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TÍTOL DEL TFG: *DYNAMICS OF FLIGHT DISRUPTIONS ON THE JFK-LAX ROUTE: A COMPREHENSIVE ANALYSIS OF CAUSES AND PERFORMANCE*

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Títol: DINÀMICA DE LES ALTERACIONS DE VOLS A LA RUTA JFK-LAX: UNA ANÀLISI INTEGRAL DE CAUSES I RENDIMENT

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Resum

Aquest projecte examina la congestió i els retards del transport aeri als Estats Units, amb especial atenció a la ruta entre l'aeroport John F. Kennedy (JFK) de Nova York i l'Aeroport Internacional de Los Angeles (LAX). L'objectiu principal és identificar els factors que provoquen retards en els vols i avaluar el rendiment de les companyies aèries que operen en aquesta ruta. L'estudi analitza les operacions aeroportuàries, la capacitat i demanda de les infraestructures, les condicions meteorològiques, la congestió del trànsit aeri i les qüestions tècniques per a proporcionar una comprensió global dels factors que afecten els temps de sortida i arribada dels vols.

A més, l'anàlisi comparativa del rendiment de les aerolínies examina indicadors com els índexs de retard dels vols, els temps mitjans de retard i la capacitat de recuperació davant situacions adverses. Aquesta anàlisi es centra en les estratègies de les companyies aèries per a fer front als retards i en les maneres de millorar la gestió operativa en la ruta entre tots dos aeroports.

Per a aconseguir aquests objectius, la metodologia d'anàlisi inclou l'ús d'un codi MATLAB especialment dissenyat que permet l'anàlisi de les dades obtingudes de l'Oficina d'Estadístiques de Trànsit Aeri dels Estats Units (BTS) durant 2017, per a obtenir un examen detallat de les raons dels retards.

La recerca pretén aprofundir en els factors que causen un impacte en el rendiment dels vols. Aquest enfocament innovador mostra la capacitat de proporcionar informació valuosa i recomanacions per a optimitzar les estratègies de gestió de vols i millorar l'eficiència operativa en la ruta. Els resultats del projecte tenen implicacions pràctiques per al sector de l'aviació, les companyies aèries i les autoritats aeroportuàries. Gràcies als coneixements adquirits en aquest estudi, els agents del sector poden prendre decisions amb coneixement de causa i aplicar estratègies per a fer front als reptes de la congestió i les alteracions en les rutes i aeroports estudiats.

Título: DINÁMICA DE LAS ALTERACIONES DE VUELOS EN LA RUTA JFK-LAX: UN ANÁLISIS INTEGRAL DE CAUSAS Y RENDIMIENTO

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Resumen

Este proyecto examina la congestión y los retrasos del transporte aéreo en Estados Unidos, con especial atención a la ruta entre el aeropuerto John F. Kennedy (JFK) de Nueva York y el Aeropuerto Internacional de Los Ángeles (LAX). El objetivo principal es identificar los factores que provocan retrasos en los vuelos y evaluar el rendimiento de las compañías aéreas que operan en esta ruta. El estudio analiza las operaciones aeroportuarias, la capacidad y demanda de las infraestructuras, las condiciones meteorológicas, la congestión del tráfico aéreo y las cuestiones técnicas para proporcionar una comprensión global de los factores que afectan a los tiempos de salida y llegada de los vuelos.

Además, el análisis comparativo del rendimiento de las aerolíneas examina indicadores como los índices de retraso de los vuelos, los tiempos medios de retraso y la capacidad de recuperación ante situaciones adversas. Este análisis se centra en las estrategias de las aerolíneas para hacer frente a los retrasos y en las formas de mejorar la gestión operativa en la ruta entre ambos aeropuertos.

Para lograr estos objetivos, la metodología de análisis incluye el uso de un código MATLAB especialmente diseñado que permite el análisis de los datos obtenidos de la Oficina de Estadísticas de Tráfico de Estados Unidos (BTS) durante 2017, para obtener un examen detallado de las razones de los retrasos.

La investigación pretende profundizar en los factores que causan un impacto en el rendimiento de los vuelos. Este enfoque innovador muestra la capacidad de proporcionar información valiosa y recomendaciones para optimizar las estrategias de gestión de vuelos y mejorar la eficiencia operativa en la ruta. Los resultados del proyecto tienen implicaciones prácticas para el sector de la aviación, las compañías aéreas y las autoridades aeroportuarias. Gracias a los conocimientos adquiridos en este estudio, los agentes del sector pueden tomar decisiones con conocimiento de causa y aplicar estrategias para hacer frente a los retos de la congestión y las alteraciones en las rutas y aeropuertos estudiados.

Title: DYNAMICS OF FLIGHT DISRUPTIONS ON THE JFK-LAX ROUTE: A COMPREHENSIVE ANALYSIS OF CAUSES AND PERFORMANCE

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Overview

This project examines air travel congestion and disruptions in the United States, with a particular focus on the route between John F. Kennedy Airport (JFK) in New York and Los Angeles International Airport (LAX). The main objective is to identify the main drivers of flight delays and assess the performance of airlines operating this route. The study analyses airport operations, infrastructure capacity and demand, weather conditions, air traffic congestion, and technical issues to provide a comprehensive understanding of the factors affecting flight departure and arrival times.

Additionally, the study provides a comparative analysis of airline performance, examining indicators such as flight delay rates, average delay times, and resilience to adverse scenarios. This analysis focuses on airline strategies for dealing with delays and ways to improve operational management on the studied route.

To achieve these objectives, the research methodology includes the use of a specially designed MATLAB code that allows the analysis of data obtained from the United States Bureau of Traffic Statistics (BTS) for 2017, allowing a detailed examination of the reasons for flight delays on the route.

The research aims to gain deeper insight into the factors that cause an impact on flight performance. This innovative approach shows the ability to provide valuable information and recommendations to optimize flight management strategies and improve operational efficiency. The results of the research project have practical implications for the aviation industry, airlines and airport authorities. Using the insights gained from this study, industry players can make informed decisions and implement strategies to address the challenges of congestion and disruption on the studied routes and airports.

CONTENTS

FIGURES

TABLES

INTRODUCTION

The United States air transport system is one of the most congested in the entire world. Due to a lack of rail transportation and distances being that long, flying is the fastest and most comfortable way to travel throughout the country. Since the beginning of the first flight performed by Wright brothers in 1893 until today, the United States, US in advance, has experienced an incredible growth in air traffic numbers and so has done its infrastructure which involves Air Traffic Management (ATM), airports and airlines. As a consequence, air traffic congestion and disruptions have become a major challenge for its aviation industry due to an increase in air traffic demand and a lack of capacity, affecting not only passengers but airlines, airports and the entire economy. As air travel has grown in popularity, the strain on the air transport system’s infrastructure and operational capacity of the country's airports has reached critical levels. This leads to more delays, runways congestion and a higher chance of flight cancellations.

This project aims to provide a comprehensive and advanced analysis of flight congestion between two of the biggest and most saturated airfields in the world: John F. Kennedy Airport (JFK) in New York (NY) and Los Angeles International Airport (LAX) in Los Angeles (CA), with a focus on identifying root causes and assessing the performance of airlines operating on this route.

First, airport operations will be studied in detail, taking into account key technical and operational aspects. An evaluation on JFK’s and LAX's infrastructure capacity will be performed. The goal is to understand how these factors affect the departure and arrival times of flights on this route.

Next, an analysis on the most common causes of delays on the JFK-LAX route will be performed. Factors such as weather conditions, air traffic congestion and technical problems will be taken into account. The main goal is to study how these elements contribute to flight delays and identify patterns or trends in specific route conditions. The aim is to identify the most significant causes of delays and their impact on flight schedules.

In addition, a comparative study of the airlines operating on this route will be conducted to assess their performance in terms of on-time performance and their ability to address the identified causes of delays. Key metrics such as delayed flights percentage, average delay time and resilience to adverse scenarios will be examined. We will then find out how each airline addresses the challenges associated with disruptions on the route.

The research methodology involved using data from 2017 flights collected from the Bureau of Traffic Statistics of the United States (BTS) and analyzing it by using MATLAB coding tool in order to figure out disruptive causes and how each airline addresses that factors such as weather, air traffic congestion, technical issues, and more. The average delay time for each airline in relation to these causes will be examined and their overall performance will be compared. By performing this comparison, it is expected to gain valuable information on the best practices and strategies implemented by each airline to minimize delays associated with the identified causes. This will make it possible to identify opportunities for improvement and share recommendations in the area of flight management for this route.

To sum up, this undergraduate research project will focus on analyzing flight delays between JFK and LAX airports (both directions). Check variables such as taxi times, weather effects, airport capacity and other factors that may cause delays. In addition, a comparative analysis of the airlines operating on this route will be carried out to assess their performance with regard to the identified causes of delay. The goal is to gain a better understanding of the challenges and opportunities to improve the punctuality and efficiency of flights on this busy route.

CHAPTER 1. AIRPORTS DESIGN AND CAPICTY

The United States of America has the most complex airspace in the world. With main transportation method being aircraft there are more airports per inhabitant in the country than any other place in the world. The Federal Aviation Authority, FAA in advance, handled in 2021 more than 13 million flights with half of those being unscheduled. If we keep talking about numbers, there are more than 19.000 airports with 5.000 of those being public and the rest having private owners. This amount of airfields and traffic is also caused by the large size of the country being around 24 million squared miles the oceanic airspace and 5,1 million of squared miles the domestic airspace. [1]

Most of those airfields are used for regional or local routes with a few hub airports in which passengers are expected to connect. This major airports are the ones we are going to focus on this project. We are talking about, for example, Atlanta's airport, hub for Delta Airlines, the one with highest traffic volumes around the globe, JFK, hub for American Airlines or Newark Liberty, home for United Airlines.

As mentioned earlier, in order to understand and analyze how traffic behaves under different conditions and during different time periods, we focused on JFK and LAX.

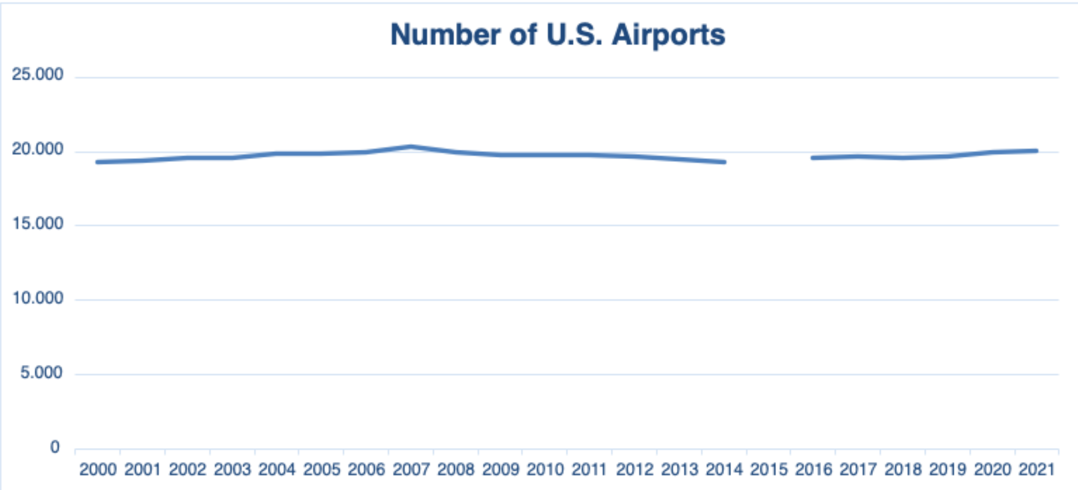

Fig. 1.1. Evolution of the number of US airports from 2000 to nowadays.[1]

1.1. New York - John F. Kennedy Intl. Airport (JFK)

John F. Kennedy International Airport is the main airfield in New York City and New York state. Located 16 miles southeast of Midtown Manhattan, in the borough of Queens, is used by more than 90 airlines. It is a hub for American Airlines and Delta Air Lines and a focus city for JetBlue. In 2022 it passed through its gates more than 55 million passengers being the 10th busiest airport by passenger numbers in the US. [2] It has eight passenger terminals which are normally operated by main airlines. In those terminal buildings, airlines are distributed in them depending whether they are the owners or if the owner is a partner of the carrier within an agreement between both operators.

The airport covers around 21 square kilometers with over 40 km of taxiways of mainly asphalt concrete. It has eight runways named 13L/R, 31L/R, 4L/R and 22L/R. From this nomenclature and from next figure it can be seen that there are two parallel runways in directions 40°or 220° and two other parallel runways in directions 130° or 310°. It is interesting to mention that runway 13R/31L is the third longest commercial runway in North America being used as a backup for Space Shuttle missions. All runways are equipped with ILS system being runway 4R/22L the most modern of all four runways as is equipped with ILS Cat. III in both directions. [3]

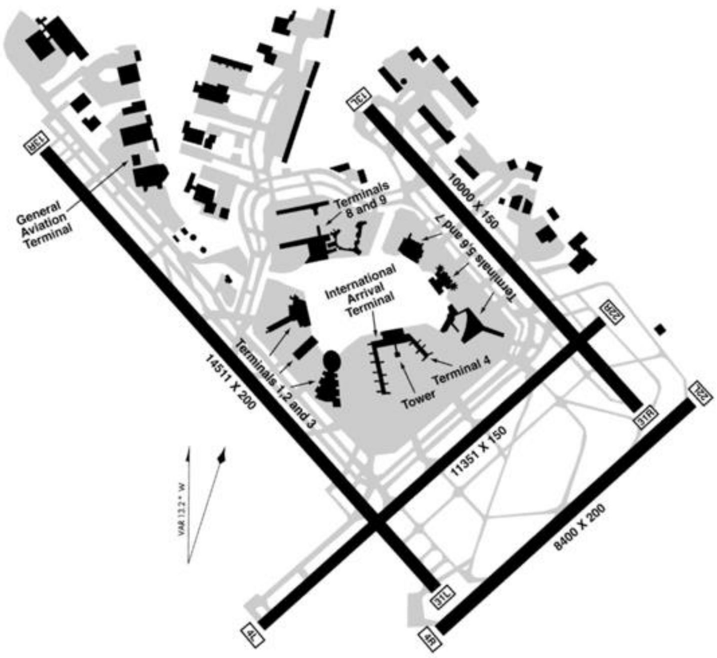

Fig. 1.2. Schematic map of JFK airport showing passenger terminals and runways as same as other facilities in the airfield.[4]

When talking about more technical features of JFK airport we need to first discern between three main possible scenarios at the airport: visual, marginal and instrumental conditions.

- Visual conditions are considered when ceiling and visibility allows visual approaches with at least 2000 feet ceiling and 4 miles visibility.
- Instrument conditions appear when ceiling and visibility is below 100 feet ceiling or 3 miles visibility.
- Marginal conditions are those where ceiling and visibility are below visual approach minima but better than instrument conditions.

The airfield is operating in visual conditions a total of 87% of all time in a year, whilst instrument a total of 8% and marginal 5% of annual time.
Current operations show that most of the time headers 13L and 22L are used for landings and 13R for departures, when prioritizing arrivals. Otherwise, when prioritizing departures, 22L is used for arrivals and headers 22R and 31L are used for departures. When arrival priority is set, a maximum capacity of 84 to 87 operations per hour is reported to be reached and when prioritizing departures, an hourly rate of 90 to 93 can be stablished.

The arrival priority is set by the airport 7% of all time the airport is operating in visual conditions which means a 6% of all operation annually. Departure priority mode is used 13% of the time in visual conditions which means a 11% annually.[4]

In conclusion, the airfield is normally operating in visual conditions and mainly setting departure priority, as shown in the figure below.

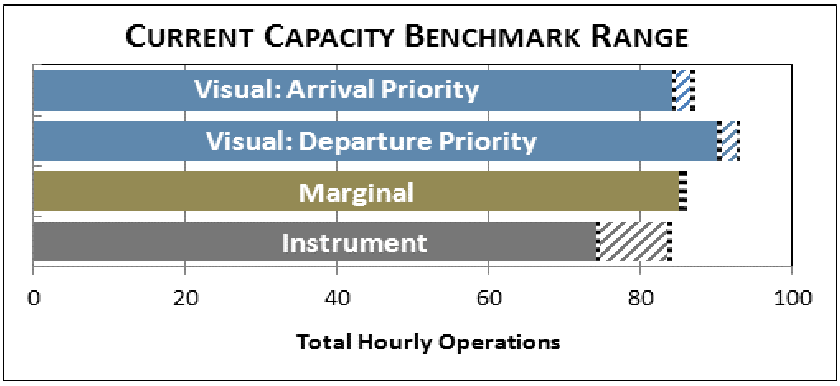

Fig. 1.3. JFK capacity rate range depending on weather conditions.[4]

1.2. Los Angeles International Airport (LAX)

Los Angeles International Airport, LAX in advance, is the main airport of the city of Los Angeles and the biggest one in California state and in the west coast of the United States. It is located in Westchester, 30 kilometers southwest of Downtown Los Angeles. The airfield is equipped with 9 passenger terminals with a total of 146 gates. In 2017 went through its gates more than 84 million passengers being the 5th busiest airport in the world per passenger numbers. [5]

With an extension of 14 square kilometers there are four runways at the airport: 06L/24R, 06R/24L, 07L/25R and 07R/25L.

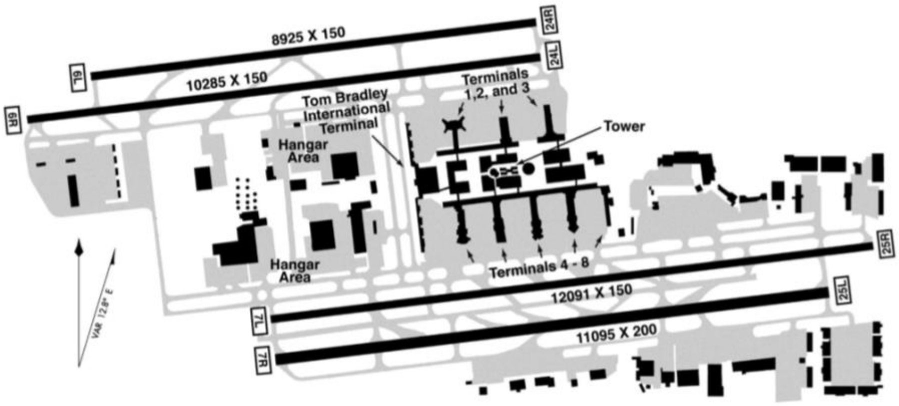

Fig. 1.4. Schematic map of LAX airport showing passenger terminals and runways as same as other facilities in the airfield.[6]

Airport's operation is 81% of annual time in visual conditions, 11% in marginal and 8% in instrumental conditions. For each mode of operation here are its characteristics:

- Visual conditions: Ceiling of at least 2500 ft and visibility up to a minimum of 3 miles.
- Instrumental conditions: Ceiling below 1000 ft and visibility behind 3 miles.
- Marginal conditions are considered when ceiling and visibility is below approach minima but better than with instrumental conditions.

In visual conditions, the airport is normally operating at a capacity around 167 to 176 operations per hour with northwestern 24R/L and 25R/L headers being mostly used. The majority of LAX's arrivals occur on runways 24R and 25L. However, in times of heavy arrival demand, some arrivals may be offloaded onto runway 24L or 25R. The majority of LAX's departures occur on runways 24L and 25R. However, in times of heavy departure demand, some departures may be offloaded onto runway 24R or 25L.

There is no design scenario for departure or arrival priorities. This configuration is used during 96% of total time in visual conditions which translates into a 76% annual time the airport is using this configurations and can achieve this maximum capacity. Instrumental conditions are only set a total of 7% annually reaching, in those conditions, a maximum capacity rate range between 133 to 143 operations per hour. Landing and take off runways configuration is set as mentioned before.

Finally, marginal conditions are found as much as instrumental conditions, 10% annually, with a maximum capacity rate between 147 to 153 operations per hour.

