Analyzing the Impact of Take-Off Weight on Fuel Costs: A Case Study

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Introduction

Now more than ever, the cost of fuel remains as an airline’s biggest expense.

As such, airlines are constantly searching for ways to reduce their fuel consumption and optimize their fuel costs. The most crucial factor that affects an aircraft's fuel consumption is its take-off weight (TOW). The heavier an aircraft is, the more fuel it requires to take off and maintain altitude. Therefore, it's essential for airlines to understand how changes in TOW can impact their fuel costs and ultimately, their bottom line.

This report examines the effect of TOW on fuel costs and provides insights and recommendations for airlines looking to optimize their fuel consumption and reduce costs. The report will begin by analyzing the relationship between TOW and fuel consumption, and then move on to explore the impact of fuel costs on an airline's profitability. Finally, recommendations will be provided for airlines looking to optimize their fuel costs and improve their profitability in today's competitive airline industry.

Data and Methodology

This case study collected data from nearly four dozen flights conducted on the XPlane Mobile Flight Simulator, all using the Boeing 777-200ER aircraft. These flights covered short to medium haul distances, ranging from 60 to slightly over 180 minutes.

Data was recorded at four critical points during each flight: takeoff runway fuel, fuel at the end of climb, fuel at the start of descent, and fuel at the arrival gate. The flight deck clock and fuel indicator in the simulator were used to manually record the time and fuel quantities. Subsequently, an in-house program was employed to calculate various parameters such as climb time, cruise time, descent time, climb fuel burn, cruise fuel burn, descent fuel burn, and total fuel burn. For the purposes of this study, the focus will be on total fuel burn, as each stage of the flight contributes to the cost implications.

On longer haul flights, the reduced fuel burn over the course of the journey due to weight loss from fuel consumption becomes more significant. Although this factor has less impact on short to medium haul flights, the program considers it by calculating fuel burn as an average across the different flight stages. Additionally, it should be noted that any extra fuel added to the aircraft adds weight that it would not have otherwise carried, even though it is consumed during flight.

The flights took place in various locations, with approximately 93% of the flights within the United States and the remaining flights spanning Europe, Asia, and Africa. Departure locations were randomly selected, and airports within the 60 to approximately 180-minute range were chosen to ensure a reasonable flight duration.

The flight routes were determined using the Navigraph Chart Software, with an aim to closely follow real-world flight paths. However, in approximately 3% of the flights, the Lateral Navigation of the aircraft experienced malfunctions, necessitating alternate routes.

Around 95% of the flights were conducted during daytime and without rain to minimize the risk of application crashes due to high graphics demand. Flights to and from major international airports like John F. Kennedy International and LaGuardia Airport were generally avoided to reduce the graphical load and potential application crashes.

Every flight included in this study was conducted in accordance with International Standard Atmosphere (ISA) conditions at sea level. Runway conditions at takeoff and landing (regardless of field elevation) maintained a temperature of 59 degrees Fahrenheit (15 degrees Celsius), and the atmospheric pressure was maintained at 29.92 inches of Mercury (Hg). As flight altitude increased and decreased, temperature and pressure changed consistently with ISA standards. It is important to note that the in-house program used for calculations did not incorporate temperature or atmospheric pressure, as they remained consistent with the ISA standard.

This report will investigate the impact of pilot technique, field elevation of the departure airport, N1% during cruise, go-arounds/long descents, and wind on fuel burn, examining whether these factors directly influence fuel consumption, indirectly affect it, or have no effect at all.

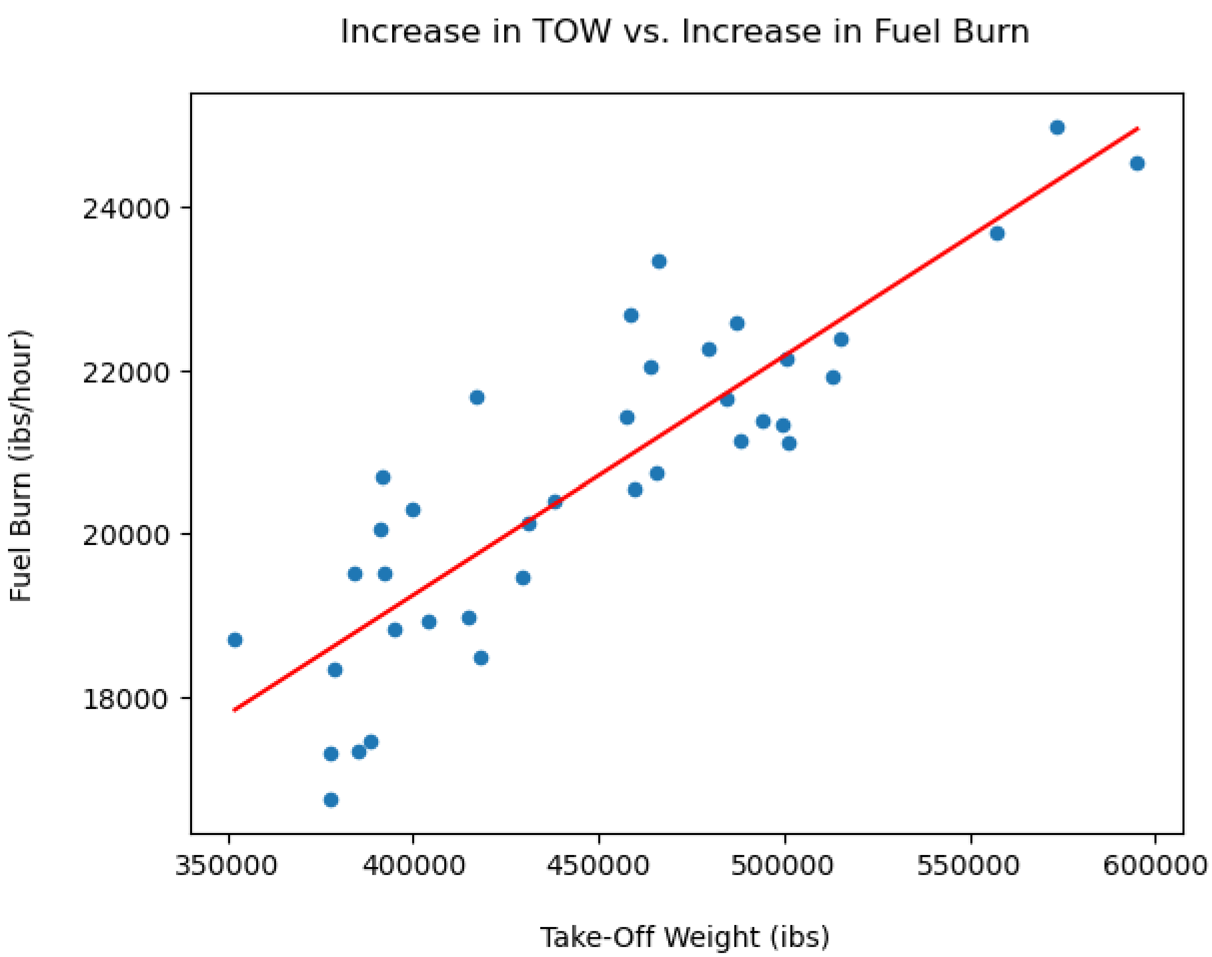
Autopilot was engaged for approximately 95% of the duration of each flight. During the climb phase, a vertical speed was selected to maintain a minimum speed of 260 KIAS (Knots Indicated Airspeed). Step climbing was employed as necessary to allow the aircraft to accelerate before continuing the ascent. Below 10,000 feet, a speed of approximately 250 KIAS was maintained. N1 settings were adjusted to 94% when climbing from 10,000 to 20,000 feet, 95% from 20,000 to 30,000 feet, and 96% from 30,000 feet to the predetermined cruise altitude. During cruise, the Mach speed was maintained between 0.75 and 0.85.

The center of gravity (COG) was determined by the in-house program based on TOW. COG ranged from 0.5 to 3.5 pounds aft.

The cruise altitudes were chosen based on the most fuel-efficient altitude for the aircraft's load. Lighter loads enabled flight level 380 to be maintained, while heavier loads may have required flight level 300. The direction of the flight also played a role in determining the altitude, with westbound flights typically opting for slightly lower altitudes.

