ANALYSIS OF AIRPORT SURFACE OPERATIONS:

A CASE-STUDY OF ATLANTA HARTFIELD AIRPORT

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Abstract

Over the last two decades the successes of Traffic Flow Management (TFM) initiatives have successfully decreased the airborne delay for the flights in the National Airspace System (NAS). The next opportunity for efficiency improvement is airport surface operations. Research on surface operations has focused on methods of analysis and metrics using time-stamped event data and surface track data to quantify performance of "normal" operations. This paper describes a method using time-stamped event data to quantify and diagnose "irregular" surface operations (i.e. surface counts in excess of two standard deviations from the mean worst-case surface count). An analysis of surface operations at Hartsfield-Jackson Atlanta International (ATL) airport for 2012 identified an average surface count of 25 active flights, with an average daily *maximum* surface count of 67. The daily maximum surface count ranged from 46 to 124 active flights. On 18 days the daily maximum surface count exceeded 2 standard deviations from the average (i.e. $2\sigma = 86$ flights). Fifteen of these days occurred between May and August. There are multiple patterns in the surface counts in excess of 2σ: (i) reduced airport departure rates coupled with arrivals being delayed by a ground delay program (ii) changes in runway configuration, (iii) fluctuating arrival capacity (iv) high early arrival count with no or minimal capacity reduction (i.e. "blue sky days"). The high surface counts in 9 of the 18 days were compounded by interaction between arrivals and departures. These results suggest an opportunity to coordinate arrivals, gate operations, and departures to balance operations at the overall airport.

Keywords: Airport surface congestion, surface operations, airport surface management

Introduction

The successes of Flow Management (TFM) over the last two decades have significantly reduced airborne delays. The next opportunity to improve National Airspace System (NAS) efficiency is airport surface operations. As a consequence, the "safe and efficient planning of airport surface operations using decision support tools" is a focus of the NextGen modernization initiatives [1], [2], [3], [5], [6].

The specific improvement opportunities for surface operations have been identified by analysis of "normal" airport surface operations such as the framework using surface surveillance track data developed by Khaldikar et. al,[8] and Sandberg et. al [9]. This framework includes surface performance metrics and is demonstrated in a case study for BOS [8]. One of the major findings of Sandberg et. al. is the interaction between arrivals and departures in LGA.

In addition to improving efficiencies in normal operations, "irregular operations" with excessive surface counts (e.g. greater than 2 standard deviations from average surface count) have a significant impact on airline operations at the airport as well as the within the airline network. In some cases, a single extreme event can be an order of magnitude more costly to airlines than a month of normal operations inefficiencies. Research on "irregular" operations includes an examination of "grid-lock" at airports [10]. This analysis identified 192 incidents on 125 distinct days at 32 different airports in the U.S. National Airspace System (NAS) in 2004 and 2005. The analysis was conducted using a biased total surface and gate count metric using ETMS DZ (departure) and AZ (arrival) messages. The analysis showed that surface counts and the reported "grid-lock" incidents were related.

This paper describes a methodology for characterizing surface operations using time-stamped event data. The methodology keeps track of surface counts throughout the day and can be used to isolate causes of excess surface counts (i.e. greater than 2 standard deviations) and develop strategies for mitigation.

A case-study analysis of Atlanta- Hartsfield International Airport for 2012 yielded the following highlights:

- The average flight surface count at ATL was 25 flights.
- The daily maximum surface count ranges from 45 to 124 flights.
- The average daily maximum surface count was 67 flights.
- In 2012, 18 days experienced a daily maximum surface count greater than 86 flights (i.e. 2σ).
- Excessive daily surface count is the result of 4 major phenomenon: (i) reduced airport departure rates coupled with high arrival EDCT, (ii) Fluctuating capacity coupled with early arrivals, (iii) high early arrivals with no or minimal capacity reduction, (iv) reduced departure capacity coupled with high arrival EDCT

Nine of the 18 days experienced high surface counts with interaction between arrivals and departures. This suggests an opportunity to coordinate arrivals, gate operations and departures to balance the airport. This paper demonstrates the ability to rapidly assess surface operations at an airport using time-stamped event data, and to identify opportunities for productivity improvement.

This paper is organized as follows. The next section describes the methodology for generating surface counts. The next section describes the results of analysis of ATL in 2012 with detailed analysis of observed patterns of behavior during days with high congestion. The final section provides some conclusions and implications of these results.

Methodology

Airports are composed of three interconnected capacity constrained resources on the flight side: runways, taxiways, ramps and gates. Taxiways and ramps are known as the airports surface. Runways increase the surface count from landings (L). Gates increase the surface count from gate-outs (GO). Gate-ins (GI) and takeoffs (TO) reduce the surface count. Figure 1, shows the elements and relationships.

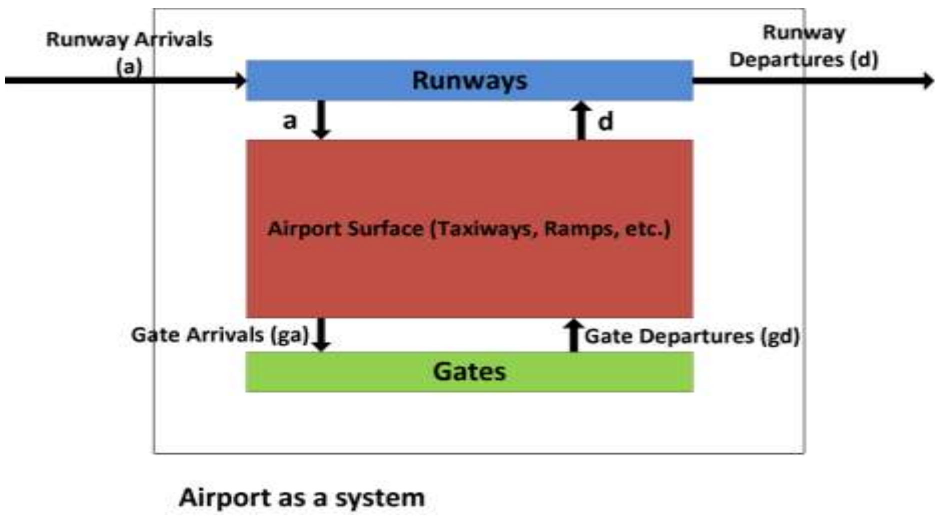

FIGURE 1-Simple view of existing flows and interactions in an airport

A count of the number of flights on the surface at any given time can be generated using Wheels-On, Wheels-Off, Actual Gate-In and Gate-Out times. The analysis divides each day into several time windows with equal length (e.g. 10 minute periods)

The following parameters are used in the analysis:

- ***D***: Set of all the days that are observed (all the days of 2012 in this study)
- ***T***: Set of all the time windows of a day
- L_{td} : Number of landings during time window *t*, on the day *d*.

