Analysis of Gate-Hold Delays
At the OEP-35 Airports

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Abstract—One point of congestion in the air transportation system is the set of gates at a terminal. When an inbound flight is unable to pull into its assigned gate, the flight, its connecting passengers, and its flight crews experience delays and missed connections. Previous research has focussed on optimizing gate assignments, both scheduled and disrupted, and optimizing surface flow. This paper analyzes the degree to which gate hold is a problem and the functional causes of gate hold. Analysis of flight performance data for 35 OEP airports for the summer of 2007 identifies that: (i) Significant gate-hold delays, in which more than 30% of arriving aircraft are delayed, occurred at 11 of the OEP-35 airports, (ii) major gate-hold delays are rare events (e.g., once a month at ATL), (iii) on days when there is a major gate hold, large delays are experienced by all major carriers at the airport, (iv) the primary causes of gate-hold delays are increased turnaround times and/or disrupted arrival/departure banks. The methodology for analysis, the results, and the implications of these results are discussed.

Keywords—gate; congestion; delay; disruption; gate hold

I. INTRODUCTION

The objective of this paper is to evaluate the degree to which airport gates are a limiting resource in the flow of airplanes arriving to and departing from an airport. As an airplane arrives to and departs from an airport, it passes through several potential choke points. These include runways, taxiways, ramps, gates, and so forth. Depending on the demand and number of resources, different points in this process may become constrained and act as choke points.

The runways (and associated constraints) are usually the limiting resource in the flow through the airport. This is because various separation requirements – for example, wake-vortex separation requirements – limit the maximum number of operations that can be safely handled in a given time interval. Once an airplane has landed and has taxed to its gate, it can often pull directly into the gate without further delay, but sometimes it must wait for a departing aircraft to leave the gate. When the shortage of gates is more severe, an arriving aircraft may be sent to a “penalty box” where it must wait until a suitable gate becomes available (Figure 1).

While gates are not usually thought of as a choke point, this paper aims to evaluate the extent to which this can be the case. Conditions under which gates act as a limiting resource may increase over time if capacity is added to other parts of the system (say, through capabilities proposed in NextGen) without an appropriate analysis of the matching gate capacity.

At a high level, we can view this problem from the perspective of queueing theory [1]. In a theoretical queue, delays are related fundamentally to one or more of three issues: (a) a large arrival rate, (b) a low service rate, or (c) a small number of servers. Here, the gates are the servers and the service rate is the rate that aircraft can be turned at the gate. For example, if an aircraft has a longer turnaround time than what is scheduled, this is effectively a reduction in the service rate of the gate. For a queueing system operating near capacity, reducing the service rate – even by a little bit – can lead to significant delays [1]. In summary, gate-related delays...
are attributable in some way to either (a) too many arriving aircraft, (b) long turnaround times, or (c) insufficient gates. A second goal of this paper is to identify functional origins of gate-related delays related to these three fundamental causes.

This paper is organized as follows. Section II summarizes literature related to gate delay. Sections III and IV discuss several methods for estimating gate delay using the BTS and ASPM databases. Section V presents results for the OEP-35 airports as well as detailed results for Atlanta Hartsfield International Airport (ATL) and John F. Kennedy International Airport (JFK).

The results indicate that on most days, gate delays do not significantly limit throughput of the airport. However, on certain bad days, the limited number of gates leads to extreme delays. The problematic days appear to be linked to disruptions in the schedule. Disruptions in the schedule have the tendency of keeping aircraft on the ground longer, effectively reducing the gate “service rate.” For example, a disruption in the schedule may require using a different crew on a given flight. In a similar manner, if a flight is cancelled, then the aircraft may either be held at the gate or reassigned to a later flight, thus increasing the time at the gate. Ground delay programs for outbound flights may also increase the number of gates required as airlines choose not to enplane or not to push back these flights. Finally, disruptions in the schedule may lead to sets of aircraft arriving at the same time.

II. BACKGROUND AND RELATED LITERATURE

A. Gate Assignment

Gate assignment is usually handled in three phases [2]. The first planning phase occurs several months before the day of operation. Ground controllers check that a feasible gate assignment can be made with the proposed flight schedule, without making an actual gate assignment. The second phase involves the development of a single-day plan prior to the start of the actual day of operation. A gate assignment tool (similar to what is shown in Figure 2) can be used to get the initial gate assignment plan at the start of the day, or the initial gate board. The third phase revises these daily plans throughout the day of operation due to irregular operations such as delays, bad weather, mechanical failures and maintenance requirements [3]. The same gate assignment tool can be used to create the initial gate board at the beginning of the day (phase 2) and to update the gate assignment throughout the day (phase 3). These updates affect gate hold, and hence flight on-time performance, as well as airport manpower and passenger relocations.

