

## Flight delay performance at Hartsfield-Jackson Atlanta International Airport

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### **Abstract**

**Purpose:** The main objective of this paper is to determine the annual cyclical flight delays at Hartsfield-Jackson Atlanta International Airport. Then using other data such as annual precipitation, passenger and aircraft traffic volumes and other factors, we attempted to correlate these factors with overall delays. These data could assist airport management in predicting periods of flight delay.

**Design/methodology/approach:** Data were taken and analyzed from the data base “Research and Innovation Technology Administration” (RITA) for the years 2005-2011 for Hartsfield-Jackson Atlanta International Airport. The data included 2.8 million flights originating and departing from this airport.

Data were also gathered from the National Oceanic and Atmospheric Administration (NOAA) showing precipitation. Additional data were gathered from the FAA regarding delay causes, number and types of delays and changes to the infrastructure of ATL airport.

**Findings:** There is a repeatable annual pattern of delays at ATL that can be modelled using delay data from the Bureau of Transportation Statistics. This pattern appears to be caused primarily by the frequency and amount of precipitation that falls at ATL and by the amount of flights that arrive and depart at ATL.

**Originality/value:** This information could assist airport operations personnel, FAA air traffic controllers and airlines in anticipating and mitigating delays at specific times of the year.

**Keywords:** Flight delays, weather delays, air carrier delays, NAS delays, air traffic control delays

## 1. Introduction

In June of 2010, Consumer Reports surveyed 2,000 air travellers and asked them to rate the 12 most annoying things about air travel on a scale of 1 (least annoying) to 10 (most annoying). Flight delay was 7th on the list with a score of 6.8 on their scale (Priority Pass, 2010).

Flight delays not only annoy air travellers and disrupt their schedules, but they incur costs to the airlines when flight connections are missed, or flight crews and aircraft need to be re-allocated due to maintenance problems or crew duty time limits. Flight delays can have a domino effect on subsequent flights when the delayed flight aircraft and/or flight crew causes a delay for subsequent flights scheduled that day for the aircraft and crew.

Flight delays may be caused by such factors as weather, maintenance issues with the aircraft, the financial state of the air carrier, constraints of the airport infrastructure, the National Airspace System (NAS), Air Traffic Control (ATC), previous delays by other flights and aircraft, airport security or how the airlines schedule flights at a particular airport.

This paper investigated flight delay performance at Hartsfield-Jackson Atlanta International Airport between 2005 and 2010 to determine if there were patterns of delay over an extended period of time.

Analysis of data obtained from the Federal Aviation Administration (FAA) and the Bureau of Transportation Statistics (BTS) showed evidence of cyclical patterns of daily delay.

Evidence also suggests that these patterns of increased delay occur at specific times, days and months. This type of data analysis could assist in airports being able to predict increased times of delay and investigate these cyclical patterns to determine what causes these predictable patterns of delay.

Potential contributors to the pattern of delay could be weather, airport capacity, airline flight scheduling or time of day, week or month.

## 2. Background

A review of the literature was conducted to determine:

- The definitions of "delay"
- What other research has been completed on airport flight delays.

The Bureau of Transportation Statistics defines an airline delay as a flight that is delayed more than 15 minutes and is caused by one of the following (BTS 2012):

- **Air Carrier:** The cause of the cancellation or delay was due to circumstances within the airline's control (e.g. maintenance or crew problems, aircraft cleaning, baggage loading, fuelling, etc.).
- **Extreme Weather:** Significant meteorological conditions (actual or forecasted) that, in the judgment of the carrier, delays or prevents the operation of a flight such as tornado, blizzard or hurricane.
- **National Aviation System (NAS):** Delays and cancellations attributable to the national aviation system that refer to a broad set of conditions, such as non-extreme weather conditions, airport operations, heavy traffic volume, and air traffic control.
- **Late-arriving aircraft:** A previous flight with same aircraft arrived late, causing the present flight to depart late.
- **Security:** Delays or cancellations caused by evacuation of a terminal or concourse, re-boarding of aircraft because of security breach, inoperative screening equipment and/or long lines in excess of 29 minutes at screening areas.

A breakdown by these categories for all flights within the United States for September 2012 showed the percentage of each type of delay (Table 1). Diverted and cancelled flights were not considered since a cancelled flight never arrives at its destination and a diverted flight lands at another airport.

	<b>Number of Operations</b>	<b>% of Total Operations</b>	<b>Delayed Minutes</b>	<b>% of Total Delayed Minutes</b>
<b>On Time</b>	408,355	83.30%	N/A	N/A
<b>Air Carrier Delay</b>	22,817	4.65%	1,405,706	32.98%
<b>Weather Delay</b>	1,650	0.34%	109,777	2.58%
<b>NAS Delay</b>	24,427	4.98%	1,043,458	24.48%
<b>Security Delay</b>	135	0.03%	5,301	0.12%
<b>Aircraft Arriving Late</b>	28,046	5.72%	1,697,951	39.84%
<b>Cancelled</b>	3,953	0.81%	N/A	N/A
<b>Diverted</b>	816	0.17%	N/A	N/A
<b>Total</b>	490,199	100.00%	4,262,193	100.00%

Table 1. National on time arrival performance for September 2012 (BTS, 2012)

Umang (2008) concluded in his research that for the month of May, 2009, 80.49% of all U.S. flight were on time, meaning they had departed within 15 minutes of their scheduled time. 12.57% of all flights were delayed due to extreme weather, National Airspace System (NAS)

delays, security or air carrier delay, 5.84% were caused by late arriving aircraft. Umang illustrated that passenger traffic volume and passenger delays were both highest on Friday, and both lowest on Saturday, suggesting a relationship between the two (Figure 1).

