A Statistical Analysis of the Potential Impact of Boeing 737 MAX Crashes on Passenger Behavior

By

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ABSTRACT

There were two fatal air crashes in 2018 and 2019, Lion Air Flight 610 and Ethiopian Airlines Flight 302; aircraft type of both crashes was Boeing 737 MAX 8. In the aftermath of the two crashes, the Boeing 737 MAX 8 was grounded globally. According to the latest announcement of the Federal Aviation Administration (FAA), the MAX will be grounded until the summer of 2020.

After the grounding, the MAX will return to the fleets of airlines in North America, such as American Airlines and Air Canada. However, will travelers accept this aircraft type as before? Or, to what extent travelers will avoid flying the MAX? The purpose of this thesis is to use statistical methods to quantify travelers' avoidance of MAX. Based on the booking data of American Airlines (AA) and Air Canada (AC), I use three metrics to measure travelers' attitudes, including bookings of the targeted flights, total daily bookings, and the proportions of bookings.

The findings of the current study on two routes of AA and AC didn't reveal any statistically significant evidence of MAX avoidance on any of three key metrics. Accordingly, I concluded that the specific customer segment in this thesis didn't show a clear avoidance of MAX.

Thesis Supervisor: Arnold I. Barnett

Title: George Eastman Professor of Management Science

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1. Introduction

Boeing 737 MAX 8 (737-8) is a fourth-generation Boeing 737. Boeing's first 737-8 left the factory in Renton, Washington, U.S., December 8, 2015. This model was highly anticipated by Boeing, and it was believed to have a leading market position for the next ten years. However, the occurrence of two tragedies caused the aircraft to be grounded until now. On the morning of October 29, 2018, a Lion Air Indonesia Boeing 737-8 aircraft flying from Jakarta to Bangka Penang crashed near the Karachi area shortly after takeoff, claiming 189 lives. The crash was the first accident on a Boeing 737-MAX 8. On March 10, 2019, an Ethiopian Airlines Boeing 737-MAX 8 passenger plane disappeared from the air traffic control radar about 6 minutes after takeoff. The aircraft was subsequently confirmed to have crashed, causing the death of 149 passengers and eight crew members. After two accidents, dozens of countries, including China, Indonesia, France, etc. quickly grounded this model, and the US FAA also issued a ban on 737-8 on March 10, 2019. As of March 18, 2019, all 737-8s in the United States were grounded, disrupting 8,600 flights per week by 59 airlines. The 737 MAX has been grounded since that time, and it is not known when it can resume flying.[1]

This is not the first time the FAA has grounded an aircraft. In 1979, the McDonnell Douglas DC-10 was grounded because of a Chicago Crash, but the aircraft was allowed to fly only one month after that crash. But the current ban on the Boeing 737-8 is the most influential and longest-lasting in the history of aviation. For airlines, the economic loss of this grounding is enormous, consisting of two aspects: the loss during the grounding period and the loss after the grounding period. During the grounding period, the flights that were initially operated by Boeing 737 MAX 8 were either canceled or replaced by other models.

This ban costs a loss both in revenue and customers' satisfaction. Moreover, losses do not end with the grounding period: customers may have a negative attitude towards this model and could continue to avoid the flights operated by Boeing 737-MAX 8 after it returns. This thesis aims to consider what might happen, by probing customers' attitude and forecasting customers' behavior: to what extent customers will avoid taking the MAX in the long term?

Research on consumers' actual response to the incident could help major airlines and Boeing make managerial decisions. For the airlines, such as American Airlines, Air Canada and WestJet, they need to design marketing strategies to drive customers back to Boeing 737 MAX 8. Airlines need the forecast of customers' behavior to determine to what extent they should implement promotions or other types of campaigns. Either excessive promotion or insufficient promotion could be financially harmful to the airlines, so they need to use appropriate means to try to get the MAX 8 passenger volume to its normal level. For Boeing, an accurate forecast will help them better negotiate with airlines about existing 737-8 orders. Also, the statistical methods to be used in this paper, such as paired comparisons, can be used in the analysis for customers' responses to other "Black Swan" events to assess the real impacts of the events. I hope this paper may help people better and more accurately understand trends in customer behaviors after certain incidents.

We begin our analysis from Section 2, where I summarized some current news and surveys and derived from them how customers claimed they would behave when the MAX returns. I also included information about public opinion towards this incident in this section. In Section 3, I introduced the research methods of this paper as well as the data resources. Then in Section

4 and Section 5, I collected some booking data from some major airlines that operate Boeing 737-8, including ticket prices for future MAX flights and the number of seats sold. Based on this data, I conducted analytics on how customers are behaving now in connection with MAX bookings, currently. Lastly, in Section 6, I made a comparison between how customers appear to be behaving and how they claim to behave.

Because the grounding will last until Sept. 2020 if not longer, we cannot directly analyze the actual flight data now. Because of the coronavirus crisis, few passengers are booking trips to fall 2020. However, we can still use other methods to conduct some research about passenger demand for MAX flights. In the next section, we will present the results of some existing surveys and researches. One may doubt the credibility of such surveys, because people may not act the way they contend that they will. Therefore, the third part of this paper will introduce data-driven analytics based on current booking information for future MAX flights with American Airlines, Air Canada, etc., which might provide more reliable evidence about whether passengers will fly the MAX once it is back.

2. What did people say?

After the crashes and the ban of Boeing 737 MAX 8, many scholars and organizations conducted surveys to probe people's attitudes towards MAX. Some of these organizations are investment institutions, and they want to figure out the potential loss to Boeing and airlines and adjust their investment strategies based on survey results. But if those organizations simply evaluate the situation based on survey results of people, they might well overestimate the negative aftermaths.

At the end of 2019, the Bank of America Merrill Lynch surveyed travelers, and the result seemed terrible. Only one-fifth of travelers said that they would take flights operated by MAX immediately after MAX returns into airline fleets. On the other hand, over two-third of travelers claimed that they would like to wait for over six months or would never take flights operated by MAX. Most of the travelers indicated that no matter how high the difference in prices is, they would alter other non-MAX flights if available. [2]

A study, led by Rian Mehta, an assistant professor of aviation at the Florida Institute of Technology, showed similar results.[3] The majority of passengers are not going to take flights operated by MAX after they are available. When asked what would make them assured about the MAX, respondents said they needed to have a wait and see more tests and successful flights. According to the study, most people were taking a wait-and-see attitude to MAX.

In his article "Are Americans Warming Up To A Return Of The Boeing 737 MAX?", Professor Stephen Rice introduced his longitudinal study on travelers' attitudes. As mentioned in the article, within the six months in September 2019, part of people did change their minds:

proportion of survey respondents who were willing to take MAX in the future grew from 32% to 46%. However, 48% of survey respondents showed a fairly negative attitude towards MAX, and this proportion remained stable in six months. This outcome made travelers' avoidance of MAX unique given what happened: after former accidents, travelers’ concerns about aircraft models with accident records diminished quickly after the accident happened. The resilience of travelers’ attitudes is highly associated with what travelers understood to have caused the crashes. In some cases, people thought the crashes were due to pilots’ one-off maloperations, so people would come to trust the aircraft type again soon after the crashes. This isn’t the case for MAX crashes: because MAX 8 crashed twice within six months, many people believed the crashes were due to failure in aircraft designs and thus would not trust MAX easily after MAX resumes operation.

Investors also showed deep concerns regarding passengers’ acceptance of MAX. A Bank of America research report surveyed over 2000 people and concluded that MAX still had a long way to go to get passengers’ trust.[4] Although this result consisted of plenty of bad news, there was also some optimistic information inside: about 50 percent of people didn’t even know what the MAX is, or they had no idea that MAX was grounded. This information is crucial, because the existence of people who are unaware of MAX can dilute the overall avoidance of MAX. So, at least we have some facts that support that the situation may not be that bad. On the other hand, those who knew nothing about the MAX might be people who fly very little.