Findings

The data collected from XPlane shows a clear relationship between takeoff weight (TOW) and fuel burn. As TOW increases, so does the amount of fuel required to complete the flight. This is demonstrated in the chart below, which illustrates the average fuel burn for each TOW range:



The Average TOW was 448,030 ibs

The Median TOW was 447,774 ibs
The TOW Range was 243,068 ibs

The Average Fuel Burn was 20,647 ibs/hour
The Median Fuel Burn was 20,714 ibs/hour
The Fuel Burn Range was 8,247 ibs/hour

Similar values between the Average and Median suggests there were not outliers significant enough to skew the results.

A correlation of 0.868 further confirms that fuel burn is strongly affected by TOW. A slope of 0.02930 denotes that for every additional 35 pounds added to the TOW, fuel burn will increase by one pound per hour.

Additionally, the data suggest the following:

Using the current standard weight of an adult passenger, **195** pounds as of May 8, 2023, fuel burn will increase by **5.713** ibs/hour for every additional adult passenger.

For every **100** pounds added to the TOW, fuel burn will increase by: **2.93** ibs/hour

For every **500** pounds added to the TOW, fuel burn will increase by: **14.65** ibs/hour

For every **1,000** pounds added to the TOW, fuel burn will increase by: **29.30** ibs/hour

For every **5,000** pounds added to the TOW, fuel burn will increase by: **146.50** ibs/hour

For every **10,000** pounds added to the TOW, fuel burn will increase by: **293.00** ibs/hour

For every **50,000** pounds added to the TOW, fuel burn will increase by: **1,465.00** ibs/hour

For every **100,000** pounds added to the TOW, fuel burn will increase by: **2929.99** ibs/hour

For every **150,000** pounds added to the TOW, fuel burn will increase by: **4394.99** ibs/hour

For every **200,000** pounds added to the TOW, fuel burn will increase by: **5859.99** ibs/hour

For every **250,000** pounds added to the TOW, fuel burn will increase by: **7324.99** ibs/hour

For every **300,000** pounds added to the TOW, fuel burn will increase by: **8789.99** ibs/hour

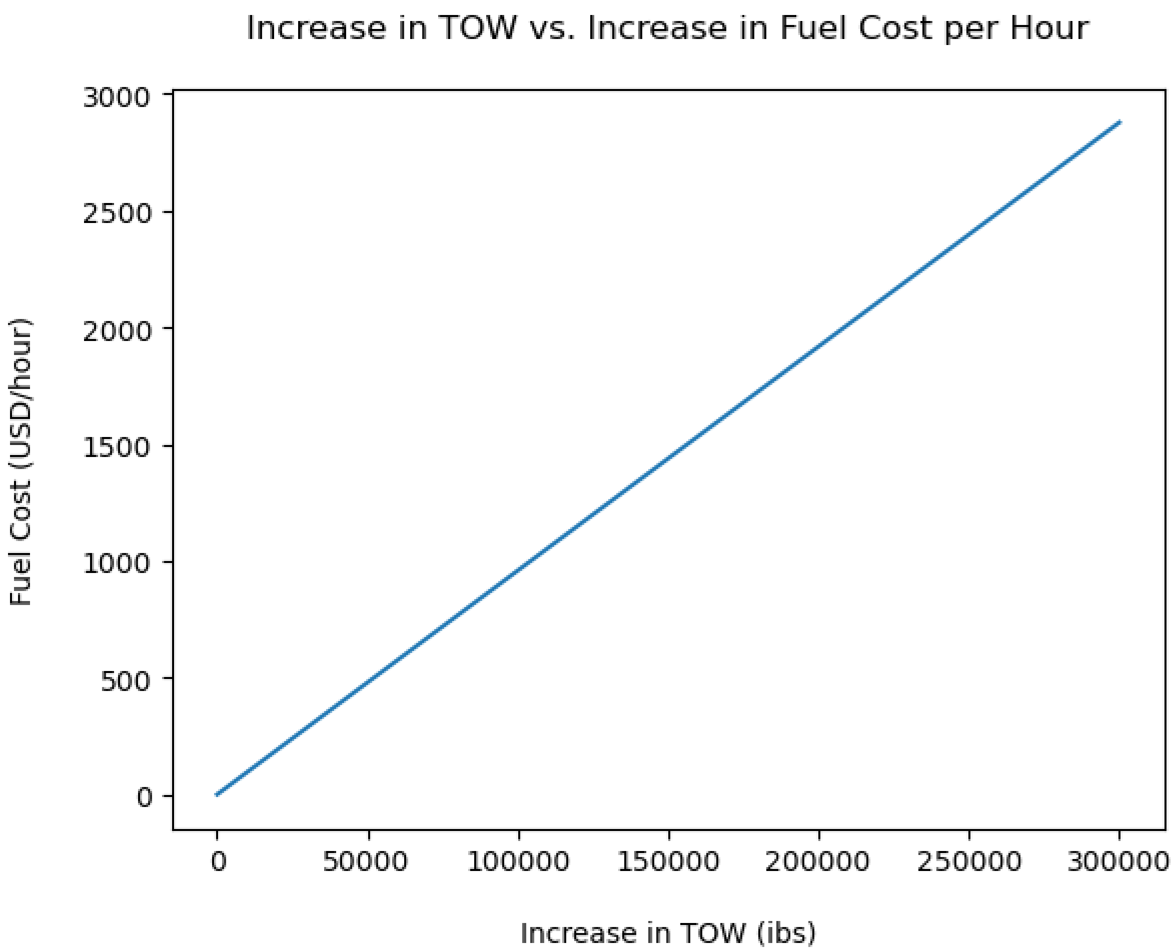
While many of these fuel burn increases appear insignificant with the ibs/hour parameter, the mass volume of flights throughout the world often ranging from 5 to over 10 hours, allow these figures to substantially add up over the course of one year.

For example, there are an average of 28 flights between New York City and London per day (half to NYC and the other half to London) with flight times of about seven hours. This totals to 10,220 flights per year.

With 1000 additional pounds on every flight (roughly five additional adult passengers), an additional 2,096,322 pounds of fuel will be burned per year, or approximately 311,000 gallons.

Confirming that TOW and Fuel Burn have a strong positive correlation, the increases in fuel burn means more fuel will be burned, meaning more fuel must be purchased. The following chart illustrates the increased fuel costs in relation to increased TOW:

This chart uses the cost of Jet A1 Fuel per gallon on May 8th, 2023, at $2.21.



The average fuel cost per hour of flight on the 777 is $6760.05. A slope of 0.00959 indicates the fuel cost will increase by 0.00959 USD/hour for every additional pound, or 1 USD/hour for every 104 pounds.

Additionally, the data suggests the following:

The cost increase per every additional standard adult passenger (**195 ibs**) is **1.871** USD/hour

For every **100** pounds added to the TOW, fuel cost will increase by: **0.959** USD/hour

For every **500** pounds added to the TOW, fuel cost will increase by: **4.797** USD/hour

For every **1,000** pounds added to the TOW, fuel cost will increase by: **9.593** USD/hour

For every **5,000** pounds added to the TOW, fuel cost will increase by: **47.965** USD/hour

For every **10,000** pounds added to the TOW, fuel cost will increase by: **95.930** USD/hour

For every **50,000** pounds added to the TOW, fuel cost will increase by: **479.652** USD/hour

For every **100,000** pounds added to the TOW, fuel cost will increase by: **959.304** USD/hour

For every **150,000** pounds added to the TOW, fuel cost will increase by: **1,438.955** USD/hour

For every **200,000** pounds added to the TOW, fuel cost will increase by: **1,918.607** USD/hour

For every **250,000** pounds added to the TOW, fuel cost will increase by: **2,398.259** USD/hour

For every **300,000** pounds added to the TOW, fuel cost will increase by: **2,877.911** USD/hour

Referencing back to the example of yearly NYC/LON round trips, having an additional 1000 pounds on all 10,220 seven-hour flights per year will cost an additional $687,310 per year.

Discussion:

This study demonstrated the strong correlation between TOW and fuel burn, and the fuel cost as a result. It goes further by detailing the degree of the additional costs, and also provides an example of how the costs add up.