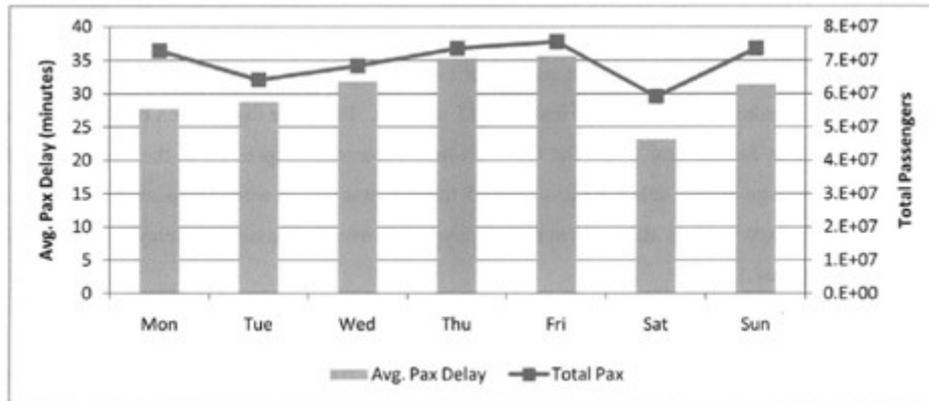


Figure 1. U.S. passenger delays and passenger by day for 2007 (Umang, 2008)

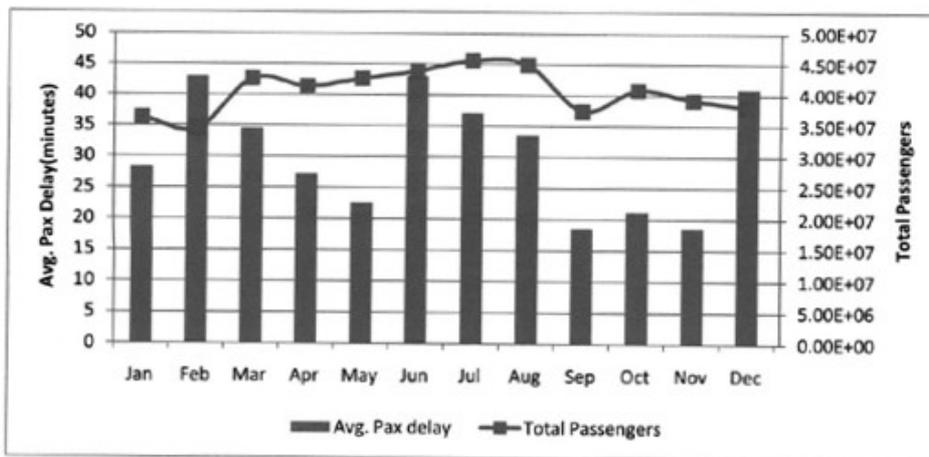


Figure 2. Flight Delays vs. passenger quantity for 2007

Umang (2008) suggested that the relationship between passenger quantity and passenger delay by month was not the same as day of the week due to the influence of seasonal weather patterns (Figure 2).

In Figure 3, Umang (2008) shows that in 2007, Atlanta was prone to more passenger delay than 22 other airports analyzed. While Umang’s research looked at delays by day of the week and by month, the research did not include exploring daily delay trends over the period of a year or more.

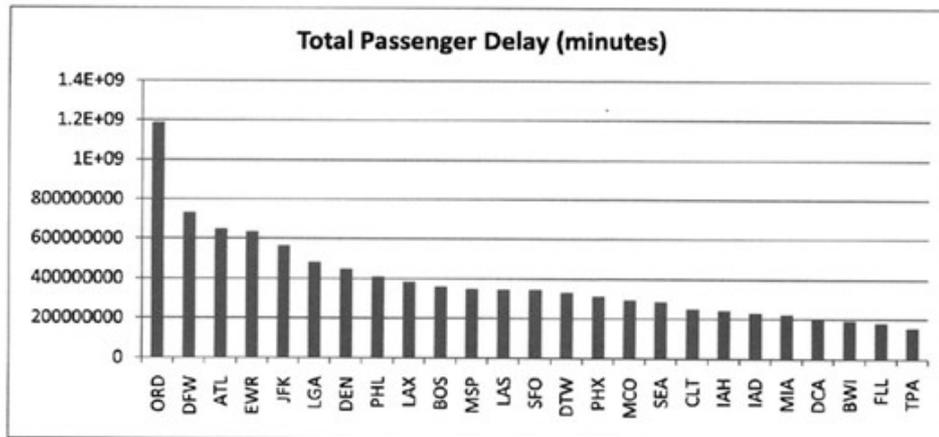


Figure 3. Total Passenger Delay by Airport, 2007

Yufeng, Ball and Jank (2006) conducted research on estimating flight departure delay distributions using a statistical approach with long term trend and short term pattern. They used flight data from United Airlines at Denver International Airport for the year 2000/2001.