Atmosphere Research Group found that people were terrified of MAX instead of just being merely scared of it. Only 19 percent of business travelers and 14 percent of leisure travelers would be willing to take MAX within six months from it resumes operation, according to their surveys.[5] Half of the respondents claimed that they would pay more to switch to other aircraft models. Atmosphere recommended Boeing Company to release a report with video to show people why MAX crashed twice and what did Boeing do to fix the problems. Only by this Boeing could earn back travelers' trust, said John Dekker of Surf City Travel.

Meanwhile, the airlines that fly the MAX are prepared to fight for it to gain public acceptance. Bloomberg described how Southwest Airlines, the Airline that owns most MAX in the US, planned for the MAX return. A series of measures will be taken, including (1) Revise the flight manuals and new pilot training based on the updates or requirements of the new MAX automation system; (2) Plan a transition of 30 days for all its 9700 pilots to learn about the changes thoroughly; (3) Overhaul its existing 34 MAX aircrafts as well as its 41 in orders with Boeing and install new systems. All the aircraft will undergo an FAA examination for safety; (4) Make several testing flights before carrying passengers. [6]Southwest's executives, FAA officers, and journalists will participate in the testing flights. After all these preparations, Southwest will conduct some campaigns on social media and TV advertisements to mitigate concerns of customers as well as its employees. Similarly, all other Airlines in North America planned to take similar measures to recover customers' trust.

From all these news and surveys, we may conclude that the situation is far from optimistic for MAX. Both airlines and customers are nervous about the MAX's return. On the customer side, fewer than half of the travelers would be willing to take MAX within six months. On the Airlines side, all of Airlines that own MAX are planning to implement a lot of costly measures to get customers back on MAX. A further complication is that it isn't clear how easy it will be for passengers to find out which flights will be operated by the MAX. Some airline websites show aircraft models clearly with the flights, but not all of them do so. For example, on online agency websites, customers need to click on some icons to check the aircraft flights.

In an article, Professor Arnold Barnett listed rationale behind the possible outcome that people may take the MAX flights as usual after MAX's return.[7] Travelers as a group are forgetful of some incidents. For example, passenger's resistance to flying the DC-10 was at undetectable levels a few months after two deadly crashes. He concluded that, once the MAX returns, resistance to reboarding the plane would be weak.

3. Research methods and data resources

3.1. Related researches

There are many mature methodologies to analyze the impacts of a fatal air crash on the attitudes of airline passengers. Scott R. Winter et al. (2016)[8] indicated that, after the Germanwings Flight 9525 flight, travelers' attitudes towards flying went back within 12 weeks to the level that prevailed before the crash. The study involved a repeated survey for a total of 1015 (406 females) participants, who were recruited via an online platform. The surveys were targeted at people's general willingness to fly rather than their attitudes towards a single airline or an aircraft type. The conclusion was generated purely based on survey respondents and without taking into account customers' real behaviors.

A. Barnett and A. Lofaso (1983)[9] used the regression method to analyze the changes in market shares of Airlines that flew the DC-10 jet from before a DC-10 crash that killed 273 people to after that crash. The results of their research showed that there was no statistically significant change between pre-crash market shares and those six to nine months after the crash. However, the method they proposed does not apply to the event discussed in this thesis for two reasons: (1) Their research was made one year after the 1979 crash, so there was actual data about flights taken to analyze, while now only data about future bookings is available for analysis; (2) During the period surrounding the 1979 DC-10 crash, the ticket prices of flights on the same route were fixed, while nowadays, we need to consider the impacts of changes in ticket prices on customer behavior.

A. Barnett et al (1990) studied the market response to the Sioux City DC-10 crash.[10] They tracked booking shares on 14 intercity routes in a 4-month span centered at the crash on July 19th, 1989. Based on the booking shares distribution, they conducted a data-driven research to confirm whether there is an avoidance of DC-10. In this case, they also considered the impacts of ticket prices. Their conclusion was that, immediately after the crash, bookings dropped substantially, but the avoidance dissipated within 6 months.

3.2. Research methods

In this thesis, I use booking levels for flights on different dates before and after the Boeing 737 MAX 8 resumes service as the main metric to analyze customers' behaviors. Different Airlines arranged different dates that MAX would resume operating. For example, American Airlines plans to start operating MAX from Aug 18th, 2020, while Air Canada will start operating MAX on Sept. 8th, 2020. Also, airlines plan different proportions of flights on each route that will be operated by MAX. For American Airlines, on the Miami (MIA) to New York City (LGA) route, 5 out of 12 nonstop flights will be operated by 737-8, while on the Miami (MIA) to Boston (BOS) route, only 1 out of 7 nonstop flights will be operated by 737-8. These airlines don't expect to change the flights schedule before and after MAX return; rather they will simply switch the aircraft type for certain flights from non-MAX aircraft to MAX's. This thesis therefore makes direct "before/after" comparisons between flights in the same route and different dates one preceding the MAX's return and the other following it. For example, I compared the bookings of the American Airlines route from MIA to LGA before and after Aug 18th, 2020, to find out whether there is evidence of significant avoidance of the MAX among customers.

The data I used in my research mainly came from the official website of each Airline. We can get the ticket price and seat map for each flight from the Airline's website. Through the seat map, I can count the number of occupied seats for each flight. Here, I have to acknowledge that number of occupied seats doesn't necessarily match the number of bookings, because some of customers may not select a seat right after they book the flights, and those who buy the cheapest tickets are not allow to choose seats when they book. However, because of the limitation of the data resources, the numbers of occupied seats are the only data I could acquire from open resources. Meanwhile, if the *proportion* of travelers who select their seats after booking tickets is relatively stable, the number of occupied seats could be a reasonable indicator for the number of bookings, as there is a linear relationship between the two numbers. This means that if flight A has a higher number of occupied seats than flight B, then flight A also has a higher number of bookings than flight B has.

Because of the limitations of data resources, I focused my research on major north American Airlines, including American Airlines and Air Canada. But for some other MAX operators in North America, one cannot learn how many seats have been booked. There are two US major Airlines operated many MAX flights before the crashes: American Airlines and Southwest Airlines. Southwest Airlines didn't show any information about which flights would be operated by the MAX, so I couldn't conduct any analysis based on Southwest Airlines data. Also, Southwest follows open seating, so there are no seat maps. The Canadian airline WestJet also flies the MAX, but it too offers no seat maps. Only American Airlines and Air Canada offer seats map of each flight, from which I could get the information of occupied seats, so the analysis targeting at demands was mainly based on flights of American Airlines and Air Canada.

Specifically, I studied the following routes, which offer both MAX flights and flights on other aircrafts.

Table 3.1: the routes I analyzed quantitatively in this thesis

Routes	Airlines	From	To	Date of MAX return	# of daily flights	# of daily MAX flights
1	AA	Miami (MIA)	NYC (LGA)	Aug 18th	12	5
2	AC	Calgary (YYC)	Toronto (YYZ)	Sept 8th	12	2

A problem in working with seat maps is that, sometimes, a seat is made unavailable even though it has not been booked by a passenger. But it is still generally true that, the more seats listed as unavailable, the more bookings have been made. Thus, we can work with bookings data even though they are imperfect. I also conducted data cleaning to mitigate the impacts of the seats taken by default: I subtracted the numbers of seats taken by the numbers of seats that are clearly listed as unavailable even if not booked, such as the seats in the first and last row, and the seats around the emergency exit.