Previous research on gate assignments has stressed improving the performance of initial gate assignments. The problem has been modeled as an integer program [4], [5], a mixed integer program [3], [6] and a network flow problem [7], [8]. Recently, some models have been developed to focus on gate changes [9]. Some research has even evaluated the robustness of the initial gate assignment plan and the real-time gate changes necessary to meet the stochastic flight delays that occur in real operations [8], [10], [11]. Such research has typically considered small stochastic disruptions in the schedule and not major disruptions. This paper shows that major schedule disruptions can have a significant impact on gate congestion, and hence corresponding gate assignment strategies need to be developed for these scenarios.

Other research has given benchmarks for the operational efficiency of airports based on input measures such as the number of gates, the number of runways, airport operating costs, the number of airport employees, and so forth [12], [13]. Research in [13] shows that terminal efficiency is improved by expanding the number of gates and managing them in a way to ensure their effective utilization. This can best be accomplished by placing them in common or exclusive use but not preferential use.

B. Airport Surface Operations

Queueing models and integer programming models have been used to model the taxi-in process [14], [15], [16]. The minimum service time under ideal turnaround operations has also been modeled [17]. But the impact of schedule disruptions on turnaround operations has not been studied thoroughly. Modeling turnaround times in irregular operations could lead to a better understanding of gate utilization.

More accurate departure demand prediction is another potential benefit of improved ground-operations modeling. Departure demand is based on the push-back time, which is determined by gate arrival time, the turnaround time, and the schedule. Departure demand prediction is important to air traffic controllers for runway and taxiway scheduling. But it has been found that the prediction of departure demand is not accurate because the turnaround time can not be predicted well [18]. Also, a gate shortage can result in pushing back aircraft from the gate, even though the downstream departure runway is a constraint [18]. This has implications on matching the runway and gate capacity under disruption scenarios. If departure runway capacity drops while arrival runway capacity remains the same, gate demand is higher because holding at the gate is preferred since it is more expensive to hold on the taxiway due to fuel burn, crew cost, aircraft maintenance, and taxiway congestion.
III. DATA SOURCES

Gate-hold delay is not recorded in actual operations and thus is not directly available in any database. In particular, although several databases record the taxi-in time of individual flights, they do not break this time into its component parts, such as the delay specifically due to waiting for a gate. Thus, gate-hold delay must be inferred or approximated using other information available.

This section discusses several data sources – in particular, the BTS and ASPM databases – and associated fields that can be used to infer or approximate gate-hold delay. The precise algorithms used to to estimate gate-hold delay are discussed in Section IV. Key differences between the ASPM and BTS databases are the following [19], [20] (see also Table I):

- BTS includes data for air carriers that have at least one percent of total domestic scheduled-service passenger revenues (20 carriers); ASPM includes data for all carriers.
- BTS includes data for operations to and from airports that account for at least one percent of the nation’s total domestic scheduled-service passenger enplanements (32 airports); ASPM includes data for 77 airports.
- BTS includes cancelled flights; ASPM does not.
- BTS does not include international flights; ASPM does.
- BTS covers nonstop scheduled-service flights between points within the United States, including territories.
- BTS does not include information regarding aircraft type; ASPM does.
- BTS contains the tail number of flights; ASPM only contains the tail number of flights that are also in BTS.

Table II shows the number of flights recorded in the data sources for two example days at two airports. In both days, ASPM records more flights than BTS, due to the inclusion of international flights. Also, the gap between ASPM and BTS is larger for JFK than for ATL, since JFK has a higher percentage of international flights. As a reference, the third line gives the average number of daily flights for each airport (averaged over one year, 2007) obtained from Airport Council International. The last line shows the number of flights observed from the public website www.flightstats.com. This site provides flight information by airport and day, including the flight’s final gate assignment, flight number, arrival time, departure time, carrier, and aircraft type. For example, we found that 179 different gates were used at ATL on June 11, 2007. We use this value as an estimate of the number of gates at ATL in the summer of 2007. However, the present number of gates is different, since new gates have been added [21].

