The Impact of Rising Jet Fuel Prices on Global Connectivity

A Research Paper submitted to the Department of Engineering and Society

Presented to the Faculty of the School of Engineering and Applied Science

University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements for the Degree

Bachelor of Science, School of Engineering

Catherine DeScisciolo

Spring 2023

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

Advisor

Pedro A. P. Francisco, Department of Engineering and Society

Introduction

Amidst rising jet fuel prices, the need for cost-effective solutions to air travel has expanded. According to Bouwer (2022), the price of jet fuel was around $4 a gallon in the United States in June 2022, which is an almost 215 percent increase since January 2021. Prices are expected to continue trending up over the next decade, but this is still a rapid increase. Due to the Covid-19 pandemic air travel significantly decreased, leading oil refineries to shift their capacity away from jet fuel due to lower demand. In addition, Russia's invasion of Ukraine has drastically decreased international exports of both crude oil and refined products, pushing up the price due to the high demand for jet fuel from other sources. Even just an increase in the price of a few cents can raise airline yearly operating costs by tens of millions of dollars (ibid) so a 215 percent increase is cause for change. With global demand for jet fuel expected to double between 2019 and 2050, it is essential to find creative solutions to both the demand and price (Holladay et al., 2020). The price increase is not just reflected in operating costs. Consumers have seen an increase in ticket prices of 20% at the end of summer 2022 in comparison to 2019 (Pande, 2022). Less travel due to high prices decreases the international flow of people, goods, and services, leading to a disconnected world. Connectivity is vital to the spread of information and ideas as well as creating a flourishing economy. The rising price of jet fuel since the pandemic has led to a decrease in global connectivity.

Background

The Federal Aviation Association (FAA) predicts an overall rise in the price per barrel of jet fuel by about 5.9 percent per year through 2041. Prices skyrocketed in 2022 and are gradually decreasing, but are still significantly higher than pre-pandemic levels. This is likely due to the shock of a rapid increase in fuel demand once lockdowns were lifted, borders reopened, and

people became more comfortable traveling safely again. Despite the current downward trends, the price will continue to rise at a more gradual rate once it reaches a stabilization point.

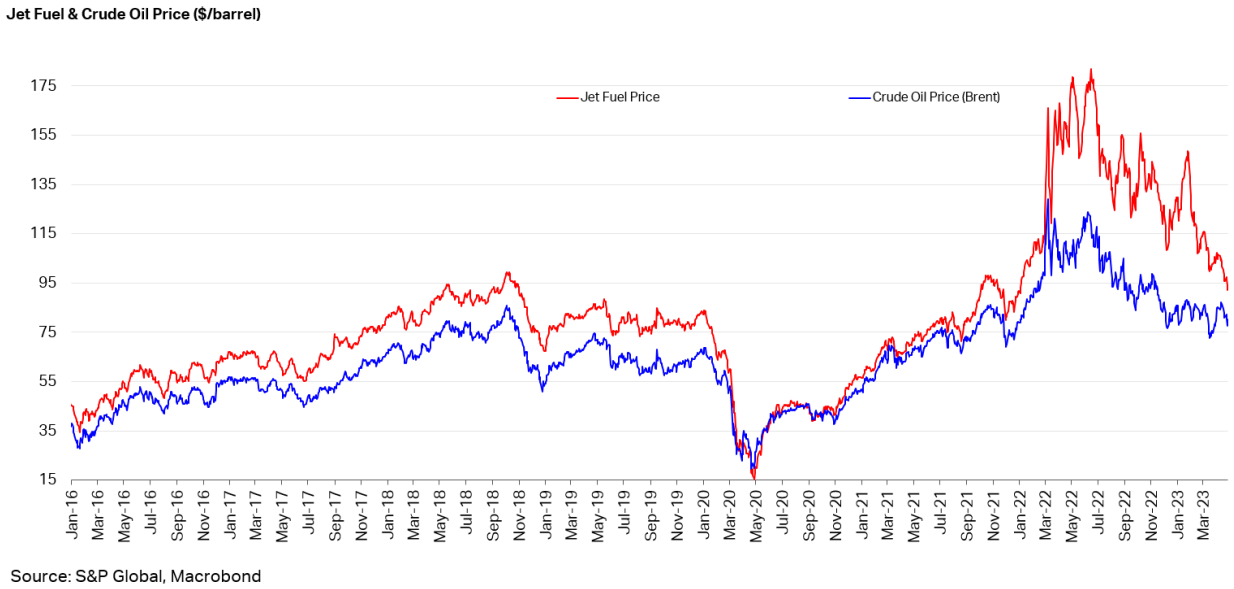

Figure 1. Jet fuel and crude oil prices since January 2016 (IATA, 2023).