Considering that there are routine fluctuations in customer demands, it is hard to differentiate the actual impacts of an event from random fluctuations in demand. From my research, I saw that various factors might influence the demand for a flight: (1) Demands vary from Monday to Sunday. As shown in the graph, for all American Airlines flights from MIA to LGA in August 2020, average booking per flight is highest on Saturday while lowest on Thursday. (2) Customers have

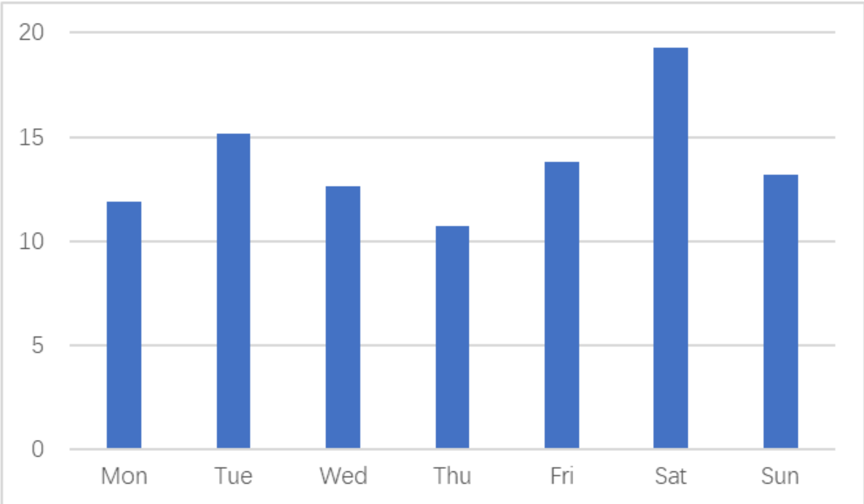

Figure 3-1: The average bookings per flight grouped by weekdays

different preferences towards each time slot within a day. Usually, flights in early morning and afternoon will experience relatively high demand. (3) Also, price is a critical element for customers, especially for leisure travelers. Price variation is thus an effective method for airlines to mitigate demand volatility. (4) Beyond all these preferences, a desire to avoid the MAX may also have significant impacts on customers' selections. In the interest of simplicity, I only studied nonstop flights in this thesis.

Based on the metric selection and some obstacles I discussed above, I designed study methods that can uncover travelers' true attitudes to MAX while removing the influence of noise to the greatest extent. These methods have three layers. Firstly, I use data visualization to make a qualitative judgement of whether there is a clear pattern on the number of occupied seats before and after MAX's return. Secondly, I computed average differences for two groups of flights, namely, between average numbers of occupied seats on flights before and after the return of the MAX. Thirdly, I use a power-test algorithm to examine whether this mean difference is statistically significant, meaning that it cannot easily be attributed to random fluctuations. This layer also involved other methods such as linear regression to explore the changes of customers' selection. If the layer two analysis showed a negative change and layer three showed the change is statistically significant, we have noteworthy evidence that there is an avoidance of MAX.

Table 3.2: layers of analysis in this thesis

Layers of analysis	What to answer?	Property	Methods
1	Is there a clear and visible change in metrics?	Qualitative analysis	Visualizations
2	How great is the change?	Quantitative analysis	Quantitative comparisons
3	Can we say the change is due to MAX?	Quantitative analysis	Power test Regression

Sometimes the changes may not directly emerge in the key metric-number of occupied seats. For example, although numbers of occupied seats didn't change before and after airlines switched a given flight's aircraft type to MAX, the numbers of occupied seats of the flights with unchanged aircraft type might increase. That could happen because, while passenger demand increased in the period after the MAX's return, the MAX did not take part in that increase because people wanted to avoid the MAX. Also, as I mentioned before, the price has a critical influence on bookings. So, if the numbers of occupied seats didn't change before and after the date of MAX return while tickets price are lower after that date, we would also say this proved customers' avoidance of MAX. Thus, viewed alone, the number of MAX seats sold might not tell whether passengers are booking away from the aircraft.

As I will show, I ultimately concluded that there was no significant change in demands for flights after aircraft type of those flights were changed to MAX. I made this conclusion based on my methods and the data I collect in March and April 2020. However, I discuss some limitations of this conclusion in the last section of this thesis.

3.3. Data Analysis

I divided flights of the same routes into two groups, group I and group II. The two groups are on the same routes and the same time slots on different dates, which are before and after the date of MAX return, respectively. After that date, some of the flights in group I will be switched to aircraft type of MAX. I made the following research hypothesis:

Hypothesis I (H1): we will see a demand change between the two groups. Flights that shift to MAX's will see less demand, while flights that do not shift will either see no change or an increase in demand.

4. Qualitative analysis

Firstly, I studied the American Airlines route from Miami (MIA) to New York City (LGA). This is an excellent group of flights for research because it is in relatively high demand, so there will be less randomness and, because in this group, half of the flights will be operated by MAX after the MAX's return, so the comparison has more validity. I collected data of prices and numbers of occupied seats from Aug 4th, 2020 to Aug 31st, 2020, so that I have two weeks' data before and after the date of MAX return, respectively. I collected this data on March 1st, 2020, before the coronavirus crisis reduced demand for all flights.

American Airlines operates 12 flights each day on this route, aircraft types of which are Embraer RJ-175 (E75), Airbus A321 (321), Boeing 737 (738) and Boeing 737MAX 8 (MAX), the daily schedules of two groups are as follow:

Table 4.1: Flight schedule and aircraft type for AA route from MIA to LGA

Group I (before MAX return)			**Group II (after MAX return)**		
Date	**Departure Time**	**Aircraft Type**	**Date**	**Departure Time**	**Aircraft Type**
08/04/2020-08/17/2020	6	E75	08/18/2020-08/31/2020	6	E75
	7	738		7	MAX
	9	738		9	MAX
	11	321		11	321

12	738	12	738
14	738	14	MAX
16	738	16	MAX
17	738	17	738
18	738	18	MAX
19	738	19	738
20	738	20	738
21	738	21	738

All these flights are non-stop so that I could exclude the impacts of flights with stops that last longer. As shown in the schedules, starting on Aug 18th, 2020, the aircraft types of the flights at 7, 9 am and 2, 4, 6 pm, will be switched from Boeing 737 to MAX. I collected the number of occupied seats of each flight and visualized the data to make a qualitative analysis.

4.1. Comparison among numbers of occupied seats

We care about whether bookings will change with the aircraft types, so I first compared the bookings for Aug 17th and Aug 18th. Secondly, to exclude the differences of different days within a week, I also compared the bookings for Aug 18th and Aug 11th, the last Tuesday before MAX return.

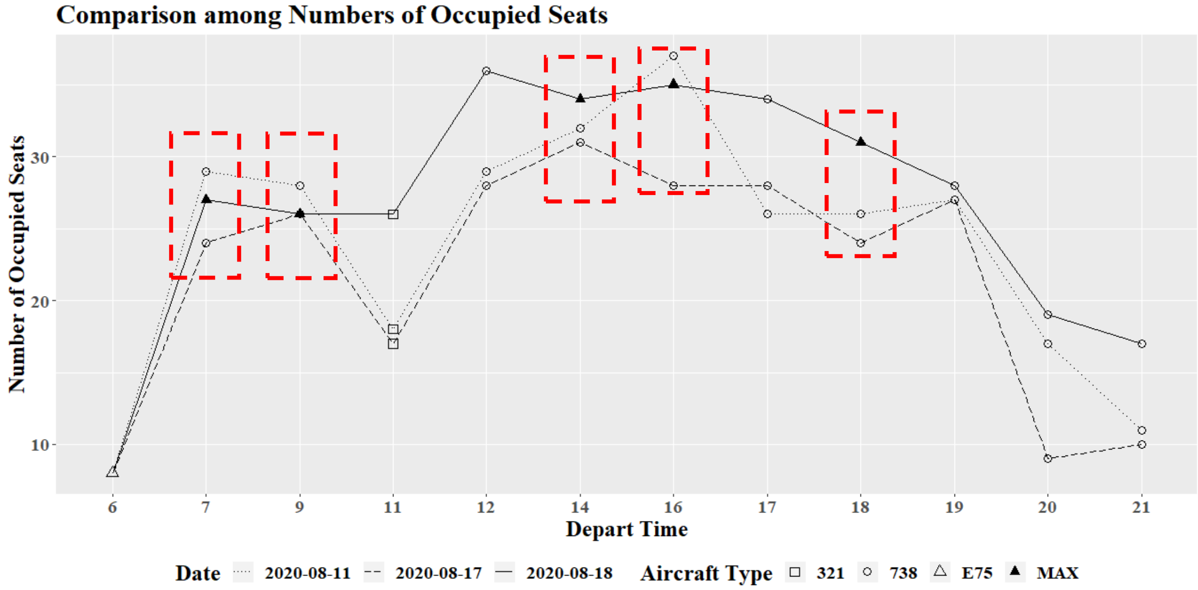

Figure 4-1: Comparison among numbers of occupied seats on specific dates. (AA route)

In this graph, each point represents a flight. The x-axis is the departure time of each flight, and the y-axis is the number of occupied seats of that flight (by the time of data collection). The shapes of points are used to distinguish different aircraft types, and the lines where these points are located represent different dates. We can find that from Aug 18th, American Airlines changed the aircraft type of 5 flights. The graph does not suggest any clear patterns of changes in bookings. For the flight departing at 9, bookings for Aug 18th are slightly lower than those for Aug 11th-one week earlier-and Aug 17th-one day earlier. For the flights departing at 2 and 6 pm, the bookings for Aug 18th were higher. In conclusion, I couldn't get any clear trends from the comparisons among these three dates.