IV. ESTIMATION OF GATE-HOLD DELAY

This section describes several methods to infer gate-hold delays based on information in the ASPM and BTS databases. We also describe a method to estimate gate-occupancy time by tracking the tail number of aircraft.

Roughly speaking, we approximate gate-hold delay as a certain portion of taxi-in delay, where taxi-in delay is the difference between the actual taxi-in time and the unimpeded taxi-in time. More specifically, we assume that, at most, 5 minutes of the taxi-in delay is comprised of non-gate-related delay such as taxi-way and ramp congestion. That is,

\[
\text{Gate-hold delay} \approx \max(\text{Taxi-in delay} - 5 \text{ min}, 0). \tag{1}
\]

The maximum function ensures that the estimated delay is non-negative. For example, if the actual taxi-in time is 7 minutes, and the unimpeded taxi-in time is 6 minutes, then the estimated gate-hold delay is set to 0. If the actual taxi-in time is 12 minutes, then the estimated gate-hold delay is set to 1 minute.

Of course, this is an approximation, since the method assumes that non-gate-related delays comprise exactly 5 minutes...
(or less) of the total taxi-in delay. The approximation may be partially justified, since it has been observed that gate-related delay is a dominant contributor to the total taxi-in delay [15]. Also, we can vary the 5-minute parameter to check the sensitivity of results to this value. However, the overall implication of the approximation is that the gate-delay statistic does not provide an exact magnitude. Thus, it is generally more useful as a relative metric to identify qualitative trends and/or differences between airports, carriers, and so forth.

We now describe two specific methods for calculating gate-hold delay from the ASPM and BTS databases and one method for calculating gate-occupancy time.

A. Method 1a: ASPM Database

The first method is based on data found in the ASPM database in the “Individual Flights” table (Figure 3). Here, taxi-in delay is a specific field in the database (equal to the taxi-in time minus the unimpeded taxi-in time). The method extracts the taxi-in delay from the database and substitutes it into (1) to obtain the gate-hold delay. A limitation of this method is that it does not track data associated with cancelled flights.

B. Method 1b: ASPM and BTS Databases

Figure 4 shows a modified version of the basic method that combines information from the ASPM and BTS databases. First, data on each flight is obtained from the BTS database (from the on-time performance table), including actual taxi-in time, date, carrier, and airport. The last three fields are used to look up the unimpeded taxi-in time from the ASPM database. We assume that any date between June 1 and August 31 is mapped to the summer season for the purpose of looking up the unimpeded taxi-in time in the ASPM database. The taxi-in delay is then calculated as the difference between the actual taxi-in time and the unimpeded taxi-in time. The rest of the procedure is similar to method 1a.

C. Method 2: Arrival-Departure Pairing

Figure 5 shows a method to estimate the gate-occupancy time of a flight using its tail number. The aircraft tail number is usually available for a flight in the BTS database but not for a flight in the ASPM database. Each arriving flight is paired with its departing flight as follows. For each arriving flight, the method searches for the earliest subsequent departure with the same tail number. If no such departure exists, or if the next available departure is more than 24 hours later, then the arriving flight is termed “unpaired” and is eliminated from the set. If a match is found, the gate occupancy time is the “out” time of the departing flight minus the “in” time of the arriving flight.

There are several limitations of this method. First, because of missing tail numbers, not all of the arrivals can be paired, resulting in missing turnaround times. For example, for the data at ATL on 6/5/2007, 2.5% of the flights are unpaired. Secondly, a missing departure can result in more than one arriving flight being paired with the same departing flight, resulting in an abnormally long gate-occupancy time for the earlier arrival. Finally, the method is limited to flights in the BTS database, so international flights are excluded.

V. Results

The results in this paper are based on data collected from the summer of 2007, June 1 through August 31.

A. OEP-35 Airports

We first give an overview of gate-hold severity at the major US OEP-35 airports. These airports serve major metropolitan areas and also serve as hubs for airline operations. More than 70 percent of passengers move through these airports. Delays at the OEP-35 airports have a ripple effect to other locations. Key FAA performance measures are based on data from this set of airports [22].

Figure 6 shows the gate hold severity at the OEP-35 airports, calculated using Method 1a in the previous section. The bars in the graph, corresponding to the left-hand side of the y-axis, show the fraction of days during which 30% or more of the flights experienced a strictly positive gate hold. Out of the OEP-35 airports, 11 had at least 1 such day; the other 24 airports did not have any such days, so they are not shown on the x-axis. The right-hand side of the y-axis shows the estimated average daily gate-hold delay in minutes for the gate-congested days considered (that is, the days in which 30% or more of the flights experienced a gate-hold delay). The figure shows that gate-hold delay can be a significant problem for some (but not all) of the major airports in the NAS.
example, ATL had 50 days out of 92 in which 30% of arrival flights had gate hold.