This is assuming a full recovery post-pandemic and the addition of new fleets of regional jets. Regional jets typically seat between 50 and 100 people and are popular options for short-haul travel. Should a full recovery take more time than predicted, the costs could be higher than expected. At this moment in time, the aviation industry has not fully recovered from the consequences of the pandemic so it is safe to say this problem will continue in the future. It is essential to evaluate the current effects of the increases that have already occurred to predict how the market will look in the future. If prices continue to rise, air connectivity will continue to suffer as airlines are forced to cut routes from their flight plans to save money. This means fewer destinations will be serviced, connections will be more difficult to make, and some routes will not be flown at all. The focus will be maintaining profitability as opposed to servicing the highest number of locations possible. Large regional jets enable airlines to run high-capacity

flights and sell more tickets for the same amount of fuel consumption. With high fuel costs it is not economically feasible for airlines to fly to destinations where it is difficult to pack the flight to at or near maximum capacity. This decreases both tourism to those remote locations and imports and exports.

Global connectivity in the context of this paper refers to the level of accessibility and interconnectivity of air travel between different regions and countries around the world. It encompasses the number of flights, unique routes, and travel frequency. A high level of global connectivity is essential for economic growth because it facilitates trade and tourism between countries around the world. It also allows for the movement of people, goods, and services, opening markets for both businesses and individuals.

The ongoing conflict between Russia and Ukraine has resulted in a multitude of sanctions both by and against Russia. The restrictions causing the biggest issues in the aviation industry are those on oil and fuel and airspace. Both the European Union and Western countries have been trying to become energy independent from Russian products, however, the higher demand for fuel from other sources has contributed to the extreme price increases. The humanitarian crisis this conflict has caused, as well as the counters implemented by Putin, motivates the EU and the West to maintain their sanctions despite the negative impact on fuel prices.

Many countries, including the US, Canada, and the EU have banned Russian aerial vehicles from entering their respective airspaces. As a result, Russia has banned over 36 countries from flying through its airspace, which has resulted in many flights being rerouted or canceled (Karadima, 2022).

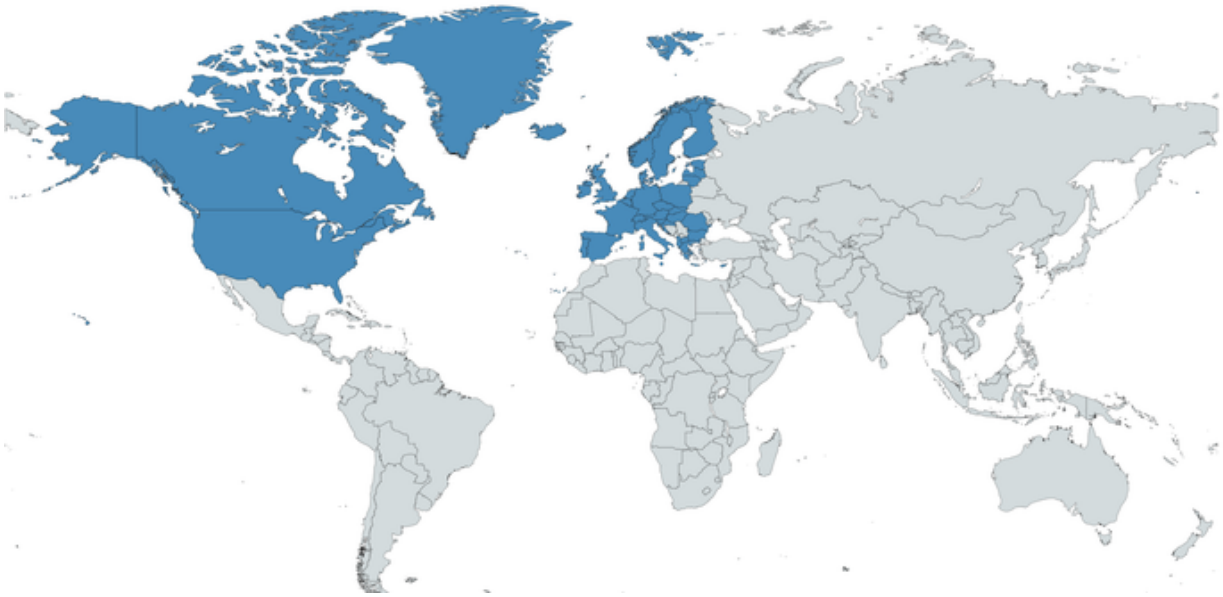

Figure 2. The 33 countries highlighted in blue have banned Russian aerial vehicles from their airspace (Jankowicz, 2022).