4.2. Comparisons among ticket prices

As I explained in Section 2, although I couldn't see any patterns in changes in bookings, I can still verify my hypothesis if I can find some patterns in changes in ticket prices. If Airlines offer lower prices for a flight but get similar number of bookings, then that could be viewed as evidence of avoidance.

Similarly, I visualized the dataset of ticket prices on Aug 11th, Aug 17th, Aug 18th.

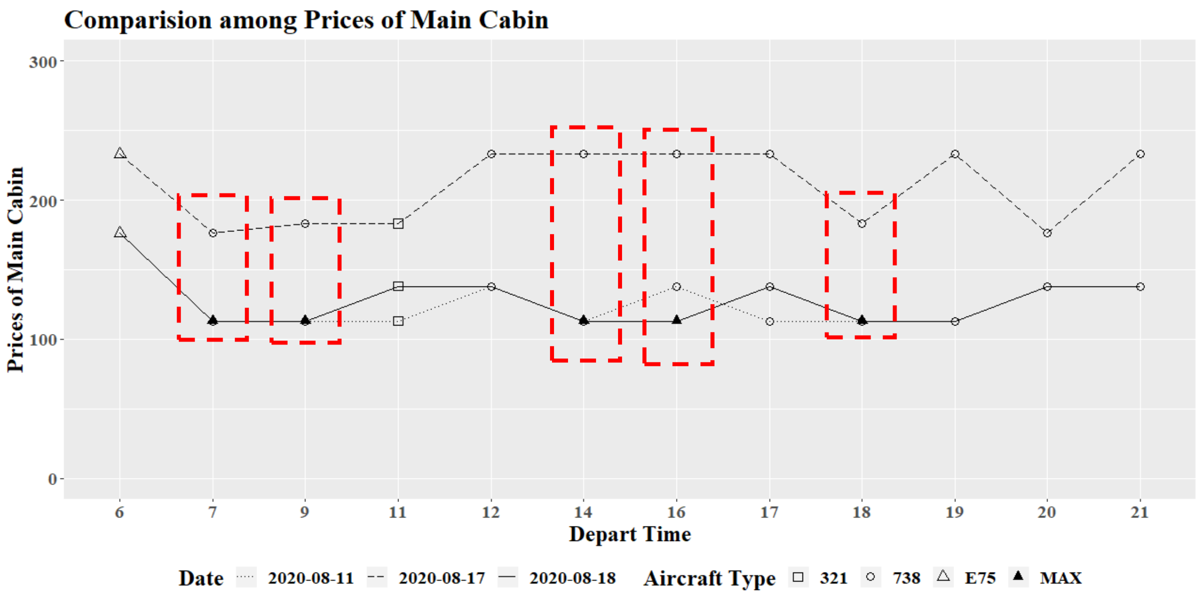

Figure 4-2: Comparison among ticket prices on specific dates. (AA route)

Here, I did find some patterns: ticket prices on Aug 17th are significantly higher than those on Aug 11th and Aug 18th. However, we couldn't conclude that this is a remedy for customers who avoid taking MAX because the price differences are mainly caused by the routine premium on Monday discussed earlier. Between the two Tuesdays, Aug 11th and Aug 18th, there was no significant price difference: except for the flight at 5 pm, all the other four MAX flights are priced the same as four 738 flights.

4.3. Comparisons among Proportions of Bookings on Targeted Flights

After studying each flight individually, I want to get some full pictures of the change in bookings. Suppose that the bookings for individual MAX flights stayed unchanged before and after the MAX return. If overall bookings increased, then staying the same could indicate MAX avoidance. So, I further studied the proportion of bookings of those five flights in the total daily bookings. Definition of "proportions of bookings" means:

$$\text{Proportions of bookings} = \frac{\text{sum of bookings for targeted flights on date N}}{\text{sum of bookings for all flights on date N}}$$

The five targeted flights are at 7, 9 am and 2, 4, 6 pm, which became MAX flights on 8/18/20.

I visualized this proportion among dates from Aug 4th, 2020 to Aug 31st, 2020 as follow:

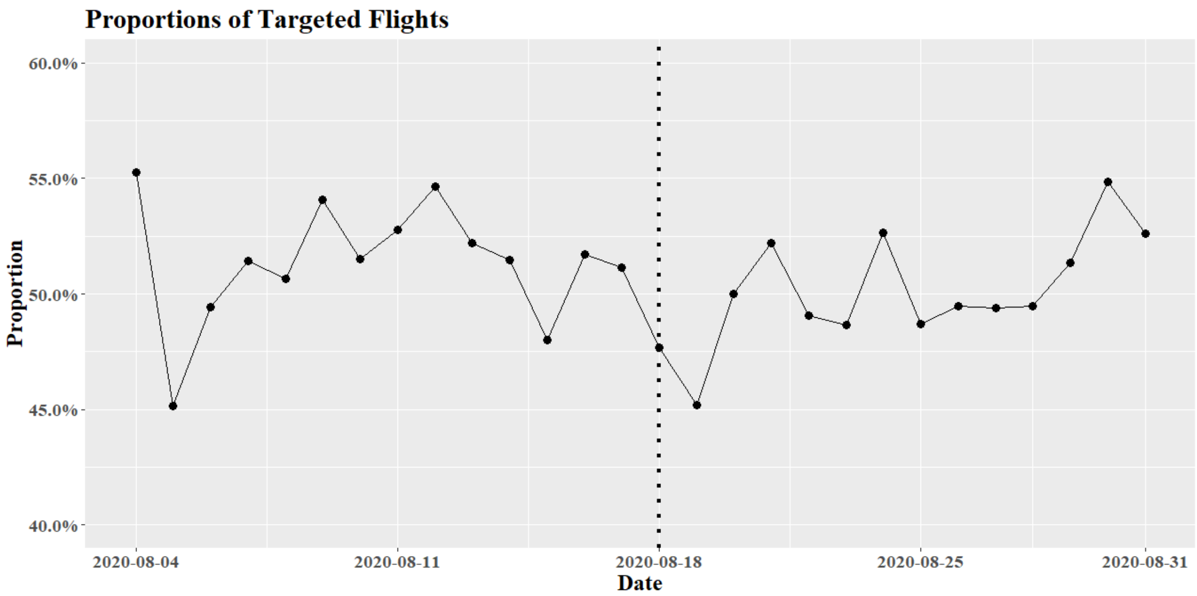

Figure 4-3: Trend in proportions of the targeted flights in specific period. (AA route)

Also, there is no significant difference shown in the graph. The proportions of bookings for those five flights in the total daily bookings seem to be in a similar range before and after aircraft type of them were switched to MAX.

After using visualization to make a preliminary judgment, I found that we can't find any clear and direct evidence for the existence of avoidance of MAX. A similar conclusion could be made after I checked an Air Canada route. Unlike American Airlines, Air Canada rearranged the daily flights after putting back MAX into aircraft fleets, namely, after Sept 8th, 2020. So, I use different methods to visualize the demand changes. Some of the visualization I use are as below. Targeted route is the Air Canada route from Calgary (YYC) to Toronto (YYZ), from Aug 26th, 2020 to Sept 21st, 2020.

The data collection date of this group was Apr 14th, 2020. Due to the impacts of COVID-19, the patterns were significant changed. Many flights had no bookings.