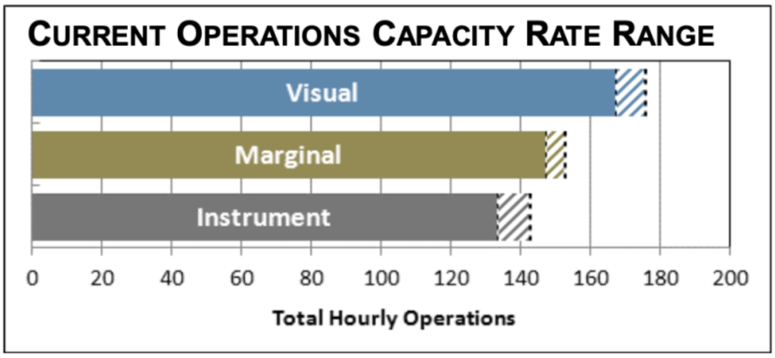

Fig. 1.5. LAX capacity rate range depending on weather conditions.[6]

1.3. Airfield capacity

One of the greatest concerns of airport users and operators are delays. Flights cannot begin or end on time due to the long line of aircraft that are queuing for takeoff, landing, or the crowded use of taxiways and gates at terminal buildings. These lags have an effect on increased operating costs for airport users and wasted time for passengers. The reason for this delays are commonly referred to as a "lack of capacity", this means that the airport lacks facilities like runways, taxiways, or gates in the necessary number to accommodate all of the aircraft which want to use the airport during peak times.

The association between capacity, demand, and delay is more complex than anticipated. Before attempting solutions, it's important to examine more closely the issues of definition and to investigate how and where delays occur. Also, it's important to examine specific airports such as JFK and LAX that are experiencing high delays. This will help to have a more precise understanding of the severity of the issue and the places it can be addressed.[7]

1.3.1. Long term slots and expected capacity

A slot at an airport is considered the authorization that an operator (airline in our case) has to take off or to touch down at a given time in a given airport. When talking about slots we are referring to take-off slots but there are also other types such as catering or maintenance slots.

Each slot is allocated twice a year, referring basically to seasonality, summer (high season) and winter (low season). So, slots are assigned twice a year by a coordinator designed in each country.

In slots distribution it is defined that airlines keep their slots from previous season, a technique called father rights, only if 80% of previous season slots have been used. This is the reason why, as we will see afterwards, in main American airports legacy carriers are the ones that operate the majority of flights, not because other newer or younger airlines do not want to operate more flights at the considered airport but because they are not allowed to do so caused by lack of capacity. Year by year those slots have been assigned to the same airlines and so, the older the time of operation at an airport an airline has, normally the bigger the amount of slots it operates. This is not certainly true as there are other rules which force legacy carriers not to operate all slots in order to have a fair competition**.** This constitutes a market gap used by younger or newer airlines in order to try to operate in most congested airports around the globe.

Sometimes new slots become available in case of bankruptcy of an airline operating in the airport or because an airline is not interested in flying as much as it flown the previous season from that airport or even due to increase of capacity at the airport because of an expansion of the infrastructure. Then, the lasting slots are allocated following a common pattern. Half of the slots are allocated among airlines present at the airport ant the rest to “new comers”, airlines that are interested in operating in the airport. [7]

At the beginning of the times there was no slot control. Airlines set flights without thinking in terms of capacity. This was caused as air traffic was, at that times, not as popular and usual as nowadays. In the coming times where air traffic numbers have increased exponentially due to reduction of air fares, the fact that more and more flights where being planned in main airports around the globe started causing delays as the system started to collapse. There was not enough infrastructure neither physical nor temporal to handle all that amount of flights and so the authorities set restrictions.[8]

AAL	AMERICAN AIRLINES	210
AAR	ASIANA AIRLINES	2
ABX	ABX AIR	1
AEA	AIR EUROPA	2
AFL	AEROFLOT	4
AFR	AIR FRANCE	11
AIC	AIR INDIA	2
AJT	AMERIJET	1
AMX	AEROMEXICO	8
ANA	ALL NIPPON AIRWAYS	4
ARG	AEROLINEAS ARGENTINAS	2
ASA	ALASKA AIRLINES	24
AUA	AUSTRIAN	2
AUI	UKRAINE INT'L AIRLINES	1
AVA	AVIANCA	5
AZA	ALITALIA	8
BAW	BRITISH AIRWAYS	24
BEL	BRUSSELS	2
BWA	CARIBBEAN AIRLINES	2
CAL	CHINA AIRLINES	2
CAY	CAYMAN AIRWAYS	1
CCA	AIR CHINA	6
CES	CHINA EASTERN AIRLINES	2
CFG	CONDOR	2
CMP	COPA AIRLINES	3
CPA	CATHAY PACIFIC	7
CSN	CHINA SOUTHERN AIRLINES	1
CXA	XIAMEN AIRLINES	2
DAL	DELTA AIR LINES	422
DHK	DHL AIRLINES	1
DLH	DEUTSCHE LUFTHANSA	6
EIN	AER LINGUS	6
ELY	EL AL ISRAEL AIRLINES	3
ETD	ETIHAD	4
EVA	EVA AIRLINES	1
FDX	FED EX	5

Fig. 1.6. Slot allocation at JFK airport for summer 2022 showing airlines and number of slots assigned. See that US legacy carriers are the ones with the most slots assigned (Delta and American Airlines for example) with international airlines getting the rest. [9]

In this project we will also analyze the amount of flights offered by each carrier in ours studied airports focusing on the amount of slots allocated to each one and its influence to the general delay.

1.3.2. Short term slots and real time capacity

Short-term slots are considered a real-time impact on long-term planned slots at the airport, which actually play a large role in flight delays. In situations where capacity needs to be reduced, such as in bad weather conditions, where a number of aircraft are expected to depart according to a previous allocation of long-term slots made in the preceding season, but the conditions limit the capacity to, for example half as expected, delays would start to occur as there is not enough physical availability for all aircraft to depart at the expected time. It is then said that there is a lack of capacity in relation to the expected and planned initially.

But there are many curious facts about the set of restrictions and the amount of delay in flights. According to a study conducted by Alexander Luttmann at UC Irvine, imposing slot controls at congested airports does not actually reduce delays because major airlines at these airports do already anticipate congestion and incorporate it into their scheduling plans. This is called the block time, the elapsed time between scheduled departure and arrival airports. This term will be analyzed throughout the paper. This is logical since congested airports require more time to accommodate takeoffs and landings, which leads to longer flight times and more expensive flights due to the increased aircraft usage and crew costs for airlines.[10]

Even though the busiest airports see a high volume of flights, their largest airlines refrain from adding flights due to the associated high costs, not only for new flights but also for their existing ones, which would experience greater delays and extended flight times.

CHAPTER 2. DELAY ANALYSIS IN THE ROUTE

As mentioned at the beginning of the paper, we will focus on studying the performance of flights in the routes JFK to LAX and LAX to JFK. This constitutes the most flown and profitable air corridor in the United States connecting the two biggest metropolitan areas in the entire country.

2.1. Flight disruptions and delays

The Federal Aviation Administration (FAA) defines a flight delay as the alteration of the duration of a flight after the aircraft has been pushed back from the gate. More specifically, delays that occur on taxiways, runways, enroute or on airspace holding patterns are considered enroute delays.[11]

Most commercial flights in the United States follow regular flight schedules. Actual arrival time depends on flight delays. While airlines will accommodate minor anticipated delays depending on the region in which they operate, unforeseen circumstances often cause enroute delays. We will talk about this situation later on the paper.

By obtaining flights data obtained from the Bureau of Transportation of the United States (BTS) we will analyze the performance of all flights from JFK to LAX and from LAX to JFK during 2017 in order to understand why flights are delayed on this route and how to improve this performance by finding out the main reasons of those disruptions.

2.1.1. Percentiles

When analyzing data it is extremely relevant the way the information is calculated and compared. Percentiles are usually used in aviation data analysis to discuss and evaluate the various aspects of flight performance such as on time performance, flight duration, and delay metrics. Percentiles have a significant role in the distribution of data points and the identification of patterns, trends, and outliers in a dataset.

In the aviation industry, percentiles are particularly beneficial in order to understand the regularity of flights and the impact of disruptions. For instance, the 50th percentile is also called the median, this is because the middle value of a dataset is represented by this percentile. This value is normally used to gauge the typical or average performance of flights. If the average flight delay is 15 minutes, it implies that half of the flights have a delay of 15 minutes or less.

Percentiles that are greater than the median, such as the 70th and 80th percentiles, offer additional information about the upper end of delay values. The 70th percentile is the value that represents 70% of the data, while the 80th percentile is the value that represents 80% of the data. These higher percentiles indicate the degree to which flights have experienced delays that are significant or long-lasting, respectively.

Let’s see an example in order to understand how data will be treated along the paper.

Table 2.1. Percentile comparison in departure delay for two flights in January 2017 in the route JFK-LAX-JFK. (i.e. P50 means the 50th percentile) Delay values are expressed in minutes. Source: MATLAB (BTS Data)

Departure	Arrival	Flights	DelayedFlights	DepartureDelayP50	DepartureDelayP70	DepartureDelayP80
LAX	JFK	1047	550	-1	11	26
JFK	LAX	1046	615	-2	3,4	12

From the previous table it can be seen that, in the flights from LAX to JFK, the 50^{th} percentile was -1 minute, which means that, if lining up delay values in January 2017 from less delay to more delay, 50% of flights had -1 minute departure delay (1 minute before scheduling), 70% of all flights had 11 minutes or less delay and also that in the 80^{th} percentile flights had a 26 minutes departure delay as maximum.

The utilization of percentiles is useful for analysts in order to understand delay distribution and identifying the most significant indicators of performance. For instance, the 80^{th} percentile delay is typically significant, and it represents the level of delay that is uncommon but still significant. This understanding can facilitate the planning of operational actions, prepare for capacity, and develop strategies to reduce delay.

The percentiles can be used to assess the quality of different airlines, airports, or routes. By placing different percentages in different organizations, stakeholders can differentiate between differences and methods to improve. For example, if one airline consistently has lower percentiles for delay that are comparable to their competitors, this suggests that they are more dedicated to punctuality and have a higher degree of operational efficiency.

All airlines have commercial strategies and thus their percentile considered in calculations is adapted to each ones’ strategy but, from what we can extract from data, for approximately all carriers in the US, this value is normally set from 50^{th} percentile and 70^{th}. In our study, in order to make it the most realistic in the intend of analyzing most critical situations we will set it up to 70^{th} percentile. Then, all data shown in the paper is calculated by using this amount of percentile.[12]

2.1.2. Arrival and departure delays

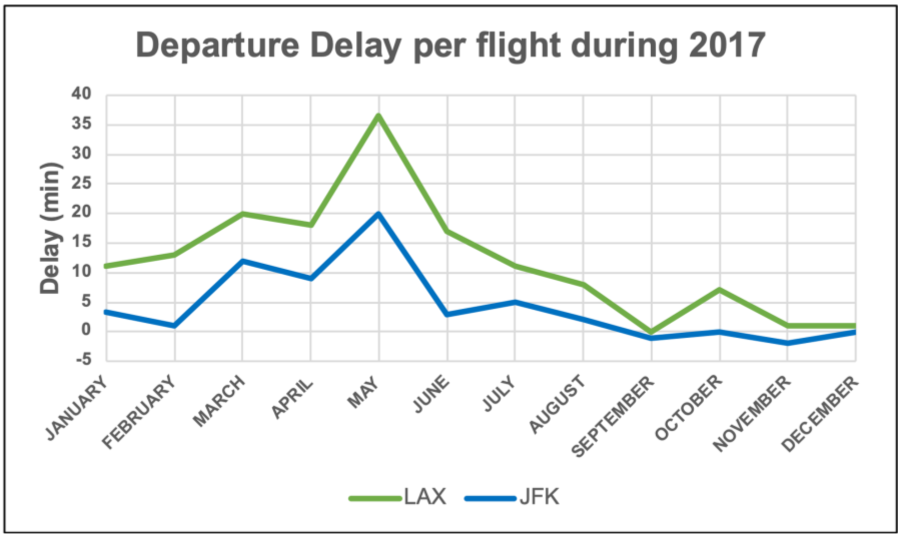

Fig. 2.1. Departure delays in JFK and LAX for flights on the route JFK-LAX-JFK during 2017. Source: MATLAB (BTS Data)

At first impression, we can see how flights departing from LAX to JFK had a higher delay than departing from JFK. Usually LAX had a departure delay between 5 to 15 minutes higher than JFK. The biggest difference was found in between February and September as in LAX demand was higher and capacity was quite limited translating it into an increase on delays. In JFK this increase on demand was better managed and so, from February to September 2017, this difference in departure delay went from 10 to 15 minutes between both airports but from September to January delays were around none to 7 minutes.

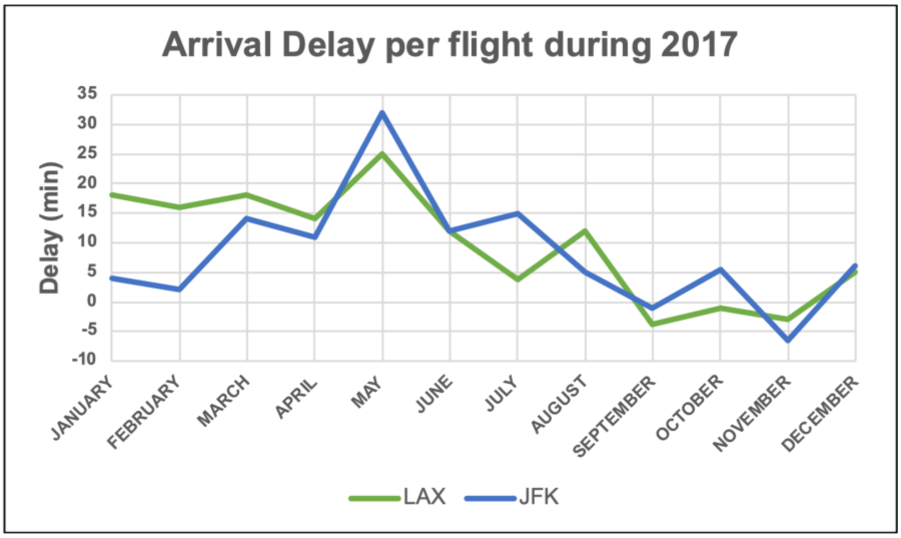

Fig. 2.2. Arrival delays in JFK and LAX for flights on the route JFK-LAX-JFK during 2017. Source: MATLAB (BTS Data)

When arriving, both airports behaved similarly with difference in delays between 0 to 5 minutes except in January, February and July 2017 when this difference raised up to 10 and even 15 minutes between destinations. Only from September to November flights were getting to their destination airport without any delay, but for the rest of the year this delays raised up even reaching 25 minutes for LAX and 30 minutes for JFK when arriving at mentioned airfields.

Overviewing the figures shows that despite JFK manages a little less traffic than LAX, it is really good at dealing with departure delay but manages quite worse its arrivals mainly caused by holding patterns when aircraft get into the airfield. By contrast, LAX handles really bad its departures by generating much delays but its behavior is better than JFK when flights arrive as this last has much more traffic to handle if considering it has a much limited capacity than LAX. At the same time while arrival and departure delays are much different in JFK, in LAX they are quite similar as used runways are the same for landing an taking off

2.1.3. Seasonality

Seasonality can have a significant impact on flight delays due to various factors that change depending on season. One factor is weather, which can cause delays and cancellations due to winter storms or summer thunderstorms. Another factor is that there can be a lot of travel during peak seasons like summer and winter holidays, which can lead to airport congestion and potential delays, as we mentioned before when we talked about long term capacity in airports which actually changed between seasons. In addition, airlines may adjust flight schedules seasonally to accommodate changes in demand, which sometimes causes delays in repositioning aircraft or adjusting crew schedules. Finally, seasonal downtime for routine aircraft maintenance results in fewer aircraft and crews available, leading to delays and cancellations. It's important to understand how seasonality affects flight delays so travelers can plan accordingly and be aware of potential delays during peak travel periods. High season is considered to last from April to October and low season from November to March, also called summer and winter seasons, respectively.

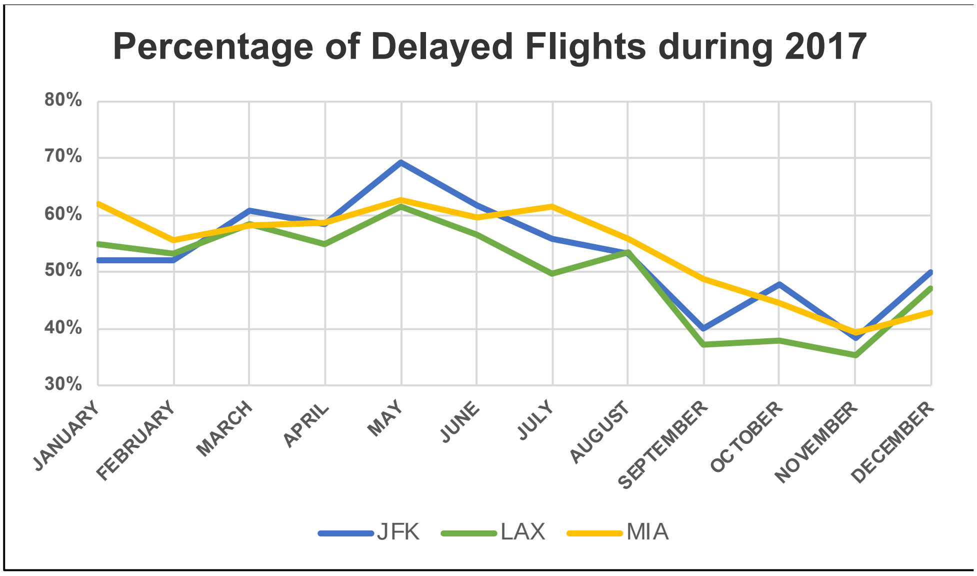

Fig. 2.3. Percentage of delayed flights for different airports during 2017. Source: MATLAB (BTS Data)

In it can be easily seen the effect of seasonality in previous figure. When departing, while in November 2017, in the way to JFK, 390 flights out of 1051 where delayed, in the way around to LAX out of 1052 flights, 363 were delayed. This corresponds to a 37,1% and a 34,5% delay percentage, respectively, which means that one third of all operated flights in both ways of the route where delayed during November 2017. But, when looking at July the same year, in the bound for JFK 56,7% of flights were delayed and in the the way to LAX this percentage was set to 48,2%. In the case of 2017 there was a delay peak in May with JFK reaching 70% of flights delayed at departure. It is important to mention that this corresponds to delay at departure but it could be recovered or increased during the flight, as seen before, and we will analyze this effect along the paper.

It is then concluded the effect of seasonality. Whilst in winter season approximately 1/3 of all flights in the route were delayed, in summer season this number raised up to approximately 1/2 of all operated flights.

The amount of delay per flight is also affected which is actually shown in figures 2.1 and 2.2. Although in November 2017 this value was around 1 minute delay, when arriving in JFK the amount had reduced 4 minutes in advance of schedule, considered then on time. In the bound for LAX this numbers were set to no delay at departure from JFK, actually 1 minute in advance, and almost 4 minutes again in advance when reaching destination, on time as well.

By contrast, in summer season departure delay from LAX raised up to 8 minutes in July 2017 and arrival delay to JFK to 5 minutes. In the bound for LAX, departure delay was about 6 minutes and arrival delay was set to 12 minutes, quite higher than in low season.

It is necessary to mention that the amount of flights is the same in this route during winter and summer due to its relevance in the US market. This is not common for all routes as in summer vacation destinations raise demand, new seasonal routes are added and airport slots raise up to its maximum capacity. This results in an increase on delays as whether there is any reduction in capacity delays may appear due to the little margin between available capacity and real demand.

But, why is there a lack of capacity if long term slots where assigned considering the physical declared capacity at both airports? We will then focus on explaining the reason of this disruptions in the following lines.

