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# Analyzing the Effect of Delta Airlines' Fleet Upgrade on Operations at Atlanta-Hartsfield Jackson International Airport

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Commercial aviation has seen a growth in terms of passengers traveled and flights operated in the past decade (BTS, 2020). To cope up with this growth, airlines adopt various strategies such as network expansion and fleet upgrades. Airlines adopt fleet upgrade strategies to modernize their fleet, reduce costs, expand network coverage, and improve customer loyalty and experience. Research suggests that change in wake turbulence categorization and aircraft performance can directly impact the movements and delays at an airport. For this study, Delta Airline's fleet upgrade program and its effect on operating parameters at Atlanta-Hartsfield Jackson International Airport were analyzed. The operating parameters analyzed for this study included runway delays, take-off delays, and runway movements. The traffic schedule of 11th November 2019 was simulated for the analysis with a total of 2,538 flights. A change in the fleet configuration would lead to a change in the wake turbulence categories of the aircraft that would directly impact operating parameters such as runway movement and delays. The results of the simulation indicate that operating Delta's upgraded fleet would lead to an increase in runway delays and take-off delays and a decrease in runway movement for all five runways at Atlanta. The consistent results across all parameters indicate that Delta's upgraded fleet and the corresponding change in aircraft performance and wake turbulence categorization would lead to a decrease in airport efficiency at Atlanta Airport.

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Commercial aviation has seen growth in terms of passengers traveled and the number of flights operated in the past decade (2010-2019). As per the data recorded by The Bureau of Transportation Statistics (BTS), the total number of flights increased from 10,000,333 in 2010 to 10,220,184 which translates to an increment of 2.20% (U.S DOT, 2020). This steady increase in flight operations has presented challenges to airports, airlines, and various other aviation/airspace stakeholders seeking to increase the National Airspace System (NAS) capacity and reduce operational delays. Operational delays can lead to increased costs for airlines due to passenger compensations, as well as loss in revenue due to flight cancellations. The Federal Aviation Administration (FAA) has taken various steps to increase the efficiency of the NAS, which includes various measures under the FAA NextGen program (FAA, 2018). Catering to this growing demand, airlines often undergo long-term fleet upgrades. Fleet upgrades help an airline reduce the average fleet rate, maintain customer loyalty, expand route networks, and reduce operating costs.

The purpose of this study is to analyze Delta Airlines fleet upgrades on operations at Atlanta-Hartsfield Jackson International Airport (KATL). A major factor that is expected to impact operations at KATL due to the upgraded fleet is the change in the wake turbulence categories of the newer aircraft.

## Statement of the Problem

There is a lack of literature analyzing the impact of a large-scale fleet upgrade on the operations of an airport. Delta Airlines is undergoing a large-scale fleet upgrade program that will result in a significant change in the fleet composition of the airline (CAPA, 2018). Atlanta is Delta Airlines' largest operating base where Delta operated more than 260,000 flights in 2019 (Cirium, 2020). Some of the factors that were analyzed in the study were changes in aircraft speed, performance profile, and wake turbulence category. Literature suggested that change in the wake turbulence category can significantly impact the delays and operations at an airline as a change in the wake turbulence category leads to a change in separation minimums in the terminal airspace. There is a lack of literature to study the impact of such factors on the operations at Atlanta Airport. There needs to be research conducted to forecast the impact of fleet upgrades on the long-term operations of an airport. While the study was focused on Delta Airlines at KATL, the results of this study lay a theoretical foundation for further research on fleet upgrades, airport operations, and wake turbulence categorization.

## Purpose Statement

The purpose of this study is to analyze the effects of Delta's fleet upgrade on operations at KATL. To perform this analysis, the researchers utilized a modeling and simulation method. Total Airspace and Airport Modeler (TAAM) software was used to create an operational model and perform simulations for KATL.

## Research Question

The study utilized a simulation of the operations at Atlanta Airport (KATL) to answer the following research question:

- How does Delta's fleet upgrade affect the operations at Atlanta Hartsfield Jackson International Airport?

## Literature Review

Runway capacity is a major limiting factor for the growth of an airport's operations capacity and the airlines that operate from the airport (Coleman et. al, 2019). Aircraft are categorized according to their Maximum Take-Off Weights (MTOW) for wake turbulence categorization that is used for air traffic spacing and separation. The FAA has mandated separation minimums that are followed by Air Traffic Controllers for different aircraft types operating in all civil airports in the US. This separation directly affects the capacity and throughput of a runway at any airport. For an airline, the wake turbulence category of its fleet is vital. Due to the wake turbulence recategorization (RECAT) program and Delta's long-term fleet upgrades, it is of significant interest for Delta and other airlines to estimate the impact of the fleet upgrades on the airline's operations at its major hub airport.

### Wake Turbulence Separation

Every aircraft produces vortices that result in wake turbulence (FAA, 2014). There is plenty of literature that studies the pattern and behavior of these vortices and their effects on other aircraft. The FAA published an Advisory Circular 90-23G on the subject *of Aircraft Wake Turbulence.* The FAA emphasized that the wake turbulence generated by larger aircraft poses a hazard to smaller aircraft behind it and can cause damage to aircraft components and equipment and can even cause injury to crew and passengers. This wake turbulence causes a hazard for the aircraft flying behind, and therefore it is necessary to maintain a separation between two aircraft.

Controllers have the important task of ensuring wake turbulence separations. Separation minimums vary for different phases of the landing/take-off, departure/arrival, and en-route phases. The FAA is leading a RECAT effort for all civil aviation operations in the US. The RECAT effort is part of the FAA NextGen program. As explained by Edward Johnson, FAA Chief Scientific and Technical Advisor for Wake Turbulence, the RECAT process will be undertaken in three phases. The preliminary phase started in 2012 and the third phase is expected to take place between 2020 and 2030 (Johnson, 2017). The NextGen program itself is being implemented in four segments and is named Alpha (2010-2015), Bravo (2016-2020), Charlie (2021-2025), and Delta (2026-2030). The third phase of the wake turbulence RECAT program is expected to take place in the Charlie and Delta segments of the NextGen Program (FAA, 2018).