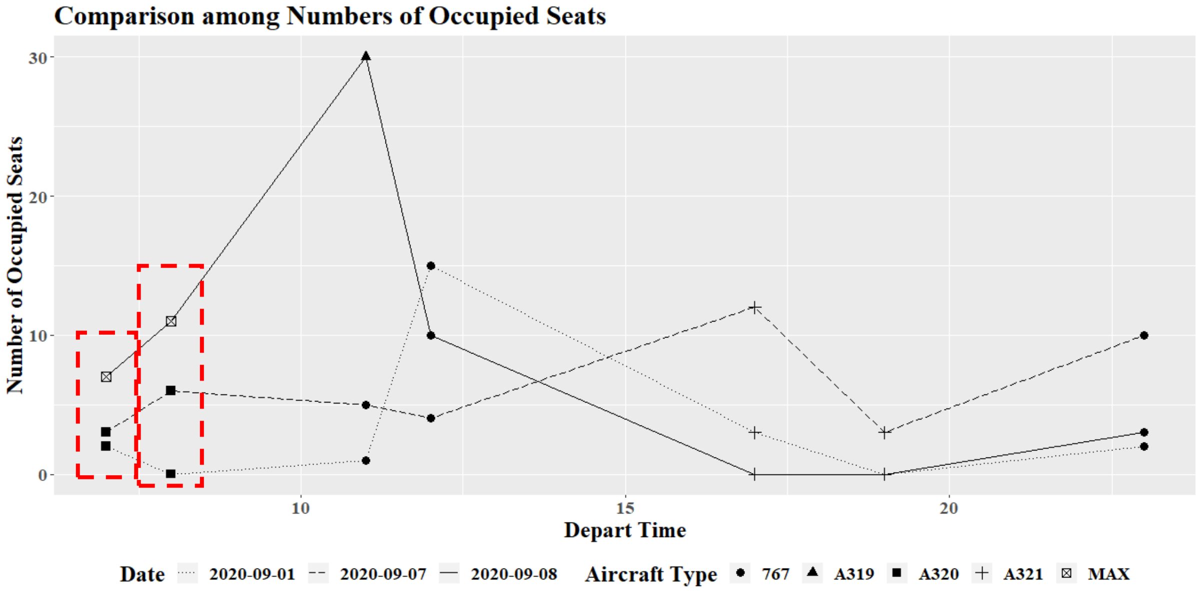

Figure 4-4: Comparison among numbers of occupied seats on specific dates. (AC route)

Still because the decrease in bookings brought by COVID-19s, the bookings are not high

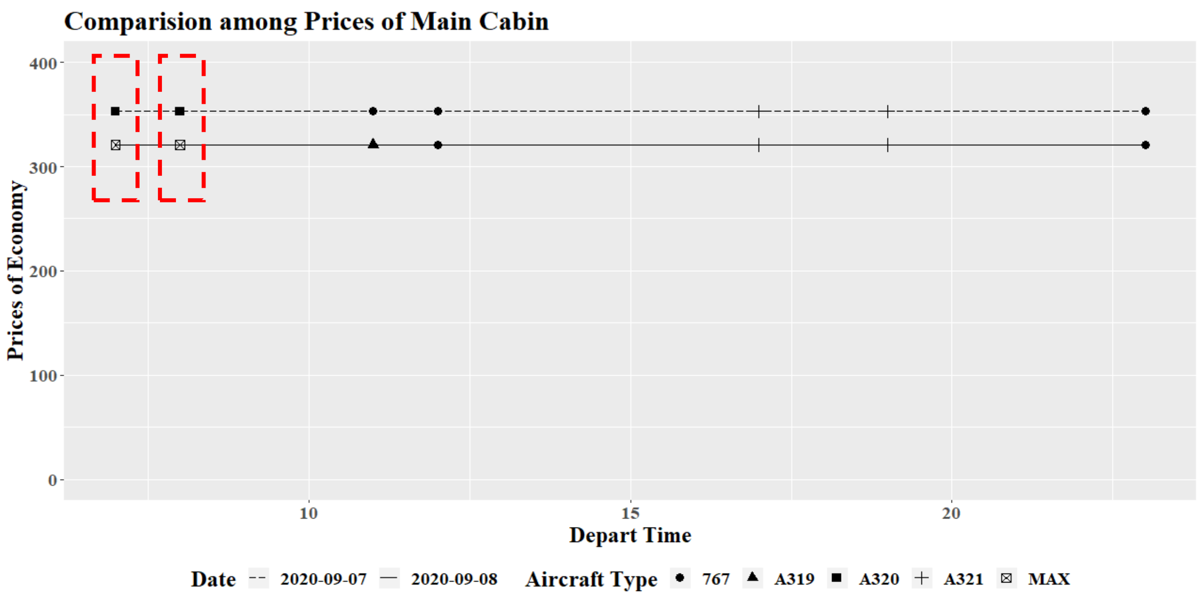

Figure 4-5: Comparison among ticket prices on specific dates. (AC route)

enough to change the ticket prices. In Figure 4-5, since the ticket prices on 2020-09-01 are exactly same with those on 2020-09-08, we only present two dates on this graph.

Similarly, there is no significant change in proportions of targeted flights.

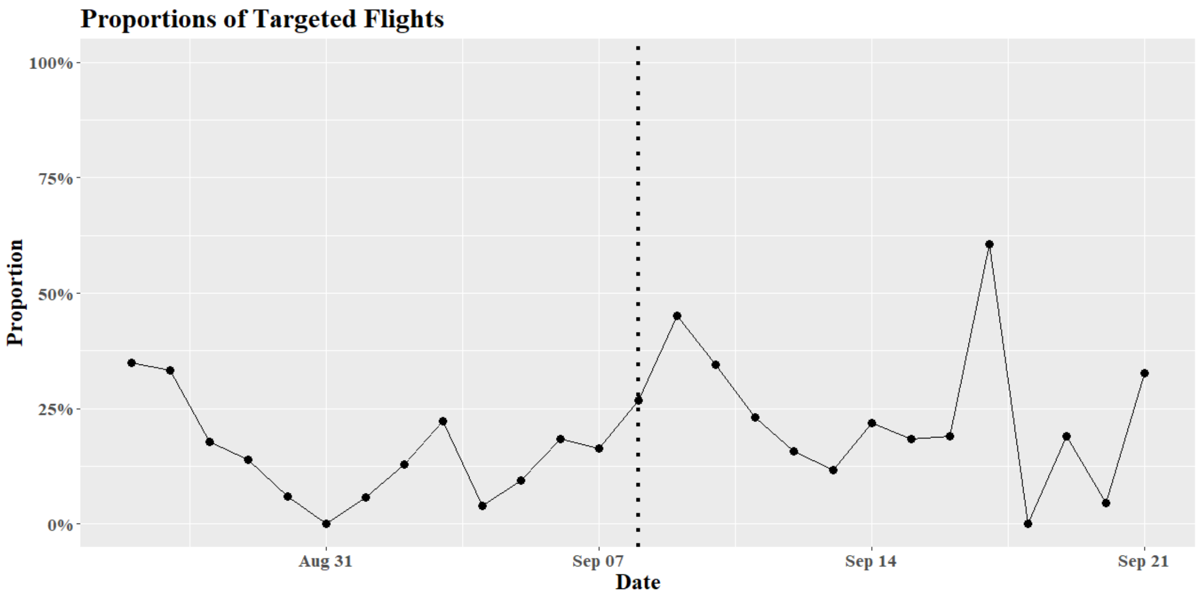

Figure 4-6: Proportions of passengers booked on the targeted flights in specific period. (AC route)

5. Quantitative Analysis

5.1. Metrics for quantitative analysis

As I mentioned above, I chose the number of occupied seats of each flight as the main metric for analysis. There could be many interpretations of this metrics. I selected three of them for the quantitative analysis part.