- $\boldsymbol{TO_{td}}$: Number of take-offs during time window *t*, on the day *d*
- $\boldsymbol{GI_{td}}$: Number of gate-in operations performed during time window *t*, on the day *d*
- $\boldsymbol{GO_{td}}$: Number of gate-out operations performed during time window *t*, on the day *d*
- $\boldsymbol{S_{td}}$: Number of aircrafts/flights on the surface (and not gates) during time window *t*, on the day *d*

The following relationships exist between the different airport components:

$$TotalFlight_{td} = TotalFlight_{t-1,d} + L_{td} - TO_{td}$$
$$GateCount_{td} = GateCount_{t-1,d} + GI_{td} - GO_{td}$$
$$S_{td} = TotalFlight_{td} - GateCount_{td}$$

Or,

$$S_{td} = S_{t-1,d} + L_{td} - GI_{td} + GO_{td} - TO_{td} \quad (1)$$

An estimate of the the initial conditions of the system ($\boldsymbol{S_0}$, $\boldsymbol{TotalFlight_0}$ and $\boldsymbol{GateCount_0}$) are important. The analysis makes an assumption that at the beginning of the day, all the flights in an airport are at the gates and no flight is on the surface, therefore:

$$S_{0d} = 0, \quad TotalFlight_{0d} = GateCount_{0d} = InitialCount_d$$

S is defined as a measure of operations on the surface of the airport. In ideal conditions the airport would not have surface count of zero, especially for the departure queue. No flights in the departure queue results in under-utilization of the runways. Likewise too many flights in the queue results in unneccessary delays. In some cases, long deoparture queues can impact arrival taxiing by blocking access to taxiways, ramps, and gates.

The count of the aircraft on the surface can be broken into two general flows: arrivals and departures (see Equation 1). At each time window, the net amount of $\boldsymbol{L_{td}\text{-}GI_{td}}$ is added to the surface from the arrival side, while $\boldsymbol{GO_{td}\text{-}TO_{td}}$ is added to the surface from the departure side.

The impact of the combinations of levels for each these parameters on the surface congestion at an airport is illustrated in the heat-map in Figure 2. The red cells occur when arrival rates and gate-out rates are in excess of gate-in and departure rates. Likewise, green cells occur when gate-in and departure rates are in excess of arrival and gate-out rates.

Surface Ops Combinations effect on Congestion				Gate In								
				High			Med			Low		
				Gate Out			Gate Out			Gate Out		
				High	Med	Low	High	Med	Low	High	Med	Low
Take-off	High	Landing	High									
			Med									
			Low									

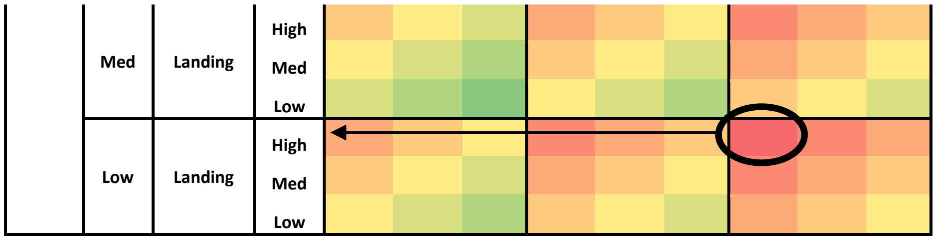

FIGURE 2- Effect of various combination "control levers" on surface operations Red indicates a high surface count (e.g. high landing, low gate-in, high gate-out, and low takeoffs), Green indicates a low surface count

The temporal nature of congestion can be visualized in the phase-plane in Figure 3. On the horizontal axis, ***L-GI***, represents the net rate of increase in surface count from the arrival side. The vertical axis, ***GO-TO***, represents the net rate of increase in surface count from the departure operations. The color-coding shows how the combinations of rates result in increases in surface congestion (red) and decreases (green). The neutral zone (yellow) represents balanced operations.

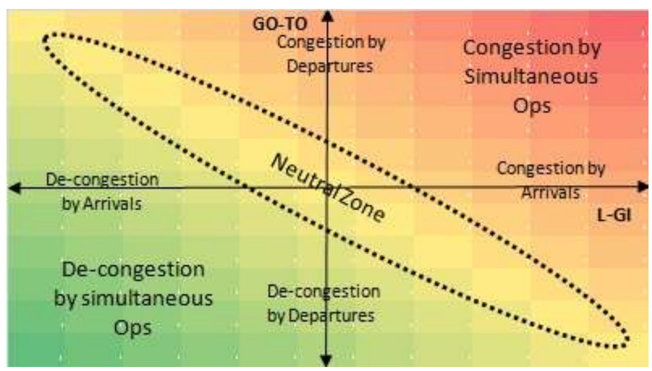

FIGURE 3-Phase plane and effect of operations on surface congestion

Estimating Initial Surface Counts

This analysis makes an assumption that at the start of the day (midnight) all aircraft at the airport are at gates (i.e. the initial surface count is zero). To ensure accurate counts, an accurate estimate of the initial number of flights at the gates in beginning of the day is required. The following matching algorithm was developed to match inbound and outbound flights.

The algorithm tracks the tail numbers in the departure flight list and finds the earliest departure assigned to a tail number. Next, the arrival flight list is searched for the same tail number and the earliest arrival time for assigned to the tail number is found. The comparison between these times can determine if that tail number was at the airport in the beginning of the day. Here is the algorithm:

1. Initial Count =0
2. For each DepTail# in Departures
    a. Find all matching Tail# with DepTail# in the same list

b. Find the earliest *Actual* departure assigned to that Tail#
c. For each Tail# in Arrivals
   i. Find all matching Tail# with DepTail#
   ii. Find earliest *Actual* arrival assigned to that Tail#
   iii. If Earliest Assigned DepTime< Earliest Assigned ArrTime for that Tail#
   iv. InitialCount= InitialCount + 1

TABLE 1- Hypothetical arrival and departure operations

Departure List		Arrival List	
Tail No.	Departure Time	Tail No.	Arrival Time
N1	10:00	N1	14:00
N2	11:00	N2	7:00
N3	8:00	N5	22:00

Using the data in Table 1 as an example, the algorithm finds N1 as the tail number in the departure list with an associated departure time is at 10 am. A search of the arrival list, finds N1 with the arrival time at 14:00 to the airport. Comparison between these times shows that N1 first departs from the airport and later in the day comes back to the airport. Therefore N1 was at the airport from the beginning of the day (Note that this is the complete list of operations from midnight to midnight). N2 with an arrival to the airport later during the day departed from the airport; therefore it was not at the airport initially. For the case of N3, it is only one departure operation which implies that the aircraft is at the airport at the beginning of the day. N5 is an arrival to the airport which indicates it was not at the airport at the beginning of the day. Therefore in this case, N1 and N3 are at the airport at the beginning of the day and initial count is equal to two.