The former wake turbulence categorization system used weight as the sole parameter for categorization. Aircraft were categorized into Light, Medium, and Heavy. Aircraft such as the Airbus A380 fell into a special category called *Super Heavy*. ICAO published its separation standards in ICAO PANS-ATM 4444 and aircraft designators in ICAO Doc 8643. The FAA separation standards were mandated in Joint Order 7110.65. However, these documents have now been reviewed and revised as revised separation minimums are being adopted by different aviation regulators around the world as part of the RECAT effort. The RECAT Phase 1 was launched in 2012 which categorized the aircraft type into six categories. Cheng et. Al (2016) explained that Phase 1 of the RECAT program defined the "static categorical pairwise separation" while Phase II defines the "static pairwise wake turbulence separations" which allows for lower separation standards between particular pairs of aircraft (Cheng et.al, 2016, p.2). The goal of Phase III is to further enhance the separation minimums and define "dynamic pairwise wake turbulence separation minimums" (Cheng et.al, 2016, p.3). As of August 2020, the FAA has been implementing Phase II of the RECAT process in the Bravo segment of the FAA NextGen program. However, the RECAT program is being updated under the different phases of the program to improve efficiency and as of August 2020, the program is at the end of the second phase of its implementation which is named Consolidated Wake Turbulence (CWT). As of August 2020, the latest guidance on CWT is published in Joint Order 7110.126A. The list of aircraft types and their designation according to the RECAT program is published in Joint Order 7360.1E (FAA, 2019) and the separation standards are published in Joint Order 7110.126A (FAA, 2019). This analysis will only utilize the FAA categories, guidance, and separation minimums as mandated in JO 7110.126A and JO 7360.1E.

**Delta Airlines**

Delta Airlines is the airline whose operations will be modeled and simulated for the analysis. Delta Airlines was selected for this analysis because the airline is undergoing a medium and long-term fleet upgrade program (CAPA, 2018). Delta Airlines is a scheduled air carrier that is registered in the US. As of January 2020, Delta Airlines operated to 242 destinations worldwide and possessed 913 aircraft in its inventory (Cirium, 2020). The company's fleet consisted of a mix of wide-body and narrow-body aircraft.

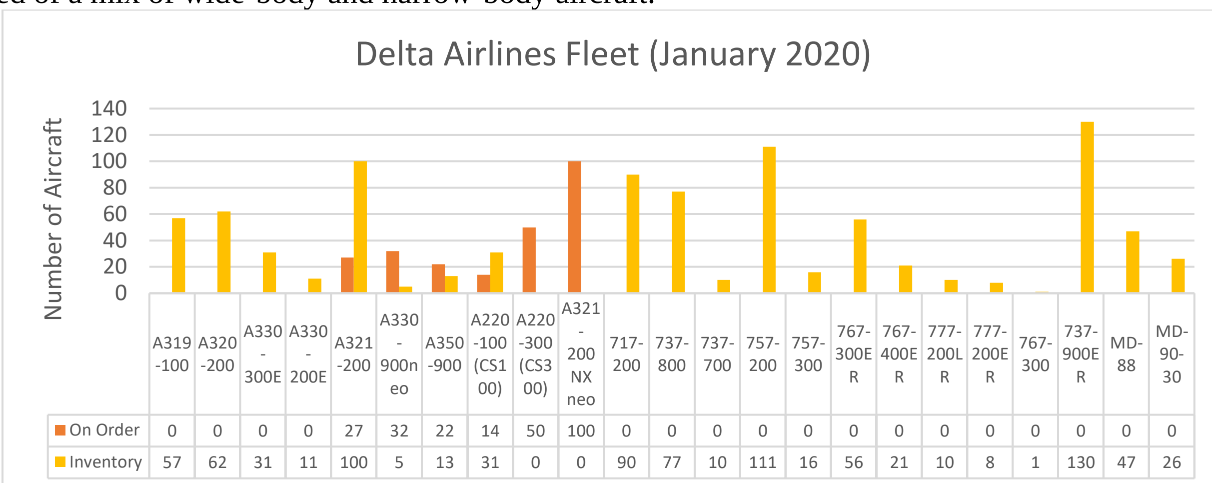


*Figure 1*. Delta Airlines Inventory and On-Order aircraft (Does not include regional jets operated by subsidiaries) (Cirium, 2020)

Figure 1 illustrates the fleet details of Delta Airlines as of January 2020. Figure 1 details the number of aircraft for each fleet type in inventory and 'on order' as of January 2020. Delta Airlines had 913 aircraft in the inventory and had 245 aircraft 'on order'. Delta Airlines operates from Atlanta-Hartsfield Jackson International Airport (KATL) and considers it its primary hub (Cirium, 2020). As illustrated in figure 2, Delta Airlines operates the greatest number of flights from KATL (BTS, 2020).

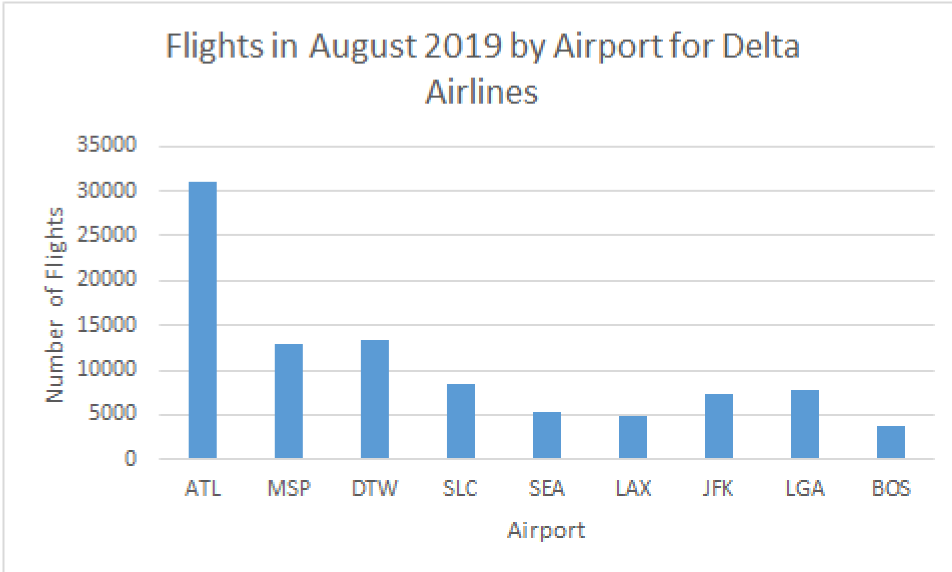


*Figure 2.* The flights operated by Delta Airlines in August 2019 from its 9 largest hubs. Atlanta is Delta's largest hub.