Figure 7 shows the same analysis when the threshold is reduced from 30% of flights with gate hold to 20%. In general, the airports from the previous figure appear in this figure in roughly the same order (plus or minus a few places). In both Figures 6 and 7, the magnitude of delay appears to be at least somewhat correlated with number of congested days. There are a few notable exceptions. For example, in Figure 7, ORD and DEN have a small number of gate-congested days. But when these days occur, the total daily gate-hold delay is high relative to the other airports. This is due to the large volume of traffic at the two airports.

**B. ATL**

This section gives a more detailed analysis of ATL airport, since it was among the highest in terms of gate delay (Figures 6 and 7).

Figure 8 shows a break-down of the data for each day of the summer of 2007, calculated using method 1b. The bars in the graph (corresponding to the left-hand side of the y-axis) show the total daily gate-hold delay in minutes. Visual inspection shows that most days experience a relatively mild gate-hold delay around 2,000 minutes. However, a few days stand out as having exceptionally high delays. For example, on June 11, 50% of flights experienced a gate hold and the total delay was 14,000 minutes. The three worst days – June 11, July 29, and August 24 – will be examined in more detail shortly. The general observation is that gate-hold delay is not a problem on most days. However, when it is a problem, it tends to be a big problem.

Figure 9 shows a break-down of the data by carrier. The figure shows the average gate-hold percentage for the three major carriers at ATL on various days, as well as a summer average. The three major carriers are Delta Air Lines, Atlantic Southeast Airlines, and AirTran Airways, where Atlantic Southeast is a feeder carrier for Delta and also uses Delta’s gates. Each of the three carriers has at least 200 arrivals per day while no other carriers at ATL have more than 35 arrivals per day. Although the figure shows that there are differences between the major carriers, no major carrier is exempt from gate-hold delay on the “bad” days. That is, when it is bad for the airport, it is bad for all the carriers.

We now give a more careful comparison of the differences between the carriers. Table III shows the results of a t-test (at the 95% confidence level) comparing the delay between the carriers. (In all cases, the assumption that the carriers have equal delays is rejected if the t-statistic is greater than 1.96 in absolute value.) There is no statistical difference between Delta and AirTran. However, there is a statistical difference between Delta and its feeder carrier, Atlantic Southeast. This may indicate that Delta gives gate preference to its main flights over the feeder flights. Also, the differences between AirTran and the combined operations of Delta and Atlantic Southeast
may indicate that a higher fraction of common gates would reduce gate hold.

In general, when two aircraft compete for one gate, preference may be given to the larger aircraft since it carries more passengers and the delay cost is higher. Figure 10 shows the scatter plot of gate-hold delay by aircraft number of seats for all flights in the summer of 2007 (using method 1a). It shows that with a higher number of seats are less likely to get a very high gate hold delay. A t-test shows that gate-hold-delay and aircraft-seat-number are correlated (with a confidence level greater than 99.99%). The correlation coefficient is -0.026, meaning that 100 more seats bring down the gate-hold delay by 2.6 minutes per flight on average.

Figure 11 shows gate hold percentage for different major aircraft types in different days (using method 1a). All major aircraft types were affected on the worst days, despite the difference among their number of seats. So even though larger aircraft get some preferential treatment when a gate is assigned, this treatment did not exempt larger aircraft from experiencing gate-hold delay on the worst days.

C. Bad Days at ATL

We now examine more closely the system behavior on the three worst summer days. It is helpful in this regard to also examine the system behavior on a good day for comparison. Figures 12-15 show system characteristics on four days: June 5 (a sample good day), August 24 (the second-worst day), July 29 (the third-worst day), and June 11 (the worst day).

We first compare the first two figures, Figures 12 and 13. Each figure has three graphs. The first graph shows the percentage of arriving flights that experience a non-zero gate-hold delay, grouped by hour of the day according to the actual wheels-on time of the arriving flight (method 1b). On the good day (Figure 12), the gate-hold percentage is typically around 20% or less. There are three mild peaks in the morning, afternoon, and evening. In contrast, on the bad day (Figure 13), the gate-hold percentage climbs steadily throughout the day to values near 100%. The morning peak at 9am is still visible. In addition, a number of late arriving flights from the previous day contribute to a peak shortly after midnight.