It was calculated prior that having an additional 1000 pounds on every flight between NYC & LON would cost the airline an additional $687,310 per year. While this amount may seem insignificant to a multi-billion dollar company, the notorious razor-thin profit margins in the industry require airlines to cut costs wherever they can.

This example also only covers one route. Extra weight on flights throughout the world will experience costs on a significantly greater scale.

It is indeed true that the airline will earn revenue if this additional weight is from passengers or cargo through airfare or shipping costs, and these figures can help airlines determine how to set their prices.

The additional weight may also be from extra fuel. Airlines will load extra fuel as passenger weights are only estimated. This extra weight accounts for major additional costs each year.

Finally, the additional weight may be from the aircraft manufacturer’s design and materials used. Manufacturers continuously stride to build planes with strong, yet lighter materials resulting in huge fuel savings. Future planes are likely to become more and more fuel efficient, especially with increasing regulations and incentives from governments around the world to reduce emissions and save resources.

For current planes, airlines could reduce on-board supplies and source lighter interior parts.

Limitations:

There were four flights that were dropped from the study because the cruise & descent fuel burn could not be obtained, or could not be reasonably obtained accurately.

Flight 0 ran out of fuel just after the descent start. The plane did not make it to the airport, therefore an accurate descent fuel burn could not be obtained.

Flight 27 was ended during cruise because the iPad went into an auto-update. Cruise & Descent Fuel Burn was not obtained.

Flight 30 was ended during cruise due to an autopilot malfunction. The autopilot was automatically descending the plane and the flight could not be continued. Cruise & Descent Fuel Burn were not obtained.

Flight 34 was ended during cruise due to an app crash from overheating. Cruise & Descent Fuel Burn were not obtained.

There were multiple factors that were hypothesized to variate fuel burn in flights with similar parameters. These factors were believed to cause a different total fuel burn for flights that should otherwise be the same. This study answers whether these factors did variate fuel burn, and/or whether this variance was consistent or to a relevant degree.

These factors in question include:

Pilot Technique:

Manual flying was performed from take off until 10,000 ft, and again from approximately 1000 ft on final approach to landing. For the climb above 10,000 ft, autopilot was set to maintain a vertical climb speed from approximately 3500 feet per minute (fpm) down to 1500 fpm at altitudes over 30,000 feet. The vertical speed was adjusted as such to maintain a speed over 260 KIAS, so variations are present from flight to flight.

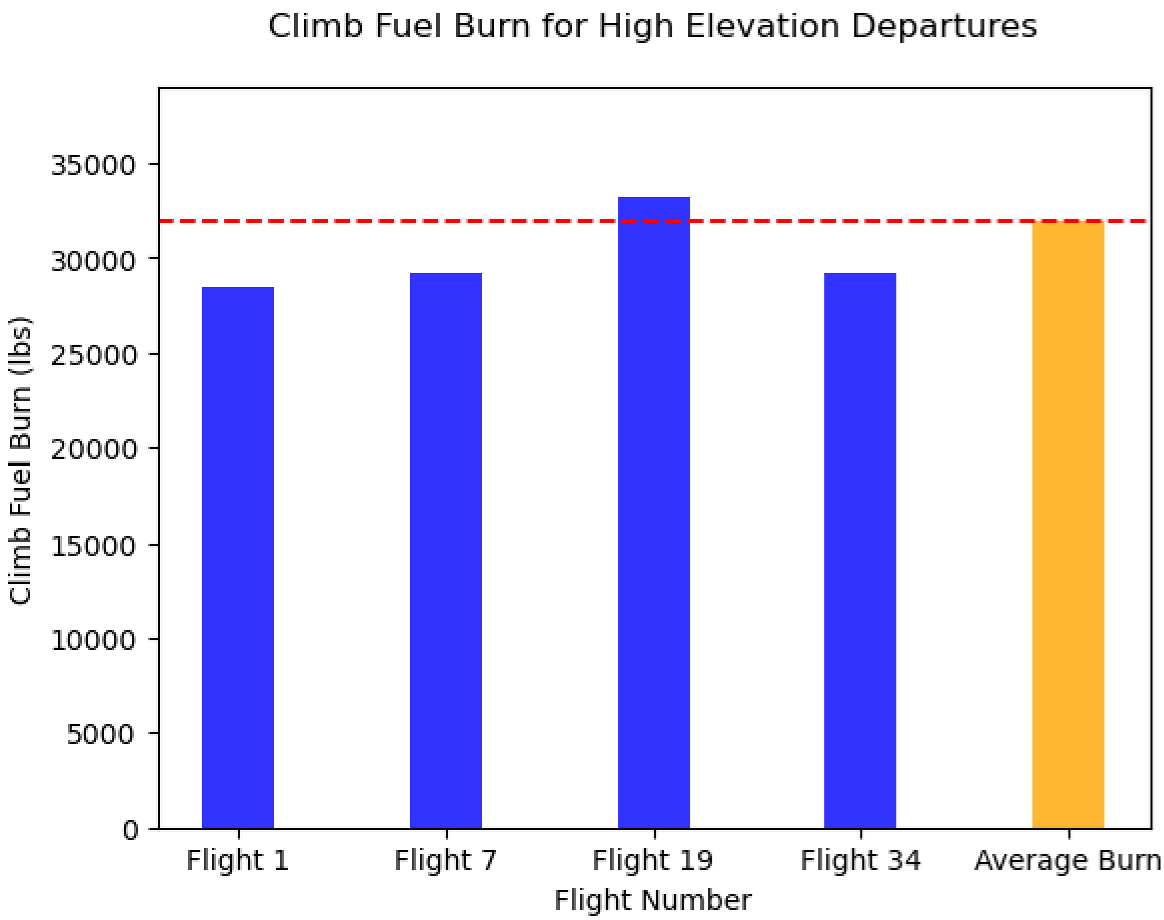
As a result, the length of the time to cruise altitude slightly varies for each flight, even at similar TOWs. The extent this played in the fuel burn is present, but likely insignificant because a relatively stable vertical speed was maintained throughout the climb to 10,000 feet.

Field Elevation:

Field elevation of the departure runway, defined as the altitude of the airport, was hypothesized to play a significant part in the climb time, and hence fuel burn. This was predicted to occur where departure airports had higher elevations. The two departure airports with the highest elevations included Denver (DEN) with an altitude of 5,430 ft, and Lhasa (LXA) with an altitude of 11,713 ft.

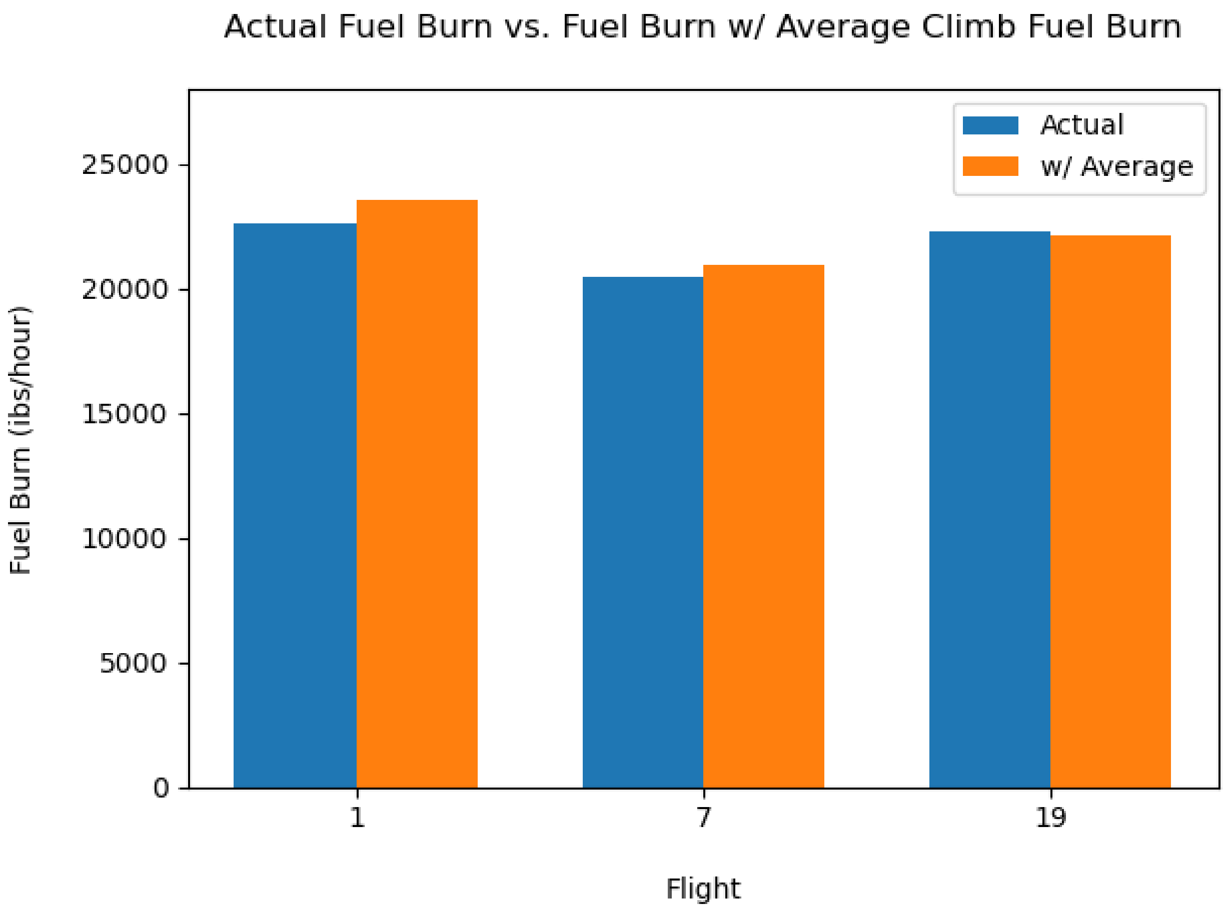
There were three flights that departed from DEN, Flight 1, 19, and 34, and Flight 7 departed from LXA.