Their model takes into account seasonal trend and daily propagation patterns (Figure 4). This approach showed promise in forecasting delays in future time periods. Their goal is to transfer this model from just one airline at one airport to all airlines at all airports.

Mueller and Chatterji (2002) showed that in 2000, 84% of all delays were ground based (Figure 5) with 50% of delays occurring at the gate, 26% occurring during taxi out, and 8% occurring during taxi-in.

They also showed that 69% of departure and arrival delays were caused by weather, 14% by traffic volume and 6% by runway delays (Figure 6).

Changnon (1996) in a study comparing precipitation to transportation accidents showed 57% of the 30-min. flight delays at Chicago's O'Hare Airport occurred during rainy weather conditions. Results suggest a future climate with more summer rain days would mean more total vehicular accidents, more aircraft accidents and flight delays.

A review of other studies conducted throughout the United States showed they examined delay patterns in terms of time of day, day of week or month of year. This study appears to be one of the first to study potential repetitive cycles of delay on an annual basis using data for 6 consecutive years, 2005-2011.

Summing up our analysis, one can conclude that up to now delay patterns were investigated in terms of time of day, day of week or month of year. In our knowledge, the result presented in this paper appears to be the first one or better to say one of the first to study potential repetitive cycles of delay on an annual basis using data for 6 consecutive years, 2005-2011.

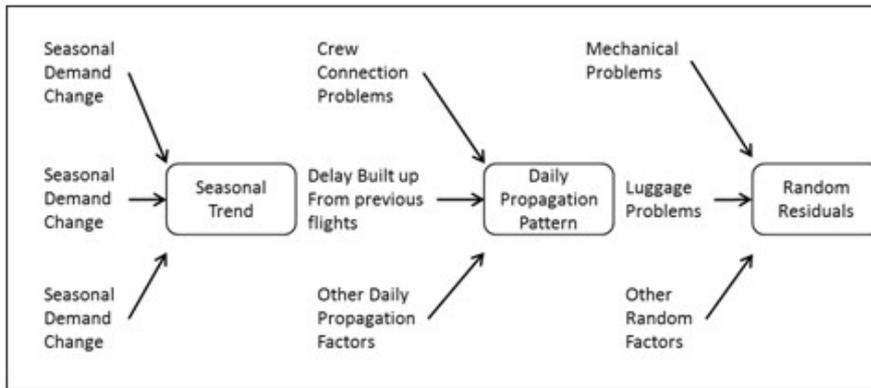


Figure 4. Factors influencing departure delay Yufeng, Ball and Jank (2006)

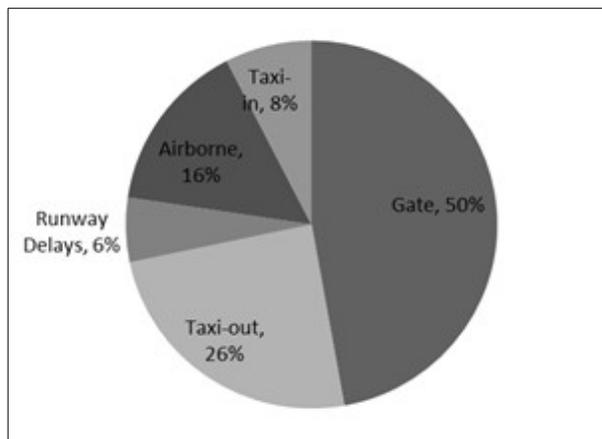


Figure 5. Distribution of delays by phase of flight (Mueller & Chatterji, 2002)

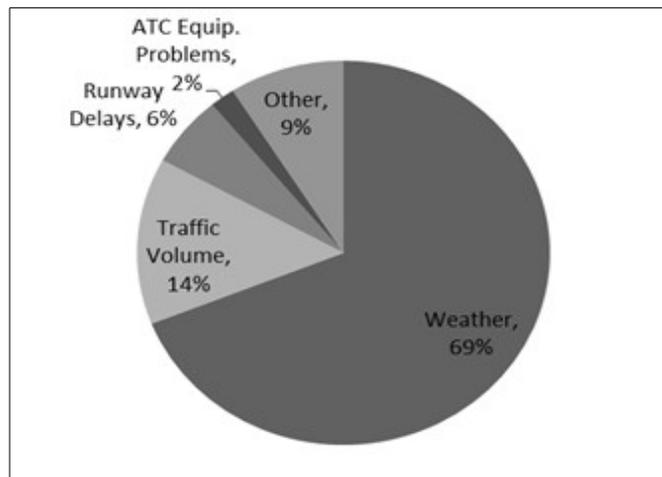


Figure 6. Distribution of arrival and departure delay by cause in 2000 (Mueller & Chatterji, 2002)

### 3. Methodology

Data were taken and analyzed from the data base "Research and Innovation Technology Administration" (RITA) for the years 2005-2011 for Hartsfield-Jackson Atlanta International Airport (ATL). The RITA database is a subsection of the Bureau of Transportation Statistics that looks at many forms of transportation. RITA contains several different databases that relate to aviation, with the airport snapshots and flight delay being the main focus of this research. From the database, flight information can be obtained for any United States airport and for individual flights. Atlanta International airport was chosen for this research due to the large volume through ATL and by ATL being in of the busiest airports in the United States. The data included 2.8 million flights originating and departing from this airport, making the results of the research very reliable.