The second graph shows a comparison of scheduled arrivals with actual arrivals (BTS data). (The scheduled arrivals correspond to arrivals at the gate while the actual arrivals correspond to arrivals at the runway.) On both days, the schedule has peaks roughly at 8am and 7pm, with perhaps an intermediate peak around 4pm. These peaks correspond with the three peaks in the gate-hold percentage graph on the good day (Figure 12). The main difference between the two days is that on the good day, the actual operations roughly follow the scheduled operations; on the bad day, there is a significant schedule disruption at 7pm, right at the evening peak. In particular, the arrival rate drops to near zero during this hour. The incoming flights are delayed and the peak is shifted later by about three hours.

The third graph shows the turnaround delay experienced by each aircraft, by time of day (method 2). Turnaround delay is defined as the actual turnaround time minus the scheduled turnaround time. (Based on this definition, it is possible for the turnaround delay to be negative. This typically occurs when an aircraft arrives late, but leaves on time. In particular, an aircraft that stays overnight, arriving late, but departing on-time the next morning can have a large negative turnaround delay.)

On the good day (Figure 12), turnaround delays are typically no more than ±60 minutes, though there are some aircraft that experience larger deviations from the schedule. On the bad day (Figure 13), the situation is somewhat different. First, there are significantly more aircraft with turnaround delays that exceed 60 minutes. Second, there is a gap in the arrival process around 7-8pm (consistent with the schedule disruption discussed previously). These effects are related.

Considering that both major carriers, Delta and AirTran, operate their flights in a hub and spoke network, this type of network relies heavily on predictability of its schedule so that crew and passengers can transfer efficiently between the arrival and departure banks. A disruption during this time can cause significant problems. For example, if half of the flights in the bank are delayed, then some of the flights that have arrived may wait for the delayed flights in order to establish continuity of passengers and crew. This causes the aircraft to remain at
June 5, 2007 (sample good day)

Fig. 12. ATL gate-hold delay on 6/5/2007 (a sample good day)

August 24, 2007 (2nd worst day)

Fig. 13. ATL gate-hold delay on 8/24/2007 (the second-worst day)

July 29, 2007 (3rd worst day)

Fig. 14. ATL gate-hold delay 7/29/2007 (the third-worst day)

June 11, 2007 (worst day)

Fig. 15. ATL gate-hold delay 6/11/2007 (the worst day)
their gates longer, thereby reducing the number of available gates and contributing to gate-hold delay. Disruptions can also require crew changes which can delay aircraft at their gates.

In summary, the good day (June 5) is characterized by a close adherence to the schedule without much disruption. The bad day (August 24) is characterized by a significant schedule disruption, leading to long turnaround times. The long turnaround times limit gate availability and contribute to gate-hold delays.

Now we consider the other two bad days at ATL: July 29 (the third-worst day) and June 11 (the worst day). From a qualitative perspective, July 29 (Figure 14) is very similar to August 24. Specifically, there is a significant drop in arrival capacity in the late afternoon (this time around 4-6pm). This leads to significant deviations from the schedule where the disrupted arrival bank comes in several hours after its planned arrival time. This disruption leads to large increases in turnaround times, which in turn leads to large gate-hold delays.

The system behavior on June 11 (the worst day, Figure 15), on the other hand, is qualitatively different than the other two bad days. In particular, June 11 does not appear to have a significant schedule disruption, except for perhaps a modest drop in arrivals around 7-8pm. One possible explanation is the number of cancellations (Figure 16, BTS data). This graph shows the number of arrival and departure cancellations by hour of the day. There is a large spike in departure cancellations around 5pm, followed by a large spike in arrival cancellations around 8pm. When departure flights are cancelled, the airplanes remain on the ground at the gate. Because the departure cancellations precede the arrival cancellations, there is a period of time when there are more airplanes on the ground, but the arrival rate into the airport has not yet been reduced, leading to a shortage of gates.

In a similar manner, Figure 17 shows the hourly cancellation rate for the four focused days. The cancellation rate is low on June 5, 2007 when the gate-hold performance is good. The cancellation rate is high on the three worst days, especially from 3-10pm, coinciding with the periods of high gate hold. Cancellations can have a negative effect on gate delay, because a cancellation grounds an airplane for a period of time typically longer than it would otherwise remain at a gate, thus reducing overall gate capacity. In another words, flight cancellations reduce the number of active flights. This decreases the overall fleet’s airborne time, which increases the overall fleet’s ground time, which has the potential to increase gate delay.