The analysis, calculates the count of the aircrafts/operations done in each time window of the day (e.g. 10 minute period) for the runways, surface, and gates. The focus is on the surface since it is both the source and the sink to the other two nodes. For each day of the analysis, the value of the maximum surface count as a measure for the severity of congestion on that day (worst case congestion) is computed. Also, average number of aircrafts on the surface and the median of the number of aircrafts for each day are reported.

$$M_d = \underset{t \in T}{Max}\{S_{td}\}, \quad \forall d \in D$$

After obtaining the values for the worst case congestion at each airport (***M_d***), the annual performance of the airport is analyzed by considering the average, standard deviation, minimum and maximum congestion at the airport. Therefore, we have the following definitions:

$$\mu = \underset{d \in D}{Average}(M_d)$$
$$\sigma = \underset{d \in D}{St.Dev}(M_d)$$

Using the daily worst-case congestion data, the frequency, the magnitude of the worst-case congestion is calculated. The distribution of the daily worst-cases is used to identify group of "bad days" on which the worst-case congestion surpassed the $\mu+2\sigma$ threshold.

Each day is studied in depth to better understand the underlying potential reasons of congestion. To capture the possible reasons for a high number of aircraft on the surface, both runway capacity and operations are examined through following variables:

- Airport runway capacity
- Gate operations
- Airport runway configuration
- Early arrivals
- Existence of Expect Departure Clearance Time (EDCT)

Runway capacity is measured using Airport Departure Rates (ADRs) and Airport Arrival Rates (AARs) . Gate operations are examined by identifying the failure of flights to gate-in when there exists an arrival queue (e.g. lightning shuts down gate operations). The percentages of arriving flights with EDCTs are calculated. The number of arrivals more than 15 minutes in advance of the scheduled gate-in time minus estimated taxi-in time is calculated. Airport runway configuration changes are also documented.

Data Sources

To perform this analysis, Aviation System Performance Metrics (ASPM) flight level data is used. ASPM data provides detailed data on flights to and from the ASPM airports (currently 77); and all flights by the ASPM carriers (currently 22), including flights by those carriers to international and domestic non-ASPM airports [4]. All IFR traffic and some VFR traffic for these carriers and airports are included. ASPM flight level data includes OOOI (gate out, Wheels off, Wheels on and gate in) data which makes it possible to calculate the number of operations and flights at each phase of the flight and in our case, phase of surface operations.

Gate times are converted to time windows to calculate the number of flights at the gate and the flows from/into the gates. Wheels data which is the time of landing and take-off for flights is used to calculate the number of runway operations and flows into/from the surface. Merging the information from the runway flows and gate flows will provide us with the evolution of congestion (traffic) on the surface of the airport.

Since ASPM does not include cancellations and diversions, Airline On-Time Performance (AOTP) is used to show the number of disrupted operations at each day for ATL.

ANALYSIS OF ATL SURFACE OPERATIONS IN 2012

An analysis of Hartsfield-Jackson Atlanta International (ATL) airport was conducted for 2012. ATL is considered one of the busiest airports in the world by flights and by passengers. The airport is configured with five parallel runways (Figure 4) configured for eastbound and westbound operations. The general runway operation is to use the innermost runways (8R/26L, 9L/27R) for departures, and the outer runways for (26R/8L, 27L/9R, 28/10) arrivals. The terminals are located in the center of the airport. Arrivals on the south side of the airport must cross active runways to reach the terminals. Arrivals on the north side by-pass crossing the runways by using taxiways at the runway ends.

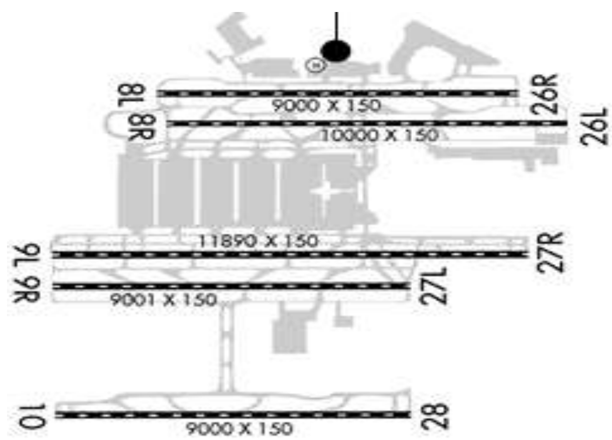

FIGURE 4 -ATL airport runways and surface configuration

ATL Flight Performance

In 2012 more than 457,000 departures and 456,000 arrival operations were recorded for ATL [4]. Statistics for ATL operations in 2012 are summarized in Table 2.

In 2012, flights operating at ATL experienced approximately 3.99M minutes of departure delays and more than 4.17M minutes of arrival delays (in excess of the 15 minute on-time buffer). These operations required a total of 8.60M minutes (16.4 years) of departure taxi and 4.50M minutes (8.6 years) of arrival taxi time. The average departure taxi-out time was 18 minutes. The average arrival taxi-in time was 10 minutes. Flight cancellations and diversions from the BTS Airline On-Time Performance (AOTP) data-base are included (BTS, 2013).

TABLE 2- Operations Summary at ATL-2012

ATL-2012	Dep Count	Delay Min	DepTaxi Min	Dep Cancel#	Dep Div#	Arr Count	Delay Min	ArrTaxi Min	Arr Cancel#	Arr Div#
Jan	36713	284398	704584	203	68	36683	347684	368034	242	78
Feb	35156	227902	633582	103	52	35106	245981	354163	126	18
Mar	39634	361675	755570	112	70	39471	390695	401082	185	26
Apr	38195	208240	700957	64	48	38013	218884	367525	95	22
May	39494	335448	782304	89	78	39307	330609	412338	116	64

Jun	39710	387411	745013	152	87	39610	374042	417680	197	114
Jul	40468	634944	853841	315	103	40469	618038	408105	386	172
Aug	40169	468420	777587	407	74	40139	491301	406779	463	78
Sep	36831	248713	676166	87	56	36741	279167	347607	117	15
Oct	38376	299560	691142	456	56	38224	325196	363861	485	29
Nov	36351	197808	639592	78	40	36200	210004	334085	119	17
Dec	36415	337577	648225	193	66	36200	346324	324961	251	22
Sum	457512	3992096	8608563	2259	798	456163	4177925	4506220	2782	655
Daily Avg.	1250.03	10907.37	23520.66	6.17	2.18	1246.35	11415.1	12312.08	7.6	1.79

Daily Surface Operations

The surface operations for a typical day are represented by the scheduled operations for July 3 2012 (Figure 5)[1]. The arrival surface count averages 10, peaking to 20 in the morning, midday and in the evening. The departure surface count average is 15, with extended peaks to 28 in the morning, midday and evening. At the scheduled peaks in the day, the total surface count (arrivals + departures) is approximately 40. This value for surface count serves as useful baseline for comparison with the actual surface count.