These four flights were compared to the average climb fuel burn of 32,313 ibs/hour. **Note: The dropped flights were included in this calculation as their climb fuel burns were accurately recorded**



Flight 1, the chart’s lowest climb fuel burn, was roughly 3,000 ibs/hour below average.
Flight 19, the chart’s highest climb fuel burn, was roughly 1,000 ibs/hour above average.

To better understand the impact this variance had on the total fuel burn,
a new total fuel burn was calculated for the flights using the average climb fuel burn of all flights in the study:
Note: Flight 34 was excluded as it’s cruise and descent fuel burn were not recorded



For Flight 1, the Actual Total Fuel Burn was **22,592** ibs/hour.
The Total Fuel Burn w/ Average was **23,533** ibs/hour.
The Total Fuel Burn w/ Average was **4.17%** **greater** than the Actual Total Fuel Burn.

For Flight 7, the Actual Total Fuel Burn was **20400** ibs/hour.
The Total Fuel Burn w/ Average was **20949** ibs/hour.
The Total Fuel Burn w/ Average was **2.69%** **greater** than the Actual Total Fuel Burn.

For Flight 19, The Actual Total Fuel Burn was **22255** ibs/hour.
The Total Fuel Burn w/ Average was **22100** ibs/hour.
The Total Fuel Burn w/ Average was **0.69% less** than the Actual Total Fuel Burn

As shown, there is a small decrease in total fuel burn for Flights 1 and 7. As for Flight 19, the explanation for the slight decrease in fuel burn w/ the average may be due to decreased airspeed from the higher elevations. Engine performance was reduced starting with the takeoff roll, therefore the plane could not climb as aggressively as typical because of the lower airspeed.

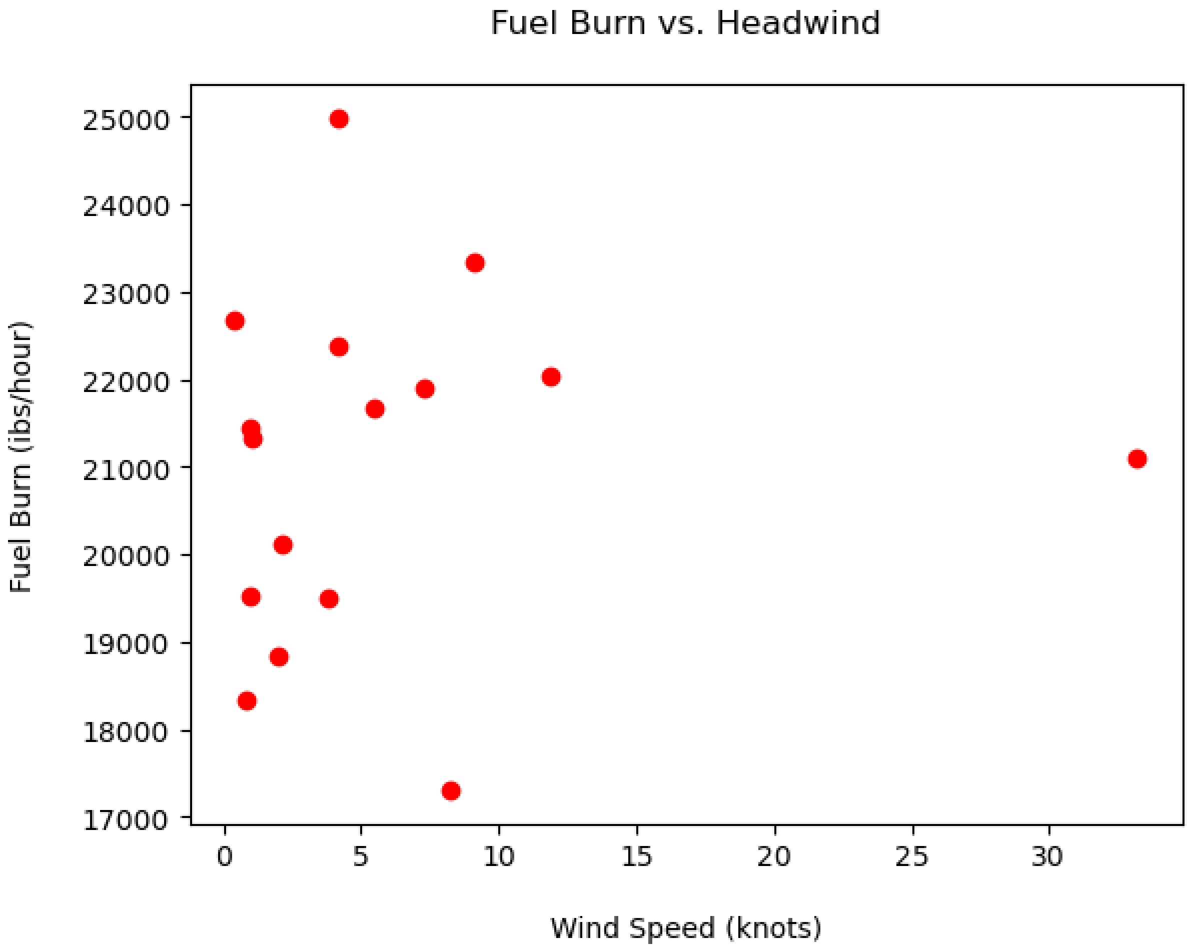
Overall, this comparison was for departure airports with the highest elevations. Data showed a decreased fuel burn up to approximately four percent when departing from higher elevations. Considering most other airports will have a lower elevation, it is reasonable to conclude that elevation has minimal, if any effect on overall fuel burn.

However, more tests should be done from high elevation departures to arrive at a set in stone conclusion.