2.1.4. Weather

As the name implies, weather-related delays are caused by extreme weather conditions around an airport or along a flight route. In this section we will focus on studying the effects at the considered airports. Extreme winds, thunderstorms, rain and snow are some examples of weather-related delays.[11]

The primary cause of air traffic delay in the National Airspace System is weather. The diagram of slices located below illustrates that weather caused 75.48% of greater than 15 minute delays that were system-impacting over the six years from June 2017 to May 2022, as documented in the OPSNET standard "delay by cause" reports. The weather is the primary cause of delay due to a large demand for resources impacted by it, volume alone, caused by a large demand even with unrestricted resource capacity, contributes 14.54% to the delay. Equipment failure causes 0.38% of the delay, runway inoperability causes 5.84%, and "other" causes 3.76% of the delay. These statistics on delay include air carriers, air taxis, amateur, recreational and military aircraft.[13]

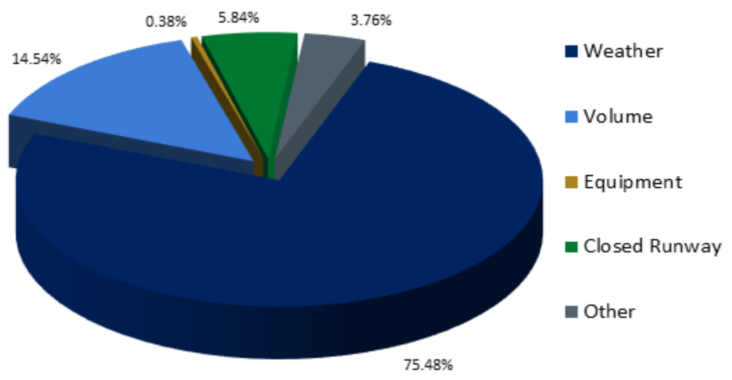

Fig. 2.4. Main causes of delay by 2017 in the United States. Weather was the main cause with a 75,5%. [13]

The physical characteristics of airports and layout of runways, taxiways and aprons are fundamental determinants of the ability to accommodate different types of aircraft and the speed at which they can be handled. Also important is the type of equipment (lighting, navaids, radar, etc.) installed throughout the airport or in specific sections. For any given runway and taxiway configuration in use, the capacity is constant. However, the capacity will vary with the configuration.

Capacity limitations are the main cause of delay. This capacity restrictions can be affected by many factors such as constructions at airport facilities, personnel strikes and, as mentioned before, bad weather.

According to FAA statistics, weather is responsible for more than 70 percent of delays in the US National Airspace System (NAS). In addition, weather continues to play an important role in many aviation accidents and incidents. While National Transportation Safety Board (NTSB) reports most often list human error as the immediate cause of accidents, weather is a major factor in 23 percent of all aviation accidents. The total impact of the weather is estimated at $3 billion in national costs, including accidental damage and injury, delays, and unexpected operating costs.[14]

Aircraft are affected mainly by visibility, low temperatures which could imply ice formation and snow, and the most common, high wind gusts.

Let’s see an example on how the weather has a direct effect on air delays. On January 24th 2017, New York City JFK airport was affected by heavy showers and winds as shown in the table below.

Time	Temp	Weather	Wind	Humidity	Barometer	Visibility
08:51	-1 °C	Heavy snow. Ice fog.	19 km/h	96%	1000 mbar	0 km
09:36	-2 °C	Snow. Ice fog.	22 km/h	96%	1001 mbar	0 km
09:51	-2 °C	Snow. Ice fog.	20 km/h	93%	1000 mbar	0 km
11:05	-2 °C	Heavy snow. Ice fog.	17 km/h	96%	1001 mbar	0 km
11:51	-2 °C	Snow. Ice fog.	N/A	93%	1001 mbar	0 km
12:51	-2 °C	Light snow. Ice fog.	11 km/h	89%	1000 mbar	1 km
13:14	-3 °C	Light snow. Cloudy.	13 km/h	78%	1001 mbar	2 km
13:51	-3 °C	Light snow. Cloudy.	N/A	74%	1001 mbar	1 km
14:14	-3 °C	Light snow. Cloudy.	24 km/h	69%	1002 mbar	2 km
14:51	-4 °C	Light snow. Cloudy.	17 km/h	69%	1003 mbar	2 km
15:31	-4 °C	Haze.	19 km/h	55%	1005 mbar	5 km

Fig. 2.5. Weather forecast in New Yor City on the 2nd January 2017. [15]

Wind gusts reached up to 24 km/h and this situation had an affectation to arrivals and departures in JFK airport. Next table shows flights departing and arriving that day in and out JFK towards LAX.

Table 2.2. Flight departures in JFK on the 9th February 2017. Bad weather was affecting the airfield. Source: MATLAB (BTS Data)

Year	Month	Day	Airline	FlightNumber	Origin	Destination	ActualDeparture	ScheduledDeparture	DepartureDelay	ActualArrival	ScheduledArrival	ArrivalDelay
2017	2	9	DL	41	JFK	LAX	21,15	18,27	168	0,19	21,52	147
2017	2	9	DL	408	JFK	LAX	20,29	15,51	278	23,33	19,15	258
2017	2	9	DL	424	JFK	LAX	18,24	16,55	89	22,33	20,3	123
2017	2	9	DL	439	JFK	LAX	16,22	8,33	469	20,08	11,55	493
2017	2	9	DL	453	JFK	LAX	21,24	20,55	29	1,09	0,25	44
2017	2	9	DL	458	JFK	LAX	17,45	14,06	219	21,35	17,15	260
2017	2	9	AA	21	JFK	LAX	18,54	19	-6	22,2	22,44	-24
2017	2	9	AA	23	JFK	LAX	22,47	22,15	32	2,25	2,03	22
2017	2	9	AA	293	JFK	LAX	20,22	20	22	23,49	23,47	2
2017	2	9	B6	1323	JFK	LAX	22,44	21,4	64	2,13	1	73
2017	2	9	B6	2023	JFK	LAX	22,59	22,5	9	2,18	2	18
2017	2	9	VX	413	JFK	LAX	17,56	16,55	61	21,44	20,15	89

By contrast, on 14th February 2017 the weather was the opposite with sunny skies, low wind gusts and excellent visibility as shown in the table below.

Time		Temp	Weather	Wind		Humidity	Barometer	Visibility
08:51		-1 °C	Sunny.	No wind	↓	61%	1015 mbar	16 km
09:51		-1 °C	Sunny.	6 km/h	↓	59%	1014 mbar	16 km
10:51		0 °C	Sunny.	9 km/h	→	59%	1014 mbar	16 km
11:51		1 °C	Sunny.	13 km/h	→	56%	1012 mbar	16 km
12:51		2 °C	Sunny.	11 km/h	↗	54%	1011 mbar	16 km
13:51		3 °C	Sunny.	11 km/h	↑	52%	1010 mbar	16 km
14:51		3 °C	Sunny.	11 km/h	↓	51%	1009 mbar	16 km
15:51		4 °C	Sunny.	11 km/h	↓	48%	1009 mbar	16 km
16:51		4 °C	Sunny.	7 km/h	↗	49%	1008 mbar	16 km

Fig. 2.6. Weather forecast on the 14th February 2017. Nice and sunny cold day with low winds and perfect visibility.[15]

In next table we can see the same flights shown in table 2.1 but in a different weather scenario.

Table 2.3. Sample of flight departures from JFK on the 14th February 2017. It was a sunny cold day with good visibility. Source: MATLAB (BTS Data)

Year	Month	Day	Airline	FlightNumber	Origin	Destination	ActualDeparture	ScheduledDeparture	DepartureDelay	ActualArrival	ScheduledArrival	ArrivalDelay
2017	2	14	DL	472	JFK	LAX	7,08	7,1	-2	10,18	10,4	-22
2017	2	14	DL	41	JFK	LAX	17	16,55	5	20,34	20,3	4
2017	2	14	DL	408	JFK	LAX	15,5	15,51	-1	19,4	19,15	25
2017	2	14	DL	422	JFK	LAX	9,54	9,58	-4	13,09	13,25	-16
2017	2	14	DL	423	JFK	LAX	12,06	11,59	7	14,57	15,1	-13
2017	2	14	DL	426	JFK	LAX	19,3	19,3	0	22,22	23,1	-48
2017	2	14	DL	439	JFK	LAX	8,39	8,33	6	11,49	11,55	-6
2017	2	14	DL	458	JFK	LAX	14,04	14,06	-2	16,54	17,15	-21
2017	2	14	AA	1	JFK	LAX	7,53	8	-7	11,08	11,41	-33
2017	2	14	AA	3	JFK	LAX	11,56	12	-4	14,58	15,27	-29
2017	2	14	AA	21	JFK	LAX	18,54	19	-6	22,07	22,44	-37
2017	2	14	AA	33	JFK	LAX	6,56	7	-4	10,21	10,39	-18

As it can be seen tables above, the difference on the delay of flights between a normal weather day, referred to the 14^{th} February 2017, compared to the 9^{th} February 2017 shows easily the influence of bad weather in air disruptions. While in a sunny day with low gusts and good visibility flights don't have even any delay, on a stormy day with strong winds, like the 2^{nd} February, the amount of delay raised up to 278 min (AA408), 168 min (DL41) or even 469 minutes in the case of AA439. As due to meteorological conditions, instrumental conditions were applied that day in JFK, the capacity of the airport was reduced as regulations obliges a bigger separation between aircraft when taxing on ground and when approaching and departing the airfield. In addition, flights had to go through de-icing, as temperatures were too low, which increased the delay at departing. At the same time, as winds were blowing from the north and northwest and runways used where 4R/L and 31L, a bit of crosswinds affected take offs and landings.

This is actually a quick example on how weather can easily affect flights schedule, sometimes even before being able to plan a contingency plan.

A big part of this delays are caused as an aircraft cannot safely fly over a thunderstorm if its altitude is below the turbulent clouds. The most violent and powerful storms are typically highest, as a result, flights that are in the path of the storm will try to avoid it.

When a busy flight path is interrupted by a severe thunderstorm, traffic is redirected to an adjacent airspace, which can become overcrowded if airflow isn't managed (see animation). In these instances, a planning team that includes FAA personnel at the command center that coordinates with the center, terminals selected by the center, airlines, NAVCANADA, general aviation organizations, and the military are involved. Several options are available, some of which will be discussed in greater detail.[13]

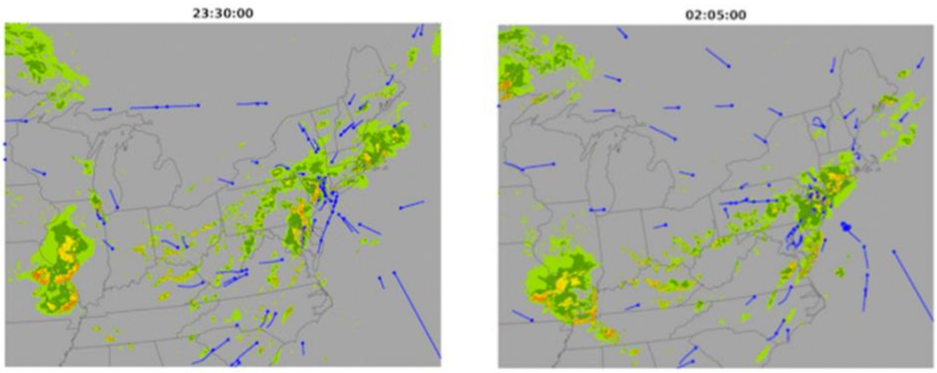

Fig. 2.7. Aircraft trajectories arriving in JFK while a thunderstorm was surrounding the airfield. Both images show the evolution of trajectories surrounding the thunderstorm in order to avoid it as it moves around. On top of this image the time when the picture was taken is shown. [13]

For example, on July 17, 2019, a low pressure swept across the southwest and across the New York metro area as a cold front approached from the north. The remnants of Tropical Storm Barry brought most of the showers and thunderstorm activity.

As can be seen in figure 2.7, only a few flights are able to pass through the weather-affected airspace, and many of these flights bypass the active area to avoid the weather. Due to the lengthy diversion, the flight to New York "couldn't arrive on time.

In the Northeast, 108 aircraft were diverted to alternate airports and 57 aircraft were on hold. There were 565 departure cancellations and 535 arrival cancellations, resulting in a total of 784 delays.[13]

We will show in next part how good weather is for predicting the amount of delay a flight is expected to have. We will focus in the implication of wind in predicting flight delays.

2.1.4.1. Wind implication in predicting flight delays

All aircraft have restrictions that must be taken into account for the daily operation. If wind gusts exceed the maximum speed limits, aircraft will not be allowed to land or take off at the designated airfield. In general, a headwind landing or take off is preferable as it helps getting to take off velocity quicker with a reduction on fuel consumption and an increase on lifting force. At the same time, for landings, it helps aircraft slowing down faster requiring less landing distance.

Crosswind landings and take offs are not always completely avoidable. They can actually make landings and take offs more difficult and potentially dangerous. In some cases, crosswinds may be strong enough to cause the plane to deviate from its intended flight path, requiring pilots to detour or divert to another airports. [16]

In our study we analyzed the effect of winds in JFK and LAX airports. A deep study on its frequency, directions and its capacity on generating delays will be carried out in next lines.

First, we will take a look at the evolution of winds affecting each airport during 2017. Next graphs illustrate it.

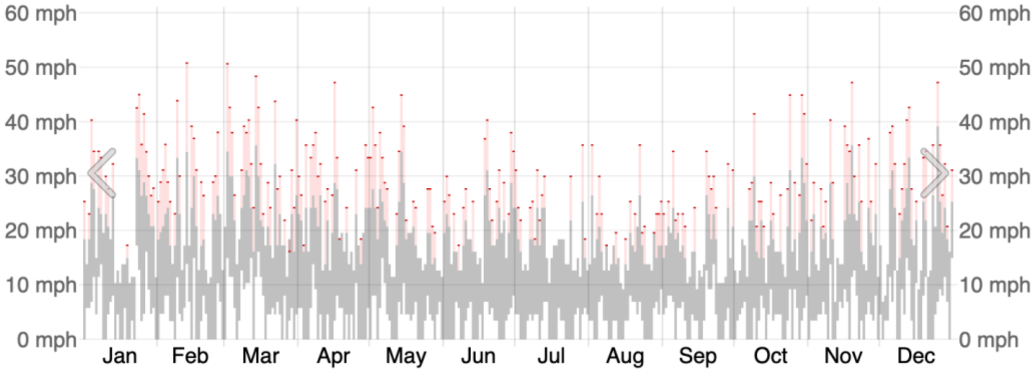

Fig. 2.8. Wind intensity depending on the month in JFK Airport. The daily range of reported wind speeds (gray bars), with maximum gust speeds (red ticks).[17]

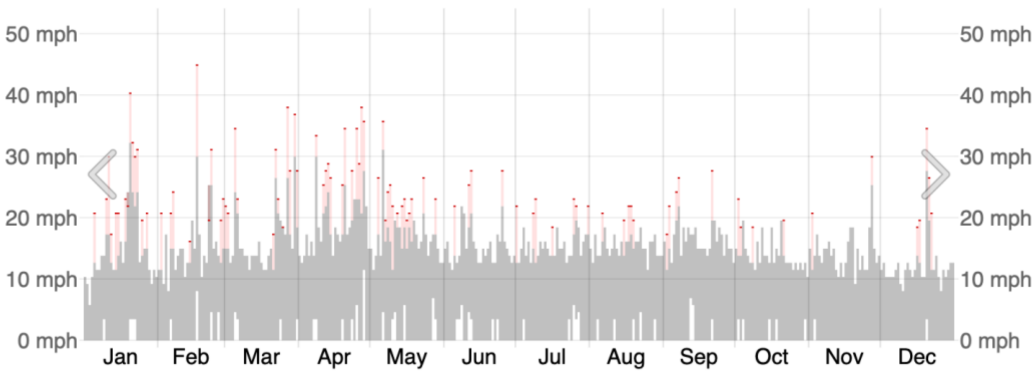

Fig. 2.9. Wind intensity depending on the month in LAX Airport. The daily range of reported wind speeds (gray bars), with maximum gust speeds (red ticks).[18]

By analyzing winds during 2017 it is shown that the windiest months in both airports were March and April. In order to be able to compare wind effect in both airport we chose March 2017 to make the study.

On next table arrival and departure data from JFK and LAX is shown.

Table 2.4. Departure and arrival delays per flight and per route in March 2017. Time values are expressed in minutes. Source: MATLAB (BTS Data)

Departure	Arrival	Flights	Delayed Flights	Departure Delay	Arrival Delay
LAX	JFK	1102	676	20,00	14,00
JFK	LAX	1103	683	12,00	18,00

In order to see which are the most predominant wind directions and its intensity, next graph illustrates a comparison between both considered airports.

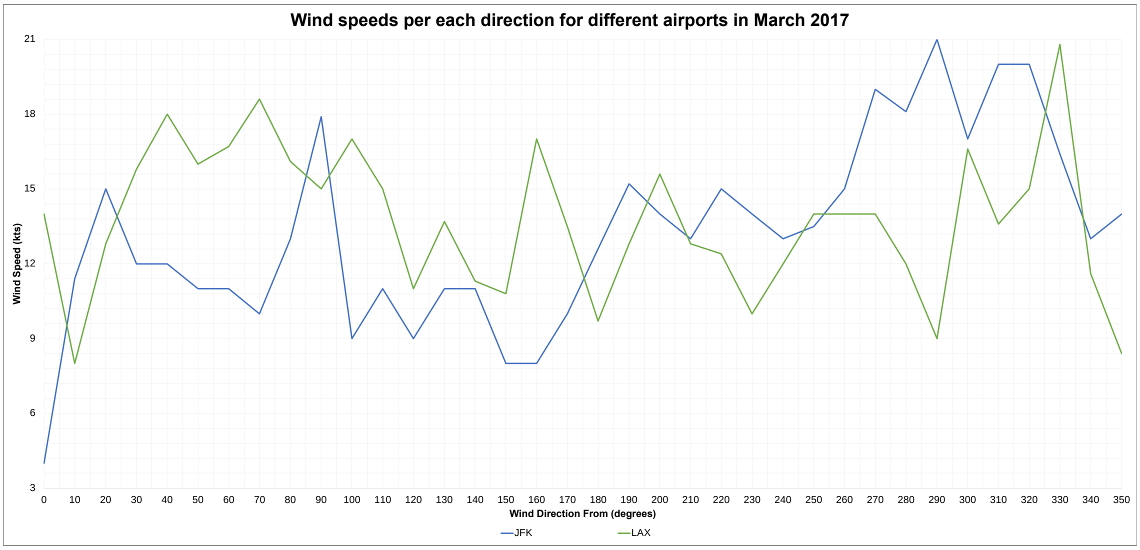

Fig. 2.10. Wind intensity per flight for each direction the wind blows from in March 2017. Source: MATLAB (BTS Data)

By looking at the blue line in previous figure, we can observe that the most intense directions the wind is blowing from in JFK are around 330º, 280º and 90º with speed values of 16.4 kts, 18.1 kts and 17.9 kts, respectively. The airport is normally operating by using runways 22R/L, 13R/L and 31L, or translated into degrees: 220º, 130º and 310º.

In the case of LAX, green line in figure 2.10, the most intense winds are found in directions 330º, 40º and 70º. The normal runway configuration uses headers 24R and 25L for the arrivals and 24L and 25R for taking off and so, its landing and departure directions are the same, 240º and 250º.

For a precise and profound analysis about wind affectation in runway operations it is also necessary to figure out the frequency this winds affect the airfield to understand the general behavior and configuration of both airports. Next graph eases this comparison.