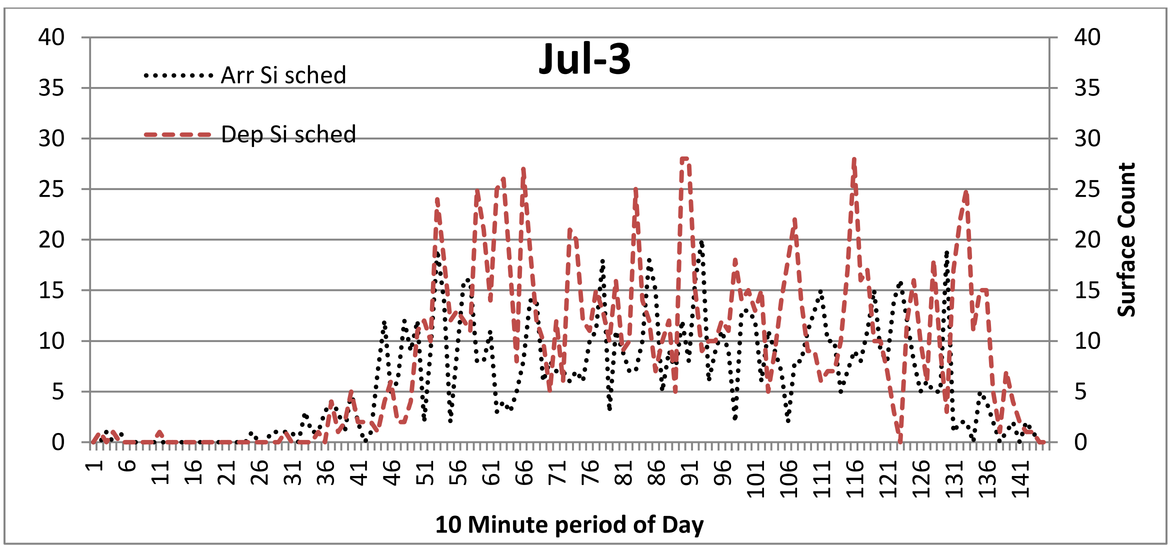

FIGURE 5– Scheduled surface count for arrivals and departures

Characterizing Daily Surface Operations

The daily average surface count on the airport from midnight to midnight, was 25 flights with a minimum average of 14 and a maximum average of 37. The median daily surface counts are close to the averages indicating the likelihood of the distribution being normal.

[1] Here are the definition of the terms used in the figures in order to keep them short:
"Arr" = Arrival
"Dep" = Departure
"sched" = Scheduled
"Act" = Actual
"Si" = count of aircrafts on the surface at time window *i*

On average, the daily maximum number of active flights on the surface is 67 flights (μ). On the days when surface congestion was at its lowest, the maximum number of flights on the surface was of 46 flights. On days when surface congestion was at its highest, the maximum count of flights on the surface was 124 flights.

TABLE 3- Statistics for daily surface counts at ATL in 2012

Statistics	Daily Maximum Surface Count (M_d)	Daily Average Surface Count	Daily Median Surface Count
Mean	66.67 (μ)	24.6	26.3
Min	46	14	9
Max	124	37	42
St. Dev.	9.65 (σ)	3.55	5.1

The distribution of the frequency for the daily average, daily median and daily maximum surface counts is shown in the histogram in Figure 6. The daily average and daily median exhibit a range between 5 and 45. These distributions are uni-modal with normal tendencies.

The distribution of the daily maximum surface count exhibits a range between 45 and 125 active flights. This distribution is skewed to the right with μ+3σ frequency of 0.016 (number of 3σ days/total days). This distribution is not Gaussian as μ+3σ for a normal distribution is approximately 0.0013. The "J-shaped" QQ-plot for $\mathbf{M_d}$, shown in Figure 7, indicates that the distribution is right-tailed. This indicates that the chance of having a day with high congestions (greater than μ+3σ) is approximately 10 times more likely than the probability if the distribution for daily maximum count followed a normal distribution throughout the year.

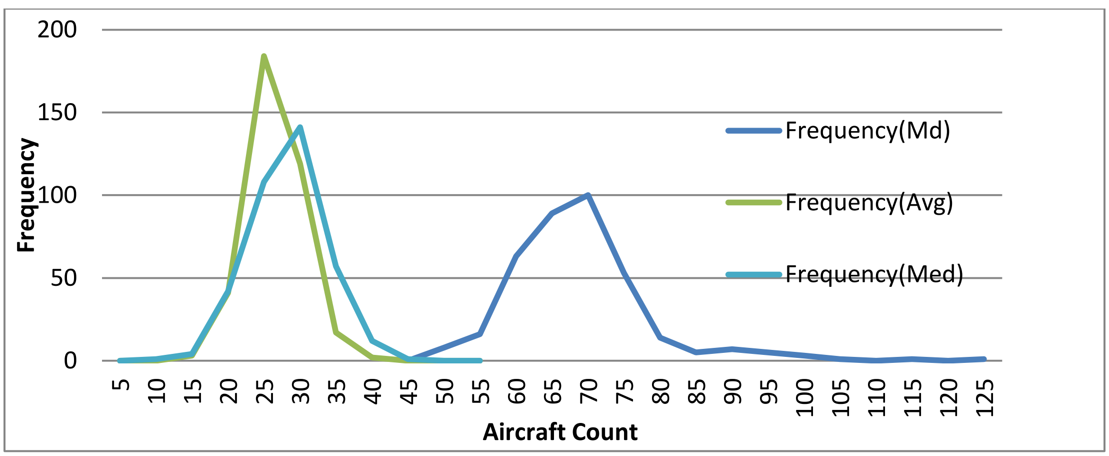

FIGURE 6- Histograms for daily average, daily median and daily maximum surface counts for ATL 2012

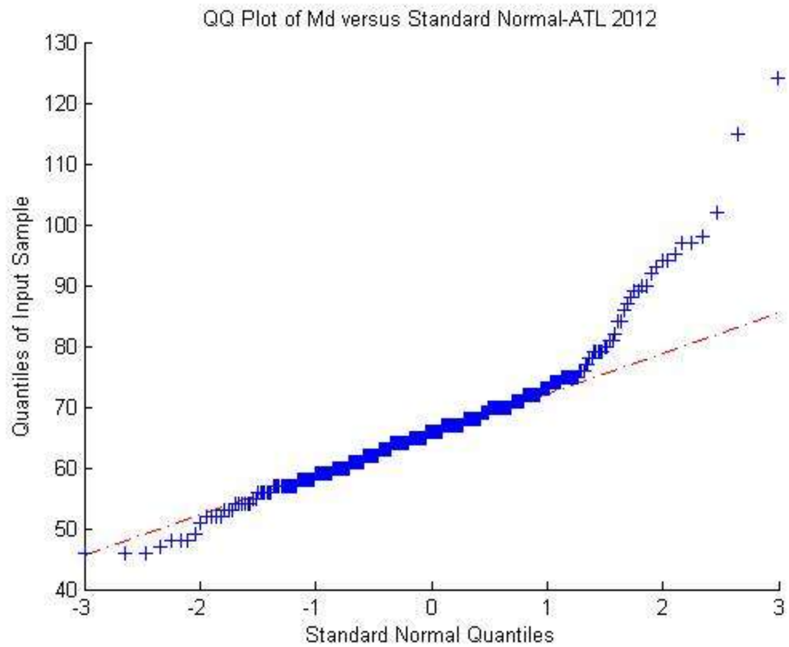

FIGURE 7- QQ-plot for the daily worst-case congestion at ATL 2012 indicates distribution of daily maximum surface count exhibits fat tail (i.e. higher probability than would be expected if the distribution was a normal distribution).