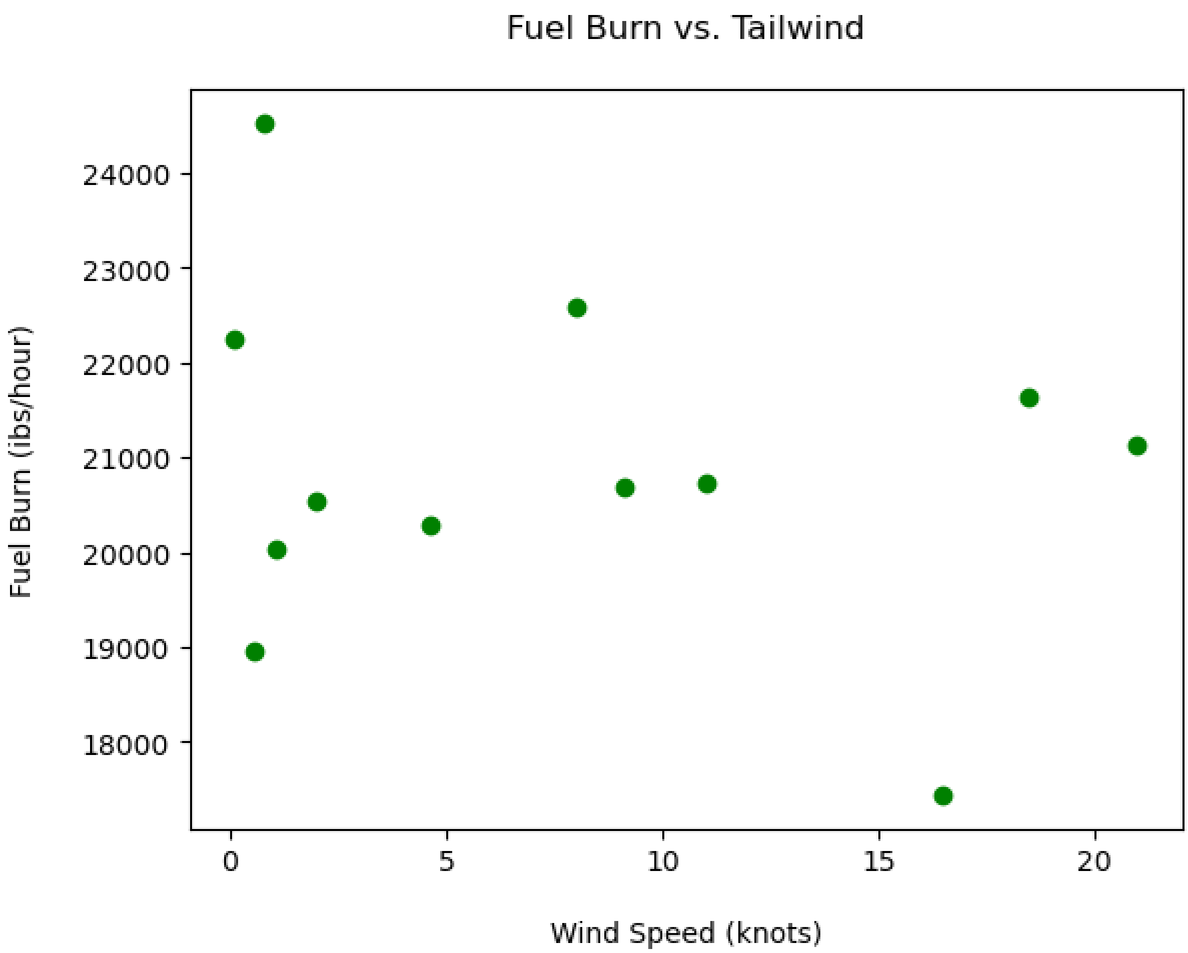
Wind:

Wind was hypothesized to affect fuel burn, as it was inferred a headwind will “work against” the plane and a tailwind will “help it”.

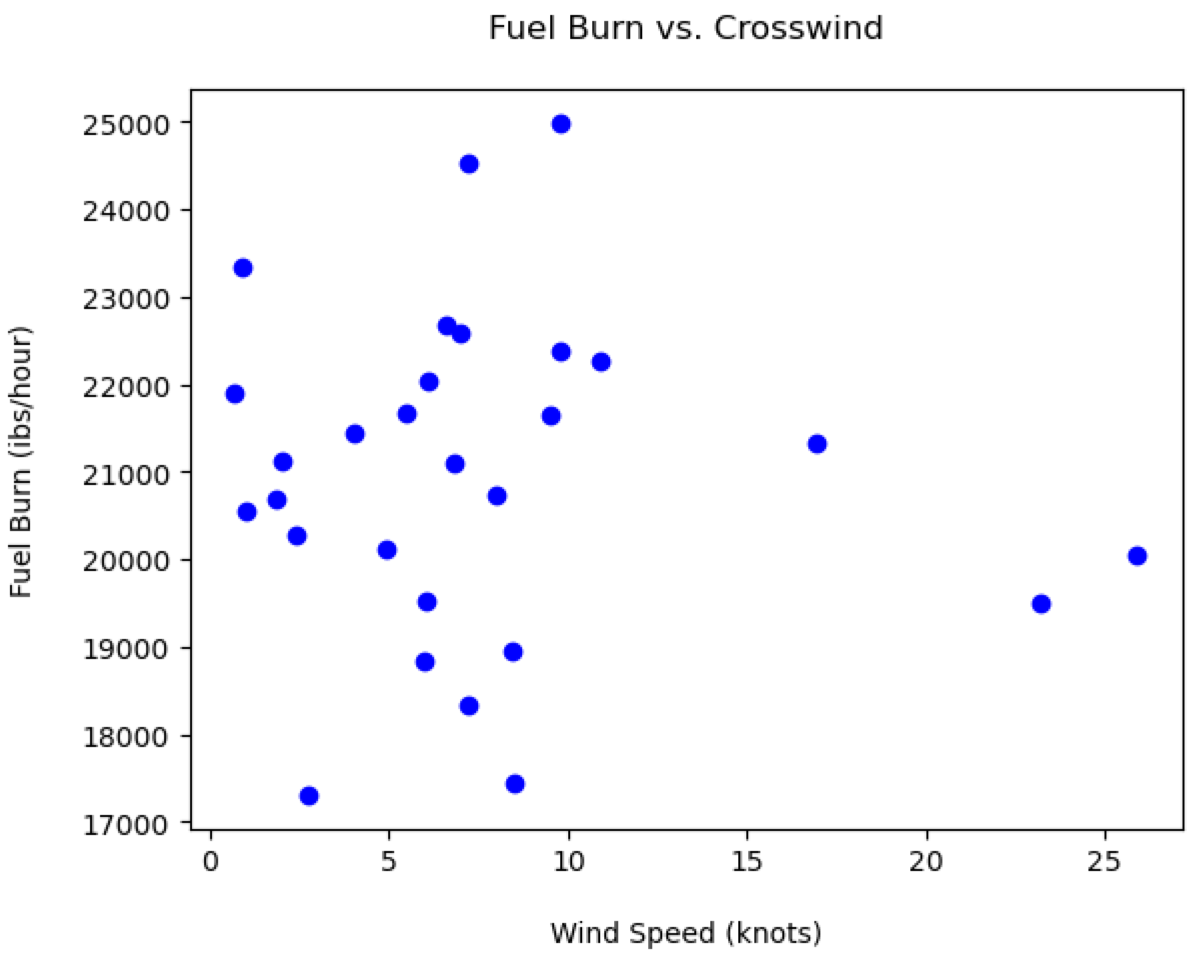
The fuel burn from all flights compared to constant headwind, tailwind, and crosswind speed over 0 knots:



Correlation: 0.094



Correlation: -0.212



Correlation: -0.071

As shown, correlation between the three wind components and fuel burn is virtually nonexistent.