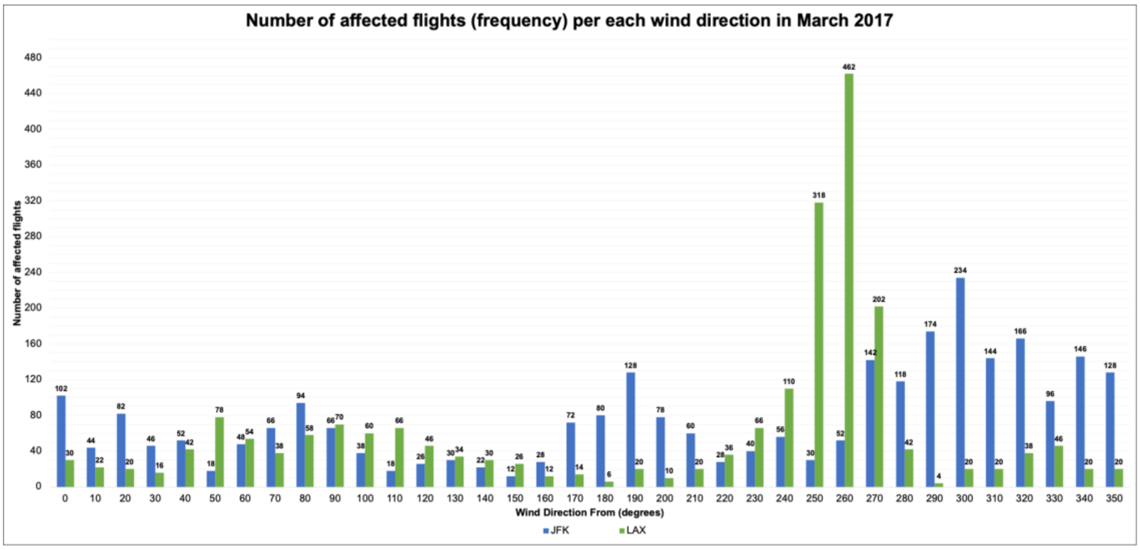

Fig. 2.11. Number of affected flights per each wind direction in March 2017. Source: MATLAB (BTS Data)

From previous figure it is extracted that the wind directions which flights more deal with in JFK, are 300º, with 234 flight operations affected in March 2017, and surrounding values from 270º to 360º with number of affected flights between 96 to 174. Also 128 aircraft encountered winds from 190º when operating in JFK. The intensity of the winds in that directions was around 20 kts for directions around 300º and 15 kts in the case of 190º. Then, it makes sense the configuration of used runways in JFK to be 22L and 13L for arrivals and 22R and 31L for departures, as aircraft depart towards directions 220º and 310º in order to make those winds become headwinds as aircraft limitations are lower for headwind rather than for tailwinds. In fact, an A320 has a technical restriction of no more than 10 kts for tailwind and 35 kts for headwind, almost 3 times more restrictive with the first rather than with the second one. For landing, directions 130º and 220º are used. The only limitation could be found at winds from 190º which become almost headwinds landing in 13L but could imply a bit of tailwind, very harmful, for runway 31L as that direction had a normal windspeed of around 15 kts in March. The same would happen for landing in 13L as winds from 300º could become tailwinds for the aircraft. Then, the most efficient operation would be using runways 22R/L all the time but, as other runways may be needed to increase capacity it is normal not finding a perfect synchronization between runways and wind direction, almost impossible actually.

In the case of LAX, the most common wind directions are 250º, 260º and 270º as affecting 318, 462 and 202 flights, respectively. The intensity of the wind in that directions was quite acceptable around 12 to 14 kts in the windiest month. In this case, those directions were not the ones with the hardest winds as those were 330º, 40º and 70º. As used runways are 24R/L and 25R/L, departing and arriving towards 240º and 250º, winds from 330º are actually not dangerous despite its intensity was around 20 kts as they become headwinds in normal runway configuration. By contrast, winds from 40º and 70º are hazardous as they become tailwinds and its intensity was quite above an A320 tolerance. Despite that, as the most common winds in LAX are the ones going from west to east the runway configuration is perfectly set as it is designed to encounter headwinds rather than tailwinds or crosswinds.

Let's compare this findings with the amount of delay generated in each direction for both airfields.

⇒ **New York JFK Airport**

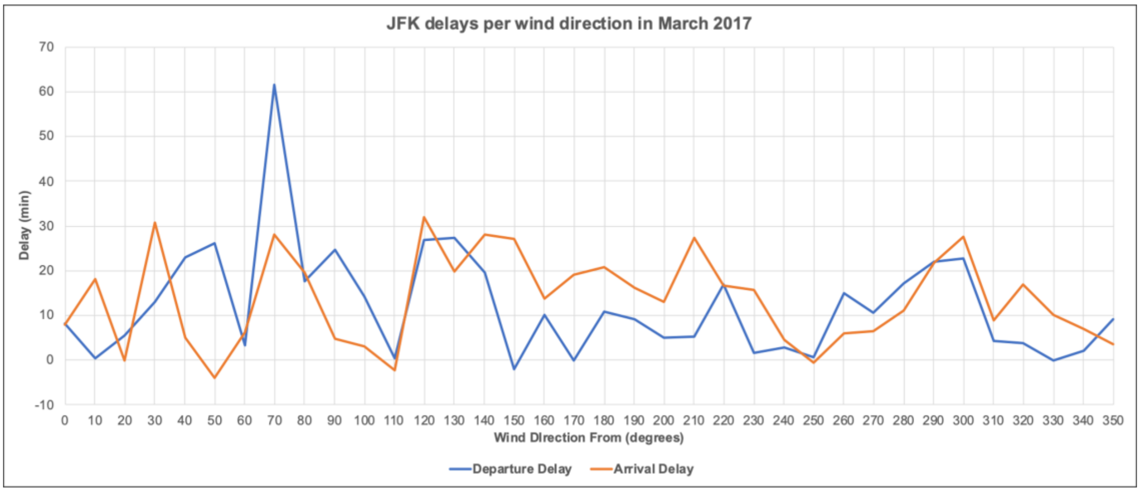

Fig. 2.12. JFK delays per flight depending on the direction the wind is blowing from, in March 2017. Source: MATLAB (BTS Data)

From figure 2.12, it is seen that when departing JFK airport the maximum delay was found for winds blowing from 70º with a maximum delay of 62 minutes, followed by directions 120º and 130º with a delay of around 30 minutes. For arrivals, highest delay peaks were about 30 minutes for directions 30º, 70º, 120º, 150º and 210º. It can be observed that arrival delay is, by tendency, higher than departure delay in JFK despite the last one having higher peaks affecting a few directions only. The rest of directions implied a maximum departure delay between 15 and 20 minutes.

When looking at normal runway configuration described in 1.1 we could see that visual conditions are the most common as far as 86% annually and departure priority is the most used configuration in that conditions. Runways 22R and 31L are used for departures and 22L for arrivals, as mentioned before. If translating headers into degrees, aircraft are departing towards directions 220º and 310º and landing towards 220º. Depending on the direction the wind comes from it could be helpful or become a hazard for airplanes. If the wind is blowing from the direction the aircraft is heading becomes a positive help for it. Instead, if it is coming perpendicular to the aircraft, named crosswind, or coming from the opposite direction to the aircraft heading, tailwind, it is then considered dangerous and could become disruptive as go arounds and diversions would be more common in that conditions.

For runways 22L and 22R crosswinds are considered for winds blowing from 270º to 360º or 0º and from 90º to 180º and tailwinds from 0º to 90º. For runway 31L crosswinds are considered from 180º to 270º as same as 0º to 90º and tailwinds from 90º to 180º.

When checking figure 2.10, we can see that winds coming from 90º in March 2017 had an intensity of around 18 knots. As this direction is critical for departing runways 22R/L, generating high tailwind, and 31L, generating crosswinds, it makes sense that 90º had the maximum delays as there is no way for avoiding it when departing the airfield due to its stablished configuration.

Wind directions around 120º also generated delays around 30 minutes as they caused crosswinds in runways 22L and 22R, the most used for landings and take-offs. By contrast, they are good for runway 31L as they behave as headwinds in that case.

It has been seen that the highest wind speeds are around 90º and 270º, actually eastern and western directions. This fact is caused as most intense winds in New York are the ones blowing from the west. So, departing towards the west would be the best option. This is what normally the airport configuration tries to enhance. Runways 22L/R and 31L/R are facing west, taking advantage of western winds to avoid disruptions. But, as long as there are gusts in the eastern direction generating then tailwinds and crosswinds, delays increase drastically. Fortunately, they are not as common as western winds so we can say the configuration of the airfield is optimized.

Arrivals in JFK are more affected by delays than departures do. Disruptions of around 20 to 30 minutes are found in directions around 120º to 210º as they generate crosswinds to runway 22L and also 30º and 70º, that generate crosswinds to runway 13L, and 300º, tailwind to 13L. As the maximum intensity is found for winds around 300º, with a velocity of almost 20 kts, this direction caused one of the maximum delays in JFK in March 2017. At the same time, 30º and 70º winds generated much crosswinds to 13L increasing arrival delays.

In conclusion, directions causing less delays would be departing and arriving towards western directions. This is why main used runways in JFK are 22R/L and 31L. Eastern directions are avoided, runways 4R/L for example, which are only used in bad conditions due to airspace restrictions. Despite that, runway 13L is commonly used for landings in order to increase capacity.

⇒ **Los Angeles LAX Airport**

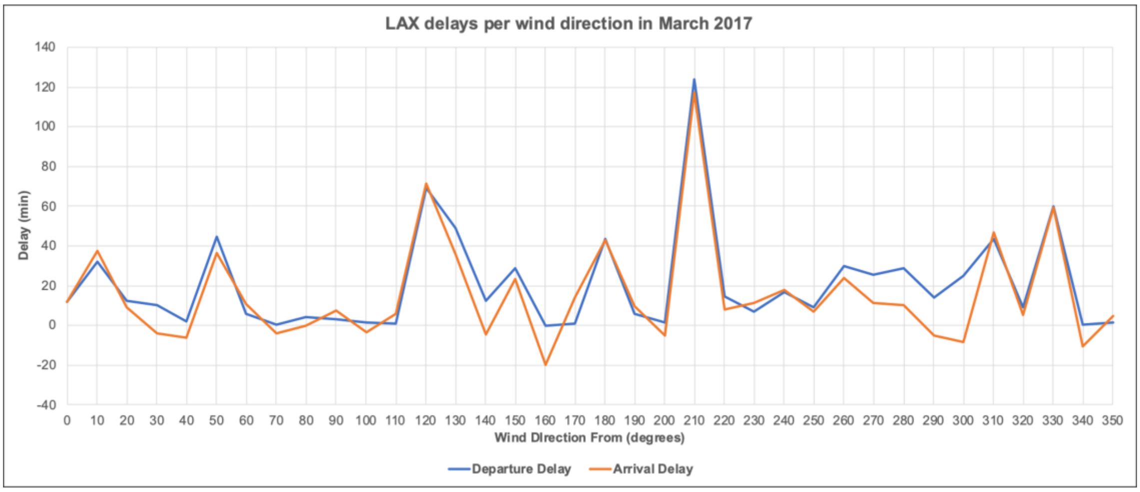

Fig. 2.13. LAX delays per flight depending on the direction the wind is blowing from in March 2017. Source: MATLAB (BTS Data)

At LAX, arrival and departure delays are similar as runway directions are the same for landing and taking off. The most affected directions are 210º, with delays around 120 minutes, and 120º, with around 70 minutes delays. At the same time, 330º generated 60 minutes delays and 10º, 50º, 310º and 180º were around 40 minutes in delay. Airport configuration sets runways 24R and 25L for arrivals and 24L and 25R for departures which means operating directions are 240º and 250º, facing west. This is caused because, if looking at figure 2.11, the most common winds are the ones blowing from the west. In fact, winds from eastern and western directions are the ones with the highest intensities and frequencies as having values around 14 to 18 kts. Then, used headers are 24R/L and 25L/R, facing west. High delays appeared on eastern winds as when they occur severe tailwinds are generated, due to its intensity, causing severe disruptions. Middle directions around 0º and 180º are the main cause of crosswinds but, as their intensity was around 12 to 14 kts and not much common, they were not much taken into account for airport design and configuration.

An exception of the rule would be direction 210º as for LAX during March 2017 it was associated to high delays which could not had been only related to wind circumstances. It could happen that the wind was related with a thunderstorm or some other phenomena, not even meteorological, generating more delays. It actually may had happened in one particular day or period affecting the entire data analysis of the month as it is not a common wind direction neither a high intensity one and so it does not reflect the general disruptive behavior in the airport, shown in figures 2.1 and 2.2. Direction 120º could be understood as the reason for crosswinds to runways despite not being the highest wind in intensity but generating much delays due to that reason.

So, it is shown that used runways are 24R/L and 25R/L due to western winds affectation, higher in intensity and frequency.

In general perspective, around 15 to 20 minutes was the normal amount of delay a flight accumulated during 2017, and also in March that year.

Wind affectation has been proved to be different depending on the directions it is blowing from as there is so much variation in delay figures but not all the delay shown in figures 2.12 and 2.13 is the only disruptive cause. We will continue analyzing other disruptive causes during next paragraphs.

2.2. Ground Time

Ground time is known as the amount of time an aircraft remains on ground, without flying. It can be considered the turnaround time between flights but, when in flight, ground time is meant to be the taxi time.

Taxi time is then the total time the aircraft remains moving on the ground. It can be the time it takes for an aircraft to get from the parking position to the runway before it is cleared to take off, or the way around when arriving. Operators use it to determine various types of information related to flight such as total fuel consumption, weight, takeoff weight, landing weight and true airspeed. Because weight plays a large role in whether an aircraft can take off or land, the amount of time a plane spends burning fuel on the ground can drastically change its take-off or landing path. Depending on the model of narrow-body aircraft, an average of 15 to 25 kilograms of fuel was consumed per minute. Airlines try to minimize their taxi time as possible in order to reduce fuel consumption.[19]

Air traffic control also invests in taxi time. The less time a plane has to taxi, the faster air traffic control can get the plane in and out of the airport. It is in the best interests of pilots, airlines and air traffic management authorities to expedite traffic to and from airports as quickly as possible, and they do so through efficient taxi routes and shorter taxi times. Larger airports tend to have more runways, allowing multiple planes to take off at the same time.[20]

The taxi time of an airplane depends on the size, layout, traffic density of the airport, season of the year, etc. Of course, relatively long taxi times are understandable at large, busy airports with heavy ground traffic.

In this context, the importance of effective techniques to minimize taxi time in airport design must be emphasized, taking into account the financial burden on companies and the environmental impact of the fuel burned during taxiing.

Let’s see the amount of ground time consumed in our studied airports. In next graph we can see the evolution during the year 2017.

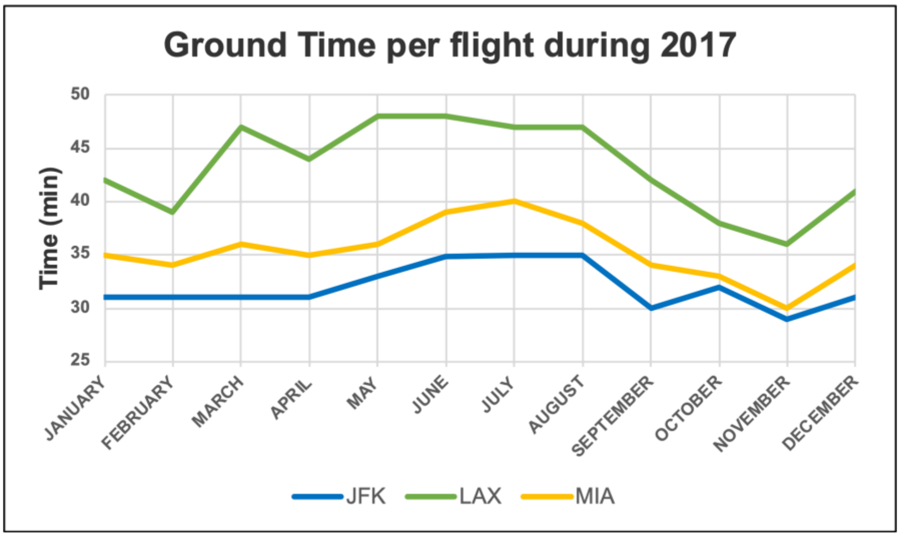

Fig. 2.14. Ground time per flight in JFK, LAX and Miami (MIA) airports during 2017. Source: MATLAB (BTS Data)

As it can be observed in previous figure, the amount of ground time is higher in LAX, followed by JFK and finally by Miami (MIA). The maximum ground time is reached in May and June as for Los Angeles Intl. there is a ground time per flight of around 48 minutes. New York's JFK airport and Miami reach its maximum ground time per flight in July with 35 and 40 minutes per flight, respectively. At that time, LAX is in 47 minutes taxi time per flight, around 10 minutes more than JFK and MIA. Seasonality effect is seen in high season as airports are crowded and more flights are planned. As so, high demand increases taxi times which translate into more ground time rather than in low season with fewer traffic. It is also important to mention the fact that the minimum time a flight spends on ground at one of the studied airports is not less than 30 minutes in total, a very high number but logical if thinking of huge American airports with high traffic values.

At this point we should mention the fact that there is no control when departing and arriving at American airports in order to reduce delay and holdings due to lack of capacity as there is in Europe. In the US, a flight can ask ATC for departure clearance and will be authorized without restrictions but it will then face a long queue at the taxiway in order to take off, especially in high demanding periods such as summer or any other holidays (high season mainly) as in those periods demand overlaps capacity.

Let's separate ground time by taking taxi at arrival and departure at mentioned airports, as the first is the sum of the two others.

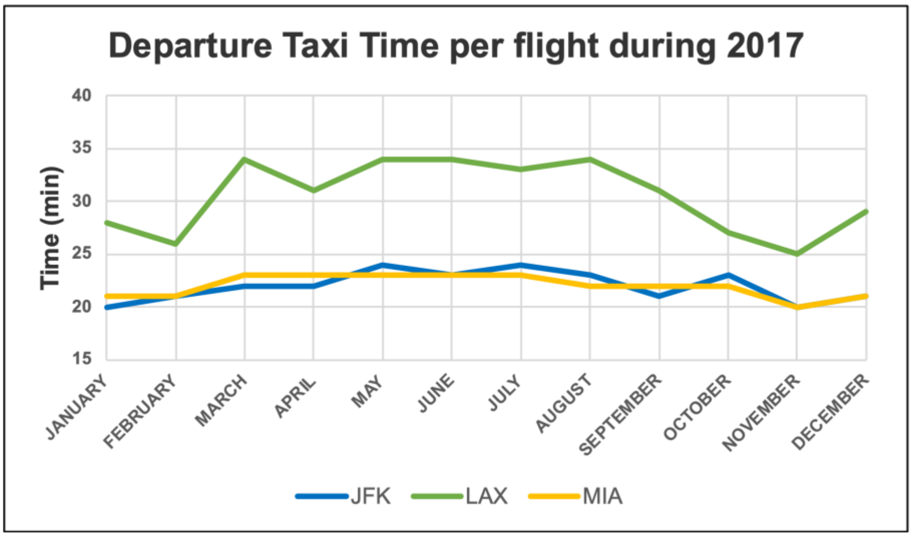

Fig. 2.15. Taxi time per flight at departure in JFK, LAX and Miami (MIA) airports during 2017. Source: MATLAB (BTS Data)

When comparing figures 2.14 and 2.15 we can check that the highest time an aircraft is staying in ground is mainly when departing, as around 70% of ground time is meant to be taxi time at departure. Long queues at runways due to exceeded demand and no regulation for departing in high traffic periods raised taxi time at departure up to 34 minutes between May and August 2017 in LAX. Los Angeles Intl. is the airport with the highest taxi times among all three studied. While taxi departing JFK and MIA is more or less static and similar in value moving around 20 in low season to 24 minutes in high season. LAX values moved from 25 minutes in lowest demand season to 34 in summer season.

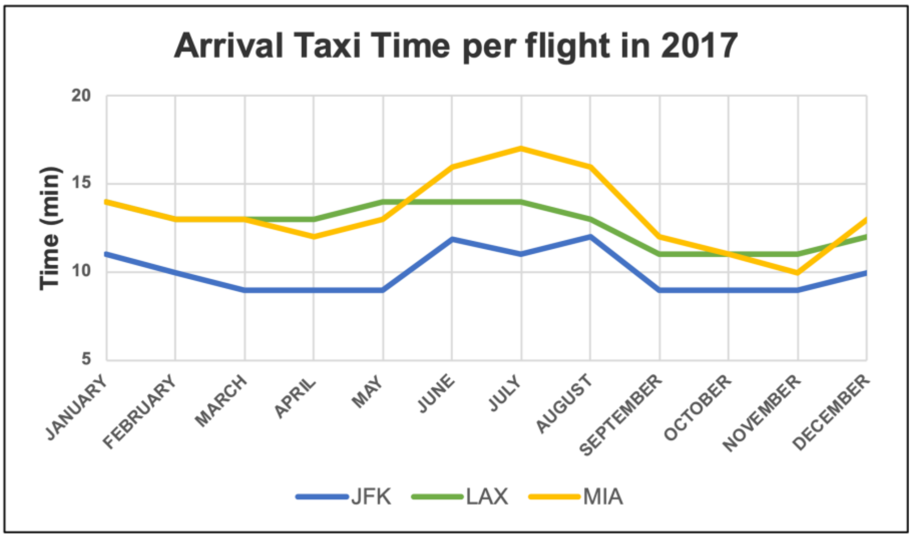

Fig. 2.16. Taxi time at arrival per flight in JFK, LAX and Miami (MIA) airports during 2017. Source: MATLAB (BTS Data)

The amount of taxi time when arriving at the airports is always lower than at departure. Planes are prioritized at landing, when reaching ground, in order to get to their gates and, as a difference between departures, there are no queues in the ground after landing, those waits are done in the air, via holding patterns affecting the air time, which will be explained later, and increasing arrival delays, shown previously. JFK had the lowest taxi time at arrivals among all three studied airports staying around 10 minutes during all year. LAX performed well in arrival taxi times moving around 13 minutes and Miami had similar values as LAX with a high peak in summer reaching, in July 2017, 17 minutes per flight of taxi time when arriving.