Daily Maximum Surface Count

The maximum surface count in a 10 minute period for each day in 2012 is shown in Figure 8. The average maximum count (67 flights) is shown along with 2σ (≈86 flights), and 3σ (≈96 flights). The daily maximum surface count exceeded 2σ on 18 days. On 6 of those days, the daily maximum surface count exceeded 3σ. Fifteen of these outlier days occurred in the months between May and August. The outlier days are summarized in Table 4.

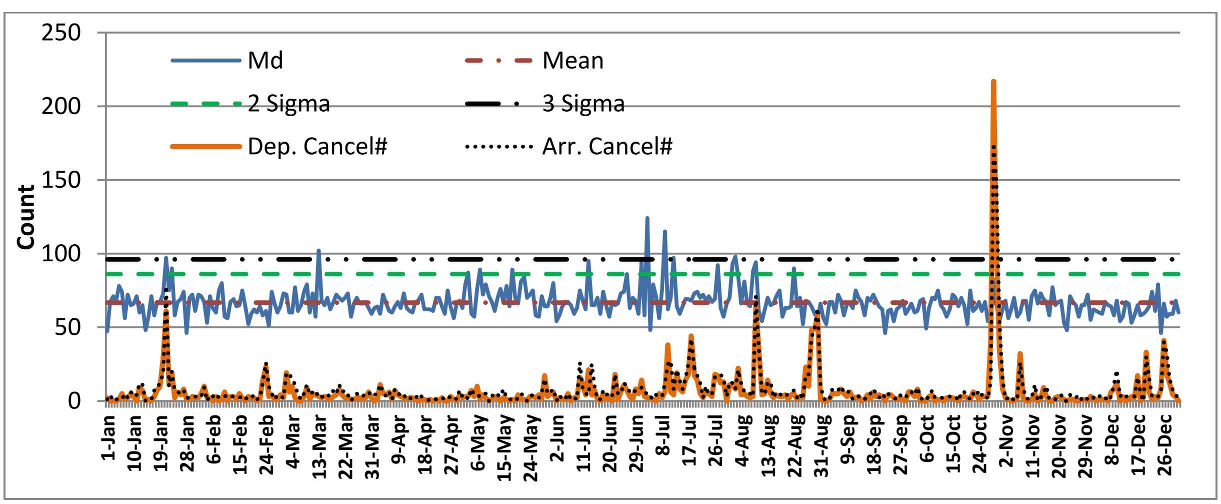

FIGURE 8- Daily maximum surface Count (M_d) for each day in 2012 along with average, +2σ, and +3σ. 18 days experienced a surface count in excess of +2σ

TABLE 4- 18 days experienced a maximum surface count in excess of μ+2σ. 15 of these days occurred between May and August.

Congested Days	1.5 Sigma#	2 Sigma#	3 Sigma#	1.5 Sigma	2 Sigma	3 Sigma
Jan	2	2	1	21,23,	21,23,	21,
Feb	0	0	0			
Mar	1	1	1	13,	13,	13,
Apr	0	0	0			
May	4	3	0	3,7,18,22,	3,7,18,	
Jun	2	2	0	13,26,	13,26,	
Jul	5	5	3	1,3,9,12,27,	1,3,9,12,27,	3,9,12,
Aug	6	5	1	1,2,3,8,9,22,	1,2,8,9,22,	2,
Sep	0	0	0			
Oct	1	0	0	29,		
Nov	0	0	0			
Dec	0	0	0			
Sum	21	18	6			

Detailed flight and taxi time statistics for each of the 3σ+ days are summarized in Table 5. For departures and arrivals, the number of performed operations and cancellations and diversions, as well as total delays (reported gate delay) and taxi times in minutes are reported. Calculated initial number of aircraft at the gates at the start of the day for both actual operations and scheduled operations are reported. The measure of congestion at each day is presented to show the severity of the traffic on the surface.

TABLE 5- Operation summary on days with high congestion (Gridlock threshold)

3-Sigma Days	Departure					Arrival					Initial Count-Actual	M_d	Initial Count-Sched
	Ops#	Cancel#	Div#	Delay Min	Taxi Min	Ops#	Cancel#	Div#	Delay Min	Taxi Min			
21-Jan	987	61	6	50889	27957	993	78	42	67780	12133	342	97	351
13-Mar	1276	3	3	12451	36175	1280	2	0	21503	13930	305	102	306
3-Jul	1152	2	0	35841	28593	1199	3	40	35577	13962	282	124	284
9-Jul	1375	6	3	22121	38039	1364	12	1	20223	14874	291	115	297
12-Jul	1379	4	1	21880	32469	1375	8	2	20423	16268	291	97	296
2-Aug	1380	8	4	24159	35092	1371	8	0	24149	14775	298	98	304

Time of Day for Surface Congestions

In 2012, the maximum daily surface count occurred at three periods in the day: Morning, mid-day and evening (Figure 9).

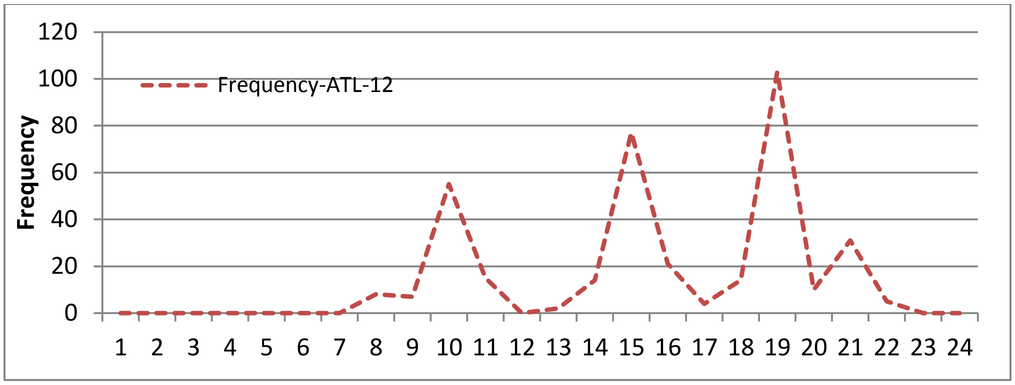

FIGURE 9- Time of occurrence for maximum surface congestion

Patterns in Surface Congestion on Two-Standard Deviation Days

The 18 days on which surface count exceeded two standard deviations from the average (i.e. 2σ days = total surface count in excess of 86), are the results of complex interactions between factors. There are four major categories of factors:

1. Reduced departure capacity
2. Runway configuration changes
3. Fluctuating arrival capacity
4. High early arrival count (i.e. Blue Sky days)

The main functional characteristics of each of these four patterns with corresponding days are summarized in Tables 6, 7, 8 and 9.