**Delta Airlines Fleet Upgrades**

Delta Airlines has one of the world's oldest fleets and is currently going through a long-term upgrade plan that will span through the next decade (CAPA. 2018). Delta airlines is expected to upgrade approximately 35% of its fleet by 2019-2024 (CAPA, 2019). Delta Airlines is upgrading its fleet by replacing its older aircraft with newer fuel-efficient aircraft. Some of the newer aircraft that Delta Airlines has placed orders for are the Airbus A220-100's/A220-300s and Airbus A321NEOs. Additionally, Delta Airlines has already signed orders for the Airbus A330-900s and the Airbus A350-900s. Table 1 details the aircraft that Delta will be utilizing for its fleet upgrades (Cirium, 2020). As of August 2020, Delta had already received the delivery of some of its new aircraft which have been tabulated under "Inventory". According to the Center for Aviation (CAPA) study, Delta Airlines will be retiring the older wide-body fleet (Boeing 767s) and older narrow-body fleet (MD88s/MD90s, MD80s, CRJ900s).

**Table 1**

*Delta Airlines Fleet Upgrade orders as of August 2020* (Cirium, 2020)

| Aircraft Name | On-Order | Inventory |
|---|---|---|
| A321-200 | 27 | 100 |
| A330-900neo | 32 | 5 |
| A350-900 | 22 | 13 |
| A220-100 (CS100) | 14 | 31 |
| A220-300 (CS300) | 50 | 0 |
| A321-200NX neo | 100 | 0 |

**Analysis of CAPA Data**

CAPA's analysis of Delta's long-term fleet upgrade program is based on Delta's publications and statements. For this modeling analysis, Delta's fleet data (inventory and orders) and CAPA's analysis will be utilized. To create a meaningful analysis, certain assumptions will be made while modeling the fleet upgrades which are described below:

***A220-100s/A220-300s*:** Airbus 220-100s/A220-300s are set to replace some of Delta's aging Bombardier CRJ-900 and Boeing 717 aircraft. However, Delta does not directly operate any Bombardier CRJ900 but operates a fleet of CRJ900s through its regional carriers such as Republic Airlines, Skywest Airlines, and Endeavor Air under the Delta Connection brand (Cirium, 2020). However, Endeavor Air is the only regional airline that Delta Airlines has 100% ownership of (Cirium, 2020). Endeavor Air is also Delta Airline's largest regional carrier. Thus, for this study, it is assumed that all the A220-100s/A220-300s that are expected to replace the CRJ900s will replace some of the CRJ900s operated by Endeavor Air operating into Atlanta Airport (KATL).

***Airbus A321-200/A321NEOs*:** The Airbus 321-200s and Airbus A321NEOs are set to replace the Boeing 717s, MD88s, MD90s, and Boeing 757s operated by Delta Airlines (CAPA, 2018). Delta Airlines operates 100 A321-200s and has 27 A321-200s and 100 A321NEOs in order.

***Airbus A330-900 and Airbus A350-900*:** Delta Airlines intends to operate 37 A330-900s and 35 Airbus A350-900s. The A330-900s and A350-900s are set to replace the Boeing 767 and Boeing 777 fleet of Delta Airlines.

**Atlanta Hartsfield Jackson International Airport**

Atlanta Hartsfield Jackson International Airport serves the city of Atlanta in the state of Georgia. As stated in the Airport Traffic Report 2019 by the Port Authority of New York and New Jersey, KATL was the busiest airport in the US in 2019 in regards to passenger movements (110,531,300) (Port Authority NY NJ, 2020). A stated by the Airport Council International, KATL had the second-highest aircraft movements in 2018 in the US just behind Chicago O'Hare International Airport (ACI, 2019). According to the data available through the FAA Operational Network database, Atlanta Airport had a total of 904,301 air traffic counts in 2019 (FAA, 2020). Figure 3 is a histogram for the traffic counts per day for Atlanta Airport in 2019 ($M$= 2,477.5, $SD$=253.508). Additionally, the highest total air traffic counts per day were observed to be on Mondays of every week with an average of 2,596 operations. Considering these factors, 11th November 2019 (Monday) was chosen for the simulation which had 2,538 traffic counts. The day for the simulation was selected to replicate the most recurring traffic condition for KATL.