Flight cancellations mean monetary losses for airline companies while rerouting increases flight time, requires more fuel, and ticket prices must go up to balance this. Certain city-city pairs cannot be reached without extensive rerouting to avoid Russian airspace, so some of these flights have been suspended indefinitely. Finnair, a Finnish airline, has canceled flights to many Eastern Asian destinations. Osaka and Hong Kong remain out of service, but routes to Seoul, Tokyo, and Shanghai have luckily been restored (Karadima, 2022).

Flight prices going out of Russia have increased massively, those out of St. Petersburg have increased anywhere from 272 to 1,344 percent. Russian citizens have been discouraged from traveling, particularly to countries with sanctions against Russia, and the skyrocketing ticket prices don't aid in motivating them to travel.

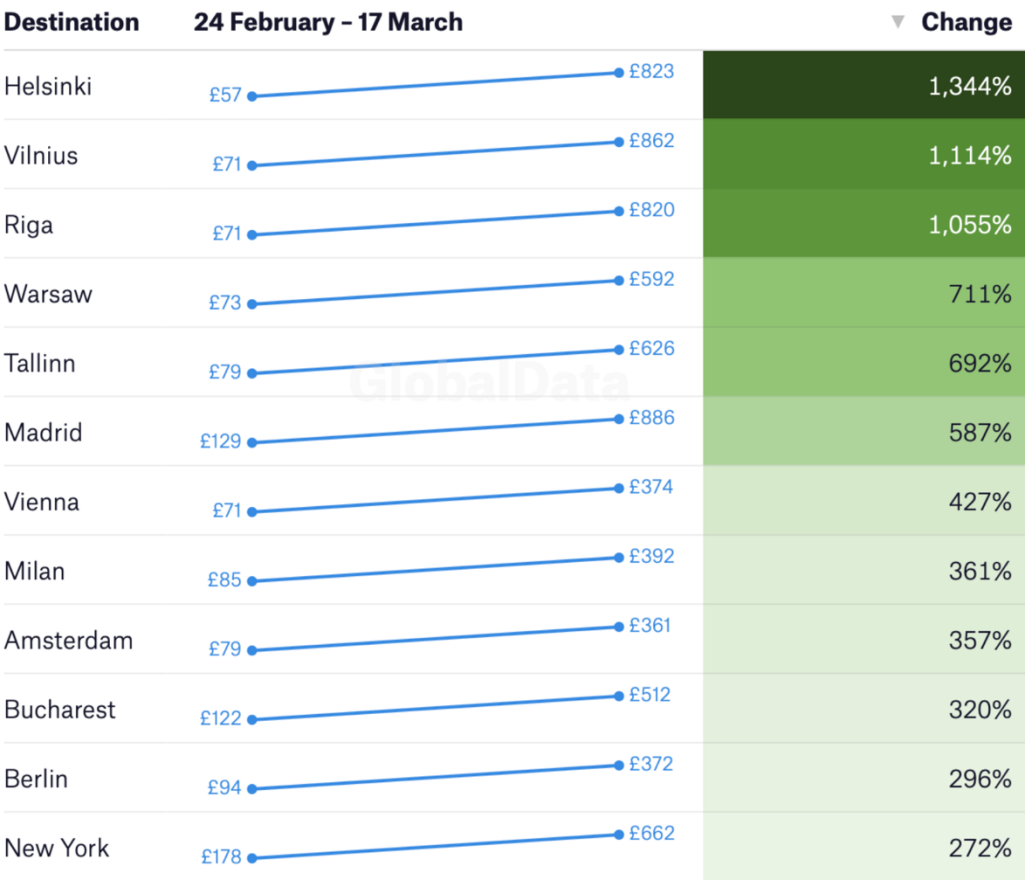

Figure 3. Changes in ticket prices out of St Petersburg Pulkovo Airport in early 2022 (Karadima, 2022).

Unfortunately for tourism industries of countries in Europe, Asia, and the Middle East, Russian travelers make up a large portion of their visitors each year. However, Turkey and China are Russia's two most popular international destinations and neither of those countries has restricted travel from Russia (Karadima, 2022).