Reduced departure capacity:

The 7 days with reduced departure capacity as the main factor resulting in high surface congestion are summarized in Table 6.

TABLE 6- Congested days with reduced departure capacity

Category Definition	Days	Duration of Surface Count > 40	Departure EDCT %	Arrival EDCT %	ADR	Departure Runway Change	No Gate-In	% Early Arrivals
Reduced Departure Capacity+ Change in runway configuration	Jan-23	5 hrs 10 mins	8.29	4.86	80 to 85 from 00:00 to 15:00	• 10:00 from (8L, 9R, 10) to (26R, 27L, 28) and (8L, 9R, 10) • 11:00 on (26R, 27L, 28)		30%
Reduced Departure Capacity+ Arrival EDCT	Aug-9	8 hrs 40 mins	8.09	44.32	Reduction from 104 to 86 at 15:00 until 20:00	(26R, 27L, 28)		33%

	Jul-27	4 hrs 10 mins	1.61	40.13	Reduced from 100+ to 85 from 15:00 to 19:00	• 15:00 to (26R, 27L, 28) • 16:00 to (26R,27L, 28) • (27L, 28) and alternating until 20:00		38%
Reduced Departure Capacity+ Early arrivals	Jul-9	7 hrs	1.02	7.55	Reduction from 100 to 78 18:00 to 24;00	(26R, 27L, 28) throughout the day		47%
	Mar-13	4 hrs 30 mins	1.88	4.14	Reduction from 115 to 50 at 06:00, then 78 07:00 to 10:00. Also reductions later in day	• 11:00 from 3 active runways (26R, 27L, 28) to 2 active runways (27L, 28) • 12:00 to 13:00 alternating between (26R, 27L, 28) and (27L, 28) • 13:00 back to (26R, 27L, 28) 0		36%
	Aug-2	4 hrs	0	4.74	100+ reduce to 50 at 18:00. Average 85 next 3 hrs	Operating (26R, 27L, 28) throughout the day		50%
	Aug-22	2 hrs 30 mins	0.62	3.15	110 until 14:00, then 45 at 15;00, then back to 110	Operating (8L, 9R, 10) throughout the day		52%

A typical example of the reduced departure capacity day is March 13, 2012. The schedule for arrivals and departures has a large morning and evening bank, with smaller bank at mid-day. Given the schedule, the surface count of arrivals should be between 5 and 15 (with an average of 10) and the surface count for departures should be between 10 and 30 (average 15).

Arrival operations approximated the schedule with a count for arrivals between 15 and 25 during the day. Taxi-in times averaged 15 minutes and peaked at 20 minutes. (Figure 10).

The departures queues were the problem on this day. In the morning, the departures built up to 70 flights in the period of 30 minutes, and then increased to 90 flights in a period of 100 minutes. A similar build up departures on the surface at midday (60 active flights), and in the evening (50 active flights) occurred. The departure queues coincide with a reduction in the ADR which was around 50 for one hour and then 78 during the congested period. Note, normal operations would have an ADR of 100 or greater.

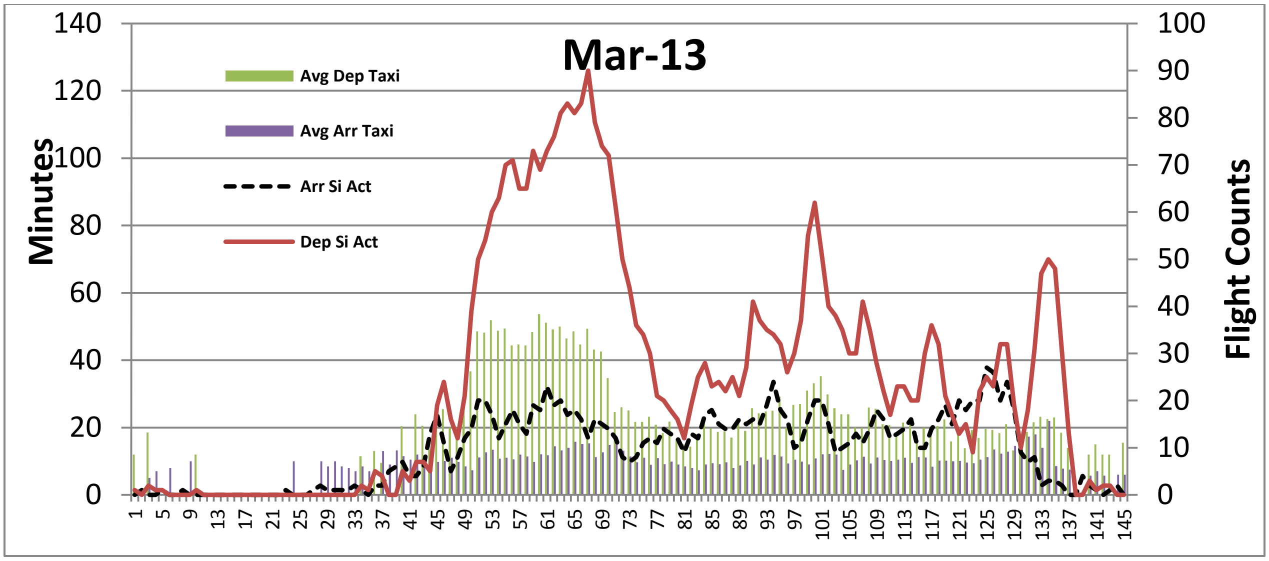

FIGURE 10 - Surface count for departures increases rapidly while ADR is reduced, No effect on arrival surface count.

Runway Configuration Changes

Changes in runway configuration resulting in surface congestion occurred on the 4 days summarized in Table 7. A typical example of this class of surface congestion is July 3, 2012. On this day, the total surface count (departures + arrivals) peaked at 124 active flights which is in excess of 3σ for ATL. The arrival surface count and departure surface count mimic the schedule all day until the 90th 10 minute period of day (i.e. 15:00 hrs EST). Starting at around 15:00 local time a bank of scheduled departures pushed back from their gates but were not able to depart at the scheduled rate. The ADR dropped from 120 to 78 from 16:00 to 18:00.