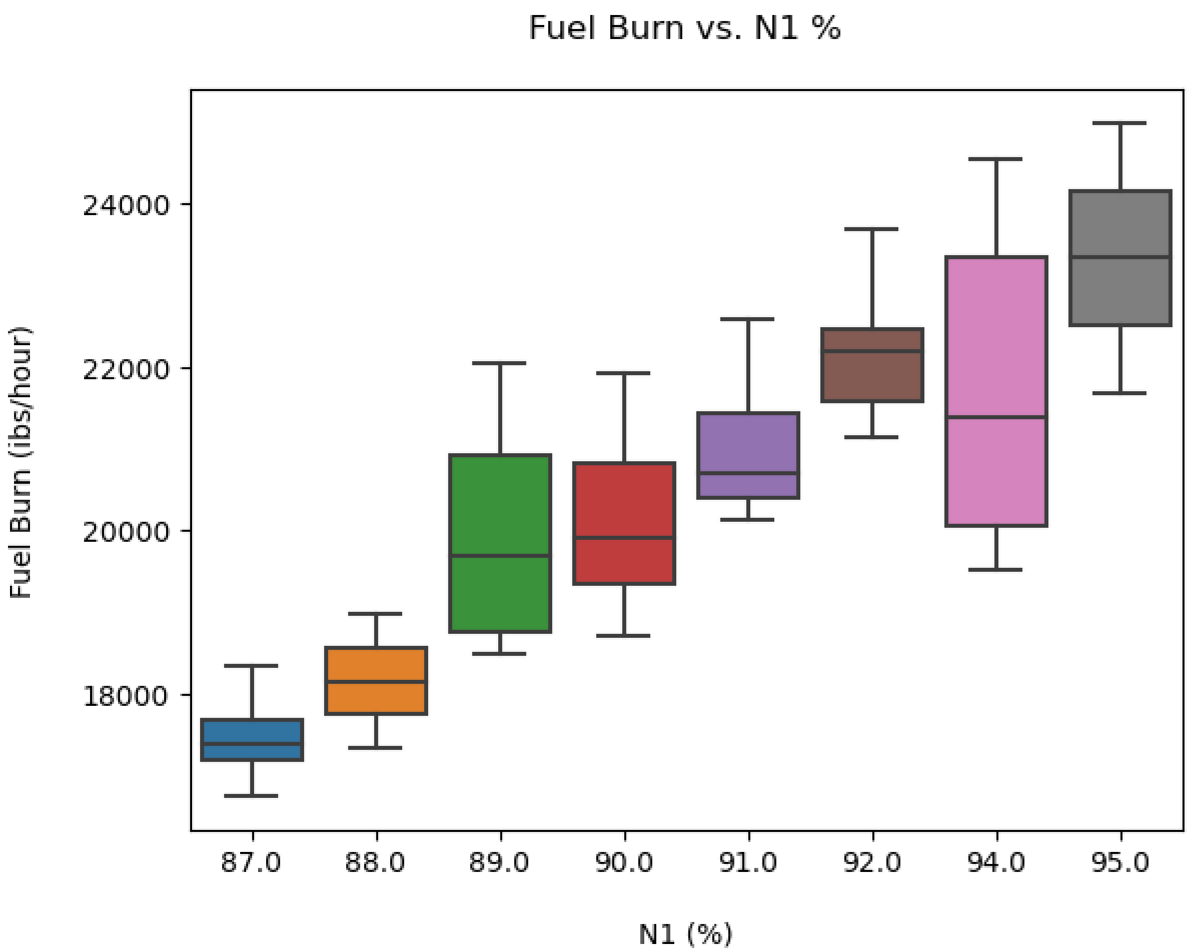
Of course, a constant wind speed only affects a plane in its relation to the ground. For example, a strong headwind will lengthen the time a plane needs to reach the arrival airport, hence more fuel is needed. However, the fuel burn will remain the same as if headwind was nonexistent.

N1:

If, for example, the pilot increased throttle to make up time flying through the headwind, it was hypothesized that fuel burn would increase. Or, oppositely, if the pilot decreased throttle in a tailwind because the plane would reach its destination faster, fuel burn may decrease.

This variance in fuel burn would of course be because of pilot input, the change in throttle. The wind would not be directly causing the fuel burn increase or decrease.

N1 percentage for the flights was compared to fuel burn:



Correlation: 0.750

As shown, a correlation of .75 indicates a strong correlation between Fuel Burn and N1 percentage.

The most efficient speed for the Boeing 777 is Mach .84. To maintain this speed, varying N1 percentages may be applied throughout the flight based on weight.

Airlines are responsible for balancing the flight time and fuel burn through thrust. A lower N1 may save fuel, but also potentially prolong the flight. A higher N1 may save time, but potentially burn more fuel.

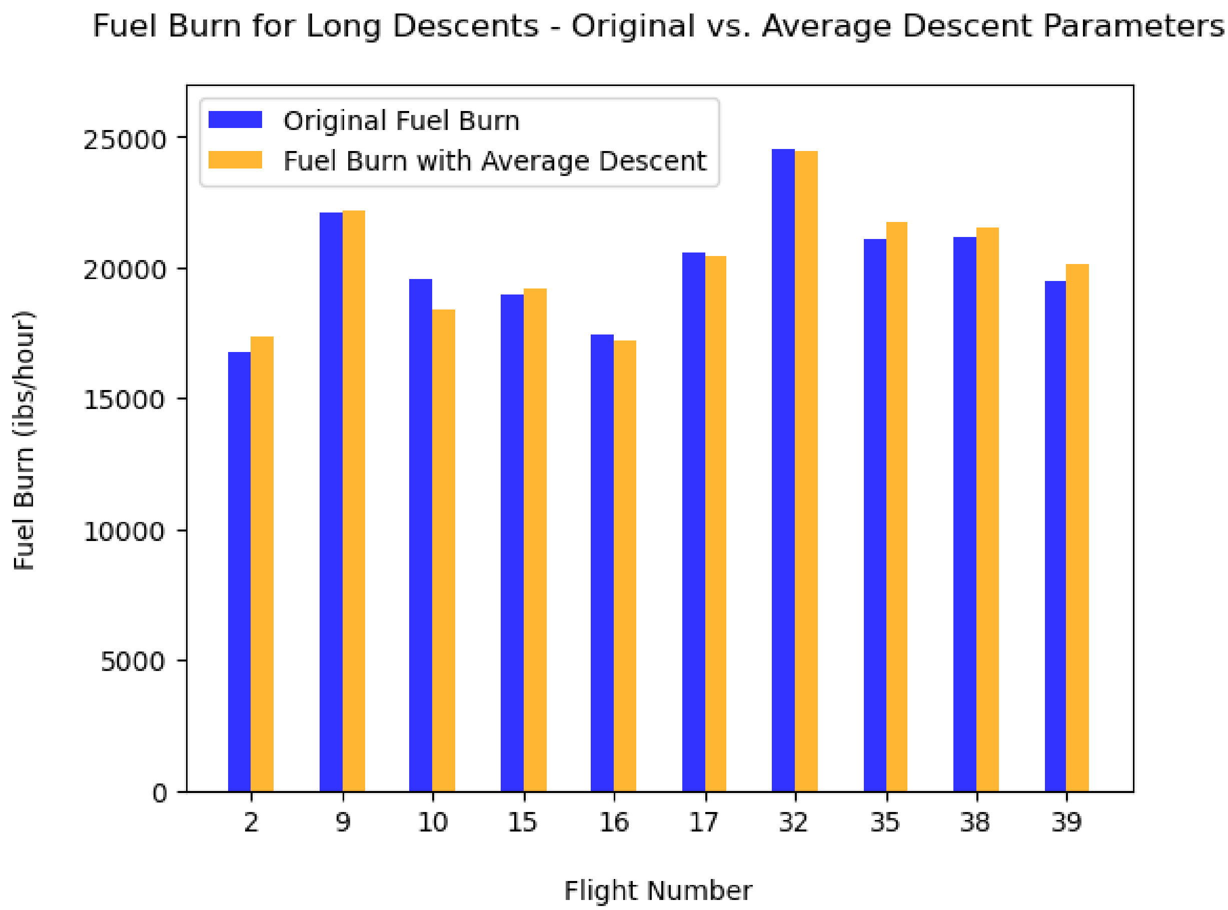
Go Arounds / Long Descents:

True for every recorded flight, the descent had the lowest fuel burn. Knowing this, long descent times were hypothesized to lower the overall fuel burn.

The average descent time across all flights was 24 minutes.
The average descent fuel burn across all flights was 8422.53 ibs/hour.

Flights 2, 9, 10, 15, 16, 17, 32, 35, 38, 39 had higher than average descent times due to go-arounds, premature descent, or alternative routing.