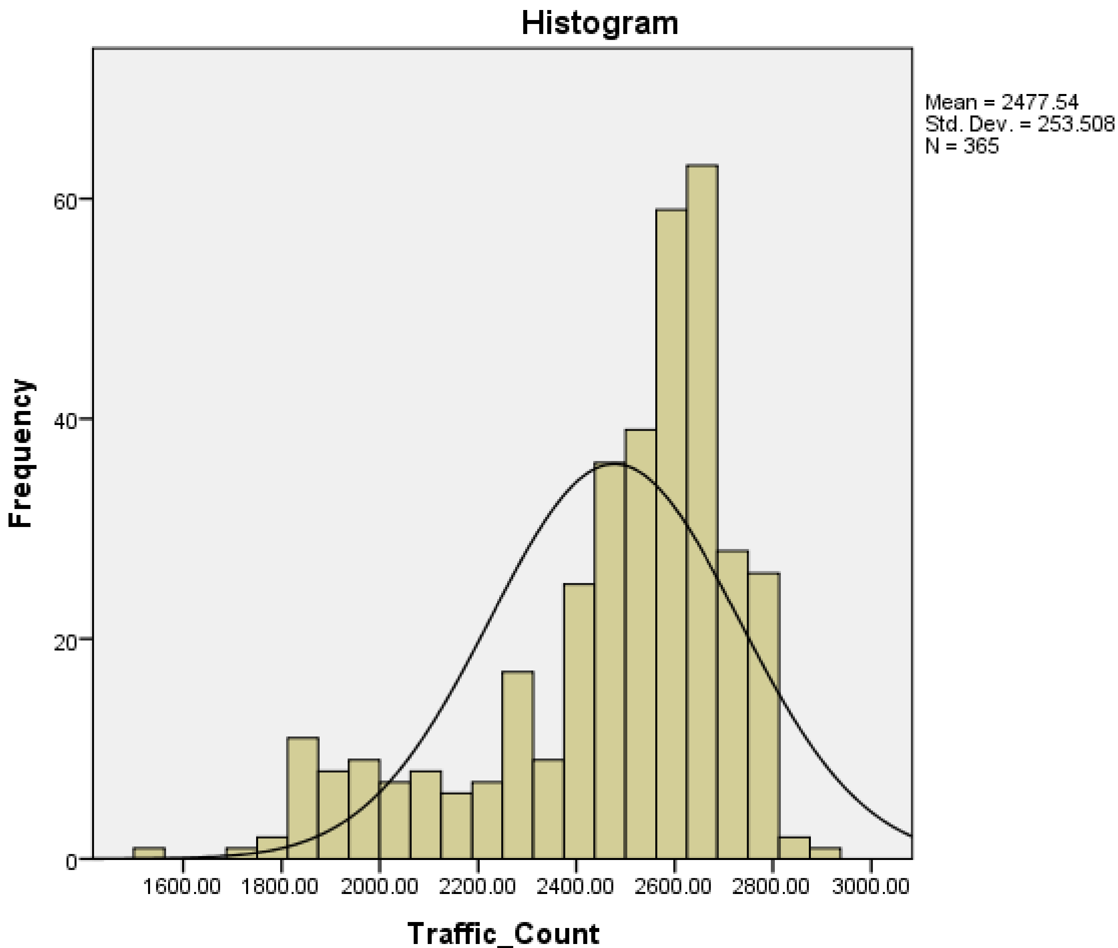


*Figure 3.* Histogram of air traffic counts per day for 2019 at KATL

## Methodology

The purpose of this study is to analyze the effects of Delta's fleet upgrades on the airline's operations at KATL. The study utilized a quantitative methodology with a simulation research design. Jeppesen Total Airspace and Airport Modeler (TAAM) was utilized for modeling and simulation.

### Total Airspace and Airport Modeler

TAAM is a modeling and simulation software developed by Jeppesen. TAAM allows users to create fast-time and gate-to-gate models to analyze and predict future airspace and airport operations (Jeppesen, 2020b). TAAM allows users to model entire airspace systems or just a subset (Atlanta Airport operations) and study the operations through detailed reports on parameters such as taxi times, departure delays, arrival delays, holding delays, and total throughputs (landings/takeoffs) amongst a range of other generated reports. These features allow users to modify some variables regarding the airspace operations and redesign the airspace and assess its impact on safety and efficiency through pre-defined parameters (Jeppesen, 2020b). TAAM Version 2020.2 was utilized for this study.

**Data**

As reviewed in the literature, the traffic data for 11th November 2019 was simulated to replicate the most recurring traffic data at KATL for 2019. The traffic data for 2019 was collected from the NextGen ERAU Applied Research Laboratory (NEAR Lab) at Embry-Riddle Aeronautical University, Daytona Beach. The traffic data provided by the NEAR Lab included the flight registrations, tail numbers, routes and procedures used, aircraft type, and runways used. The traffic data could be converted to comply with the TAAM capability to replicate the traffic conditions at KATL on 11th November 2019.

**Simulation**

To gather the data for the analysis in the study, two simulations were conducted by the researcher. Each simulation was conducted for 48 hours and started at 12 PM Local on 10th November 2019 and ended at 12 PM Local on 12th November 2019. The 48 hours simulation starting a day earlier than the day for analysis (11th November 2019) allows us to simulate long-range flights that might have commenced the trip a day before and landed at KATL on 11th November 2019. Similarly, ending the simulation on 12th November 2019 allowed to simulate flights that commenced the journey from KATL on 11th November 2019 but landed at their destination on 12th November 2019. However, only the data from 11th November 2019 was analyzed. Two simulations were performed for this study. One simulation was named Baseline and the other simulation was named Alternative.

**Baseline**

A baseline simulation on TAAM is used to simulate the airport conditions without any modifications or upgrades. It is imperative to design the simulation so that it replicates the exact working conditions of the target airport (KATL for this analysis). The baseline for this study was provided by the NEAR Lab at Embry-Riddle Aeronautical University, Daytona Beach. The baseline model was a validated model by simulation experts that closely replicated the airport layout and usage rules at KATL. The traffic data for 11$^{th}$ November 2019 was utilized on the model to create the baseline simulation.

**Alternative**

The alternative simulation was created to test the effect of a change on the operations at an airport. For the alternative simulation, the Delta Airlines fleet was updated as per the reviewed literature (Table 2). The fleet was upgraded utilizing data obtained from official Delta Airlines statements, CAPA, and Cirium (CAPA, 2018; Cirium, 2020).

**Fleet Upgrades**

The *Literature Review* detailed the fleet upgrade program of Delta Airlines. For this study, various assumptions have been made based on Delta Airlines reports and CAPA's analysis of Delta Airlines. Table 2 details the fleet upgrade assumptions that were utilized for this simulation.

**Table 2**
*Fleet upgrades plan for the simulation*

| Aircraft | Number of Aircraft (Inventory Order) | Upgrade Details |
|---|---|---|
| A220-100 | 44 | • 33% of CRJ900s operated by Endeavor Air<br>• 5% of the Boeing 717-200s operated by Delta Airlines |
| A220-300 | 50 | • 55% of the Boeing 717-200s operated by Delta Airlines |
| Airbus 321-200 | 127 | • 40% of the Boeing 717-200s operated by Delta Airlines<br>• 100% of the MD-88s operated by Delta Airlines<br>• 100% of the MD-90s operated by Delta Airlines<br>• 24% of the Boeing 757-200s operated by Delta Airlines |
| Airbus 321NEO | 100 | • 76% of the Boeing 757-200s operated by Delta Airlines<br>• 100% of the Boeing 757-300s operated by Delta Airlines |
| Airbus 330-900NEO | 37 | • 100% of the Boeing 767-300s operated by Delta Airlines<br>• 64% of the Boeing 767-300ERs operated by Delta Airlines |
| Airbus 350-900 | 35 | • 36% of the Boeing 767-300ERs operated by Delta Airlines<br>• 100% of the Boeing 767-400s operated by Delta |

**TAAM Reporter**

The TAAM Reporter function of TAAM allows the users to record operating parameters for research and analysis. The researchers recorded data in 10 minutes intervals for both simulations (Baseline and Alternative). The parameters that were analyzed for this study were take-off delays, runway delays, and runway movement (Jeppesen, 2020a).