Table 5.1: Three key metrics for quantitative analysis

Metric	Name	Mark	Definition
1	Number of occupied seats	NO	Number of occupied seats for the targeted flights
2	Proportion of occupied seats	Prop	Proportion of numbers of occupied seats for the targeted flights in total daily number
3	Total number of occupied seats per day	TND	Sum of numbers of occupied seats on a certain day

Here, “targeted flights” means the flights operated by MAX after the date of MAX return or the flights on the same time slots of those MAX flights before MAX return. I took the total number of occupied seats per day into account because some of the passengers may directly go to other Airlines when they try to avoid taking MAX but can't change the departure time. Analyzing proportion is to exclude the impact of changes in overall daily bookings.

To study each metric, I applied all the quantitative analysis, as I mentioned above. Firstly, make a simple computation of the difference between the average values of before and after groups, and check the statistical significance of this difference, namely, whether this difference was due to the MAX. Secondly, make the correlation analysis and regression analysis.

5.2. Quantitative analysis of Metric 1

I first studied the Metric 1-numbers of occupied seats of the targeted flights. Our targeted route is the American Airlines route from MIA to LGA and the targeted flights are those departing at 7, 9 am and 2, 4, 6 pm.

5.2.1. Mean Difference

Table 5.2: Mean of Metric 1 of two groups (AA route)

Group	No.	Mean
Before Group	70	29.6
After Group	70	28.96

Mean difference of two group is:

$$\mathrm{MD} = 29.6 - 28.96 = 0.64$$

The mean difference showed that, for the targeted flights, the non-MAX ones have on average 0.64 fewer occupied seats than MAX flights have. This did show a decrease in bookings, but is this difference significant enough that we can differentiate that from routine fluctuations?

Here, I use the permutation test to compute the significance of the difference. The permutation test is to enumerate all possible combinations of two variables, namely, to allocate

"MAX or not" randomly to all the targeted flights and get all possible mean differences of the groups. In this case, there are $\binom{140}{70} = 9.4\text{E} + 40$ randomizations and, theoretically, the same number of possible differences. Then, we plot all differences on a graph and see how unique the real difference is. In the permutation test, we see where that actual outcome fell among those that assume that the pre-post difference among the bookings reflects only chance. If the targeted number falls into the 90% interval, we can say the difference is caused by randomness or routine fluctuation. On the other hand, if the target number falls out of the 90% interval, we can say it is statistically significant, which means the difference is caused by reasons other than randomness, such as the avoidance of MAX.

The result of the permutation test is as below:

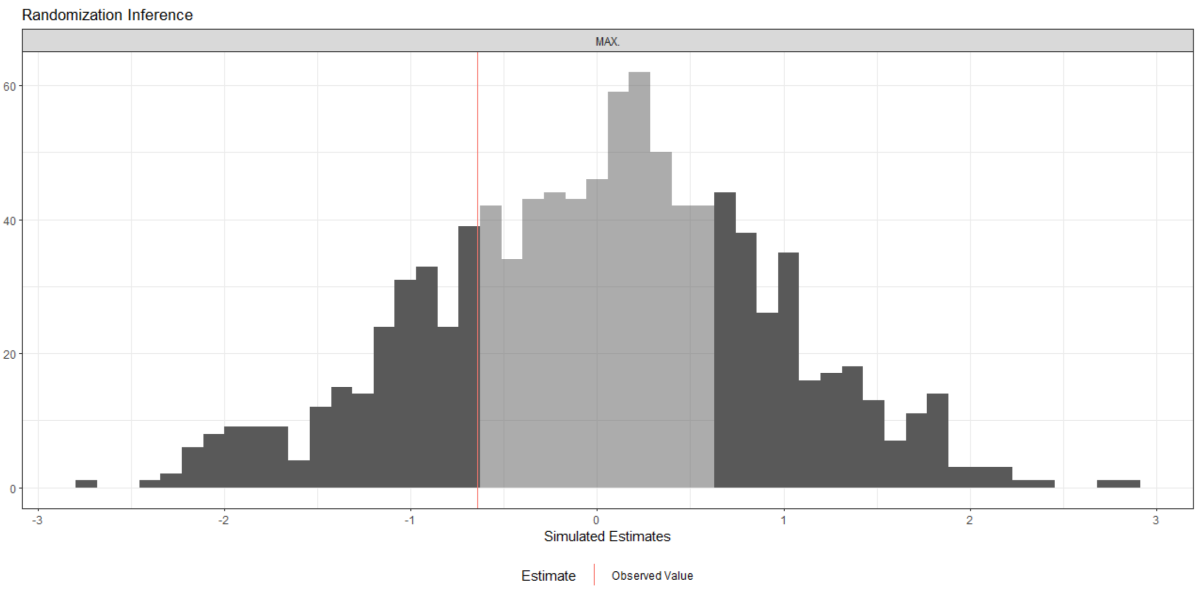

Figure 5-1: Visualized permutation test result (Metric 1, AA route)

Table 5.3: P-value of this difference by permutation test (Metric 1, AA route)

Difference	Two tailed P-value

-0.643	0.493

The p-value of this difference is only 0.493, which is not statistically significant. This means the difference between two groups is not big enough to prove the existence of an avoidance of MAX.

I also did the analysis on the Air Canada route from YYC to YYZ.

Table 5.4: Mean of Metric 1 of two groups (AC route)

Group	No.	Mean
Before Group	24	5.38
After Group	26	8.69

There is an increase in the mean number of occupied seats after the MAX return, so we don't need to check the significance. Clearly, the data does not suggest MAX avoidance.

5.2.2. Correlation and regression

In this part, I considered all the flights of the targeted route. I built a dummy variable "MAX or not" for each flight: if the flight is operated by MAX, then the value will be 1; if not, the value will be 0.

My goal is to uncover the relationship between this dummy variable and the dependent variable-numbers of occupied seats. Before the regression analysis, I first conducted a correlation test. If we found that there is a correlation between the two variables, then we can use regression analysis to find what the exact relation is.

Considering “MAX or not” is a dummy variable of values of 0 and 1, I use Kendall correlation method to check the relation.

Table 5.5: Correlation between MAX and Metric 1(seats booked) (AA route)

Kendall’s Tau	p-value
0.226	8.703e-07

The result showed that there is a significant correlation between the two variables. However, the correlation is positive. I introduced several control variables and further verify the relation between them. The control variables are as below:

Table 5.6: The control variables in the regression model (Metric 1, AA route)

Variable names	Mark	Variable interpretations
Week	week	The number of weeks from the data collection date
Departure time	TIME	Departure time of the flight (in 24)
Weekday	weekday1-7	Monday to Sunday, represented by numbers 1 to 7
Ticket price	MAIN	Price of Main Cabin

I use these four control variables, the dummy variable (MAX), the dependent variable (No) to build a model as follow (ε is the model error):

$$\mathrm{No} = \beta_0 + \beta_1 * \mathrm{MAX} + \beta_2 * \mathrm{WK} + \beta_3 * \mathrm{DT} + \beta_4 * \mathrm{WD} + \beta_5 * \mathrm{TP} + \varepsilon$$

The regression result is as follows:

Table 5.7: Result of linear regression (Metric 1, AA route)

Term	Coef	p-value
(Intercept)	-1.245535	8.60E-01
week	-0.009581	9.75E-01
MAX.	-1.716318	7.98E-02
TIME7	21.92323	1.23E-39
TIME9	20.814074	1.85E-37
TIME11	12.278455	7.26E-18
TIME12	23.755218	1.49E-50
TIME14	23.466913	1.97E-45
TIME16	24.9079	4.33E-49
TIME17	21.975124	1.41E-44
TIME18	20.985851	1.85E-37
TIME19	19.908205	3.34E-38
TIME20	7.0080245	2.95E-07
TIME21	5.9906727	9.46E-06
weekday2	6.264307	7.36E-07
weekday3	4.3351013	7.77E-04
weekday4	1.1969185	3.16E-01
weekday5	3.4160949	1.36E-03
weekday6	8.2725463	1.15E-14
weekday7	0.5874921	5.62E-01
MAIN	0.034175	8.93E-04

The multiple R-squared of the model is 0.7653. From the table, we can find that the departure time and the weekday are very significant. The p-value of MAX is 0.08, which is weakly significant, and the coefficient of that is a negative number, which is -1.72. I interpreted the regression results as follows: there is a weak negative association between MAX and numbers of occupied seats; MAX flights are estimated to have 1.72 fewer occupied seats than non-MAX flights. This could be an evidence for the existence of avoidance of MAX.