Before ending this section, we need to mention that New York and Los Angeles are metropolitan areas with high traffic demand, not as much as Miami, a very seasonal destination as its mostly demanded in vacations periods. The demand for both regions is really high. While LAX is the main and almost only international airport in the metropolitan area of Los Angeles, in New York there are three international airports that manage all existing demand: JFK, La Guardia and Newark Liberty in New Jersey. This could explain that despite LAX has a higher operations hourly rate it has to manage all demand for the region and so, delays and taxi times are higher than in JFK or Miami, having less traffic, especially in the case of Miami.

2.3. Air time

The air time is considered the amount of time between the aircraft's take-off from the runway at origin airport until it finally touches down at destination. This value can be affected by many disruptive phenomena such as airspace congestion or bad weather during the flight and at destination airport, which will imply air traffic control to give holding patterns to the flights arriving or even deviating to alternate airports.

The evolution of air time in both studied routes during 2017 is shown in next figure.

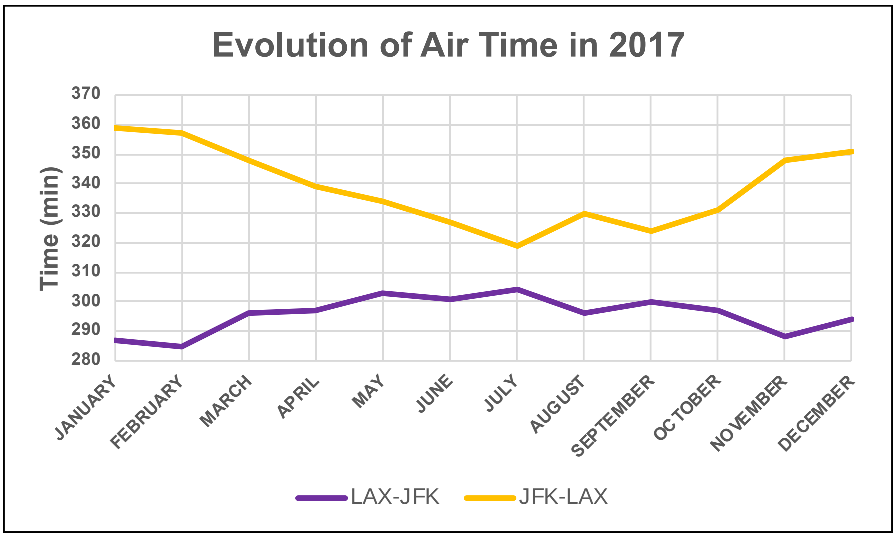

Fig. 2.17. Evolution of air time per flight in both directions of the studied route during 2017. Source: MATLAB (BTS Data)

When observing previous figure, it is seen how different the amount of air time is when an aircraft is actually flying the same route but in a different direction. Flights from JFK to LAX are longer then the other bound for JFK. This time difference can be, depending on time of the year, about 74 minutes more air time flying in one direction rather than the way around. This curiosity, seen also in transatlantic routes between the US and Europe, is mainly caused by a weather phenomena called jet streams very effective flying from west to east.

2.3.1. Jet streams

As we said before, in this paper we will focus on analyzing mainly flights between East and West coast in the US. As for that, a big weather phenomena that is set to affect these flights, and so its performance, are jet streams.

When flying routes from east to west and the way around we can observe a discrepancy in flight times, as seen in figure 2.17 between the eastern and western directions. This is caused by the spinning of the earth around its own axis. This particular turn generates a phenomena called jet streams which are relatively narrow bands of strong winds in the upper atmosphere.

Jet streams are actually generated due to the difference in temperature between the two hemispheres and the equator. This temperature difference generates simultaneously a pressure difference shown in figure 2.8. As temperature is linearly related to pressure, the northern we go in the earth, the colder it is and so the higher the pressure. In contrast the closer we are to the equator the hotter it is and the lower the pressure. As pressure tends to go from high to low an air current is generated from the equator to the north. In our case we will focus in the northern hemisphere but the same happens in the southern hemisphere.[21]

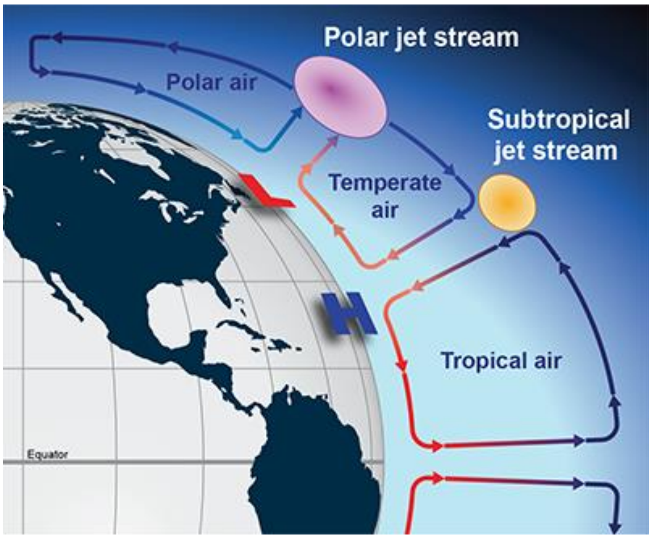

Fig. 2.18. Formation of jet streams as a difference in temperature between northern hemisphere, in our studied case, and the equator.[21]

The motion of the air is not directly north and south but is affected by the momentum the air has as it moves away from the equator consequence of the rotation of Earth on its own axis. The reason has to do with momentum and how fast a location on or above the Earth moves relative to the Earth's axis. The momentum the air has as it travels around the earth is conserved, which means as the air that is over the equator starts moving northern or southern towards one of the poles, it keeps its eastward motion constant. The Earth below the air, however, moves slower as that air travels toward the poles. The result is that the air moves faster and faster in an easterly direction (relative to the Earth's surface below) the farther it moves from the equator.[21]

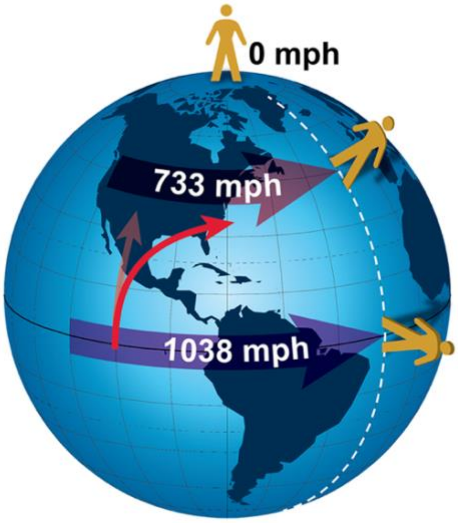

Fig. 2.19. Air currents from the equator to the north due to pressure difference are affected by the motion of the Earth around its own axis generating jet streams. At the same time currents are always higher closer to the equation as distance from the Earth axis is higher and more momentum is generated.[21]

This has a direct impact on the duration of flights going in the east and west directions. Flights from west to east are normally shorter in time considerations than the way around. This is caused as they are affected by high tailwinds increasing its relative speed with the ground without increasing its true speed. This concept is shown in our analysis of flights between New York and Los Angeles. Routes between LAX and JFK, eastern bound, have a shorter flight time duration rather than the opposite direction or, being more technical, its air time is always shorter than the way from east to west. There is a curiosity with jet streams as in February 2022 a British Airways Boeing 747-400 beat a speed record in the subsonic rate by flying from New York to London (to the east) in only 4 hours and 55 minutes flying at around 800 miles per hour.[22]

If we focus on figure 2.17 we can observe how flights from JFK to LAX had an air time between 319 to 359 minutes depending on the period of the year and flights from LAX to JFK an air time between 285 to 304 minutes. This is the direct effect of jet streams in reducing flying time. In the route the air time is not static, it depends on the season of the year for both directions. Jet streams are stronger in winter when there is more temperature difference between our location and the equator generating harder jet streams. Stronger streams make the flight to LAX harder to get there and so block time is increased. By contrast, in the flight to JFK the opposite happens. In summer flights from the west to the east are longer than in winter as currents are lower and so flight times are increased.

To sum up, we can see how jet streams can cut down flight times and reduce fuel burn with important positive revenue consequences for airlines and meaning a reduction on environmental emission when taking advantage of them. However, there are a few inconvenience related to this phenomena. There are many studies relating jet streams to clear air turbulence, CAT in advance. CAT is a sudden severe turbulence that happens in clear skies, with no clouds, causing a deep shake in aircraft. This phenomena is caused by the encounter of a higher pressure region with a lower pressure region derivate of having two jet streams with both different velocities and so different pressures, creating an pocket with extreme disturbance due to exchange of pressure, in case of faster air is beneath aircraft and lower inside a sudden downstream air current may appear as pressure goes from higher to lower making the aircraft suddenly loss of altitude and vice versa if faster currents are above the aircraft and slower below. [22]

2.4. Block time

Block time is considered the total flight time which includes air time and ground time. The block time of a flight is calculated from the moment the aircraft leaves the gate until it comes to a complete stop on arrival at the destination airport parking position. It covers all phases of flight, from taxiing to takeoff, flight time, landing and parking. Block time calculations are critical for airlines to efficiently manage flight schedules and optimize resources. Accurate turnaround time estimates are critical for flight planning and scheduling, crew planning, and revenue management. Deviations in block time scheduling calculations can lead to flight delays, missed connections and other operational issues.

Both ground time and air time are affected by delays, there is then an scheduled block time and finally a real block time, which can be equal to the scheduled one or even higher or lower.

Next figure shows the evolution of scheduled block time in studied route between LAX and JFK during 2017.

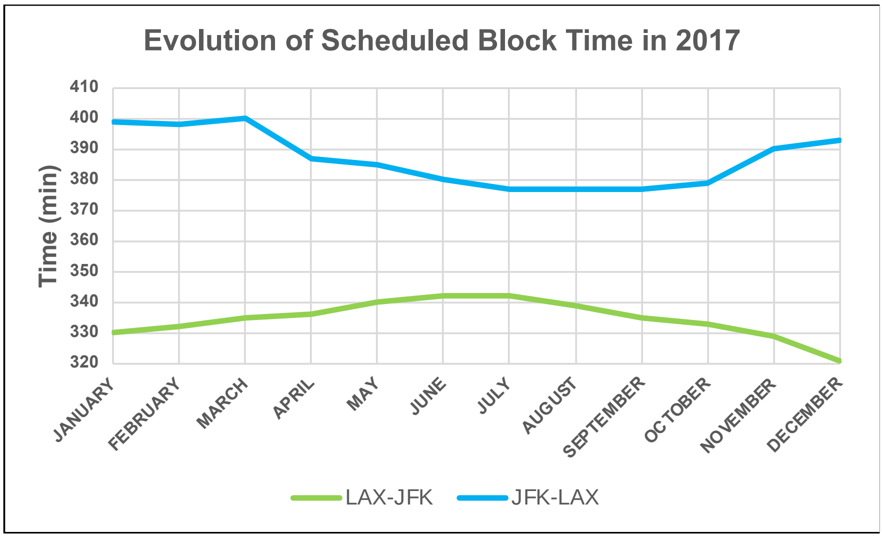

Fig. 2.20. Evolution of scheduled block time per flight in the studied routes during 2017. Source: MATLAB (BTS Data)

As mentioned before, the main reason why block time differs depending on the direction our flights are taking is mainly caused by a phenomena called jet streams. In most extreme cases, flights differed in 2017 a duration around 70 minutes between directions in winter, when jet streams were stronger and a minimum divergence of 29 minutes was observe that summer when those were actually weaker. Seasonality is extremely relevant when scheduling flights as the influence of jet streams, as same as demand, varies depending on the season.

However, despite jet streams are the major cause of this difference in flight times, it is not the only variable for scheduling a determined amount of block time. The market, operators basically, modify block times depending on various factors such as high traffic periods, commercial decisions, weather phenomena affectations, etc. During high traffic periods in summer or winter vacations block times are increased as delay in the ground and airspace congestion is expected but in the graphs it can not be appreciated as the effect of jet streams mark the general tendency of the evolution during the year. Airlines, which we will talk in advance, schedule longer block times in order to avoid having an official delay of their flights. That is one of the most commented perceptions of travelers around the world, mostly seen in long haul flights, when their flights are finally lasting long less than expected from schedule. This cases in particular will be explained in chapter 3.

Let's take a look at the real block time that flights have depending on the time of the year during 2017.

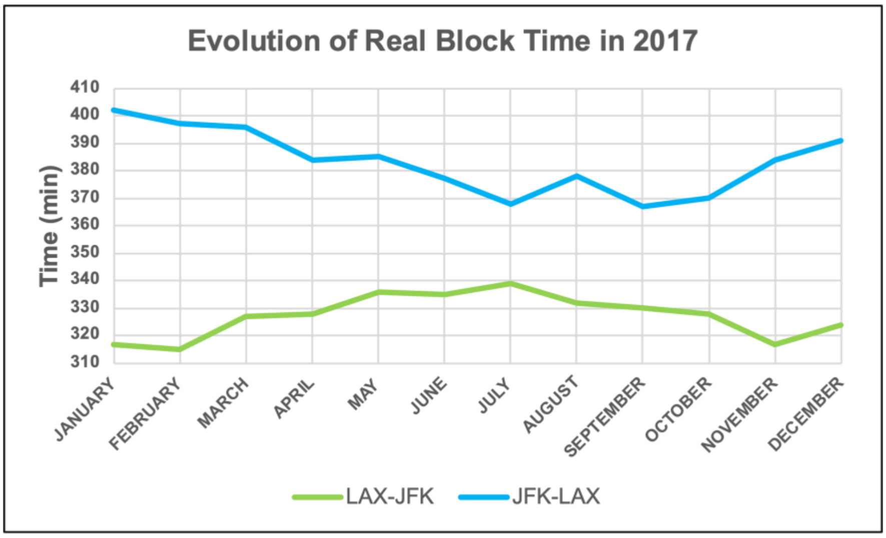

Fig. 2.21. Evolution of real block time per flight in the studied routes during 2017. Source: MATLAB (BTS Data)

At first seen, it looks like there is not much difference between figures 2.20 and 2.21 but next table can ease this comparison.

Table 2.5. Time difference between scheduled and real block time of both directions of the route. The greener the value the shorter the time separation between block times. Source: MATLAB (BTS Data)

	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
SCHEDULED	69	66	65	51	45	38	35	38	42	46	61	72
REAL	85	82	69	56	49	42	29	46	37	42	67	67
DIFFERENCE	16	16	4	5	4	4	-6	8	-5	-4	6	-5

Previous table shows scheduled time difference among flights from JFK to LAX and back and the actual difference after completing those flights, the real duration. There is a third difference calculated which actually can be understood as the difference of differences and indicates the proximity to reality between scheduled and real block times. If these difference was 0 would mean a perfect scheduling, adapting to disruptions and other effects in real time (short term planning). As it is almost impossible to anticipate to all disruptive phenomena there is always a difference. This difference indicates how far reality differs from schedule. Negative values mean there is more difference between scheduled flights than real ones and so, in the real operation block times in both routes were closer in duration rather than expected.

2.5. Delay recovery

Aircraft can actually reduce its departure delay. If a flight departs with some delay due to disruptions in ground it can recover entirely or partially this delay in the air by accelerating or changing its flight path if possible or even taking advantage of air currents like jet streams, a very common technique. The problem remains in whether there is an arrival delay due to holding patterns when arriving at destination airport or on the ground after landing but, as seen in previous explanations, departure delay is always higher than arrival one.

It is interesting to analyze how many flights recover delay in the air. Let's see again the evolution during 2017 analyzing departure and arrival delays.

Table 2.6. Delay recovery per flight for flights in the route LAX – JFK. Source: MATLAB (BTS Data)

	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
DEPARTURE DELAY	11	13	20	18	37	17	11	8	0	7	1	1
ARRIVAL DELAY	4	2	14	11	32	12	15	5	-1	5	-7	6
RECOVERY	7	11	6	7	5	5	-4	3	1	2	8	-5

Table 2.7. Delay recovery per flight for flights in the route JFK – LAX. Source: MATLAB (BTS Data)

	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
DEPARTURE DELAY	3	1	12	9	20	3	5	2	-1	0	-2	0
ARRIVAL DELAY	18	16	18	14	25	12	4	12	-4	-1	-3	5
RECOVERY	-15	-15	-6	-5	-5	-9	1	-10	3	1	1	-5

From previous tables it can be extracted that it is more common to recover departure delay in the route LAX to JFK rather than in the opposite direction. Despite LAX had a higher departure delay in 2017, the big effect of jet streams could reduce this delay in 11 minutes (February 2017) which meant up to an 80% delay recovery. However, in summer and high demand periods due to lack of capacity and increase in demand and traffic, there was no possibility in recovering delay except for December and July 2017 with an increasing delay of 6 minutes and 15 minutes respectively when arriving in JFK, despite the effect of jet streams. At the same time, in the other way jet streams make the opposite effect with flights by normally not even recovering departure delay but even increasing arrival delay.

In conclusion of this part, LAX is seen as one of the most congested airports and, from previous data, it can be seen it has more delays than JFK. Seasonality, as said before, is a big concern as in winter the difference in delays between airports is higher, JFK having small or even no delays and LAX being a little more disrupted having always delays except in September. JFK even achieved that flights to depart and arrive prior than scheduled in winter.

In summer the situation gets worse but LAX has always more delay than JFK for departures and arrivals.

It is then concluded the most efficient direction of the route is LAX to JFK. Despite LAX departure delays are higher than JFK's, the effect of jet streams reduces in a high proportion that delay and JFK arrival delay becomes not as high as LAX's. The resultant amount of delay in that route is normally dependent on departure delay in LAX. It's important to mention that as jet streams are stronger in winter there is also more in-flight delay reduction during winter rather than during summer as ground delays in winter are such lower than in summer. This case is observed in 2017 data except in December, due to Christmas vacations and New Year’s Eve which implies a rapid increase in demand and operations in the middle of the low season generating high ground delays.

CHAPTER 3. AIRLINES PERFORMANCE

The Federal Aviation Administration (FAA) handles yearly around 16 million flights with an average of 45 thousand handled per day.

United States Department of Transportation defines a major carrier as a US based airline which revenue rises up to $1 billion during a fiscal year. There are then 19 major airlines in the US, including legacy carriers such as American Airlines, Delta Air Lines and United Airlines, as well as numerous regional and low-cost carriers such as Southwest Airlines, JetBlue and even Alaska Airlines. The number may fluctuate due to mergers or bankruptcies among them. In this project we will focus on the domestic market operating between both major airports in the US, JFK and LAX.