## Results

Data was analyzed from TAAM Reporter for the two simulations conducted. The data was only recorded for a 24-hour time period for the schedule of 11th November 2019 to 11:59 PM for the schedule of 11th November 2019. The recorded parameters were take-off delays, runway movement, and runway delays.

**Take-Off Delays**

The Baseline and Alternative simulations consisted of 2538 flights. Figure 4 graphically depicts the take-off delays at KATL for the Baseline simulation. Only Runway 26L and Runway 27R were used for take-offs in the simulation. Only the take-off delay data for Runway 26L and Runway 27R was analyzed. Runway 26L had higher take-off delays for most of the day.

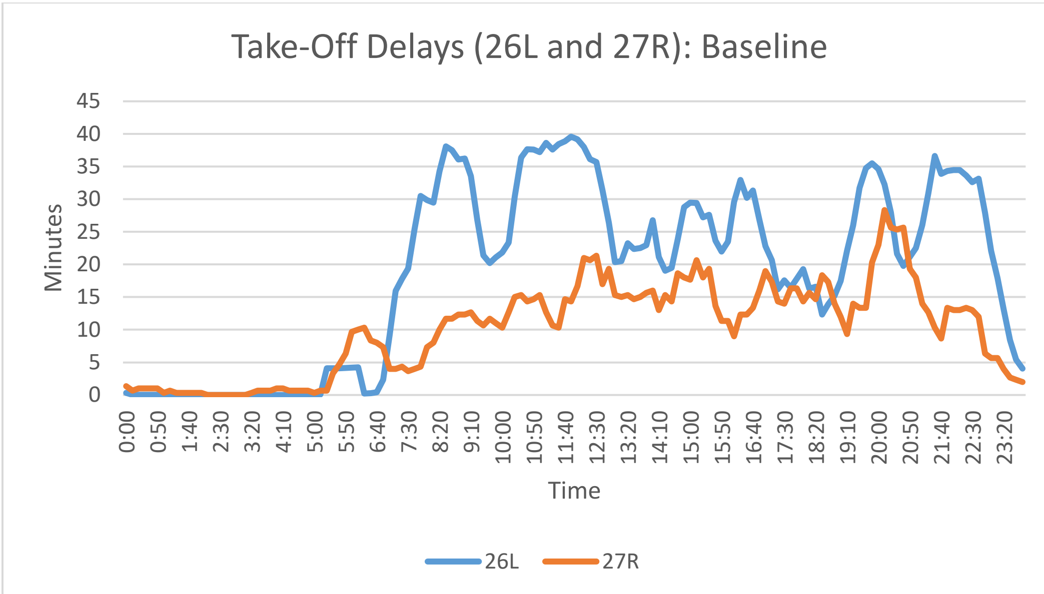


*Figure 4*. Take-Off Delays for Runway 26L and 27R in Baseline

Figure 5 graphically depicts the take-off delays at KATL for the Alternative simulation. Only the take-off delay data for Runway 26L and Runway 27R was analyzed. Runway 26L had higher take-off delays for most of the day.

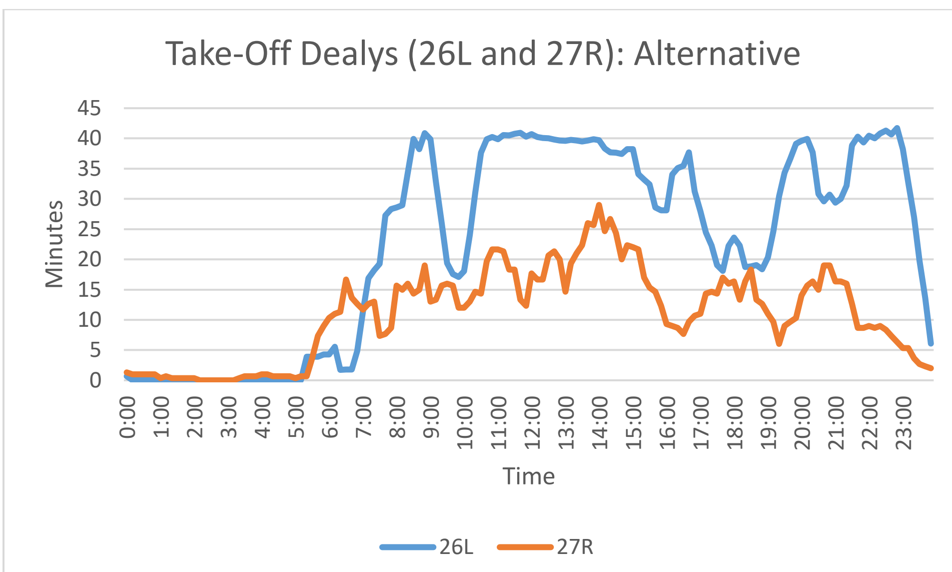


*Figure 5*. Take-Off Delays for Runway 26L and 27R in Alternative

Figure 6 depicts the total take-off delays for Baseline and Alternative simulations. Figure 6 can be used to compare the Take-off delays for Baseline and Alternative. Table 3 details the mean and standard deviation of take-off delays for the two simulations. Table 3 and Figure 6 illustrate that the Alternative had higher mean take-off delays for Runway 26L and Runway 27R.