The rapid spread of Covid-19 in 2020 caused major disruptions across the world. Economies suffered from rapid declines due to lower international trade, business closures, and a rise in unemployment. Most entities were not prepared to deal with a worldwide pandemic of this scale and, as such, recovery has been a long, winding road that continues to this day. Governments implemented policies such as social distancing, mask mandates, travel restrictions,

lockdowns, and in some cases mandatory testing. Regarding aviation, travel restrictions and safety measures have had the most visible consequences. Travel restrictions included border closures, flight suspensions, and limits on travel from certain countries. Travel restrictions vastly reduced the number of flights and routes available; many places could no longer be traveled to due to border closures.

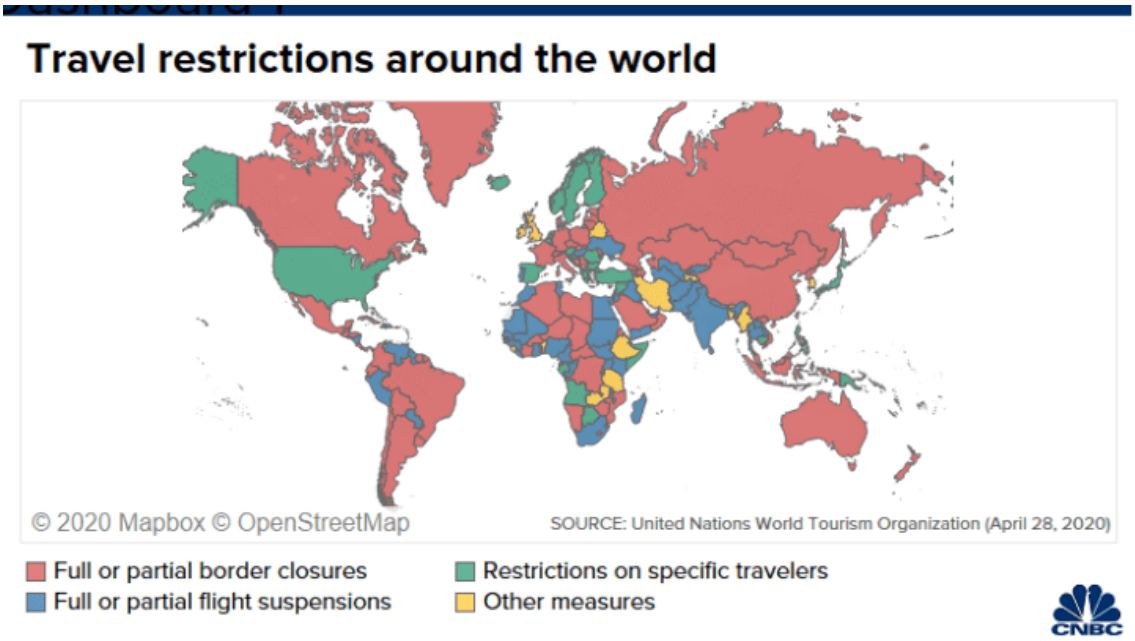

Figure 4. Travel restrictions implemented due to Covid-19 by country (Lee, 2020).

Safety measures such as mask mandates and social distancing not only restricted the number of people who could be on a single aircraft but made the overall travel experience incredibly troublesome. Airports had to adapt their infrastructure to account for these regulations in how people navigated to their gate, went through security, bordered the plane, and even used the restroom. These changes, although necessary to protect the safety of both travelers and aviation employees, made travel less desirable for the general population.

Due to low demand during the pandemic, oil refineries shifted their capacity away from jet fuel and lowered their general capacity across the board. This led to several closures of major

U.S. plants, which is now placing more strain on those still in business as the demand for gasoline, diesel, and jet fuel rapidly increased following the pandemic. High unemployment rates and a desire to travel following a long lockdown period are some of the factors contributing to the high demand. In addition, Russia's invasion of Ukraine has added further stress on U.S. refineries to increase capacity and produce more fuel. U.S. plants are currently running at 94 percent capacity, which is the highest level since September 2019 (Seba, 2022). Despite the current high demand, oil refineries could see losses in the future if fuel prices continue to be high as individuals and companies search for ways to be more fuel-efficient and save money.

Research Methods

The primary method employed to analyze this topic is a literature review. A literature review provides valuable data on the economic impact of decreased air travel on various countries and demonstrates which particular regions are being hit harder. Government documents possess data on the percent of GDP from air travel, cargo, and tourism as well as useful figures to physically represent data. Documents from the IATA (International Air Travel Association) provide metrics on the total number of routes flown across different airlines as well as international trade interactions.