It is important to have an overview the current situation in the US airline market. As shown in the figure 3.1 below, in 2022 domestic market was mainly dominated by American Airlines, with a 17,5% of the market, followed by Delta with a 17,3% stake. Southwest Airlines, America's biggest and first low cost carrier, ended 2022 with a stake share of 16,9%, followed by United Airlines having a 15,6%. Next graph illustrates this market share with data analyzed from February 2022 to January 2023. [23]

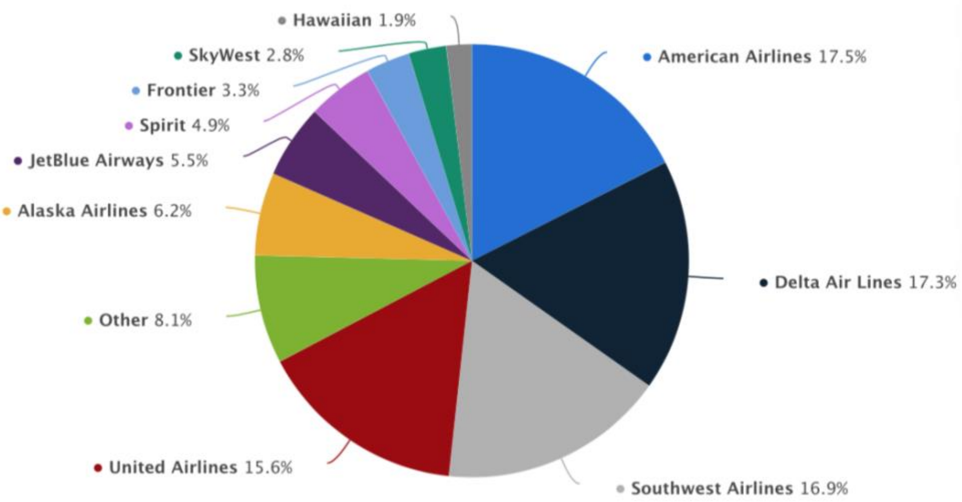

Fig. 3.1. Domestic market share of major US airlines during 2022. [24]

Despite the appearance of Southwest Airlines, the biggest low-cost airline in the US, most of the market is dominated by three major flag or legacy carriers: American Airlines, Delta Air Lines and United Airlines. All three together handle almost half of the domestic traffic in the United States.

The performance of all previous airlines will be analyzed in our route between LAX and JFK airports. From all the operators mentioned before, only four are actually operating the route from selected airports and also were doing so in 2017, the analyzed period. This carriers are American Airlines, Delta Air Lines, JetBlue and Alaska Airlines, former Virgin America. Los Angeles Intl. Airport is a hub airport for Alaska Airlines, American and Delta. John F. Kennedy Intl. Airport is also a hub for American and Delta and the base airport for JetBlue.

3.1. Scheduled and real block times

An important parameter to begin our comparison with the performance of different airlines is the block time. We will now compare airline scheduling for block times in both routes.

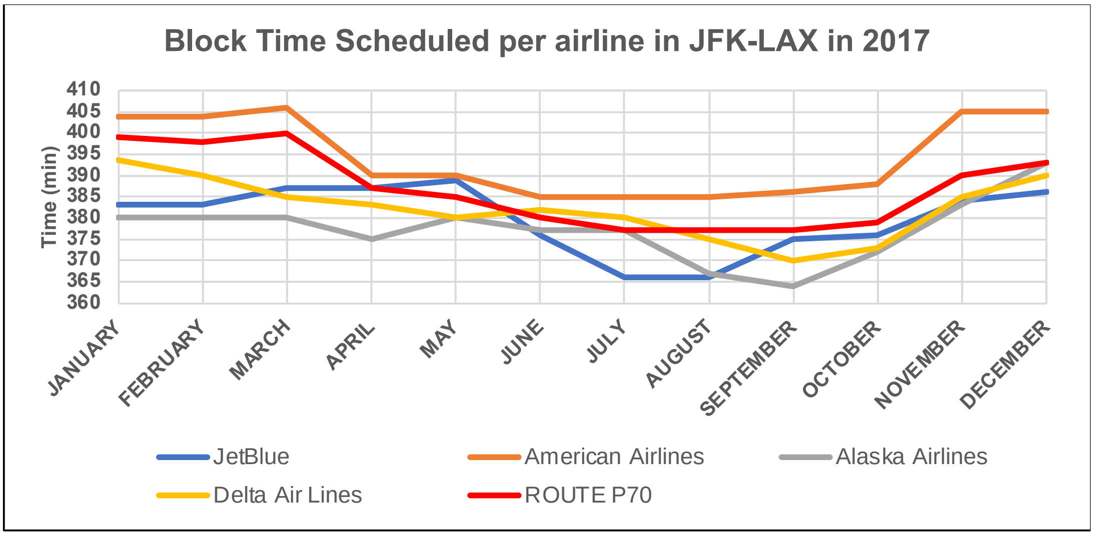

Fig. 3.2. Scheduled block time per flight for different airlines in route JFK - LAX during 2017. Red line shows the standard block time calculated in the 70th percentile. Source: MATLAB (BTS Data),[12]

As we can observe from figure 3.2, American Airlines was the carrier with the highest block time in the route during 2017. It is the only airline with always its block time being over the 70th percentile standard value (red line), calculated by taking into account the values for all airlines operating in the route. By contrast, Alaska Airlines had, almost during all year, the lowest block time scheduled among all airlines, only surpassed by JetBlue during high season. Alaska Airlines, Delta and JetBlue were normally around standard block time value marked in red, with similar block times.

Now, let's compare this values with the way around, from LAX to JFK.

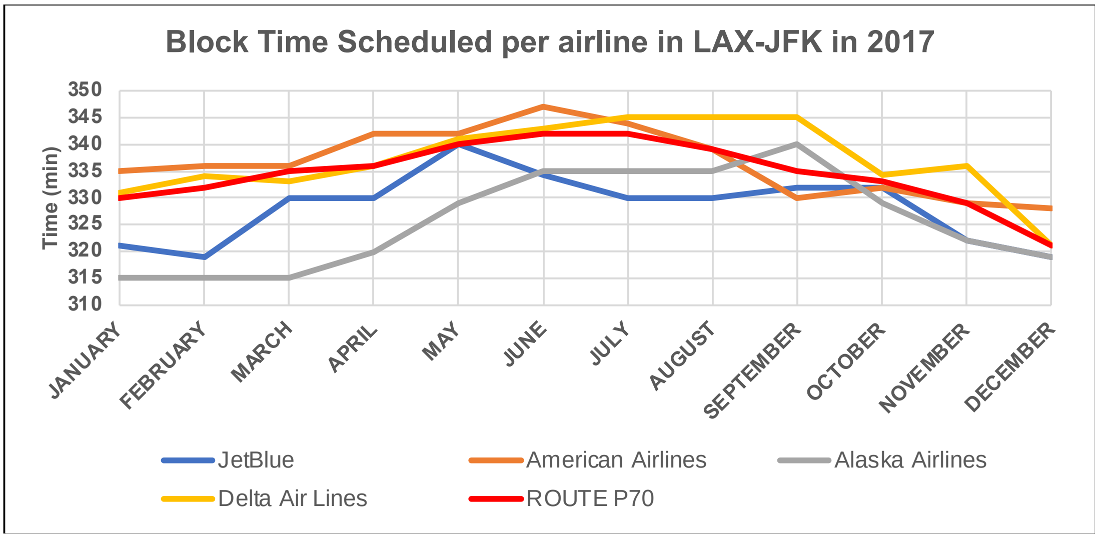

Fig. 3.3. Scheduled block time per flight for different airlines in route LAX - JFK during 2017. Red line shows the standard block time calculated in the 70th percentile. Source: MATLAB (BTS Data),[12]

In the bound LAX to JFK, American was again the airline with the highest block time, but followed closer by Delta, which actually passed above American from July to November 2017. The red line shows again routes' standard value in the 70th percentile and both airlines are normally above this value during 2017 (American was in September 2017 below this value).

By contrast, airlines with the lowest block times were again JetBlue and Alaska Airlines. Alaska, in particular, had the lowest block time from January to June with values being below the standard value from 3 to even 20 minutes below in March 2017. In the second half of the year JetBlue was the lowest scheduling.

Then, we can extract a rapid conclusion by saying JetBlue and Alaska Airlines compete in being the fastest airlines by having lower block times but probably delaying flights as their schedule is too adjusted to reality. Legacy carriers prefer to increase their block times in order to try avoiding delays.

But is that completely real? Let's check it out by looking at real block times, once aircraft have already flown the route.

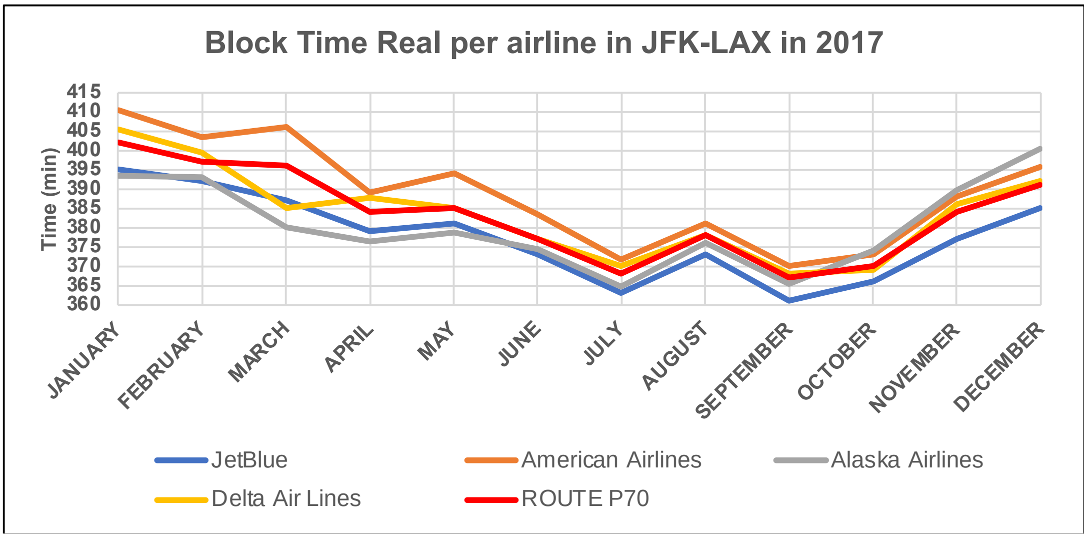

Fig. 3.4. Real block time per flight for different airlines in route JFK - LAX during 2017. Red line shows the standard block time calculated in 70th percentile. Source: MATLAB (BTS Data)

In the way for LAX, we can see that the final block time variation we talked before in which airlines scheduled above or below the main standard value in the 70th percentile value depends a lot in seasonality. Whilst in winter, or low season, Delta and American were above that value an far from JetBlue's and Alaska Airlines' values, which were below the red line with a difference between both groups of about 5 to even 25 minutes, in summer, or high season, block times got closer as delays increased and real block time for JetBlue and Alaska Airlines increased getting closer to the values of American and Delta which were not as affected as the previous ones by being higher, covering those delays as expecting them in advance. In that period, the maximum difference between JetBlue, with the lowest real block time, and American Airlines, with the highest one, was about 8 minutes by August 2017, lower than in winter season.

If looking accurately figure 3.4, a general tendency was perceived for all carriers as their real block time decreased simultaneously when getting closer to summer season. This effect was caused mainly by to the lower counter effect of flying against jet streams in this direction as they are weaker in summer than in winter.

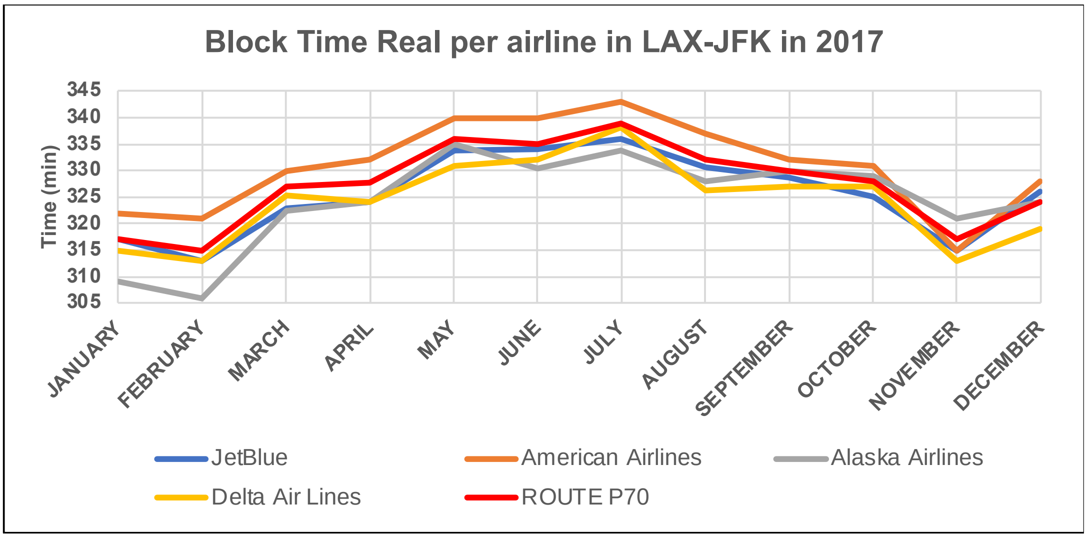

Fig. 3.5. Real block time for different four airlines in route LAX - JFK during 2017. Red line shows the standard block time calculated in 70th percentile. Source: MATLAB (BTS Data)

The same happened in the other direction for JFK, as due to the increase in delays during high season, carriers with lower scheduled block times in reality got closer to the ones scheduling higher values as they were more affected by those disruptions. In this case only American Airlines had a block time value above the standard 70th percentile marked in red.

The general tendency on the block time was this time, by contrast with the other direction of the route, to increase during summer as jet streams are weaker, not helping as much as in winter on reducing air time, actually the opposite effect shown in figure 3.4. In this case, low season block time divergences between airlines were lower being just 15 minutes the maximum time difference as for February 2017 between American and Alaska Airlines, the highest and lowest carriers performing the flight.

Consequently, it is important to mention the difference between scheduled and real block times focusing more in the values per airline than doing an overall analysis. How much do airlines tell the truth on how long their flights are? Next table will ease this comparison.

⇒ **LAX – JFK**

Table 3.1. Real vs. scheduled block time differences among the studied airlines during 2017 in the route LAX – JFK. Source: MATLAB (BTS Data)

	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
JetBlue	4	6	7	6	6,1	0,2	-5,9	-0,6	3,2	7	7	-7
American Airlines	13	15	6	10	2	7	1	2	-2	1	14	0
Alaska Airlines	6	9	-7,5	-4	-6	4,7	1,2	7	10	0	1	-5
Delta Air Lines	16	21	7,7	12	10	11	6,7	18,6	18	7,4	23	2
ROUTE P70	13	17	8	8,3	4	7	3	7	5	5	12	-3

We can see from the previous table that Delta Air Lines was the carrier with higher scheduling with respect to real block time by being planning 15 or even 20 minutes more block time than needed. By contrast in the bound for JFK, Alaska Airlines, the one with the lowest scheduled block times, showed up a negative difference in many months which means that their flights were normally longer than expected by their schedule.

⇒ **JFK – LAX**

Table 3.2. Real vs. scheduled block time differences among the studied airlines during 2017 in the route JFK – LAX. Source: MATLAB (BTS Data)

	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
JetBlue	-12	-9,1	0	8	8	3	3	-7	14	10	7	1
American Airlines	-6,3	0,5	0	1	-4	1,6	13,2	4	16	15	17	9,2
Alaska Airlines	-13,3	-13,1	0	-1,5	1,2	2,7	12,4	-9	-1,5	-2	-6,8	-7,3
Delta Air Lines	-11,7	-9,5	0	-4,8	-5	5	10	-3	2	4	-1	-2
ROUTE P70	-3	1	4	3	0	3	9	-1	10	9	6	2

In the bound for LAX, there was a big difference as many flights had a real block time higher than scheduled compared to flights departing towards JFK. This was caused by high arrival disruptions in JFK and also probably because of the counter effect of jet streams, higher in winter when real block time was higher than scheduled.

But not all airlines were performing the same way. Alaska Airlines was the one suffering more delays as much of their flights were scheduled with a block time not realistic with reality, up to 13 minutes difference appeared, except in July 2017 when there were scheduled 12,4 minutes per flight more than needed. By contrast, American had a better scheduling from January to June and actually all flights until the end of 2017 were arriving before planned time, even 13 minutes before in July 2017. JetBlue performed well from March to December except in August when flights where arriving 7 minutes after schedule and in January and February between 12 and 9,1 minutes late. In September, too much block time was calculated as flights arrived 14 minutes before schedule. Surprisingly, Delta's calculations were well performed along the year except in January and February with flights arriving around 10 minutes after schedule and in July 2017 around 10 minutes late, too. However, Delta was not performing so well as its delay could be compared to the ones of JetBlue and Alaska Airlines despite having a much higher block time scheduling. For that reason, we can then say that the worst airline scheduling is Delta Air Lines

A tendency can be appreciated as all airlines during January, February and some in August were suffering an increase of block time that they didn't actually expect. Despite carriers in the way for JFK raised their block times in order to cover counter effects of jet streams, they were actually not enough realistic as in reality the flight duration was generally increased. By contrast, in the way to JFK block time was overcalculated as all airlines expected an increase in real flight time.

But again, despite Delta had a higher block time than JetBlue and Alaska Airlines, performance of this last was questionable as it could not manage to cover all its delays in its block time and its performance was similar to the one of JetBlue and Alaska Airlines.[12]

As mentioned, the increase in real block times in some months could be related to high disruptive phenomena as jet streams would not have been the only reason for delays due to its predictable pattern.

3.2. Delays and air time comparison

Flight delays are very common in the US as seen in previous explanations. Depending on the block time airlines schedule in their flights, this delays would have an effect or not in the punctuality of their flights

A comparison on the amount of delay of each airline in each route will be performed in next paragraphs.

⇒ **LAX - JFK**

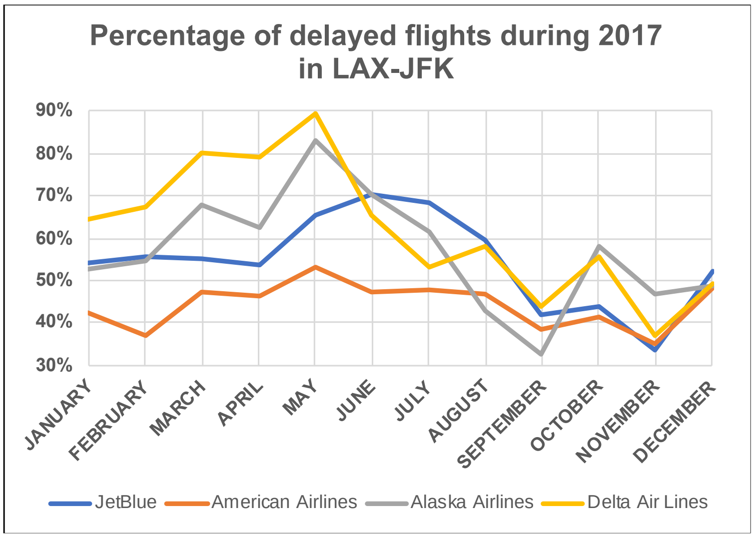

Fig. 3.6. Percentage of delayed flights per airline during 2017 in the route from LAX to JFK. Source: MATLAB (BTS Data)

As it can be appreciated in the previous figure, in the route from LAX to JFK, Delta was the airline with the highest percentage of delayed flights from January to May 2017, reaching 90% of flights delayed in May 2017. At the same time, American had the lowest percentage of disruptions reaching a difference of about 40% in May 2017 with respect to Delta by having around 50% delayed flights. American was more static in delay percentage having all months a value between 40% to 50%, approximately, whilst Delta went from 90% in May to 37% in November. Alaska and JetBlue were always in the middle of both legacy carriers. Alaska was the second most unpunctual airline from January to May 2017 with maximum percentage of delay reached in May 2017 up to 83%, but then descending to become the less affected of all four carriers in September 2017, with a value of 33% delayed flights.

In order to explain previous results, we will look at the arrival and departure delays for the route.