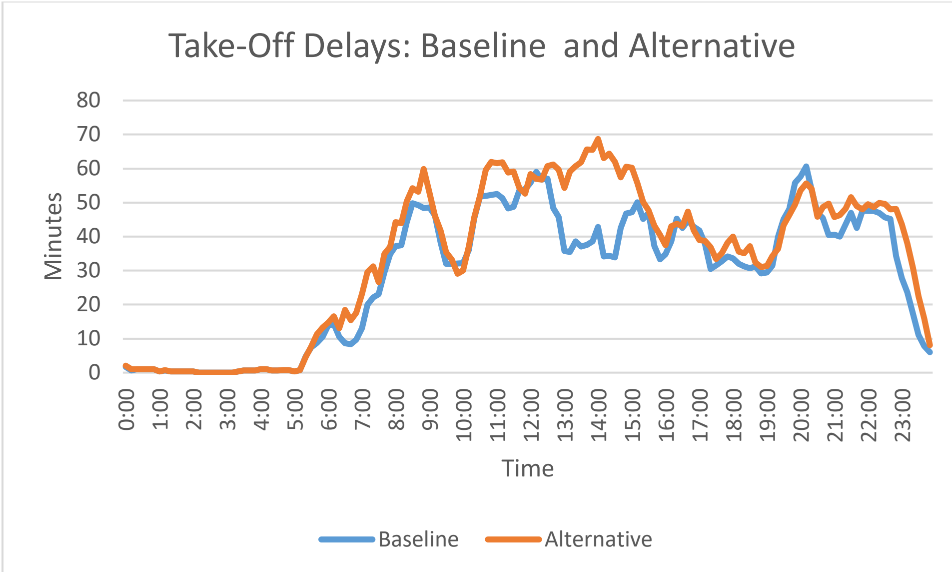


*Figure 6*. Total take-off delays for Baseline and Alternative

**Table 3**
*Mean Take-off delays for Baseline and Alternative (minutes)*

| Baseline | Mean | Standard Deviation | Alternative | Mean | Standard Deviation |
|---|---|---|---|---|---|
| Runway 26L | 18.91 | 19.71 | Runway 26L | 22.92 | 16.01 |
| Runway 27R | 10.20 | 7.07 | Runway 27R | 10.99 | 7.51 |
| Total | 29.11 | 19.48 | Total | 33.92 | 22.16 |

To compare the take-off delays between the Baseline and Alternative, an independent t-test was conducted. The assumption of the equality of variance was tested. Levene's test of equality of variance was significant (p = 0.001) and thus an adjustment to degrees of freedom was made. The mean take-off delays for the Baseline ($M$ = 29.11, $SD$ = 19.48) was smaller than the take-off delays for the Alternative ($M$ = 33.92, $SD$ = 22.16). An independent samples t-test was significant at the alpha level of .05, $t(305.411) = -2.657$, p = 0.008.

**Runway Movement**

Runway movement is the number of aircraft that landed/took-off from a runway or multiple runways in a definite period. Runway movement is a vital parameter to understand the runway usage patterns at an airport and understand other parameters such as take-off delays and runway delays. The Baseline and Alternative simulations consisted of 2538 flights. Figure 7 graphically depicts the runway movements at KATL for the Baseline simulation. Runway movement data was recorded for all five runways at KATL. Runway 26L had the highest mean runway movement among all the runways at KATL.

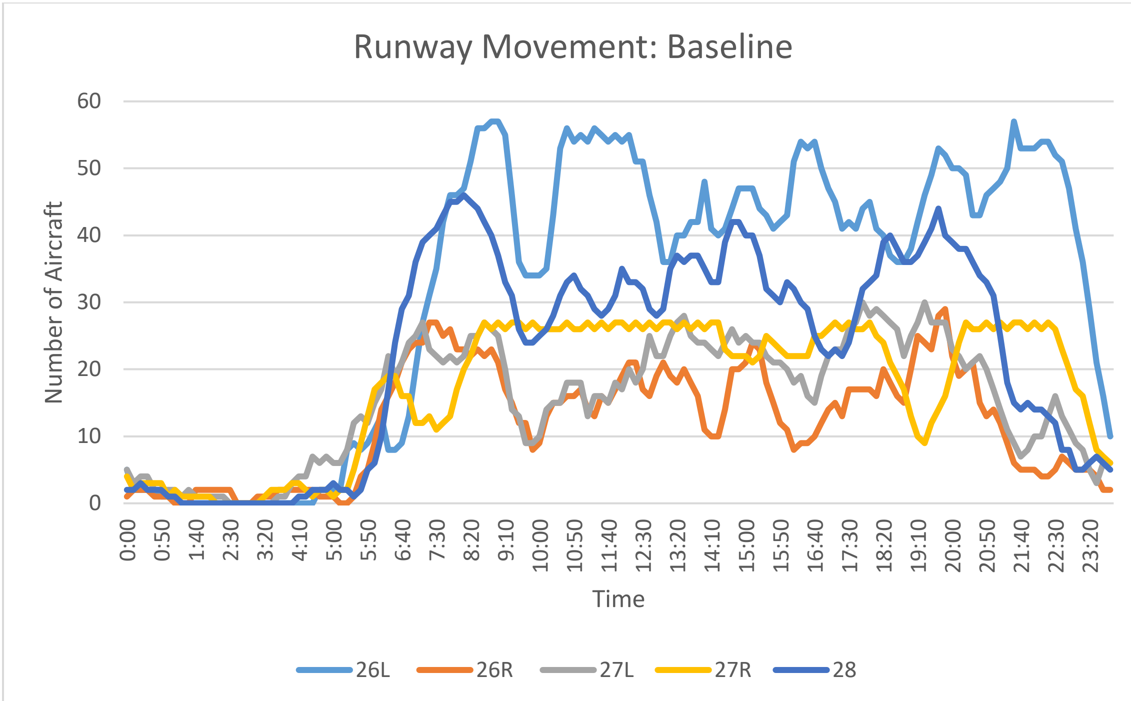


*Figure 7*. Runway movement for Baseline

Figure 8 graphically depicts the runway movements at KATL for the Alternative simulation. Figure 8 graphically depicts the runway movements at KATL for the Alternative simulation. Runway 26L had the highest mean runway movement among all the runways at KATL.