Results and Discussion

Aircraft companies have been aiming to expand both passenger and cargo capacity to increase profits from both the commercial flight and air cargo markets. Due to the rise in fuel prices, smaller regional turboprops are no longer economically advantageous, so future fleet growth will be primarily focused on the integration of larger aircraft. High-volume aircraft (over 50 seats) are less maneuverable on short, rugged, unpaved, or steep runways and therefore unable to maintain connectivity with airports possessing those conditions. Regional turboprops

capable of operating given tough runway conditions, such as the ATR 42-600S, enable access to several hundred more airports globally (ATR, 2022). If new technology could reduce fuel costs to the point where smaller aircraft could operate at the same economic level as larger aircraft, airlines would be encouraged to include more diverse routes and retain connections with remote areas. The people living in those areas would benefit from the opportunity to travel as well as the ability to ship more of their domestic products. The technical portion of this portfolio focuses on the design of a hybrid electric regional turboprop aircraft with the goal of reducing fuel burn and emissions compared to current models. This design aims to fill the connectivity gap in the aviation industry that emerged due to cost cuts.

Air connectivity is vital in creating links between the people, businesses, and economies of countries around the world by facilitating trade, tourism, travel, and information exchange. According to the IATA (IATA, 2021), "nearly 61 million tonnes of freight was carried by air in 2019…the total value of goods transported by air is $6.5 trillion, representing 35 percent of all international trade," (IATA, 2021). The air freight industry contributes significantly to the global economy, as it boosts labor productivity, creates jobs, and increases wages in competitive markets (ibid). Without the air freight industry, it would be difficult for businesses to transport goods quickly and efficiently which is essential for maintaining the global economy.

Figure 5. Global air freight traffic with hubs depicted in grey and routes in blue (Meijs, 2017).

With over a third of international trade conducted via air, the loss of regional routes due to airlines cutting costs will negatively impact the economies of those remote areas. In addition, overall loss in destinations and frequency results in longer shipping times and higher prices, disrupting the flow of both essential and non-essential goods.

Covid-19 also disrupted the air cargo market. The closure of borders and travel restrictions led to supply chain disruptions and shortages of essential goods and medical supplies. The consequences of this led to economic struggles, difficulty to obtain and provide medical treatment for those affected by the virus, and a decrease in overall cooperation and aid between countries.

Another reason for the global decrease in air connectivity, in addition to rising jet fuel prices, is the COVID-19 pandemic. The pandemic cut air travel in 2019 by anywhere from 70 to 90 percent depending on the area and the industry is still attempting to recover. The combination of these two factors makes supporting more remote routes economically unfeasible for most airlines, essentially isolating some regions from engaging with the air economy. The number of

unique city pairs, a good metric to encompass the number of cities navigable by air, rose from about 10,000 in 1995 to 22,000 in 2019, but then suffered a decline to 15,000 in 2020, over half the progress that had been made in the last 20 years (IATA, 2021).

The IATA defines air connectivity by taking into account a variety of factors including "travel time, travel costs, the number of connections, the quality of connections, the number of destinations served, frequency of service, reliability of connections and opportunities at destination (e.g. population or GDP)," to generate a number representing the air connectivity index for countries around the world, allowing for a holistic comparison. Using this index, air connectivity can be analyzed before and after the pandemic to see where the biggest losses were located.

The North America and Asia Pacific regions suffered the least losses in connectivity, despite still suffering economic losses, during the pandemic as both regions have a large market for domestic trade. On the other hand, regions such as Europe which went on lockdown for domestic travel suffered further connectivity losses during the height of the pandemic. Europe suffered losses of around 95 percent in the most traveled countries (Germany, United Kingdom, Spain, France, and Italy) and the recovery is still up to only around 50%. It can be seen in Figure 1 that the number of both commercial and total flights drastically decreased after the aforementioned countries went into lockdown, with a decrease of around 50 percent.