To assess the impact long descents had on overall fuel burns, a new fuel burn for each of these flights was calculated using the average descent time and average descent fuel burn. The results were as follows:



Flight 2 had an Actual Fuel Burn of: **16745** ibs/hour
The Fuel Burn w/ Average Descent Parameters was: **17319** ibs/hour
The Actual Fuel Burn was **3.43 percent less** than the Fuel Burn w/ Average Descent Parameters

Flight 9 had an Actual Fuel Burn of: **22133** ibs/hour
The Fuel Burn w/ Average Descent Parameters was: **22205** ibs/hour
The Actual Fuel Burn was **0.33 percent less** than the Fuel Burn w/ Average Descent Parameters

Flight 10 had an Actual Fuel Burn of: **19521** ibs/hour
The Fuel Burn w/ Average Descent Parameters was: **18388** ibs/hour
The Actual Fuel Burn was **5.80 percent greater** than than the Fuel Burn w/ Average Descent Parameters

Flight 15 had an Actual Fuel Burn of: **18962** ibs/hour
The Fuel Burn w/ Average Descent Parameters was: **19180** ibs/hour

The Actual Fuel Burn was **1.15 percent less** than the Fuel Burn w/ Average Descent Parameters

Flight 16 had an Actual Fuel Burn of: **17445** ibs/hour
The Fuel Burn w/ Average Descent Parameters was: **17211** ibs/hour
The Actual Fuel Burn was **1.34 percent greater** than than the Fuel Burn w/ Average Descent Parameters

Flight 17 had an Actual Fuel Burn of: **20542** ibs/hour
The Fuel Burn w/ Average Descent Parameters was: **20425** ibs/hour
The Actual Fuel Burn was **0.57 percent greater** than than the Fuel Burn w/ Average Descent Parameters

Flight 32 had an Actual Fuel Burn of: **24532** ibs/hour
The Fuel Burn w/ Average Descent Parameters was: **24438** ibs/hour
The Actual Fuel Burn was **0.38 percent greater** than than the Fuel Burn w/ Average Descent Parameters

Flight 35 had an Actual Fuel Burn of: **21095** ibs/hour
The Fuel Burn w/ Average Descent Parameters was: **21762** ibs/hour
The Actual Fuel Burn was **3.16 percent less** than the Fuel Burn w/ Average Descent Parameters

Flight 38 had an Actual Fuel Burn of: **21130** ibs/hour
The Fuel Burn w/ Average Descent Parameters was: **21501** ibs/hour
The Actual Fuel Burn was **1.76 percent less** than the Fuel Burn w/ Average Descent Parameters

Flight 39 had an Actual Fuel Burn of: **19469** ibs/hour
The Fuel Burn w/ Average Descent Parameters was: **20145** ibs/hour
The Actual Fuel Burn was **3.47 percent less** than the Fuel Burn w/ Average Descent Parameters

Six of the ten flights had greater Fuel Burns w/ Average Descent Parameters than their Original Fuel Burns, however four flights saw a reduced fuel burn with the average descent parameters. Explanations are as follows:

Flight 10 :
Descent Time: 38 minutes

Pilot descended about an hour earlier than planned and had to cruise at low altitude for roughly 30 minutes. The descent fuel burn in the denser air was 14,210 ibs/hour, which is 5,787 ibs/hour greater than the average descent fuel burn.

Flight 16:
Descent Time: 34 minutes

A go-around occurred. Descent fuel burn was 11823 ibs/hour, 3401 ibs/hour greater than average descent fuel burn.

Flight 17:
Descent Time: 29 minutes

A go-around occurred. Descent fuel burn was 20425 ibs/hour, 2543 ibs/hour greater than average descent fuel burn.

Flight 32:
Descent Time: 29 minutes

A go-around occurred. Descent Fuel Burn was 24438 ibs/hour, 3163 ibs/hour greater than average descent fuel burn.

Flights 2, 16, 17, and 32 were the only flights in the study where a go-around occurred.

Flight 2's Actual Fuel Burn was less than its Fuel Burn w/ Average Descent Parameter likely due to the low N1% throughout the flight at 87%, which was uncommon for the study. Flight 2 can be disregarded as an outlier for this specific Descent Fuel Burn study.

This data shows that longer descent times **may** increase fuel burn, depending on the specific circumstances during descent. When a low altitude (approximately 10,000') is maintained for an extended period of time, particularly in a long go-around, fuel burn is likely to increase as the plane is not operating at an optimal altitude.

The circumstances during long descents will also affect the extent of the change in fuel burn, where fuel burn can vary from approximately 0.5 to 5%.

In conclusion, a long descent will have a change in Total Fuel Burn, however the extent of either an increase or decrease in Total Fuel Burn will depend on the specific vertical profile of the plane. The longer an altitude is maintained at a suboptimal low altitude, the more Total Fuel Burn will increase.

While it is inferred that maintaining lower altitudes during go-arounds may result in a more significant increase in Total Fuel Burn, this study was unable to confirm this hypothesis due to the lack of recorded altitudes during the go-around maneuvers.

The impact of rain on fuel burn could not be accurately measured due to the lack of flights in rain.

Conclusion

In conclusion, this case study has provided valuable insights into the impact of take-off weight (TOW) on fuel costs for airlines. The findings clearly demonstrate a strong positive correlation between TOW and fuel burn, indicating that as the TOW increases, so does the amount of fuel required to complete the flight. The analysis reveals that even small increases in TOW can lead to significant fuel burn and cost implications over the course of a year, considering the high volume of flights airlines operate.

The study also highlights the cost implications of additional weight, whether it comes from passengers, cargo, or extra fuel. The increase in fuel costs per hour for every additional pound of TOW provides airlines with a clearer understanding of the financial impact of carrying extra weight. Furthermore, the example of the New York City to London route emphasizes how these additional costs can add up, and the importance of cost optimization in an industry with narrow profit margins.

Although the study focuses on current planes, it acknowledges the ongoing efforts by aircraft manufacturers to develop more fuel-efficient aircraft using lighter materials. As fuel costs and environmental concerns continue to drive the industry, future planes are expected to become even more efficient, helping airlines reduce fuel consumption and costs.

It is important to note that the study has some limitations, such as the exclusion of certain flights due to data collection issues and the potential variability introduced by factors like pilot technique and field elevation. However, despite these limitations, the study provides valuable insights and recommendations for airlines looking to optimize their fuel costs and improve profitability.

In conclusion, understanding the impact of TOW on fuel costs is crucial for airlines seeking to reduce fuel consumption, cut costs, and maintain a competitive edge in the industry. By implementing strategies to optimize TOW and reduce unnecessary weight, airlines can significantly reduce their fuel costs and enhance their overall profitability.

Recommendations

Based on the findings of this study, the following recommendations are provided for airlines looking to optimize their fuel costs and improve profitability:

1. Optimize Aircraft Load: Airlines should strive to optimize their aircraft load by carefully managing passenger and cargo weights. By accurately estimating passenger weights and reducing excess cargo, airlines can minimize the additional fuel burn caused by increased take-off weight. Implementing weight reduction strategies such as using lighter interior parts and reducing on-board supplies can also contribute to fuel savings.

2. Efficient Flight Planning: Airlines should prioritize efficient flight planning to minimize fuel consumption. This includes selecting optimal cruise altitudes and routes based on the aircraft's load and prevailing weather conditions. Flight dispatchers and pilots should collaborate to identify the most fuel-efficient flight paths, taking into account factors such as wind patterns and air traffic congestion.

3. Continuous Pilot Training: Pilots play a crucial role in fuel efficiency. Airlines should invest in continuous pilot training programs that focus on optimizing fuel consumption through proper flying techniques and utilizing autopilot features effectively. Emphasizing the importance of maintaining stable climb rates, cruise speeds, and descent profiles can significantly impact fuel burn.

4. Weather Monitoring and Analysis: Weather conditions have a direct impact on fuel burn. Airlines should invest in advanced weather monitoring systems and tools to obtain accurate and real-time weather data. By analyzing weather patterns and their influence on fuel burn, airlines can make informed decisions regarding flight planning, route selection, and fuel load optimization.

5. Fuel Conservation Initiatives: Airlines should explore and implement fuel conservation initiatives to further reduce fuel costs. This includes adopting advanced technologies such as winglets, more fuel-efficient engines, and lighter aircraft materials. Regular maintenance and performance monitoring of aircraft engines can also help identify and rectify any inefficiencies that could contribute to increased fuel consumption.

6. Collaborate with Fuel Suppliers: Airlines should establish strong partnerships with fuel suppliers to negotiate favorable fuel prices and explore cost-saving opportunities.

Regularly monitoring fuel prices, evaluating different suppliers, and leveraging bulk purchasing options can help reduce fuel costs significantly.

7. Continuous Data Analysis: Airlines should establish a data analysis framework to continuously monitor and analyze fuel consumption patterns. By collecting and analyzing data on TOW, fuel burn, and associated costs, airlines can identify trends, anomalies, and potential areas for improvement. This data-driven approach enables informed decision-making and the implementation of targeted fuel optimization strategies.