Data were also gathered from the National Oceanic and Atmospheric Administration (NOAA) showing precipitation. Additional data were gathered from the FAA Operations Network (OPSNET) database regarding delay causes, number and types of delays and changes to the infrastructure of ATL airport.

### 4. Results

We considered the average delay as it changes (a) within each year (b) from year to year for each month (c) the evolution in time; see Figures 7, 8.

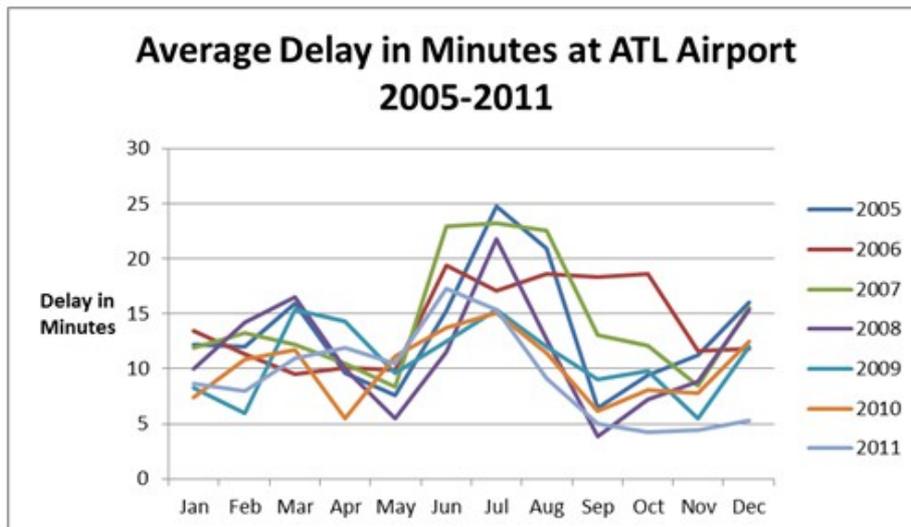


Figure 7. Average flight delays in minutes by month, 2005-2011 ATL

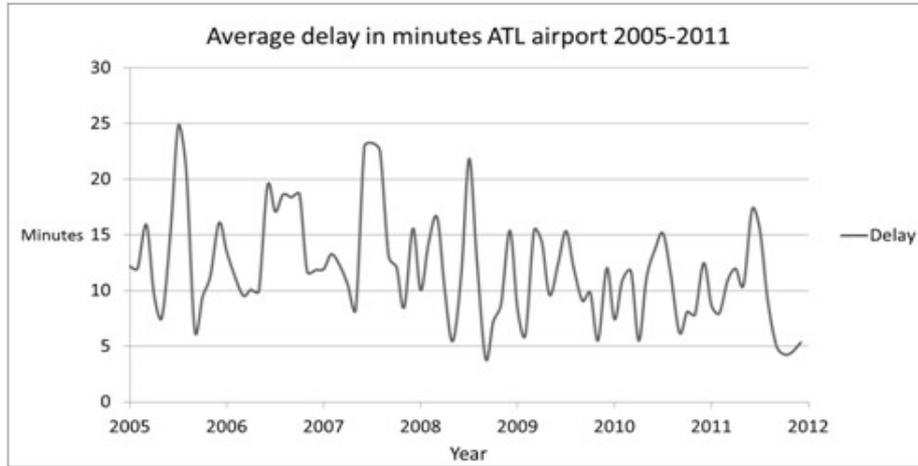


Figure 8. ATL flight delays by month, 2005-2011

Then we described this global evolution of average departure delay using a superposition of a linear trend with a superposition of sinusoidal harmonics (i.e., a Fourier series with period 1 year), see figure 11. For finding the dependence parameters, there was used the maximum likelihood method which assumes the normal distribution assumption (Hald, 1999).

(Reference is Hald, 1999). "On the history of maximum likelihood in relation to inverse probability and least squares". *Statistical Science* 14(2): 214–222. JSTOR 2676741).

The formula of the match is:

$f(x) = a + b \cdot (x - 2005) + e_1 \cdot \sin(2 \cdot 3.14159 \cdot x + f_1) + e_2 \cdot \sin(2 \cdot 3.14159 \cdot 2 \cdot x + f_2) + e_3 \cdot \sin(2 \cdot 3.14159 \cdot 3 \cdot x + f_3) + e_4 \cdot \sin(2 \cdot 3.14159 \cdot 4 \cdot x + f_4)$	(1)
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where the values of the parameters and their estimated standard errors (from the covariance matrix in the final step of the fitting algorithm) are as follows (Equations 2 through 11):

$a = 14.9527 \pm 0.7035$ (4.705%)	(2)
$b = 0.862745 \pm 0.1761$ (20.41%)	(3)
$e_1 = 2.39841 \pm 0.4983$ (20.78%)	(4)
$e_2 = 2.74608 \pm 0.4986$ (18.16%)	(5)
$e_3 = 2.15753 \pm 0.4986$ (23.11%)	(6)
$e_4 = 1.16659 \pm 0.4983$ (42.72%)	(7)
$f_1 = 1.38865 \pm 0.2091$	(8)
$f_2 = 1.52251 \pm 0.1817$	(9)
$f_3 = 1.68308 \pm 0.231$	(10)
$f_4 = 2.89947 \pm 0.4274$	(11)

The value  $a$  (14.9527 min.) reflects a time-independent component of this dependence. It is interesting that it is very close to the value 15.00 min. which is defined as the temporal "definition of delay" by the Bureau of Transportation Statistics.