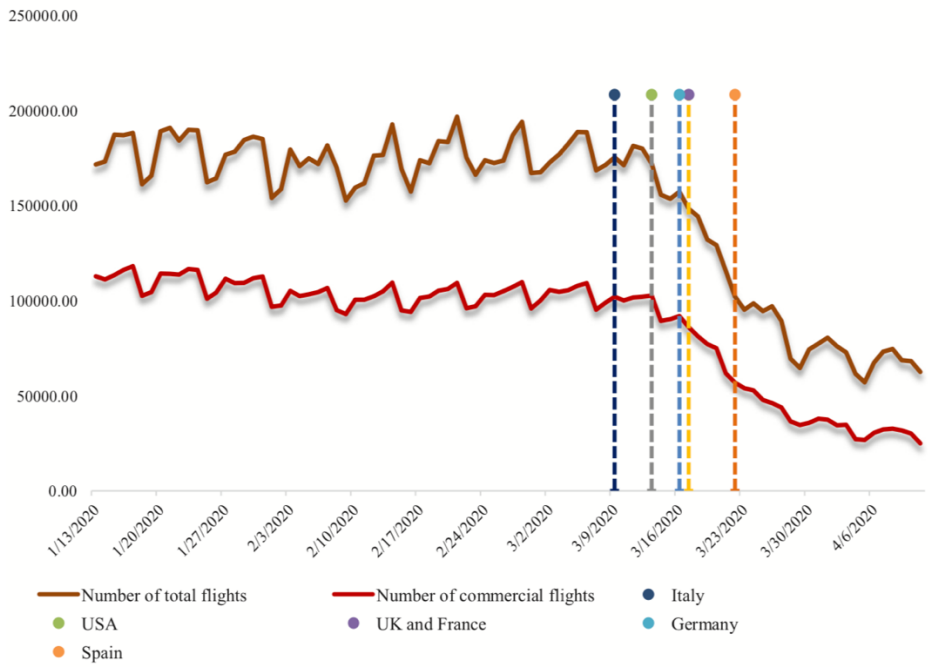

Figure 6. The number of flights before and after travel restrictions were implemented. The dotted vertical lines represent the time at which each country put restrictions into place (Youssef, et al., 2020).

In 2021, airlines faced losses of approximately 52 billion dollars given a decline in overall travel and fuel hedging. Fuel hedging is a process in which airlines purchase a large amount of fuel at a set price, so when there are fewer consumers than expected, it is a risky play and usually incurs losses. Costs were cut up to 31% in 2021 in an attempt to recover from the pandemic. Cost cutting forces airlines to decline their number of unique city pairs as routes that are unpopular with consumers are no longer advantageous to fly, causing economic declines in the aviation industry in those locations such as loss of jobs, trade, and tourism.

The Covid-19 pandemic had a severe negative impact on the aviation industry. Due to the high exposure risks of being in an enclosed space with a large number of people for a prolonged

period, many people strayed away from air travel. The industry is still trying to recover from the extensive impact of the pandemic so it is important to acknowledge this issue and demonstrate how it intertwines with rising jet fuel prices. The year 2020 saw a decline of 74% in international passenger travel as well as an 84.3 billion dollar loss across the aviation industry (Bodolica, et al., 2021).

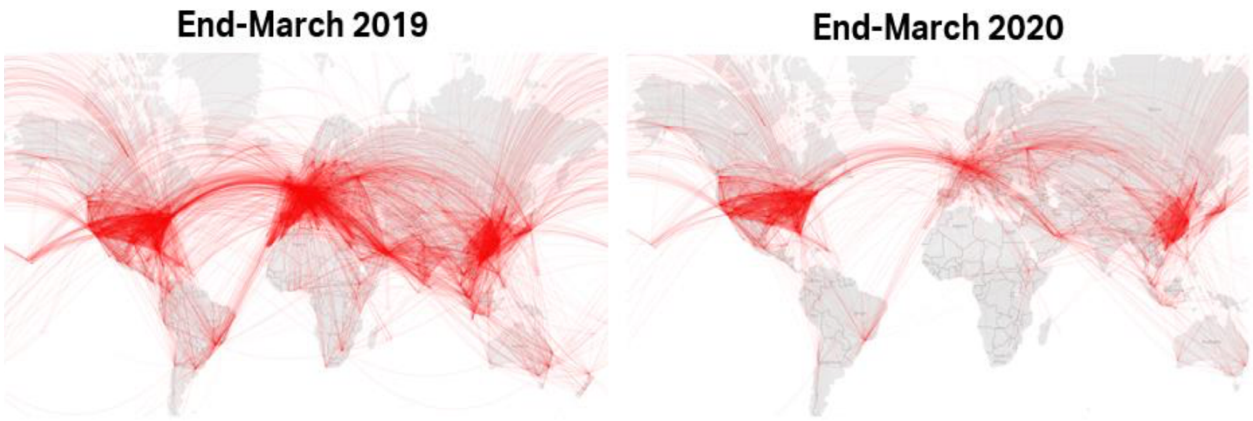

Figure 7. Number of flights in March 2019 and March 2020 after travel restrictions imposed by the pandemic using data from FlightRadar24 (IATA, 2021).

