, in other words, if the ends justify the means. Kantian deontology would refute this as it treats people as a means to an end and could violate the categorical imperative (Hoppe, 2019). Would you consider it ethical for someone else to cause you harm in the pursuit of personal benefit without your consent and without receiving any compensation? In the case of environmental issues caused by the commercial aviation industry, as the harms are mostly external to the industry, it is, at the very least, ethically necessary to minimize these harms. Given the central role that airlines and aircraft manufacturers play in the issue and could play in its amelioration, much of the responsibility rests on them. However, everyone, from employees and shareholders to the traveling public, must more carefully consider their interaction with the industry. In addition, the government will likely be necessary to support and enforce actions to reduce the industry's environmental impact.

Conclusion

For the foreseeable future, commercial aviation will play a key role in how people do business, move goods, and escape their everyday lives. The industry has shrunk the world, which has undoubtedly had a positive impact on society. However, it is not ethical for the industry to maintain its current path due to its environmental impact. It is necessary for the industry to internalize the costs it imposes on society.

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