Analysis shows that there is an observed decrease in flight delays during these years (2005-2011). It is governed by the linear term  $b*(x-2005)$ , where the value of  $b = -0.862745$ .

The amplitudes  $e_1, \dots, e_4$  are mostly decreasing with frequency 1/year, 2/year, as are their relative errors, motivating us to stop at number four. The corresponding phases  $f_1, \dots, f_4$  are listed with their standard error, but contrary to  $a, b$  and the amplitudes  $e_1$  up to  $e_4$ , they only have absolute meaning, being angular shifts expressed in radians, so their relative error values are not mathematically relevant. The root-mean-square error of the fit is 3.2 minutes.

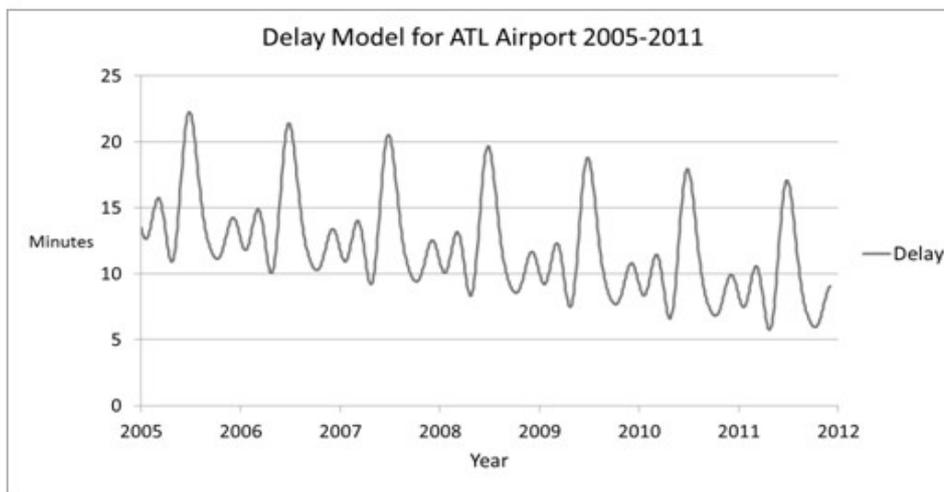


Figure 9. Cyclical patterns of delay at ATL

As a result, we find a clear seasonal effect superposed to a long-term improvement trend. These seasonal peaks are related to summer months, with side peaks in November and February (Figure 9). Because the average departure delays can effectively be modelled by such a regular dependence, it can be considered as a result which certainly must be interpreted from a seasonal point of view.

## 5. Discussion

### 5.1 Patterns of delay

Data were examined that might explain the delay patterns shown in the model (Figure 11). Delay categories defined by the FAA were used. The delay categories were:

- NAS Delays
- Late Arriving Aircraft
- Carrier Delay

- Extreme Weather Delay
- Security Delays

Figure 10 shows the types and quantities of delays by month from 2005-2011. Each of these factors was further examined to determine how they might contribute to overall delays.

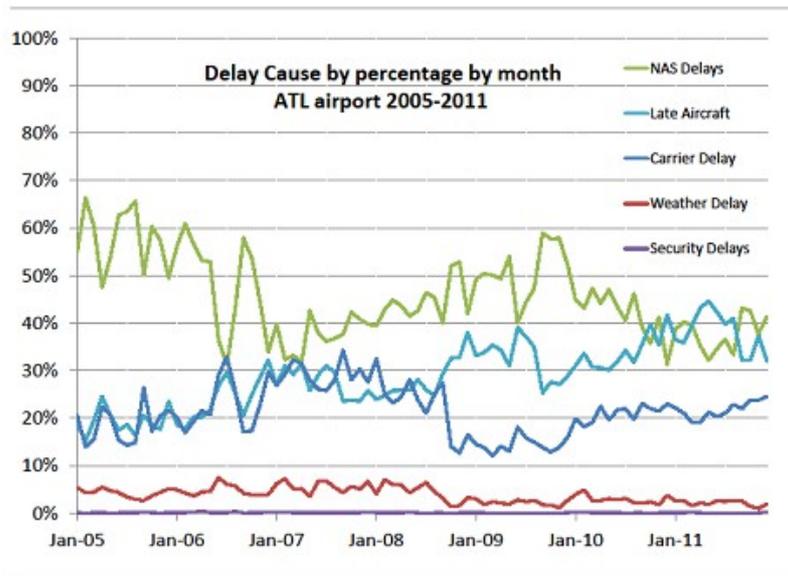


Figure 10. Delay cause by month, ATL airport 2005-2011

## 5.2 National Aviation System (NAS)

Delays and cancellations attributable to the national aviation system that refer to a broad set of conditions, such as non-extreme weather conditions, airport operations, heavy traffic volume, and air traffic control.

### 5.2.1 Non-extreme weather

NAS (National Airspace System) delays were the biggest contributor to delays at ATL. This category included non-extreme weather such as precipitation. Precipitation events can include rain, wind and fog, reducing weather minimums and thus reducing traffic flows. Winds can change landing and take off traffic patterns and can cause some runways to become unusable or require the use of runways with a lower traffic capacity.