At the start of the pandemic, specifically across the first three months (January-April 2020), jet fuel prices fell by 58% as consumer demand rapidly dropped following the implementation of travel restrictions. So, the pandemic was positive for jet fuel prices despite being negative for connectivity, however, the lower jet fuel prices were not enough to save airlines from extensive losses. This is due to hedging, in which fuel is bought in advance, at higher prices before the height of the pandemic, so some airlines ended up spending more than necessary to purchase fuel for flights that were either canceled or at low capacity. In addition, canceled flights led to many passenger refunds (Youssef et al., 2020).

While the hypothesis that rising jet fuel prices decrease global connectivity is correct, after conducting research and performing literature reviews, it became apparent that the current most critical source of a decline in global connectivity is the Covid-19 pandemic. The pandemic resulted in major financial losses for airline companies due to a sudden rapid decline in international and domestic travel. This decline continued over the course of 2020 and 2021 leaving behind a slew of consequences for trade, tourism, the movement of people, and the sharing of ideas. The rise in jet fuel prices is primarily due to sanctions against Russia resulting in high demand, but the prices are expected to continue to rise due to inflation and overuse of natural resources. The high prices have made global connectivity recovery difficult post-pandemic because of the rising cost of travel leading airline companies to shift their capacity to highly profitable routes. To continue rebuilding global connectivity through aviation, flight paths, destinations, frequency, and the number of connections need to increase while the time and cost of travel need to decrease. One solution for reducing the cost of travel is the creation of a radical invention that will disrupt the norms of aircraft design. Such inventions are in development such as hybrid electric aircraft and sustainable aviation fuel. Although the benefits of these technologies have not yet come to fruition, they represent a changing industry looking to future expansion.

Framework

Hughes' (1987) article defines technological systems and analyzes their evolution over time through different themes. Technological system artifacts consist of physical technology, organizations, legislature, and natural resources while components are the human aspects such as engineers and manufacturers. Hughes argues that if a sector of a system changes, the others will adapt to compensate for this change. Radical inventions do not contribute to the growth of

technological systems as they set a precedent for a new technological system to form but typically need assistance from a larger organization to give them momentum. However, not all large companies or organizations have the freedom to take on radical inventions. Depending on the bureaucratic environment and potential regulations some companies are “inert” and incredibly resistant to changes in momentum. The momentum of a technological system is directly related to its rate of growth. A system with artifacts and components supporting it as well as meeting the themes described by Hughes, such as invention and innovation, is more likely to have growth in the future (ibid).

Technological momentum is a good way to analyze how Covid-19 has driven change in the aviation system through the themes described by Hughes. Airlines, governments, travelers, and fuel are all artifacts of the system. They had to adapt to a changing world where health and safety from a highly contagious virus was the priority. Borders were closed by governments, mask mandates, and social distancing were put in place in airports, fuel prices rose, trade decreased, and momentum became negative. However, the components of the system reacted and came up with solutions to change the momentum to positive and encourage growth. Full connectivity recovery is still in progress and with other changes on the horizon, such as rising fuel prices, the aviation industry must continue to innovate.

Conclusion

The COVID-19 pandemic had an extremely negative impact on the aviation industry, leaving airlines facing major losses and looking for cost-effective solutions. While recovery is ongoing, the extreme increase in jet fuel prices since 2021 has not made it an easy task. Air connectivity endured incredible losses in the number of routes, destinations, connections, and

frequency of flights. New, radical inventions and technologies will be key in advancing the industry back to pre-pandemic levels and beyond as well as adapting to changing environment.

Future research would consist of further analysis into the effects of Covid-19 on not just air connectivity, but the aviation industry as a whole. This paper only delved into the industry lightly as the focus was on connectivity and jet fuel prices. By revealing which aspects of the aviation industry suffered the most and require the most support to restore to pre-pandemic levels, more comprehensive solutions for recovery post-pandemic could be developed.