8. Regulatory Compliance and Incentives: Airlines should stay abreast of regulatory requirements and incentives related to fuel efficiency and emissions reduction. Compliance with regulations and participation in incentive programs can not only contribute to environmental sustainability but also result in financial benefits through lower taxes, fees, or credits.

9. Collaboration and Knowledge Sharing: The aviation industry as a whole should encourage collaboration and knowledge sharing among airlines, manufacturers, and industry stakeholders. Sharing best practices, research findings, and innovative fuel-saving techniques can lead to collective efforts in reducing fuel consumption and optimizing costs across the industry.

10. Monitor Technological Advances: Airlines should stay informed about the latest technological advancements and research in the aviation industry. Keeping track of emerging technologies, such as alternative fuels, electric propulsion systems, and advanced air traffic management systems, can provide valuable insights for future investment decisions and long-term fuel cost reduction strategies.

By implementing these recommendations, airlines can effectively optimize their fuel consumption, reduce costs, and enhance overall profitability while contributing to environmental sustainability in the aviation sector. Continuous monitoring, analysis, and adaptation to changing industry dynamics will be key to achieving long-term success in fuel cost optimization.

Flight number	Distance nautical miles	Payload ibs	Starting Fuel ibs	TOW ibs	Climb Time minutes	Climb Fuel Burn ibs/hour	Cruise Time minutes	Cruise Fuel Burn ibs/hour
1	549	147,000	39,500	487,000	20	28,500	41	26,487
2	590	36,000	42,500	377,500	22	25,909	45	17,866
3	601	91,109	27,813	417,922	23	28,695	45	20,000
4	582	929	53,009	352,000	14	30,857	50	20,279
5	446	41,835	44,605	385,441	21	27,714	27	17,555
6	679	191,200	67,100	557,300	21	35,428	55	24,872
7	600	83,671	55,626	438,297	15	29,199	52	22,500
8	577	52,990	51,976	403,944	25	28,319	42	18,714
9	593	141,312	60,349	500,661	18	33,000	46	25,173
10	430	40,906	44,081	383,987	21	28,571	12	20,499
11	411	87,390	44,605	430,996	19	31,894	23	22,173
12	1,319	111,562	102,330	512,893	22	32,181	136	22,323
13	446	31,609	47,229	377,839	22	27,818	30	16,600
14	861	91,109	73,993	464,102	20	31,199	74	22,702
15	697	61,359	54,576	414,935	21	29,428	55	19,963
16	782	43,695	45,655	388,350	23	28,173	62	16,548
17	797	99,476	60,873	459,350	19	30,315	70	21,857
18	558	31,609	48,279	378,888	32	25,500	31	17,806
19	594	123,648	56,675	479,324	15	33,199	49	24,734
20	653	40,906	55,101	395,007	24	28,750	49	18,367
21	1,041	191,515	82,914	573,429	16	35,250	101	27,326
22	523	54,851	45,655	399,506	16	34,500	37	21,567
23	612	64,148	54,051	417,200	15	33,599	51	24,117
24	618	43,695	48,804	391,499	18	33,000	52	20,653
25	285	53,921	38,308	391,230	18	31,000	10	21,599
26	290	53,921	39,358	392,279	15	33,999	16	20,625
27	973	147,820	76,617	523,437	14	39,000	VOID	VOID
28	405	147,820	47,229	494,050	16	34,875	26	25,846
29	1,057	92,039	75,042	466,081	14	36,428	109	24,715
30	595	147,820	59,824	506,644	21	32,571	VOID	VOID
31	646	153,398	62,972	515,371	16	34,874	56	24,964
32	807	223,125	72,943	595,068	20	36,000	75	26,480
33	633	106,914	59,824	465,738	14	36,857	54	22,555
34	744	188,726	78,716	566,442	15	36,399	VOID	VOID
35	589	134,804	67,171	500,975	13	36,000	55	24,218
36	611	99,476	58,774	457,251	15	33,599	52	23,769
37	521	143,171	57,200	499,372	18	33,667	40	24,150
38	549	131,085	58,249	488,335	18	34,667	38	23,526
39	667	71,585	58,774	429,360	17	31,764	56	21,642
40	555	103,195	56,150	458,346	16	35,625	44	24,681
41	617	125,507	59,824	484,332	17	32,823	52	24,115

Flight	Descent Time	Descent Fuel Burn	Flight Time	Fuel Cons.	Fuel Burn	Headwind	Tailwind	Crosswind	N1	Fuel Remaining
number	minutes	ibs/hour	min	ibs	ibs/hour	knots	knots	knots	%	at Arrival Gate
1	20	8,700	81	30,500	22,592	0.0	8.0	7.0	91	8.0
2	43	10,834	110	30,700	16,745	0.0	0.0	0.0	87	10.1
3	18	1,667	82	26,500	18,488	VOID	VOID	VOID	89	0.0
4	22	7,364	82	26,800	18,697	VOID	VOID	VOID	90	25.3
5	23	7,565	71	20,500	17,324	VOID	VOID	VOID	88	23.0
6	22	9,545	98	38,700	23,693	VOID	VOID	VOID	92	27.0
7	18	7,000	85	28,900	20,400	VOID	VOID	VOID	91	25.1
8	23	9,130	90	28,400	18,933	VOID	VOID	VOID	90	22.1
9	26	9,231	90	33,200	22,133	VOID	VOID	VOID	92	26.3
10	38	14,211	71	23,100	19,521	0.98	0.0	6.02	90	20.2
11	23	8,348	65	21,800	20,123	2.1	0.0	4.9	91	21.9
12	23	9,652	181	66,100	21,911	7.3	0.0	0.696	90	34.6
13	18	5,667	70	20,200	17,314	8.25	0.0	2.75	87	25.7
14	19	9,789	113	41,500	22,035	11.88	0.0	6.12	89	31.0
15	30	9,800	106	33,500	18,962	0.0	0.54	8.46	88	19.2
16	34	11,824	119	34,600	17,445	0.0	16.5	8.5	87	9.4
17	29	10,966	118	40,400	20,542	0.0	1.98	1.02	89	18.7
18	24	9,500	87	26,600	18,345	0.8	0.0	7.2	87	19.8
19	22	9,273	86	31,900	22,255	0.0	0.11	10.89	92	23.4
20	21	8,571	94	29,500	18,830	2.0	0.0	6.0	89	23.8
21	22	6,818	139	57,900	24,992	4.2	0.0	9.8	95	23.6
22	23	8,348	76	25,700	20,289	0.0	4.62	2.38	90	18.3
23	24	9,000	90	32,500	21,667	5.5	0.0	5.5	95	19.9
24	19	9,158	89	30,700	20,696	0.0	9.13	1.87	91	16.8
25	19	8,842	47	15,700	20,042	0.0	1.08	25.9	94	21.8
26	17	5,647	48	15,600	19,500	3.78	0.0	23.22	94	23.2
27	VOID	VOID	0	VOID	VOID	0	4.62	2.38	94	VOID
28	22	6,273	64	22,800	21,375	0.0	0.0	0.0	94	23.9
29	21	7,429	144	56,000	23,333	9.13	0.0	0.87	94	17.4
30	VOID	VOID	0	VOID	VOID	0	7.5	2.5	87	VOID
31	24	8,000	96	35,800	22,375	4.2	0.0	9.8	92	25.5
32	29	11,586	124	50,700	24,532	0.0	0.8	7.2	94	20.5
33	22	6,000	90	31,100	20,733	0.0	11.02	7.98	90	27.7
34	VOID	VOID	0	VOID	VOID	24	0	8	91	VOID
35	27	7,555	95	33,400	21,095	33.2	0.0	6.8	90	31.8
36	22	7,636	89	31,800	21,438	0.95	0.0	4.05	91	25.6
37	23	6,783	81	28,800	21,333	1.08	0.0	16.92	92	26.5
38	36	11,833	92	32,400	21,130	0.0	20.999	2.001	92	23.9
39	25	6,240	98	31,800	19,469	0.0	0.0	0.0	90	25.5
40	21	8,571	81	30,600	22,667	0.42	0.0	6.58	92	24.5
41	20	5,700	89	32,100	21,640	0.0	18.48	9.52	92	26.5