Rainfall amounts and accompanying low visibilities, cloud ceilings and wind are most prevalent in February, July and consistently high during October, November and December of each year (Figure 11) (NOAA, 2013). These increases in precipitation coincide with increased delays.

These data support the research conducted by Changnon (1996) showing increases in aircraft delays during increases in precipitation at Chicago airports.

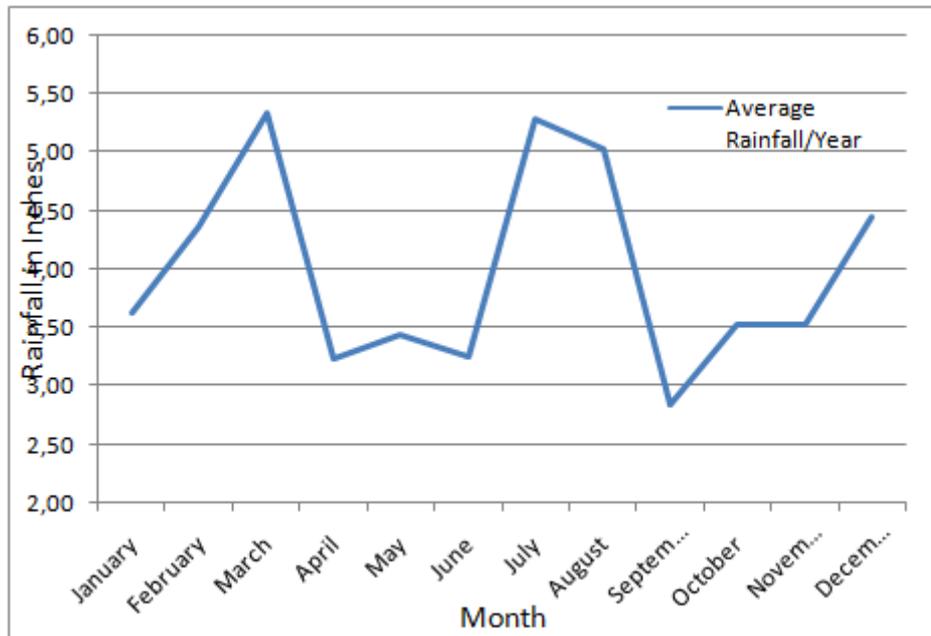


Figure 11. Average annual rainfall in inches at ATL, 2005-2011 (NOAA, 2013)

Analysis of seasonal delays in Figure 11 shows a marked increase in March, July, and an increasing trend in October, November and December, mirroring the precipitation chart in Figure 14. The FAA states that "During bad weather, however, capacity is lower, resulting in more delay" (p. 3).

### 5.2.2 Air Traffic Control

Many departure delays are caused by the FAA's Air Traffic Control (ATC) Ground Delay Program and Expected Departure Clearance Time (EDCT) program.

An EDCT is issued to a flight to indicate when it can expect to receive departure clearance. EDCTs are issued as part of the FAA's Traffic Management Programs, such as the Ground Delay Program (GDP).

A Ground Delay Program (GDP) (FAA, 2009):

...is a traffic management procedure where aircraft are delayed at their departure airport in order to manage demand and capacity at their arrival airport. Flights are assigned departure times, which in turn regulate their arrival time at the impacted airport.

GDP will normally be implemented at airports where capacity has been reduced because of weather -such as low ceilings, thunderstorms or wind- or when demand exceeds capacity for a sustained period.

GDPs are implemented to ensure the arrival demand at an airport is kept at a manageable level to preclude extensive holding and to prevent aircraft from having to divert to other airports. They are also used in support of Severe Weather Avoidance Plan (SWAP).

An EDCT time issued to a flight to indicate when it can expect to receive departure clearance. EDCTs are issued as part of Traffic Management Programs, such as a Ground Delay Program (GDP) (p.21).

EDCT delays were researched for ATL using FAA data. The quantities of EDCTs issued at ATL (Figure 12) are very similar to the patterns of total delays, with peaks in March and July.

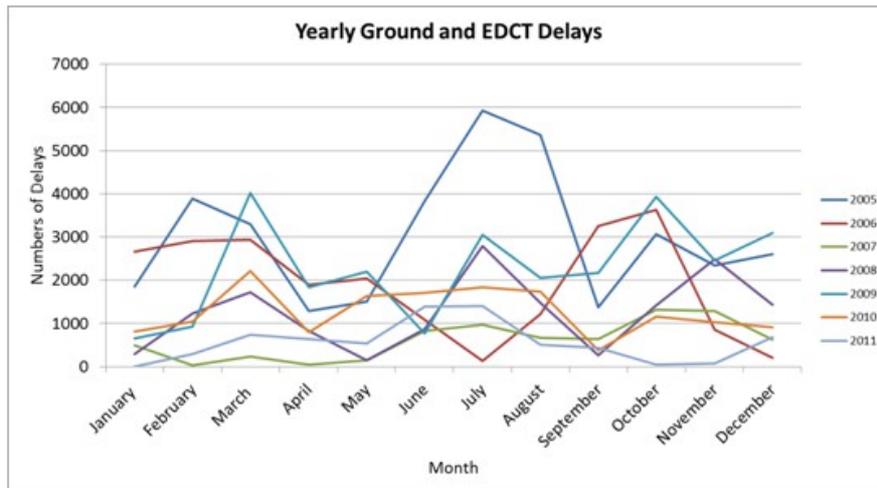


Figure 12. Yearly Ground and EDCT Delays

### 5.2.3 Airport Operations

Figure 13 (FAA, 2004) shows the number of hourly arrivals and departures to and from ATL. Note that flight operations (scheduled flights) at times exceed the benchmark capacity of the airport to handle a maximum of 92 arrivals and 96 departures per hour. The FAA defines Capacity benchmark "...as the maximum number of flights an airport can routinely handle in an hour, for the most commonly used runway configuration in each specified weather condition" (FAA, 2004, p. 1).