Moreover, departure cancellations often come before arrival cancellations, as in Figure 16. When a flight scheduled to depart late is cancelled, its aircraft may be reassigned to a later departure whose incoming flight is scheduled to arrive later and is also cancelled. This reduces flight delay by providing additional robustness in the schedule, but creates longer turnaround times which reduces the number of available gates.

Although the three worst gate-delay days have high cancellation rates, we have also observed many days with high cancellation rates and low gate-delay days. Thus, while high cancellation rates seem to occur on the worst days, they do not necessarily imply high gate delays.

D. JFK

Figure 18 shows the daily gate-hold delay and daily gate-hold percentage at JFK for each day in the summer of 2007 (similar to Figure 8 for ATL, using method 1a). The total gate-hold delay is very high on a few isolated days. The three highest days are June 1, June 10, and June 11.
Figure 19 shows a more detailed picture of the three worst days, as well as a sample “good” day, July 3. The figure shows the total arrival count (by hour) and the total number of arrivals (by hour) that experience gate hold. On the bad days, almost all flights experience gate hold between 5pm and midnight.

Figure 20 shows the actual wheels-on-time profile for the four days (ASPM data). There is a close match until about 4pm. After that, there are significant differences between the four days. The actual wheels-on profile on the good day is similar to the schedule (not shown), while the actual wheels-on profile on the bad days is typically lower than the schedule between 5pm to midnight. This is the key difference between a good day and a bad day: The schedule disruption is more of a problem than the volume of traffic because (i) the volume of traffic from 5pm to midnight in a good day is no worse than that in a bad day, and (ii) gate hold is not a problem in the arrival peak hour, 3pm. This demonstrates that the wheels-on delay is a reason that the same schedule can perform differently.

Table IV compares the gate-hold percentage among the major carriers at JFK – JetBlue Airways, Delta Air Lines, and American Airlines. There are statistically significant differences between each pair of carriers. (In all cases, the assumption that the carriers have equal gate-delay percentages is rejected if the t-statistic is greater than 1.96 in absolute value.) The differences illustrate that the individual carriers have different levels of over-scheduling relative to the number of gates. A higher fraction of common gates may reduce gate hold.

VI. Conclusions

This paper developed several methods to approximate gate-hold delay using data from the ASPM and BTS databases. We applied the methods to the OEP-35 airports using data from the summer of 2007.

Out of the OEP-35 airports, the analysis identified 11 airports with one or more days in which 30% or more of arriving flights experienced a gate delay. The three worst airports (based on this metric) were ATL, JFK, and DFW. Specifically, they experienced a daily gate-hold percentage of 30% or more on 50, 38, and 28 days, respectively (out of 92 days). Airports with moderate gate-hold delays were PHL, LAX, DTW, MIA, and MSP. Airports with light gate-hold delays were EWR, IAH, and LGA. Other airports did not experience any significant gate-hold problems. Out of these 11 airports, the average daily gate hold ranged from 904 to 3670 minutes.

Then, we applied a more detailed analysis to ATL and JFK, the two worst airports. On most days, gate hold was not an excessive problem. However, on a few isolated days, the problem was very bad. We examined hour-by-hour statistics for the worst days and compared them with typical “good” days. One common behavior of the worst days was the
disruption of the schedule, leading to less efficient operations, including increased cancellations, longer turnaround times and position times, resulting in more arriving flights than open gates. Schedule disruptions appeared to be more of a significant factor on the worst days than the absolute number of arrivals (as one might expect).

For both ATL and JFK, the worst delays occurred during the evening hours. Also, at both airports, there were statistically significant differences between the gate delays experienced by the major carriers. This suggests that more common gates could improve gate-hold delay. Aircraft type was also somewhat correlated with gate-hold delay at both airports. That is, larger aircraft experience slightly less gate delay, on average.

Overall, issues identified related to gate-hold delay included the gate assignment policy, gate-carrier compatibility (common gates), wheels-on-time delay, number of gates, cancellations, aircraft swapping, minimum service time, service-time delay, and aircraft type. Many of these issues are related to schedule disruptions which are the main common factor identified in the worst days. Other issues are strategic problems, such as the common-gate issue. Future work will study whether the unexpected events found in this paper can be taken into account in the decision making process and used to mitigate delays.

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