The results of correlation analysis on the Air Canada route from YYC to YYZ are as below:

Table 5.8: Correlation between MAX and Metric 1 (AC route)

Kendall's Tau	**p-value**
0.056	0.2884

There is no significant correlation between MAX and numbers of occupied seats. As a result, I could conclude that whether a flight is operated by MAX has no visible impact on the numbers of occupied seats.

5.3. Quantitative analysis of Metric 2

In this part, the dependent variable is the proportion of numbers of occupied seats each day that are on targeted flights, and the key independent variable is whether the flight is operated by a MAX. In some days, the overall daily bookings are significantly higher, so the bookings of MAX flights would be expected to be higher. Thus, more MAX bookings is not necessarily the evidence that people favor the MAX flights. It is possible that although many people book flights on this day, the majority of people turn out to select non-MAX flights. So, we should also check the ratio between bookings of MAX flights and total daily bookings. If we can find a negative relation between the proportion and "MAX or not", we can thus conclude that people avoid taking MAX flights

Same as the section 5.2, the targeted route is American Airlines route from MIA to LGA.

5.3.1. Mean Difference

Table 5.9: Samples from non-MAX group (AA route)

date	Proportion on MAX	week	weekday	Mean Price Difference	MAX
8/4/2020	55.24%	23	2	-$0.71	0
8/5/2020	45.14%	23	3	-$10.71	0
8/6/2020	49.44%	23	4	-$10.71	0

Table 5.10: Samples from MAX group (AA route)

date	Proportion	week	weekday	Mean Price Difference	MAX
8/18/2020	47.66%	25	2	-$26.86	1
8/19/2020	45.21%	25	3	-$9.71	1
8/20/2020	50.00%	25	4	$7.14	1

Part of the data is as above. Mean price difference indicates within that day, the difference between the mean ticket price of targeted flights and non-targeted flights. (The average difference is about the same in both groups of flights: it was -$7.38 earlier and -$9.64 later.) The mean difference of proportions of two groups is:

Table 5.11: Mean of Metric 2 of two groups (AA route)

Group	No.	Mean
Non-MAX Group	14	51.4%
MAX Group	14	50.1%

$$\text{MD} = 51.4\% - 50.1\% = 1.3\%$$

This result indicates that prior to return of the MAX, the flights that later became MAX flights had 51.4% of the bookings but, after the return, the same flights had a 50.1% share. Use permutation test to analyze this mean difference, results as below:

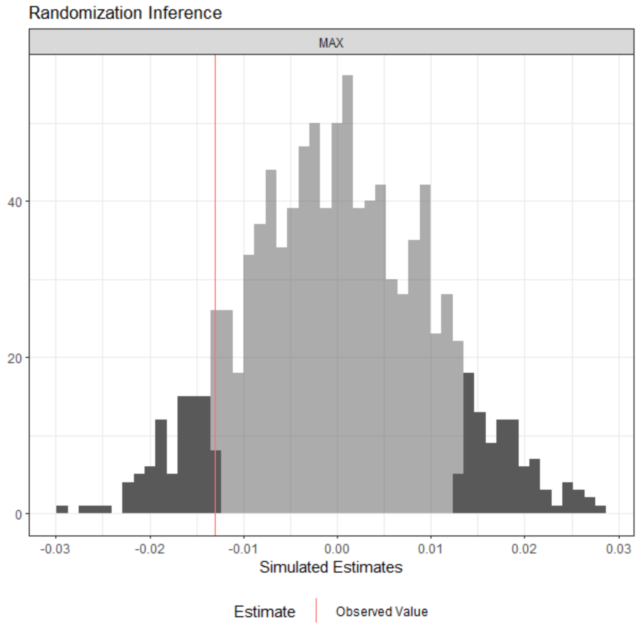

Figure 5-2: Visualized permutation test result (Metric 2, AA route)

Table 5.12: P-value of this difference by permutation test (Metric 2, AA route)

Difference	**Two tailed P-value**
-1.3%	0.185

Still, although there exists a negative difference between the two groups, this mean difference is not statistically significant to be differentiated from randomness. I couldn't tell an avoidance of MAX using mean difference method.

The results of analysis on Air Canada route from YYC to YYZ are as below:

Table 5.13: Mean of Metric 2 of two groups (AC route)

Group	No.	Mean
Non-MAX Group	13	15%
MAX Group	14	21%

Table 5.14: P-value of this difference by permutation test (Metric 2, AC route)

Difference	Two tailed P-value
6.0%	0.168

The mean difference isn't statistically significant in this route.

5.3.2. Correlation and regression

Use the Kendall correlation to check the relation between "MAX or not" and proportion of numbers of occupied seats.

Table 5.15: Correlation between MAX and Metric 2 (AA route)

Kendall's Tau	p-value
-0.235	0.1415

There did exist a negative correlation between the two variables, however, the p-value of this correlation is not high enough to be statistically significant. I further verified this through regression analysis.

In this case, I introduced three control variables to build the regression model. I took into account the mean price difference to show whether the prices play a role in driving people's selection:

Table 5.16: The control variables in the regression model (Metric 2, AA route)

Variable names	Mark	Variable interpretations
Week	WK	The number of weeks from the data collection date
Mean price differences	PD	Within each day, the difference between mean ticket prices of targeted flights and non-targeted flights
Weekday	WD	Monday to Sunday, represented by numbers 1 to 7

$$PROP = \beta_0 + \beta_1 * MAX + \beta_2 * WK + \beta_3 * WD + \varepsilon$$

In this model, PROP is the dependent variable-proportions of numbers of occupied seats of the targeted flights in the total daily numbers; β_0 is intercept; MAX represent the independent variable "MAX or not"; β_i are the coefficients of independent variables; ε is the model error.

The regression results are as below:

Table 5.17: Result of linear regression (Metric 2, AA route)

Term	Coef	p-value
(Intercept)	0.266	0.239
week	0.011	0.241
weekday2	-0.004	0.832
weekday3	-0.031	0.090
weekday4	-0.021	0.243
weekday5	-0.024	0.263
weekday6	-0.038	0.089
weekday7	-0.012	0.566
PD	0.001	0.199

MAX	-0.036	0.099

The multiple R-squared of the model is 0.3936, which means the model has weak explanatory power. I interpreted the regression result as follow: switching to MAX drove 3.6% of passengers to other non-MAX flights. Considering the p-value of 0.099, I would say the relation is weak. Noticing that the p-value for price difference is 0.199, I concluded that, in this case, the price difference didn't have statistically significant impact on the proportions.

The results of correlation and regression analysis on the Air Canada route are as below:

Table 5.18: Correlation between MAX and Metric 2 (AC route)

Kendall's Tau	p-value
0.250	0.1263

Regression analysis:

Table 5.19: Result of linear regression (Metric 2, AC route)

Term	Coef	p-value
(Intercept)	0.081	0.142
weekdayMon	0.066	0.361
weekdaySat	0.034	0.633
weekdaySun	-0.010	0.885
weekdayThur	0.167	0.028
weekdayTue	0.049	0.528
weekdayWed	0.168	0.027
MAX	0.061	0.125

There is a weak positive correlation between "MAX or not" and the dependent variable-proportions of numbers of occupied seats of the targeted flights in the total daily numbers.

5.4. Quantitative analysis of Metric 3

In this part, I explored the relationship between the independent variable and Metric 3. Metric 3 is the total daily bookings in terms of the sum of numbers of occupied seats. The key independent variable is whether there are MAX flights within the day, or whether the day is after Aug 17th, 2020. People may want to avoid taking MAX and nonetheless, keep their original schedules, so in this situation, they may turn to other airlines that provide non-MAX flights at the time slots. It is also possible that travelers are so terrified of the MAX that they discard the airline that flies MAX.

5.4.1. Mean Difference

Part of the data is as follow. "TD" represents the total demands, or the sum of numbers of taken seats for all flights within that date.