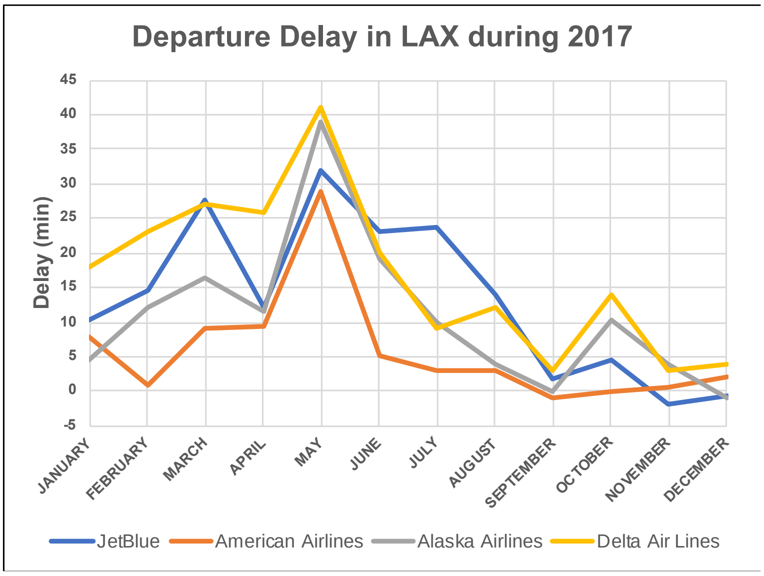

Fig. 3.7. Departure delay per flight for different airlines in LAX for flights departing for JFK during 2017. Source: MATLAB (BTS Data)

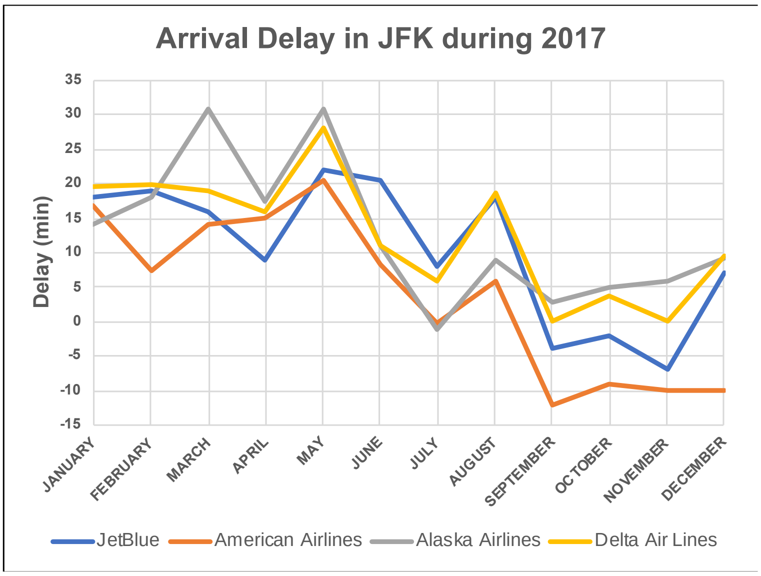

Fig. 3.8. Arrival delay per flight for different airlines in JFK for flights arriving from LAX during 2017. Source: MATLAB (BTS Data)

As seen in chapter 2, the highest delays for both considered airports were departing at LAX and arriving in JFK. So, this route should had been the most disrupted but the behavior of all airlines was not that case. By checking figures 3.7 and 3.8, it is seen that departure delays were higher than arrival delays.

Delta's and JetBlue's values were higher when departing LAX than when arriving into JFK and American and Alaska had higher delays when arriving in JFK than departing LAX, in general.

When departing LAX, as shown in figure 3.7, the airline with the highest delays was Delta. This delays gone from 5 minutes in low season to even 41 in May 2017. Delta was followed in punctuality by JetBlue and Alaska Airlines, with lower delays in high season, around 10 and 30 minutes. The most punctual airline was American Airlines by having 10 minutes delay as the maximum value during all year. In May 2017 there was an exception as all airlines increased its delays between 20% to 30% due to an external cause, probably related with the beginning of summer holidays for a lot of families within the country.

The highest delays when arriving in JFK were for JetBlue and Alaska Airlines. As having normally shorter block times scheduled than legacy carriers, they were more affected by holding patterns when reaching JFK and its real block time was then more increased, too. Alaska was actually the airline with the highest arrival delays with only July 2017 being the month when their flights arrived before schedule. By contrast, JetBlue was on time from September to November and having a similar block time scheduling. Arrival delays were higher for Alaska than JetBlue with the first having around 15 to 30 minutes arrival delay and the second between 10 to 20 minutes. Its difference on delay between both low cost carriers was around 5 minutes in low season and 10 or 15 minutes in high season.

If looking at legacy carriers, Delta had higher delay values than American when arriving into JFK. Delta's values were similar to Alaska's or even superiors in some months. American instead, performed similar to JetBlue. American Airlines' arrival delay values were a bit lower than JetBlue's, but not so far.

General block time for all carriers is normally reduced in this direction of the route due to the help of jet streams which have its maximum effect during winter. This would had helped reducing departure delays together if having a good block time scheduling. Despite that, almost all airlines landed in JFK with higher delay than when departing LAX, specially in summer. This could be caused, as mentioned in chapter 2, due to JFK's arrival congestions as having a chaotic airspace above New York and an absolute saturation of airport capacity due to exceeded demand together with no departure regulations in LAX for preventing it. Delta and JetBlue were the ones that most increased its delay when getting to their parking positions in JFK, followed by American and Finally Alaska.

If we check the difference in the arrival delay with respect to departure delay in the route shown in figures 3.7 and 3.8 we can see that Delta was the airline that most recovered its delay during the flight. It was followed by JetBlue, American and finally Alaska airlines which actually increased its arrival delay during the flight.

Table 3.3. Difference between arrival and departure delay for the route LAX to JFK. Negative values indicate an arrival delay minor to departure delay, a reduction of delay during flight (highlighted in green). Source: MATLAB (BTS Data)

	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
JetBlue	7,7	4,4	-11,6	-3	-10	-2,6	-15,8	4	-5,8	-6,6	-5	7,7
American Airlines	9	6,5	5	5,7	-8,6	3,4	-3,2	3	-11	-9	-10,7	-12
Alaska Airlines	9,4	6	14,5	6,1	-8,1	-8	-11,2	5	3	-5,2	2	10,3
Delta Air Lines	1,6	-3	-8	-9,9	-13	-9	-3	6,4	-3	-10,3	-3	5,4

In order to have a better understanding on this delay reduction we need to check air time for all four carriers.

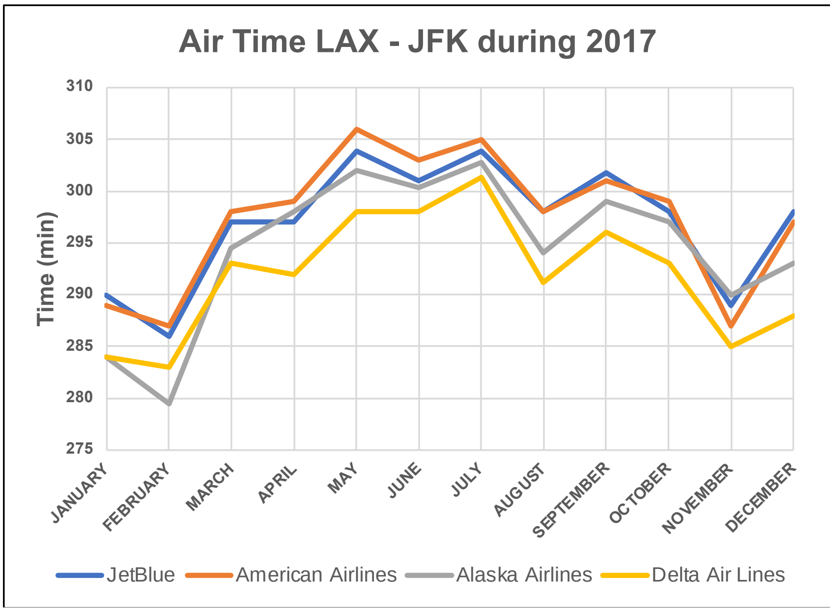

Fig. 3.9. Air time per flight for different airlines in the route from LAX to JFK during 2017. Source: MATLAB (BTS Data)

When checking previous figure, there is much difference in air time between the studied carriers. The general tendency on increasing block time during summer months and decreasing it in winter is caused by the effect of jet streams which are stronger in winter than in summer producing a reduction on air times. But this effect is general for all airlines without distinguishing among carriers. The cause airlines have different air times is mainly due to its flying speed. Delta and Alaska Airlines are the fastest airlines in the route. American is the slowest one. This is straightly related to fuel consumption policies. Airlines flying faster have a higher fuel consumption than the ones going slower. So Delta, combining high speed on air and high scheduled block times ends up being the airline that most recovers its departure delay but, as its delays from LAX are the highest, it is not enough and ends up being the one with the highest arrival delays in JFK.

Alaska Airlines as having the lowest scheduled block time , despite having a really high speed on air it is not enough for recovering departure delay and ends up having high delays in JFK but not as high as Delta's.

JetBlue has a short scheduled block time and not the fastest speeds on air but the exact combination of both makes the airline recover much of its departure delay but, as having high delays departing LAX it becomes the second more punctual airline in JFK from all four studied. American Airlines, the slowest on air, does not recover much delay in-flight despite having the highest scheduled block time but, as having the lowest departure delays in LAX it becomes the most punctual airline in JFK and the most efficient in terms of fuel consumption.

⇒ **JFK – LAX**

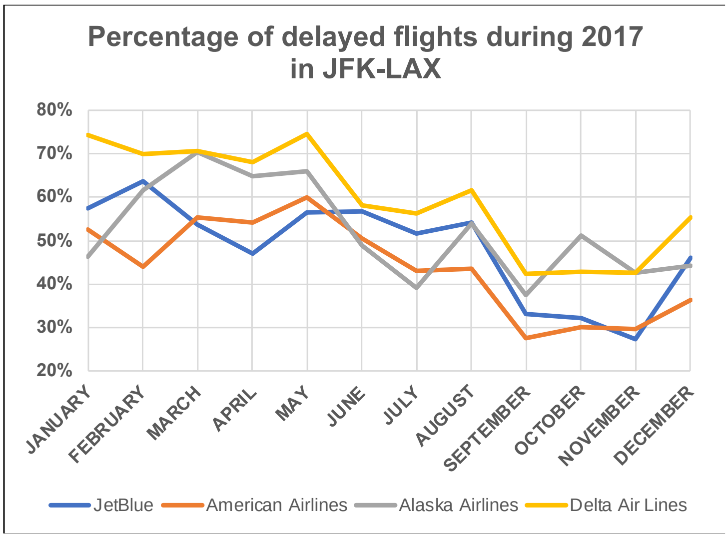

Fig. 3.10. Percentage of delayed flights per airline during 2017 in the route from JFK to LAX. Source: MATLAB (BTS Data)

In the bound for LAX we can see how the airline delaying more flights was again Delta. May 2017 was the month with the highest number of delayed flights for the carrier which affected 74% of its scheduling, as well as in January, but it was the only one that month with a delay peak. At the same time, Alaska Airlines followed Delta in delay percentage even surpassing it in October, being the worst of all four carriers in percentage of delayed flights. American Airlines was then competing with JetBlue in becoming the airline with the lowest percentage of delayed flights. American, during the first half of 2017, had around 50% to 60% of flights delayed and around 30% and 40% during the rest of the year. JetBlue was actually performing similar but normally above American or at the same level, both even reaching only 30% of flights delayed from September to November with their other competitors raising up to 40% and 50% delayed flights.

As done before, we will now analyze the amount of delay per airline in order to go deeper in previous conclusions.

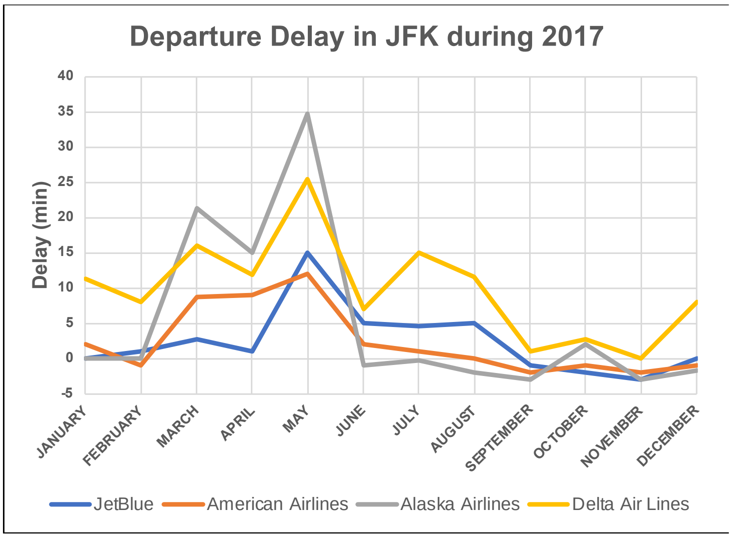

Fig. 3.11. Departure delay per flight for different airlines in JFK airport for flights departing for LAX during 2017. Source: MATLAB (BTS Data)

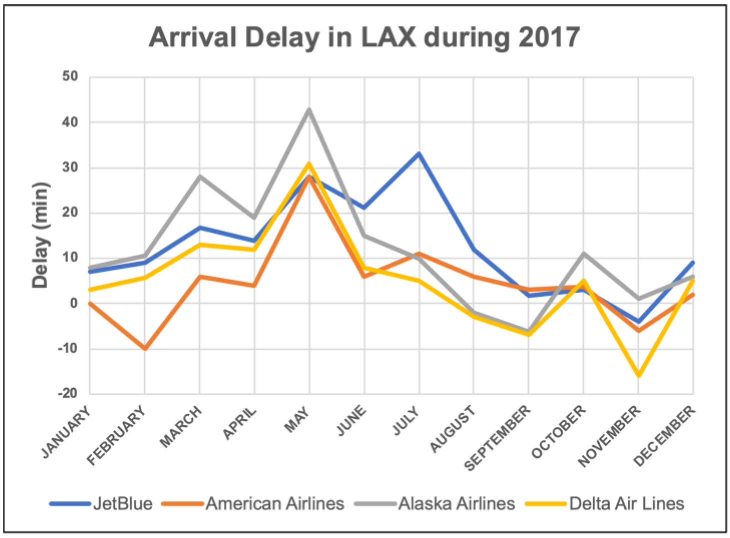

Fig. 3.12. Arrival delay per flight for different airlines in LAX airport for flights arriving from JFK during 2017. Source: MATLAB (BTS Data)

Departure delays from JFK were not as high as LAX's. The airline with the highest ones departing JFK during 2017 was Delta, with values in low season being 10 minutes as maximum and raising up to 25 minutes in summer season. Delta was followed closer by Alaska Airlines by summer 2017 as even surpassed it with a maximum delay in May 2017 10 minutes superior than Delta. JetBlue and Delta behaved similarly during 2017. American being superior in departure delay to JetBlue during first half of the year and the opposite situation happening in the second half of 2017. Both carriers had no delay during low season and raised up until a maximum of 15 minutes during high season.

When getting to LAX delays increased for all airlines. The maximum arrival delays were reached by Alaska Airlines during first half of the year ranging values from

8 to 43 minutes. JetBlue from June to September was the most delayed airline by increasing its delay during the flight around 15 minutes due to the effect of summer season reaching 33 minutes in July while the rest were around 10 minutes delayed. From September to December 2017 all airlines behaved similarly with arrival delays under 10 minutes. American and Delta had a similar behavior but the second was quite more delayed than the first but with values around no delay in low season to even 30 minutes in high season.

As done before, it is important to check the amount of delay increased or reduced during the flight. Next table eases the comparison.

Table 3.4. Difference between arrival and departure delay for the route JFK to LAX. Negative values indicate an arrival delay minor to departure delay, a reduction of delay during flight (highlighted in green). Source: MATLAB (BTS Data)

	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
JetBlue	7	7,9	14	12,8	13	16,2	28,4	7	2,8	5	-1	9
American Airlines	-2	-9	-2,8	-5	16	4	10	6	5	4,7	-4	3
Alaska Airlines	8	10,4	6,6	4	8,1	16	10,2	0	-3,2	9	4	7,7
Delta Air Lines	-8,3	-2,2	-3	0,1	5,5	1	-10	-14,6	-7,8	2,3	-16	-3

The airline which better decreased its delay was Delta Air Lines by saving up even 16 minutes in November 2017. Next was American despite in summer its values increased up to 16 minutes in May and 10 in June 2017. Alaska Airlines did not reduce its delay during the year except for November 2017 when it saved up 4 minutes delay while flying. JetBlue was the worst in time saving on air by not reducing its delay during the flight and even increasing it but, while all airlines had increases between 10 and 15 minutes as maximum JetBlue had an increase on delays of around 10 to even 30 minutes each month.

In this direction of the route flights are forced to deal with the counter effect of jet streams, so intense during winter and weaker in summer but, as seen in the delay comparison, it is considered in the block time. Legacy carriers did not even increase their delay values during winter period but decreased it. In the case of low cost carriers as JetBlue or Alaska Airlines this delay was increased as block time scheduled was not enough for covering the amount of delay.

At this time it is necessary to check air time to see how they manage flight time when on air.

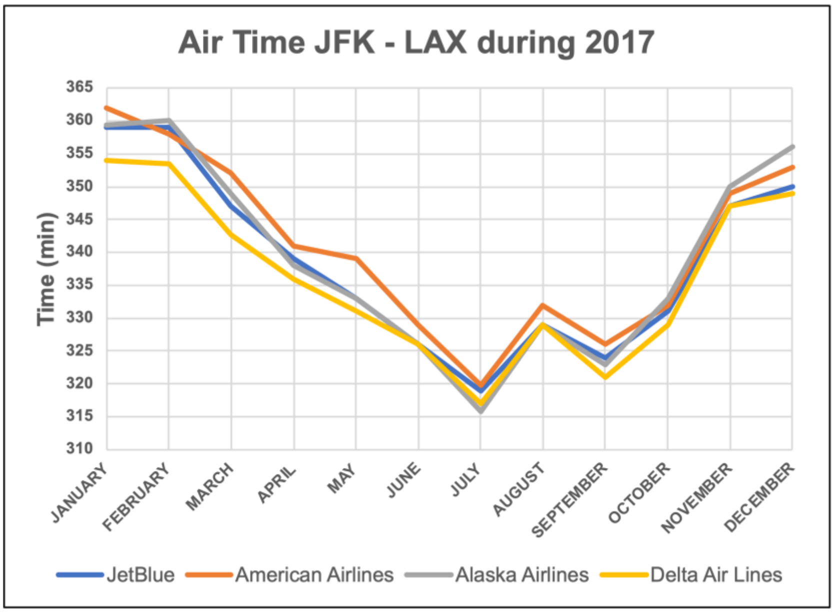

Fig. 3.13. Air time per flight for different airlines in the route from JFK to LAX during 2017. Source: MATLAB (BTS Data)

The fastest airline on air was again Delta by having the minimum air time. The general tendency on decreasing air time during summer and increasing it during winter season is the opposite that happened when going from LAX to JFK as jet streams make the counter effect to flights in this direction by slowing down the flight. As its effects are weaker in summer aircraft were less affected by this slowing down effect and got to LAX faster than in winter, by considering them flying in the same speed during all year. The slowest one and so the more fuel conscious was American American airlines as well. JetBlue and Alaska were between both previous mentioned. As happened before, in summer all airlines had their air times closer than in winter season as disruptions increased and affected all carriers and also high speeds were more restricted by ATC due to air traffic saturation.

Despite delta had the maximum speed and its scheduled block time was really high it still had a high delay when getting in LAX. In the case of JetBlue and Alaska, as having a lower scheduled block time and being a little restrictors in fuel consumption – higher than American – it was not enough to recover flight delays enhanced by the low block time. American again was the best performing as due to having a proper block time, the highest, it could handle and reduce all departure delays so much, becoming the most punctual airline, followed closer by Delta this time, even having the slowest speed on air and so being again the most fuel efficient of all four carriers.[25]

3.3. Performance on ground

When trying to compare block times for different airlines, we need to finally take into account ground time effect which can become a disruptive factor, as well . Ground time is normally different for each carrier depending on many factors. Airlines desire the less possible taxi time as it increases delays and fuel consumption. In next lines we will analyze carriers' behavior on ground per each route.