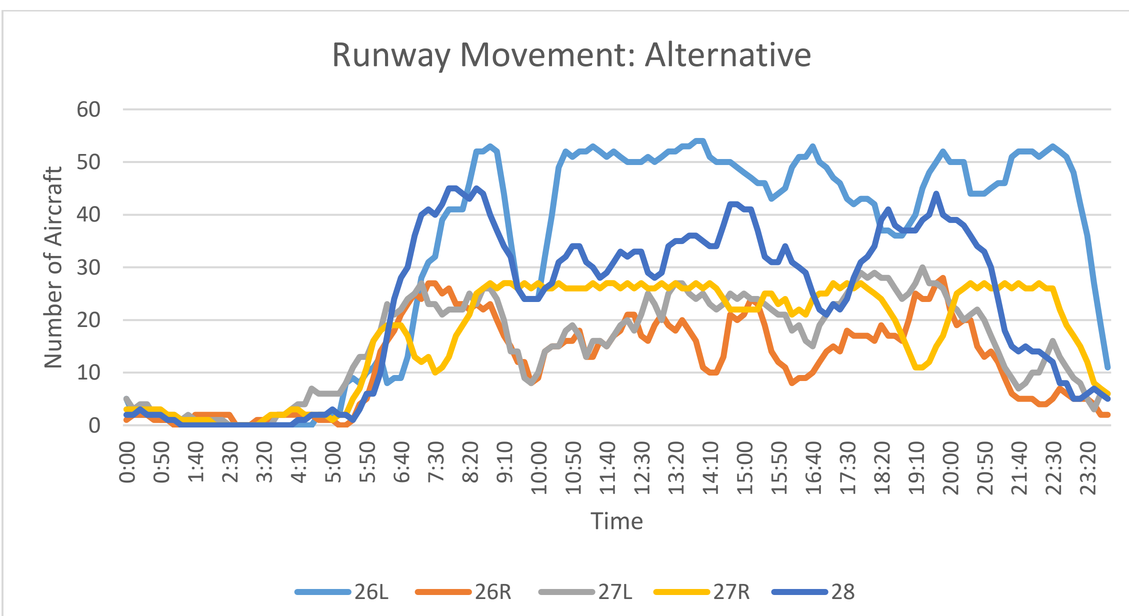


*Figure 8*. Runway movement for Alternative 2

Figure 9 compares the total runway movement for all five runways in the Baseline and Alternative simulations. Figure 9 and Table 4 can be used to compare the runway movements for Baseline and Alternative. Baseline had higher mean runway movements than Alternative.

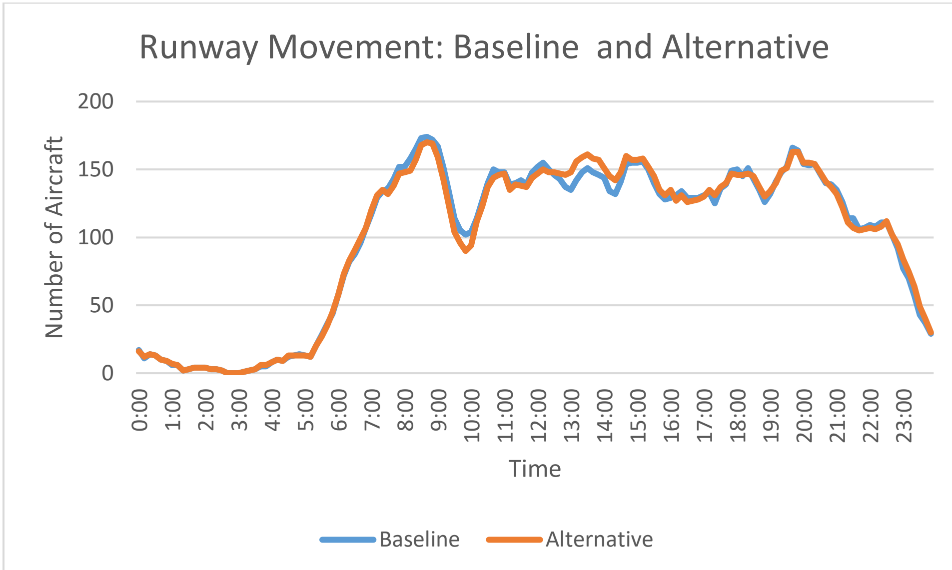


*Figure 9*. Total runway movement for Baseline and Alternative

**Table 4**
*Mean runway movements for Baseline and Alternative*

| Baseline | Mean | Standard Deviation | Alternative | Mean | Standard Deviation |
|---|---|---|---|---|---|
| Runway 26L | 32.66 | 20.74 | Runway 26L | 32.64 | 20.69 |
| Runway 26R | 12.14 | 8.37 | Runway 26R | 12.10 | 8.36 |
| Runway 27L | 15.64 | 9.12 | Runway 27L | 15.60 | 9.10 |
| Runway 27R | 17.38 | 10.14 | Runway 27R | 17.36 | 10.10 |
| Runway 28 | 22.53 | 15.52 | Runway 28 | 22.51 | 15.48 |
| Total | 100.24 | 58.19 | Total | 100.20 | 58.09 |

To compare the runway movements between the Baseline and Alternative, an independent t-test was conducted. The assumption of the equality of variance was tested. Levene's test of equality of variance was not significant ($p = 0.961$). The mean runway movement for the Baseline ($M = 100.24$, $SD = 58.19$) was larger than the take-off delays for the Alternative ($M = 100.20$, $SD = 58.09$). An independent samples t-test was not significant at the alpha level of .05, $t(455) = -0.415$, $p = 0.679$.

**Runway Delays**

Baseline and Alternative had 2538 flights. Figure 10 graphically depicts the total runway delays at KATL for Baseline and Alternative simulations. The mean of runway delays for Alternative (*M*=23.49, *SD*= 16.29) was higher than the mean of runway delays for Baseline (*M*=19.42, *SD*= 13.81)