Table 5.20: Samples from non-MAX group (AA route).

date	TD	week	weekday	MAX
8/4/2020	286	23	2	0
8/5/2020	288	23	3	0
8/6/2020	269	23	4	0
8/7/2020	284	23	5	0
8/8/2020	300	23	6	0

Table 5.21: Mean of Metric 3 of two groups (AA route).

Group	No.	Mean
Non-MAX Group	14	288.64
MAX Group	14	289..57

$$MD = 289.57 - 288.64 = 0.93$$

The permutation test is as below:

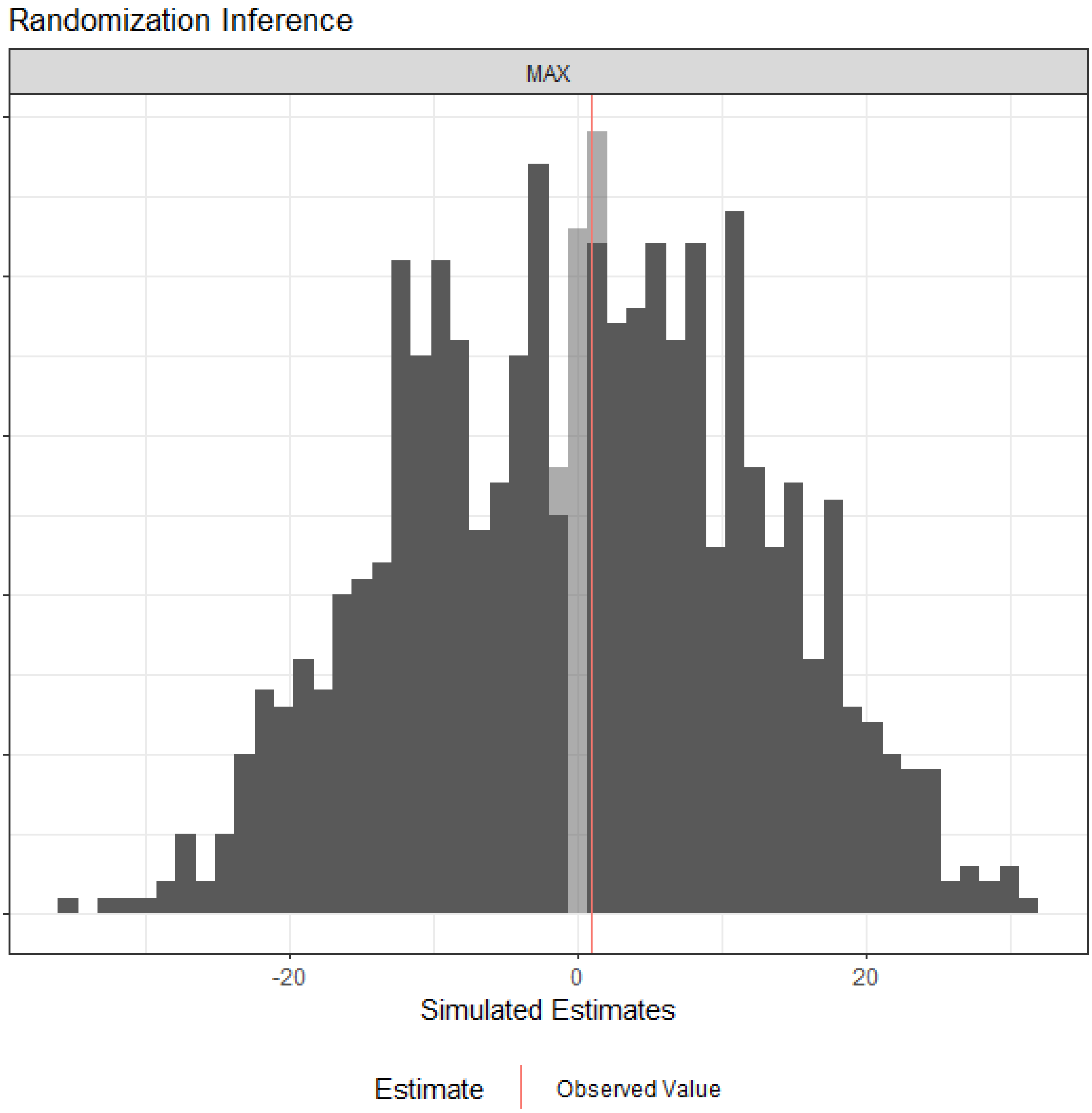

Figure 5-3: Visualized permutation test result (Metric 3, AA route)

Table 5.22: P-value of this difference by permutation test (Metric 3, AA route)

Difference	**Two tailed p-value**

0.929	0.947

In conclusion, the difference is extremely not statistically significant. The difference couldn't be found.

The mean difference analysis on Air Canada route from YYC to YYZ is as below:

Table 5.23: P-value of this difference by permutation test (Metric 3, AC route)

Difference	Two tailed p-value
16.15	0.153

5.4.2. Correlation and regression

The correlation test also showed a result of not statistically significant:

Table 5.24: Correlation between MAX and Metric 3 (AA route)

Kendall's Tau	p-value
0.052	0.7475

The relationship between independent variable and dependent variable didn't pass the correlation test. In other words, I don't need to further conduct regression analysis.

The correlation analysis result on Air Canada route from YYC to YYZ is as below:

Table 5.25: Correlation between MAX and Metric 3 (AC route)

Kendall's Tau	p-value
0.273	0.0941

The regression analysis result on Air Canada route from YYC to YYZ is as below:

Table 5.26: Result of linear regression (Metric 3, AC route)

term	estimate	p.value
(Intercept)	67.538	0.000
weekdayMon	-4.500	0.826
weekdaySat	10.750	0.600
weekdaySun	25.000	0.230
weekdayThur	-27.500	0.188
weekdayTue	-18.488	0.408
weekdayWed	1.000	0.961
MAX	17.425	0.131

I interpreted the result as: there is a weak positive relation between independent variable MAX and the dependent variable-Metric 3.

5.5. Results summary

For Route 1-American Airlines route from MIA to LGA:

Table 5.27: results summary for AA route

Metric	Mean Difference	Statistical significance	Regression	Statistical significance	Support hypothesis?
Metric 1	-	×	-1.71	Weak	×
Metric 2	-1.3%	Weak	-3.4%	Weak	Weak
Metric 3	-	×	-	×	×

For route 2-Air Canada route from YYC to YYZ:

Table 5.28: results summary for AC route

Metric	**Mean Difference**	**Statistical significance**	**Regression**	**Statistical significance**	**Support hypothesis?**
Metric 1	Positive	×	-	×	×
Metric 2	Positive	×	Positive	Weak	×
Metric 3	Positive	×	Positive	Weak	×

6. Conclusions and future studies

In this thesis, I use the quantitative methods to analyze two routes, the American Airlines route from MIA to LGA and Air Canada route from YYC to YYZ. I collected the price and seat data on March 1st and April 14th, respectively. I'm not sure whether the customer segment in this study-customers who booked flight tickets a few months in advance-can fully represent all travelers. Meanwhile, flights departing from Miami may have more leisure travelers than usual , so the behaviors observed may not reflect the business travelers' behaviors. Considering these constraints, I would say that the findings in this thesis are only applicable to the specific customer segment I studied.

Based on the data of these two routes, I didn't find any significant negative impacts, or the negative impacts were not statistically significant. The American Airlines results offer weak evidence that there is small degree of MAX avoidance, while the Air Canada results suggest none. During a period of 28 days or four weeks, with the MAX return date as the midpoint, there is no statistically significant change in travelers' booking pattern. I fully took into account the effects of departure time, ticket prices, and date when making this conclusion. So, I concluded that this specific customer group didn't show an apparent avoidance of reboarding the MAX.

There are many areas for future studies to complete the research on travelers' attitudes. For example, once the MAX returns to fleet, we can use the actual flying data to analyze the choices of travelers with different booking habits. It will become possible for us to differentiate leisure travelers and business travelers when airlines fly MAX in more routes. As of this writing, however, the strong MAX avoidance that is suggested by recent surveys does not appear in data about actual bookings by actual travelers.

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