⇒ **LAX – JFK**

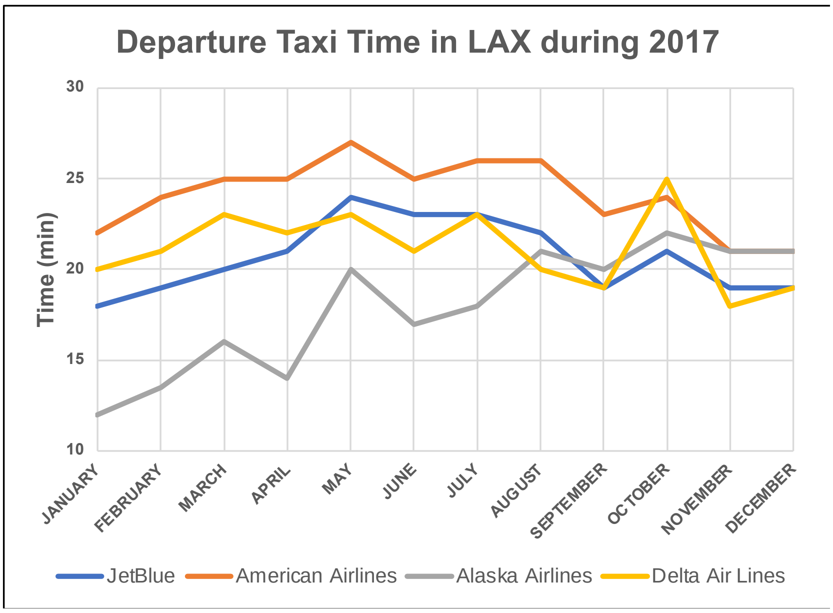

Fig. 3.14. Taxi time per flight for different airlines departing LAX for JFK during 2017. Source: MATLAB (BTS Data)

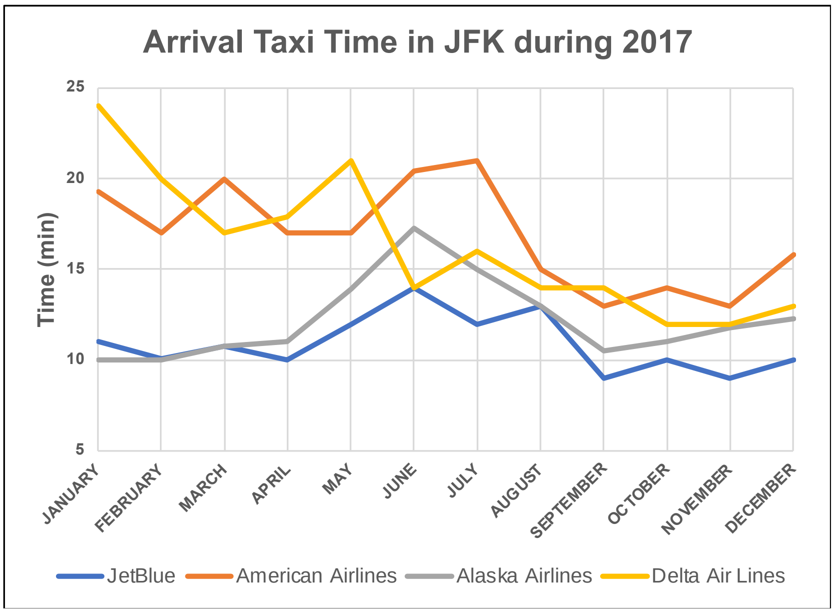

Fig. 3.15. Taxi time per flight for different airlines arriving in JFK from LAX during 2017. Source: MATLAB (BTS Data)

When departing LAX, American Airlines was the airline with the highest taxi times, up to 27 minutes, which actually reduced margins for adjusting block times. On the other side, Alaska Airlines was the one with the lowest taxi times departing JFK with minimum values of 10 minutes in January, then raising up to a maximum of 20 minutes until the end of 2017, but 10 minutes less in that month compared to American and 5 less than JetBlue and Delta.

Arriving into its parking positions in JFK took more time for Delta and American rather than for JetBlue and Alaska Airlines. American Airlines arriving taxi times into JFK actually reached 21 minutes in July 2017 and were always around 12 to 21 minutes. Delta started the year taxiing by around 24 minutes and descended until reaching 13 minutes in December 2017. JetBlue and Alaska Airlines behaved similarly with taxi times upon arrival around 10 and 15 minutes, being JetBlue the lowest carrier taxiing when arriving in JFK with actual values between 9 minutes, in September and November 2017, and 14 minutes in June whilst Alaska eventually reached 17 minutes and a minimum value in January of 10 minutes.

⇒ **JFK – LAX**

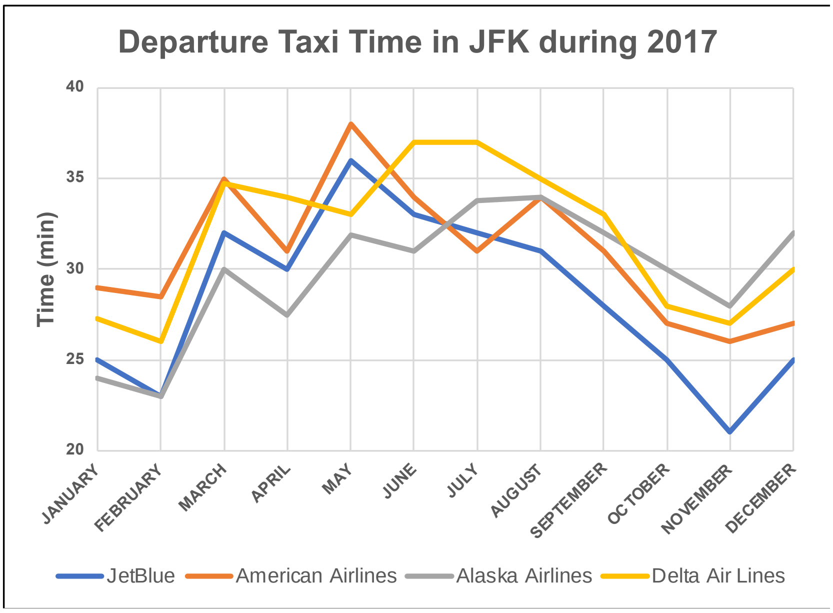

Fig. 3.16. Taxi time per flight for different airlines departing JFK for LAX during 2017. Source: MATLAB (BTS Data)

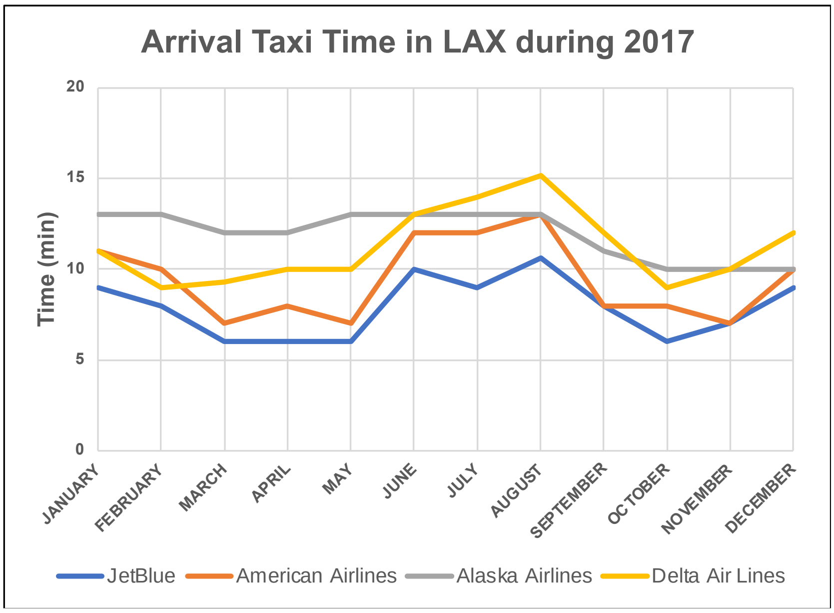

Fig. 3.17. Taxi time per flight for different airlines arriving in JFK from LAX during 2017. Source: MATLAB (BTS Data)

By looking at previous figures 3.14 and 3.16, it is observed that taxi times are higher departing JFK than departing LAX. In high season, all airlines behaved similarly with taxi times between 30 to 28 minutes, being again Delta and American the ones with the highest values. In winter values descended in between 22 and 30 minutes, clear effect of decrease in demand, less traffic and quicker departures. Alaska Airlines started being the airline with the lowest taxi times when departing JFK, followed by JetBlue until July when this last beat all airlines having the lowest taxi times until the end of the year reaching a minimum of 22 minutes in November 2017. In last half of the year, Alaska behaved close to Delta and American with values of all three around 27 and 32 minutes. American was the slowest in taking off during first half of the year and Delta in the second half of 2017.

When arriving into LAX taxi times descended between 6 to 15 minutes arrival taxi. All behaved similarly during the year increasing taxi times in high season due to increase in demand being again JetBlue the one with the lowest values keeping all year between 5 to 10 minutes arrival taxi time. Surprisingly Alaska Airlines was the one with the highest taxi times when arriving into LAX. Alaska was followed and even lightly surpassed from July to September by Delta. Below and above. American behaved a little beyond JetBlue but with little difference to its competitor.

But, why there is so much difference in taxi times among four operators? This is normally related to the distance to airport parking positions. As American airport terminal buildings are operated by airlines, as a difference to European airports, the location of the building has a direct effect on the values of taxi times.

Next figure and table shows terminal buildings distribution for each airline in JFK.

Fig. 3.18. Terminal buildings in JFK airport. Each terminal is run by an airline.[26]

Table 3.5. Airlines and terminals in which they operate in JFK airport.[27]

Airline	Terminal
JetBlue	5
Delta Air Lines	4
American Airlines	8
Alaska Airlines	7

The distance between the departure runway and the terminal building where each airline operates becomes an important feature when analyzing taxi times. Most of the time the airport is operating in visual conditions and departure priority is set. Runways 22R and 31L, south of the airport, are used for taking off which are closer to terminals 5 and 7 operated by JetBlue and Alaska Airlines, respectively. When checking figure 3.16, we can see how these last airlines were the ones with the lowest taxi times when departing JFK in 2017. By contrast, Delta and American had higher taxi times due to its farther distance of its terminals from take off headers. If arrival priority was set, not as usual as departure priority as it reduces a little bit the operations hourly rate, it would help American and Delta as runway used for taking off would be 13R, closer for them.

When checking arrivals, as departure priority was normally set, runway 22L was used for landings, closer to JetBlue's and Alaska Airlines' terminals, again reducing its taxi time when arriving and increasing American's and Delta's. American Airlines' terminal is actually the farthest from the runway, terminal 8.
If arrival priority was set, landings by runways 13L and 22L, the closest airline would be JetBlue as using terminal 5, followed in proximity by terminal 7, Alaska Airlines', the next in the list with the lowest taxi times after. Finally the distance

from American’s and Delta’s terminals is similar and so are their taxi times at arrival.

If marginal and instrument conditions were set, runways used for departures would be 4L and 31L and for arrivals 4R/L, again at the south of the airport, closer to JetBlue’s and Alaska’s, helping them to reduce their taxi times in and out the airfield.

When looking at LAX airport, next figure and table show terminal buildings distribution per airline.

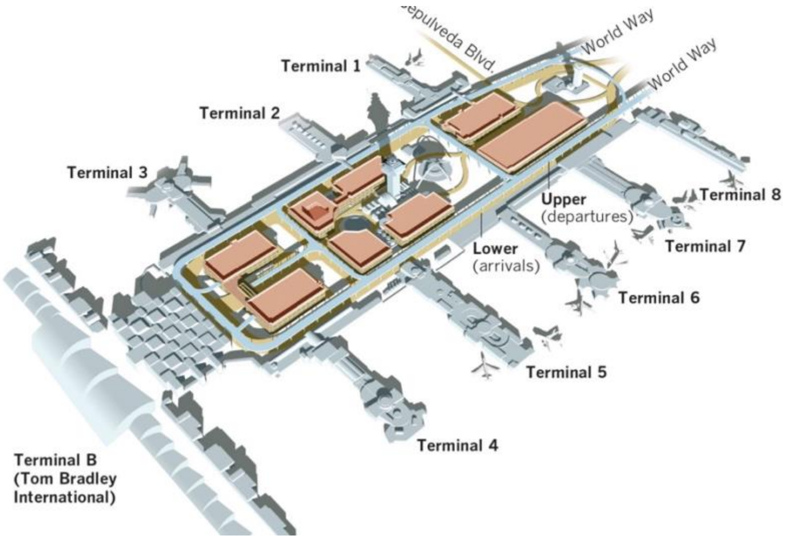

Fig. 3.19. Terminal buildings in LAX airport. Each terminal is run by an airline.[28]

Table 3.6. Airlines and terminals in which they operate in LAX airport.[29]

Airline	Terminal
JetBlue	5
Delta Air Lines	3
American Airlines	4
Alaska Airlines	6

Departing LAX in the usual configuration is performed by runways 24L and 25R. Runway 24L, located northeast, is closer to terminals 1,2 and 3. Runway 25R, situated southeast, is closer to to terminals 4, 5, 6, 7 and 8 as well as the regional terminal. Taxi times for departing LAX are lower than in JFK as runways are located closer to terminals. The terminal complex is located in between both pair of parallel runways, easing taxiing. All airlines, except Delta, are located in the south bound of the terminal complex. This means they are aimed to use probably runway 25R when departing. The closest to runway 25R is Alaska Airlines in terminal 6, then followed by JetBlue in terminal 5 and American in terminal 4. This is shown in figure figure 3.14 as Alaska is the airline with the lowest taxi times when departing LAX, followed by JetBlue and American Airlines, the same proportion in taxi time as distance far from the runway header 25R. Delta, by contrast, would depart from runway 24L as its terminal is in the northern side of the complex. It is at the same distance from the departing runway as JetBlue or American are from runway 25R, that's why its departure taxi time is in between both mentioned carriers. Alaska is the most benefited of all four airlines at the airport in proximity to used runways.

When looking at arrivals runways, 24R and 25L are used. The same as with departures happens with arrivals. JetBlue, Alaska Airlines and American Airlines would normally use runway 25L when arriving and Delta would be landing at runway 24R due to proximity to their respective terminal building. An important detail is that an aircraft starts its landing path at the threshold where, in case of departure would initiate the departure run. This means the landing path ends at the other side of the current runway. This small detail means that when landing in runway 25L the closest airline from its terminal is the opposite as when departing. Closest terminals from landing in terminal 25L are firstly American's and JetBlue's as same as Delta's, relatively, for runway 24R. Alaska Airlines terminal is then the furthest when landing and that is why Alaska and Delta have higher taxi times at arrival and American and JetBlue are the ones with the lower taxi times.

TAKE-AWAYS

Through our analysis, we found out which were the main causes of flight delays on the studied routes and assessed the performance of the operating airlines

The primary causes contributing to delays involve bad weather, airport design, including runways, taxiways and terminal buildings, management of capacity and demand in peak traffic periods and the efficiency on air traffic management on the ground.

Our analysis showed that weather conditions play a crucial role in flight delays. We have figured out which are the optimal runway configurations in order to minimize delays at LAX and JFK depending on wind direction, intensity and frequency. It was then concluded the current configuration of both airports is practically the optimal one, not even improved as being limited by constraints like surrounding airspace due to nearby airfields proximity.

When talking about airports, both are saturated. In terms of capacity, demand, and traffic distribution systems struggle to efficiently handle peak demand, especially when weather effects come into play, since American airports are not regulated as in the case of European. So, seasonality is one of the main reasons for disruptions as flight demand increases during high season and capacity is not managed optimally, leading to exponential delays due to longer taxi times on ground and holding patterns when approaching the airfields. In addition, ground time is higher at LAX than at JFK, reaching the average difference of about 30 minutes respectively. This is caused as LAX airport infrastructure and demand is larger, increasing taxi times. At the same time, taxi times are always longer when departing than after landing. Departing comes to represent almost 70% of the total time the aircraft is on ground within a flight.

It was also shown that the most efficient direction for this route is LAX to JFK. While LAX has higher departure delays than JFK, the positive effect of jet streams reduces initial delays on air and, despite JFK arrival delays are higher than LAX's, the total elapsed time in the route is reduced compared to the opposite direction. In the bound for LAX departing JFK, the counter effect of jet streams, although LAX has reduced arrival delays compared to JFK's, forces carriers to increase scheduled block times, increasing its fuel consumption. It is important to mention that, as jet streams are stronger in winter, there is also more in-flight delay reduction during winter rather than in summer season as ground delays in the first period are quite lower than in the second, as well.

To sum up, scheduled and real block times of flights from LAX to JFK are always shorter than from JFK to LAX. This difference between routes can rise up from 30 minutes to even 70 minutes in winter season.

By analyzing the performance of the airlines, we could see that American Airlines and Delta Air Lines had the longest scheduled block times during 2017, while JetBlue and Alaska Airlines had the shortest ones. Highest percentage of delayed flights and highest disruptions per flight at departing both airports were always from Delta and so were its arrival delays to JFK despite having high block times scheduled and also the highest speeds when on air, becoming the less restrictive in fuel consumption and the worst carrier in general performance. It's worth noting that due to its terminal buildings locations, the airline has one of the longest taxi times, especially at JFK, which in consequence increases its block time.

In contrast, American Airlines had the fewest number of delayed flights as it increased the block time enough to offset most of the possible departure and arrival delays on both routes. It also was the airline flying slower by having the most restrictive fuel consumption policy, the most efficient in fuel emissions then.

Alaska Airlines behavior, with the shortest block times and high speed, was more or less similar to Delta's as for delay values, but its disruptions were more reasonable than Delta's when comparing scheduled block times.

JetBlue had a similar behavior to American Airlines' but its block time scheduling was closer to reality as it was neither the lowest nor the highest. It operates from terminal buildings which are closer to operating runways reducing taxi times and required block time as well. The airline minimized ground delays at both airports by a good combination of air speed, similar to American's, and block time scheduling. Despite American was a bit more punctual, JetBlue's delays were not that big at all taking into account it had much less scheduled block time than the legacy carrier. This awareness of fuel consumption, reduced delays compared to its competitors and reduced block time scheduling, combined with the constant adjustment of the flight schedule to the demand and capacity of the airports it serves, make us to award the airline as the best performer in general aspects in the route.

Before ending, it is important to mention that airlines are businesses. Their main goal is to earn as much money as possible and to attract as much market share, as well. Airlines can schedule flights more conservatively to prioritize on-time performance and minimize the impact of disruptions on other flights on the network. However, this longer planned downtime comes at the cost of crew costs and lower aircraft utilization (i.e. fewer flights per unit of time per aircraft).[30]

Careful flight planning based on good historical data is clearly critical to successful flight operations.

CONCLUSIONS

The results of the project show that factors such as adverse weather conditions, airport design, capacity management, and air traffic control efficiency have a significant impact on flight delays.

The study identified the optimal runway configurations for minimizing delays at LAX and JFK, considering wind effects depending on its direction, intensity, and frequency. Surprisingly, it was found that the current configurations at both airports are practically optimal, despite constraints imposed by surrounding airspace and nearby airfields. Additionally, it was defined how both airports deal with lack of capacity as demand and capacity mismatch can lead to exponential delays due to long taxi times and approach holding patterns.

In addition, it was discovered that LAX has longer ground times than JFK due to greater airport infrastructure and traffic demand. Flights also have a longer taxi time when departing than after landing, accounting for even 70% of the total time an aircraft spends on the ground during a flight.

Regarding the routes studied, it was determined that the most efficient one is LAX to JFK due to the positive impact of jet streams in the reduction of accumulated delays. However, on the other direction, to offset disruptions, airlines need to extend scheduled block times, resulting in higher fuel burn. It is worth noting that as jet streams are stronger in winter, flight delays are significantly reduced this time of year compared to summer. Block time difference between directions range from 30 minutes to 70 minutes.

When analyzing airline performance, we found that American Airlines and Delta Air Lines had the longest scheduled block times in 2017, while JetBlue and Alaska Airlines had the shortest. Delta had the highest percentage of flight delays and disruptions, despite having longer block times scheduled and higher flying speeds. Delta's terminals locations leads to longer taxi times, especially at JFK. In contrast, American Airlines recorded the lowest number of delayed flights by introducing longer scheduled block times to accommodate potential delays. The airline has also improved fuel efficiency by adopting a stricter fuel consumption policy.

Alaska Airlines experienced a similar delay pattern as Delta, though the disruptions were more plausible given the shorter block times. On the other hand, JetBlue proved to be the best overall competitor on the track by achieving efficient performance at both airports with a balanced approach that includes modest block time scheduling, fuel-efficient operations, fewer delays than competitors and terminals closer to the runway.

In conclusion, the project provided valuable understanding into the main causes of flight delays and how different airlines are performing. The results focus the importance of considering weather conditions, capacity management, and efficient operational strategies to improve the global performance of the airline industry and reduce delays.

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