References

ATR 42-600 STOL aircraft: ATR aircraft. ATR. (2022, July 28). Retrieved October 27, 2022, from https://www.atr-aircraft.com/our-aircraft/atr-42-600s-stol/

Bodolica, V., Spraggon, M., & Khaddage-Soboh, N. (2021). Air-travel services industry in the post-covid-19: The GPS (guard-potentiate-shape) model for crisis navigation. *Tourism Review*, *76*(4), 942–961. https://doi.org/10.1108/tr-12-2020-0603

Bouwer, J., Dichter, A., Fuchs, G., Hartung, K., Krishnan, V., Saxon, S., & Rivas, D. (2022, July 14). *Why rising fuel prices might not be as bad for the airline sector as it seems*. McKinsey & Company. Retrieved October 27, 2022, from https://www.mckinsey.com/industries/travel-logistics-and-infrastructure/our-insights/why-rising-fuel-prices-might-not-be-as-bad-for-the-airline-sector-as-it-seems

Federal Aviation Association, FAA Aerospace Forecast Fiscal Years 2021–204172–75 (n.d.).

Hughes, T. P. (2012). The evolution of large technological systems. *The social construction of technological systems: New directions in the sociology and history of technology*, 45-76.

International Air Transport Association. (2021). *Air Connectivity: Measuring the connections that drive economic growth.* https://www.iata.org/en/iata-repository/publications/economic-reports/air-connectivity-measuring-the-connections-that-drive-economic-growth/

International Air Transport Association. (2021). *Economic Performance of the Airline*

Industry. https://www.iata.org/en/iata-repository/publications/economic-reports/airline-industry-economic-performance---october-2021---report/

International Air Transport Association. (n.d.). *Jet fuel price monitor*. IATA. Retrieved May 5, 2023, from https://www.iata.org/en/publications/economics/fuel-monitor/

Jankowicz, M. (2022, March 2). *Map shows countries that have closed their airspace to Russia over Ukraine invasion*. Business Insider. Retrieved May 5, 2023, from https://www.businessinsider.com/map-shows-countries-that-closed-airspace-russia-over-ukraine-war-2022-3

Karadima, S. (2022, March 11). *What impact will the Russia-Ukraine conflict have on the tourism industry?* Investment Monitor. Retrieved May 5, 2023, from https://www.investmentmonitor.ai/special-focus/ukraine-crisis/russia-ukraine-conflict-impact-tourism-industry/).

Karadima, S. (2022, March 22). *What impact will the Russia-Ukraine conflict have on the aviation sector?* Investment Monitor. Retrieved May 5, 2023, from https://www.investmentmonitor.ai/special-focus/ukraine-crisis/russia-ukraine-conflict-aviation-sector-impact/

Lee, Y. N. (2020, May 6). *5 charts show which travel sectors were worst hit by the coronavirus*. CNBC. Retrieved May 5, 2023, from https://www.cnbc.com/2020/05/06/coronavirus-pandemics-impact-on-travel-tourism-in-5-charts.html

Meijs, L. J. J. A., Santos, B. F., Tavasszy, L., Miranda, D. R. (2017, March). Air Transport Research Society World Conference. *Global Air Cargo Flows Estimation Based on O/D Trade Data*, 1-15.

Pande, P. (2022, April 24). *How rising jet fuel prices will hurt airlines and travelers*. Simple Flying. Retrieved October 27, 2022, from https://simpleflying.com/jet-fuel-prices-impact/

Seba, E. (2022, June 21). *U.S. oil refining capacity down in 2021 for second year -EIA*. Reuters. Retrieved May 5, 2023, from https://www.reuters.com/business/energy/us-oil-refining-capacity-drops-2021-2d-straight-year-eia-2022-06-21/

Syal, A. (2020, June 7). *Turboprops vs jets – what's the best for short-haul flights?* Simple Flying. Retrieved October 27, 2022, from https://simpleflying.com/turboprops-vs-jets/

Turboprop Aircraft. NBAA. (n.d.). Retrieved October 27, 2022, from https://nbaa.org/business-aviation/

Turboprop engine. SKYbrary Aviation Safety. (n.d.). Retrieved October 27, 2022, from https://skybrary.aero/articles/turboprop-engine

Turboprop market forecast 2022-2041. ATR. (2022, September 30). Retrieved October 27, 2022, from https://www.atr-aircraft.com/our-aircraft/turboprop-market-forecast-2022-2041/.

Verdict Media Limited. (n.d.). *Bombardier Q300 DHC-8 Dash 8*. Aerospace Technology. Retrieved October 27, 2022, from https://www.aerospace-technology.com/projects/bombardier_q300/

Youssef, A., Zeqiri, A., Dedaj, B. (2020). IAEE Energy Forum. *Short and Long Run Effects of COVID-19 on the Hospitality Industry and the Potential Effects on Jet Fuel Markets*, 121-124.