TABLE 7- Congested days with changes in runway configuration

Category Definition	Days	Duration of Surface Count > 40	Departure EDCT %	Arrival EDCT %	ADR	Departure Runway Change	No Gate-In	% Early Arrivals
Runway Configuration Change+ Reduced Departure+ High Arrival EDCT (seize in gate operations gate-in & gate-out)	Jan-21	6 hours 10 mins	2.53	62.54	80 – 95 then to 50 at 08:00, Zero from 8:45 to 9:15, then 50 – 65 from 09:15 to 12:00	• 06:00 (8L, 9R, 10) • 07:00 (26L, 27R) • 11:00 (26R, 27L, 28) • 12:00 (26R) • 13:00 (26R, 27L, 28)	11:30 – 11:50	14%
Runway Configuration Change+ Reduced Departure+ High Early Arrival (seize in gate operations gate-	Jun-13	4 hrs	4.56	2.31	78 at 19:00, Zero at 20:00 60 at 21:00 (Note: Zero landing at 20:00)	• 14:00 from (26R, 27L, 28) to (8L, 9R, 10) • 21:00 (8L, 9R, 10) to (8L, 9R) 22:00 (8L, 9R, 10)	Gate in and Gate out closed at 20:00 to	60%

in & gate-out)							21:00	
Runway Configuration Change+ No Gate In+ High Arrival EDCT + Early Arrivals	Jul-3	3 hrs 30 mins	9.46	34.95	Reduction from 100 to 76 from 18:00 to 20:00	18:00 from (26R, 27L, 28) to (8L, 9R, 10)	18:00 – 18:50	53%
Runway Configuration Change+ Early Arrivals+ Increased Taxi-in times	Jul-1	5 hrs	1.73	4.52	100 or greater	Changing from (26R, 27L, 28) to (8L, 9R, 10) between 20:00 and 21:00 until 24:00		54%
	Jul-12	5 hrs 40 mins	0.73	2.18	Reduced from 115 to 80 from 19:00 to 21:00	Change from (8L, 9R, 10) to (26R, 27L, 28) and back between 18:00 and 20:00. Alternating between (26R, 27L) and (26R, 27L, 28) from 20:00 until midnight.		38%

Over a period of 4 hours the surface count for departures increased to 80 active flights (see Figure 11). The average taxi-out time for departures was 120 minutes for the first batch of departures and 60 minutes for the second batch of the departures (see Figure 11).

During this period the arrival rate maintained the schedule. At 18:00 hrs arrival gate operations were suspended for period of approximately 30 minutes leading to a surface count of arrivals peaking at 40 (see Figure 10). The average taxi-in time peaked at 40 minutes and remained between 30 minutes and 20 minutes for the next 2 hours (see Figure 11).

The peak of the surface count of arrivals (43) and departures (81) occurred at the same time, resulting in a peak surface count of 124 active flights.

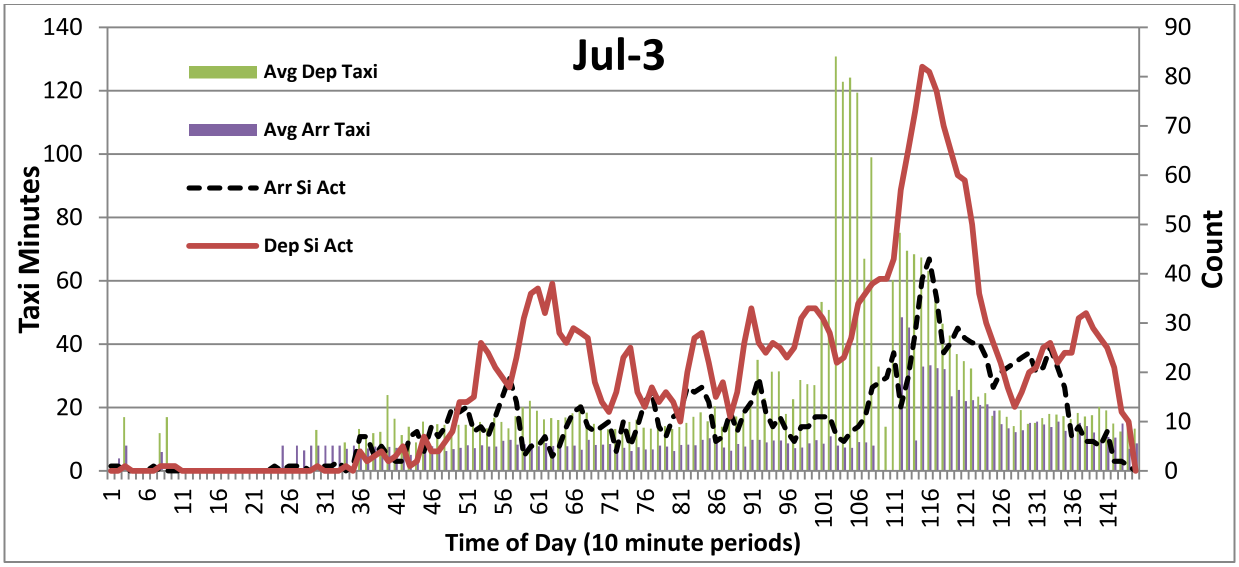

FIGURE 11 –Taxi times (bars) and Surface counts (lines) for arrivals and departures for each time window

Fluctuating Arrival Capacity

The effect of fluctuating arrival capacity coupled with early arrivals occurred on the 3 days summarized in Table 8.

TABLE 8- Congested days with fluctuating arrival capacity

Category Definition	Days	Duration of Surface Count > 40	Departure EDCT %	Arrival EDCT %	ADR	Departure Runway Change	No Gate-In	% Early Arrivals
Fluctuating Arrival Capacity+ Early Arrivals	May-7	4 hrs	0.53	4.84	90 to 100 (note: AAR reduce from 100 to 65 at 16:00 and 100 to 80 at 19:00	• 16:00 (8L, 9R, 10) to (9R, 10) • 17:00 (8L, 9R, 10)		45%
	Jun-26	1 hr 10 mins	1.11	0	100 or greater (note: fluctuating AAR)	• 10:00 from (8L, 9R, 10) to (8L, 9R) • 12:00, and • 14:00 (9R, 10) • 16:00 (8L, 9R, 10)		50%
	1-Aug	3 hrs 40 mins	9.04	2.21	100+ (note: AAR reduce 120 to 65 at 18:00	Changing from (26L, 27L, 28) to (26R, 28) between 18:00 and 19:00 and back to (26R, 27L, 28) until midnight		47%

An example of a fluctuating arrival capacity day is June 3. On this day both gate-ins and gate-outs were shut down, resulting in both a build-up of the arrival and departure surface counts.

During this period, there were no departures, resulting in a build-up surface count for departures (Figure 12).