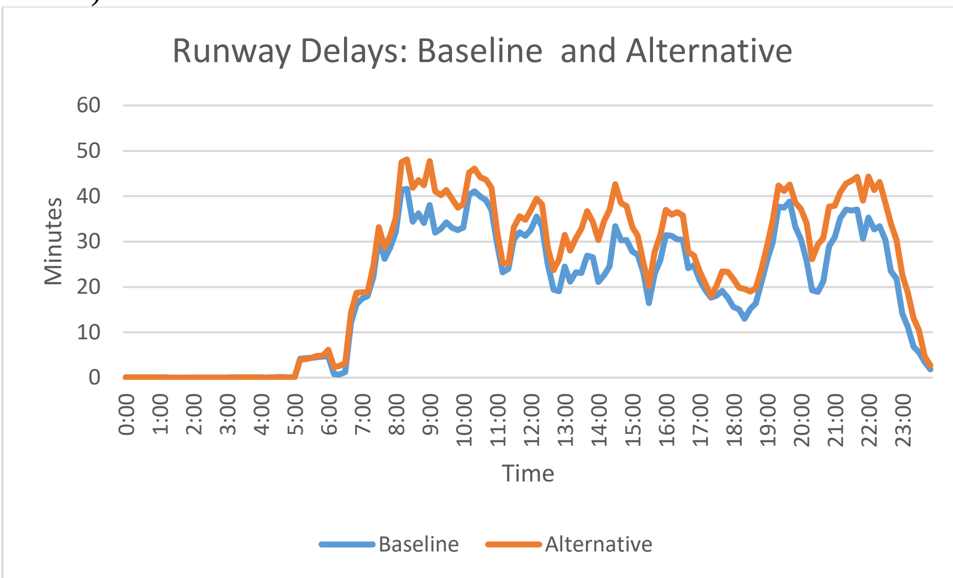


*Figure 10*. Runway delays for Baseline and Alternative

To compare the runway delays between the Baseline and Alternative, an independent t-test was conducted. The assumption of equality of variance was tested. Levene's test of equality of variance was not significant (p = 0.001) and thus an adjustment to the degrees of freedom was made. The mean runway movement for the Baseline (*M* = 19.424, *SD* = 13.81) was smaller than the take-off delays for the Alternative (*M* = 23.49, *SD* = 16.49). An independent samples t-test was significant at the alpha level of .05, $t(439.073) = -0.408$, p = 0.018.

## Discussion

The purpose of this study was to analyze the impact of Delta Airlines fleet upgrades on operations at Atlanta-Hartsfield Jackson International Airport. A modeling and simulation approach was adopted to gather data for analysis. Atlanta-Hartsfield Jackson International Airport's schedule for 11$^{th}$ November 2019 was modeled and simulated for the analysis. As depicted in the graphical representations of the parameters, the traffic flow increased significantly after 0600AM Local. The highest runway delays and runway movement were observed at 0700-0900 local time. The second phase of high runway delays and runway movements was observed from 1800-2000 local time. These observations were coherent with the researcher's observation of Atlanta's traffic flow data from the FAA's Operations Network database (FAA, 2020). Additionally, Runway 26L was the busiest runway for departures with the highest runway movement observed. Runway 26L was primarily used for northbound departures. The take-off delays for Runway 26L were significantly higher than the take-off delays for Runway 27R. Runway 28 was the south-most runway and had the highest runway movement in the arrival runways. Runway 28 was primarily used by arriving aircraft from the south.

The analysis of the parameters indicates a decrease in runway movement for the Alternative simulations. Coherently, there was an increase in take-off delays and runway delays observed for the Alternative simulation. The results indicate that Delta's upgraded fleet configuration would lead to higher delays and lower runway movements. The statistical significance of the upgraded fleet configuration is beyond the scope of this study and would require a correlational and regression analysis. However, the consistent increase in runway movement for all five runways indicates a decline in operations efficiency for Atlanta Airport with Delta's upgraded fleet configuration.

The results indicate an increase in runway delays and decrease in runway movement with the change in the fleet. This could be due to different reasons that could be investigated with further analysis. A change in fleet configuration leads to a change in aircraft performance parameters that could influence the aircraft's speed. Another significant difference with the change in aircraft fleet is the change in wake turbulence categorization. A change in wake turbulence categorization leads to a change in separation minimums during take-offs and landings that the aircraft is subjected to. The literature reviewed stated that a change in separation minimum could directly influence the runway movement and delays. The wake turbulence separation minimums utilized for the simulation were adapted from the Consolidated Wake Turbulence minimums published under Joint Order 7110.126A. The researchers conducted three independent sample t-tests to test the statistical significance of the observed differences in take-off delays, runway delays, and runway movements. The independent sample t-tests were significant at an alpha level 0.5 for runway delays and take-off delays. However, the t-test for runway movement was not significant. The difference in take-off delays and runway delays did not translate to a statistically significant change in the runway movement. Delta Airlines will be executing the fleet upgrade program in spite of a significant increase in delays at Atlanta Airport for the upgraded fleet. An upgraded fleet benefits the airline with improved fuel efficiency, better customer experience and loyalty, lower maintenance costs, and an increase in network coverage. The benefits of Delta's fleet upgrade program might outweigh the increase in delays at Atlanta. This study lays the theoretical foundation for a cost-benefit analysis for the upgraded fleet.

## Limitations

The researchers identified several limitations in the study. The results of this study could change as the FAA transitions through the Charlie and Delta stages of the FAA NextGen Program and Phase 3 of the RECAT program. The FAA is actively working towards introducing technology that could further reduce aircraft separation. The introduction of newer technologies in Phase 3 of the RECAT program and the further segments of the NextGen Program could alter the results of this study. While the results of this study could vary with the introduction of revised separation minimums, the results provide a theoretical framework for further research and evaluation into the effects of fleet changes on airport operations. Finally, the results of the study were dependent on simulation techniques embedded in Jeppesen TAAM. While TAAM has been recognized as an industry-standard and credible software for modeling and simulation, the authenticity and relevance of the results in the real world were not independently verified by the researcher.

## Conclusion

The purpose of this study was to analyze the impact of Delta Airlines fleet upgrades on operations at Atlanta-Hartsfield Jackson International Airport. The Jeppesen Total Airport and Airspace Modeller was utilized to conduct the modeling and simulation in the study. The literature reviewed for the study indicated that the wake turbulence categorization can influence the operations at an airport as the categorization impacts the separation minimums the aircraft at the airport are subjected to. The researchers aimed at understanding the effect of Delta Airlines' fleet upgrade program on the operations at Atlanta-Hartsfield Jackson Airport. A change in the fleet configuration would lead to a change in the wake turbulence category of the aircraft that would directly impact operating parameters such as runway movement and delays. The results of the simulation indicate that operating Delta's upgraded fleet would lead to an increase in runway delays and take-off delays and a decrease in runway movement for all five runways at Atlanta. The consistent results across all parameters indicated that Delta's upgraded fleet and the corresponding change in aircraft performance and wake turbulence categorization would lead to a decrease in airport efficiency at Atlanta Airport. The study only considered the Consolidated Wake Turbulence (CWT) separation minimums. As the FAA implements Phase 3 of the RECAT program and introduces further technologies under the FAA NextGen program, the results of this study could vary. However, the results provide a theoretical framework for further research and evaluation into the effects of fleet changes on airport operations.

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