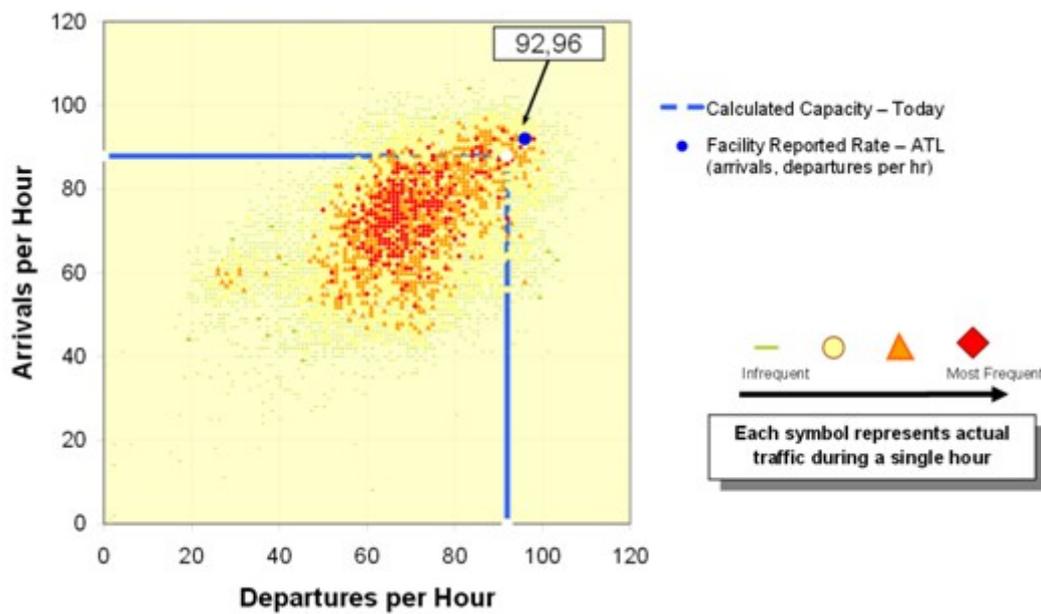


Figure 13. Airport Capacity for Atlanta Airport, 2004 (FAA, 2004)

This type of schedule distribution can adversely affect delays at an airport.

The FAA (2004) states:

- The amount of delay caused by overscheduling depends on many factors, but one of the main factors is the availability of compensating “under scheduled” periods during the day. If a schedule peak is followed by an equivalent or greater “valley”, then the scheduled traffic can be handled in the next time period and delays will be short. If the peak extends over several time periods, however, it will take longer to eliminate the backlog of waiting flights, and delays will increase accordingly.
- The delay experienced by flights in a given time period is also affected by the distribution of flights within that time period. Clustering of flights within the time period will lead to more delay than if the flights were evenly distributed. For example, suppose that a runway can accommodate one departure each minute. If the schedule provides one departure per minute, delays will be minimal. However, if 15 departures leave the gate at the same time, one will be delayed by a minute, another by two minutes, and so forth, with the last departure delayed by 14 minutes (p. A-4).

Regarding the aircraft operations “into” and “out”, the airport can be interpreted as an open system based on the thermodynamic meaning of term “open”. Under steady state conditions, the “inflow” aircraft operations equals or approximately equals to the “outflow” ones. The number of airplanes in the airport is remaining the same or rather to say approximately the same (constant).

Under non-steady-state conditions, the temporal derivative of a number of aircraft operations is not zero. This number is increased (the positive derivative) or decreased (the negative one) provoking different periods during which the airport will be characterized by periods of the "over capacity" or "under capacity" A balance of aircraft operations for airports can be an interesting subject of other studies, both applied and theoretical.

But, operations may safely exceed benchmarks in capacity. The FAA (2004) states that

At Atlanta, scheduled operations may exceed the benchmarks in optimum weather, and frequently do so in bad weather. A simple comparison of schedule to benchmarks might suggest that some action is needed to curtail the schedule.

However, air traffic controllers, airlines, and the airport operator have indicated in discussions that they are relatively comfortable with the traffic schedule, and believe that it makes efficient use of the airport. Their judgment is based on long experience and a broad understanding of air transportation.

Some of the considerations behind this judgment are applicable to transfer hub airports in general (the concentration of traffic into schedule peaks to allow passengers to make convenient transfers between flights; the ability to catch up with traffic between peaks in the schedule; and the ability of hubbing carriers to cancel and consolidate some flights during poor weather conditions).

Other considerations are applicable to all busy airports, namely the premise that some amount of congestion and delay is not inconsistent with efficient and affordable air transportation. It should be emphasized that the benchmarks are specific to the airport, and may not represent the actual capacity of the airport when other considerations are included such as airspace structure and congestion, weather patterns, and directional flight limitations (p.2).