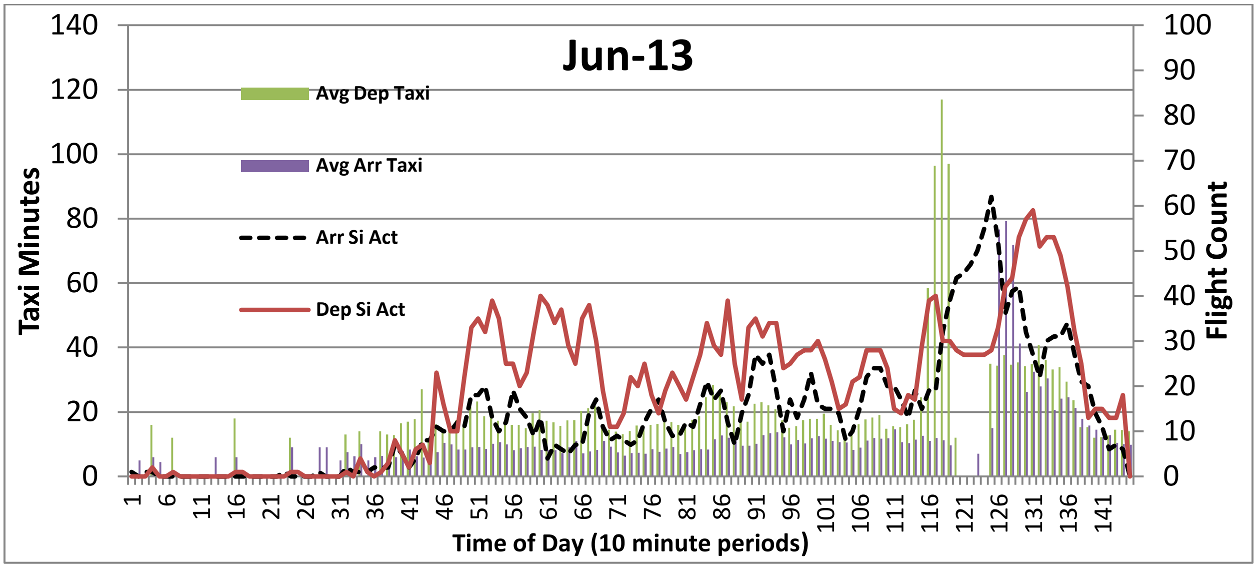

FIGURE 12 –Taxi times (bars) and Surface counts (lines) for arrivals and departures for each time window

High Number of Early Arrivals

The 3 days that had high early arrivals as the most significant factor for surface congestion are summarized in Table 9.

TABLE 9- Congested days with high early arrivals

Category Definition	Days	Duration of Surface Count > 40	Departure EDCT %	Arrival EDCT %	ADR	Departure Runway Change	No Gate-In	% Early Arrivals
High Early Arrivals+ No or minimal departure capacity reduction	May-3	5 hrs 20 mins	6.16	2.93	110 to 100 at 13:00. 100 to 90 at 19:00	12:00 to 24:00, 3 active runways(26R, 27L,28)		61%
	May-18	3 hrs 50 mins	0.15	0	100 or greater	From 10:00 to 24:00 with 3 active runway (8L, 9R, 10)		63%
	Aug-8	1 hr 20 mins	0.87	0	100+	7:00 to 24:00 (26R, 27L, 28)		54%

The airport arrival and departure rates are above 100 indicating optimum runway operating conditions. Despite these conditions, a departure queue builds during the day. One common factor among these days is that there were large weather systems elsewhere in the NAS. These may have affected operations at ATL (Figure 13).

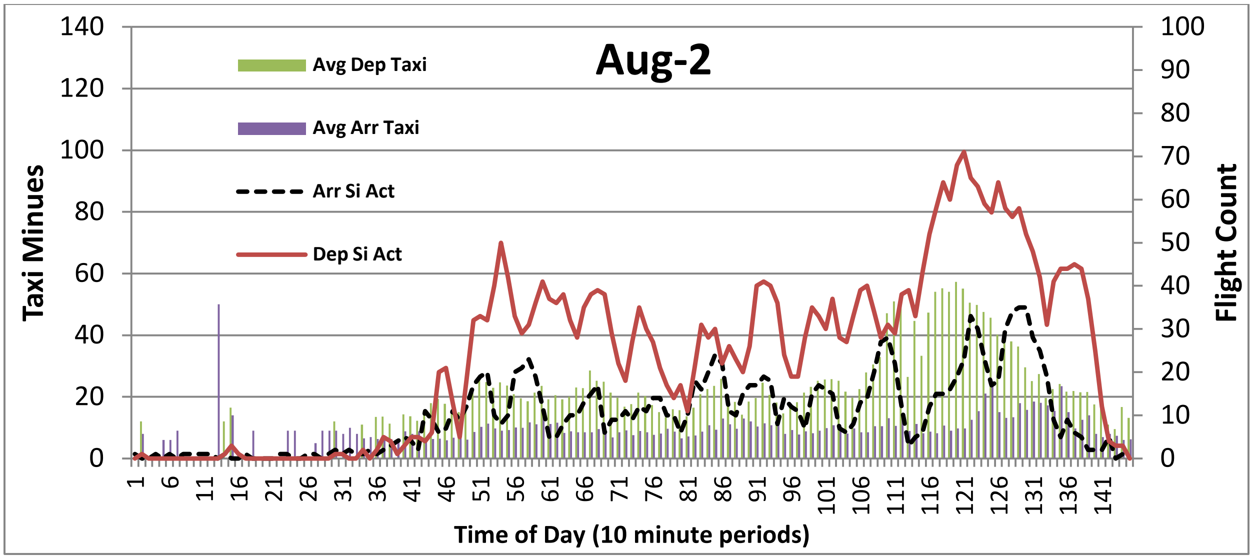

FIGURE 13 –Taxi times (bars) and Surface counts (lines) for arrivals and departures for each time window

5 Conclusions

This paper demonstrates a methodology to assess airport surface operations. The proposed methodology employs time-stamped event data to determine the flight count on the surface. A case study of surface operations at ATL for 2012 identified the following 18 days experienced a daily maximum surface count greater than 86 flights (i.e. +2σ, deviation from the average). These "2σ days" are the result of combinations of factors including: (1) Reduced departure capacity, (2) Change in runway configuration, (3) Fluctuating arrival capacity, and (4) High number of early arrivals.

The reduced departure fix capacity, runway configuration change, and fluctuating arrival capacity are phenomena out of control of the operators. There appear to be opportunities to anticipate these events and take pro-active steps to diminish the impact by adjusting the sequence and timing of critical operations to avoid bottlenecks and/or starved resources. In the case of the early arrivals, alternate procedures have been proposed to manage this scenario differently than regular operations. In all cases, the interactions between arrivals and departures leading to high surface counts suggests the need for a scheme to simultaneously balance the arrival and departure rates at the airport.

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