#### **5.2.4 Late-arriving aircraft**

The aircraft arrived at the airport late, which subsequently caused the next flight to depart late.

Late arriving aircraft are a major cause of delays for ATL (Figure 12). Late arriving aircraft will be affected by the following factors:

- Weather at the departure airport, en route, or at Atlanta airport could cause the incoming aircraft to arrive late.
- Ground Delay Program at departing airports. Flights may be delayed on the ground at the departing airport due to arrival constraints at ATL.

- Aircraft mechanical issues.
- Crew scheduling.

These delays can also have a ripple effect throughout the system, which can cause subsequent flights throughout the system to also become delayed. A flight with three legs such as Denver to St. Louis to Atlanta could have been affected by a weather delay at Denver, thus delaying the flight arrival and departure times at St. Louis and Atlanta.

The Government Accounting Office has stated:

Delays...at such airports, particularly those with large numbers of flights, can quickly create a "ripple" effect of delays that affect many airports across the country...an aircraft late in leaving the airport where delays are occurring may be late in arriving at its destination, thus delaying the departure time for the aircraft's next flight (p. 5).

### **5.2.5 Air Carrier Delay**

The cause of the cancellation or delay due to air carrier delay was due to circumstances within the airline's control (e.g. maintenance or crew problems, aircraft cleaning, baggage loading, fuelling, etc.). These type of data detailing the exact causes of air carrier delay reside with the air carrier and were not available for this study.

### **5.2.6 Extreme Weather**

Extreme weather is significant meteorological conditions (actual or forecasted) that, in the judgment of the carrier, delays or prevents the operation of a flight, such as a tornado, blizzard or hurricane.

Extreme weather delay was a minor cause of delays at ATL (Figure 12). During these events flights are cancelled or diverted, eliminating the potential for delays. Airlines are becoming more proactive, cancelling flights in advance of hurricanes or blizzards when there is sufficient warning, even moving aircraft to other locations so they are not stranded at the airport being affected (Associated Press, 2013).

### **5.2.7 Security**

Delays or cancellations caused by evacuation of a terminal or concourse, re-boarding of aircraft because of a security breach, inoperative screening equipment and/or long lines in excess of 29 minutes at screening areas.

As Figure 12 shows, security delays were minimal at an average of 0.12% delays per year for ATL and do not appear to have an adverse effect on delays.

Researchers investigated ATL airport improvements and/or changes that might have affected flight delays during this time period. In 2008, ATL revised taxiways and aircraft routing between the terminal gates and the runways. As shown in Figure 11, there is a marked decrease in overall delays starting in 2008.

## 6. Conclusions

The obtained analytic 'harmonic' expression (1) for calculating the average delay at the ATL airport is an expression which can be used as a prototype for calculating the similar dependences for different airports allows the long-term seasonal prediction of the flight delay on the annual basis.

This expression shows at a minimum an annual pattern of delays at ATL that can be modelled using delay data from the Bureau of Transportation Statistics. Other patterns may be linked to other factors not yet revealed in this study. This annual pattern appears to be caused primarily by the frequency and amount of precipitation that falls at ATL and by the amount of flights that arrive and depart at ATL. Precipitation/weather and its associated low visibility, lower cloud ceilings and wind at ATL reduce the amount of traffic that ATL can handle during these precipitation periods. The infrastructure is less tolerant to schedule perturbations when the airport is operating at or near capacity during periods of precipitation.

These factors along with the following factors then create further delays::

- Late arriving aircraft
- FAA Ground Delay Program (GDP) and specifically the Expect Delay Clearance Time (EDCT). The delays induced by this program are based on the ability of destination airports to accept flights from ATL.

Higher flight operations coincide with higher periods of precipitation, which work against each other to increase delays

Cancelling flights in advance of adverse weather will reduce delays and allow for a more orderly recovery from the adverse weather.

Additional airport infrastructure, though expensive, can reduce delays. Delays were reduced by revising procedures for the more efficient use of taxiways and runways at ATL.

This paper supports the conclusions of Capozzi, Andre and Smith (2007) where they concluded "key changes in operational philosophy and procedures (are) required in order that the future National Airspace System (NAS) to be less susceptible to the impact of weather" (p. 13).

## 7. Future Research Questions

Is some amount of flight delay acceptable to the air carriers and passengers? In some cases, delays may be beneficial. A pilot might delay a flight until a thunderstorm passes through the airport, or not depart until the aircraft is functionally correctly. Should air carriers have those types of delays count against them when the purpose of the delay is to improve safety? Of course, there would be the temptation to lump all delays as "safety delays". Are airports willing to add more taxiways and runways to handle peaks in traffic? The air carriers' response might be to increase the frequency of flights to take advantage of the added capacity and have the airport face the same problems it was trying to solve.

Should flight schedules and flight operations account for airport weather patterns? How can air carriers better anticipate and adjust schedules for something as unpredictable as weather? While air carriers are doing better in anticipating and mitigating the effects of severe weather, what can be done to mitigate the effects of normal precipitation?

Can technology be advanced where air traffic flows at the same rates and capacity as if precipitation wasn't present? Innovations in enhanced vision systems, required navigation performance (RNP) and cockpit displays may allow pilots to safely fly regardless of weather.

These and other questions raised by this and other research will require the collaboration of researchers, aircraft manufacturers, air carriers and the FAA to decrease flight delays while maintaining a level of safety that the flying public expects and demands.

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