REAL-TIME ALERTING OF FLIGHT STATUS FOR NON-AVIATION SUPPLIERS IN THE AIR TRANSPORTATION SYSTEM VALUE CHAIN

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Abstract

The air transportation system has a broad and deep value chain. Some of the stakeholders are directly part of the air transportation system and use real-time flight, airport and air traffic control data as part of their operations. Other stakeholders are several layers removed and do not have access to system status even though it impacts their business. For these stakeholders it may be outside their core competency or cost prohibitive to purchase access to a data feed and the required hardware/software infrastructure to support real-time status alerting. In many cases, the need for status alerting is only temporary (e.g. seasonal, during period of construction, or transition to new gate leasing arrangement).

This paper describes a low-cost software application that can be deployed to provide real-time alerts to stakeholders whose operations are directly impacted by flight and system status changes, but cannot afford to maintain their own status alerting system. The flight status alerting system described in this paper can be configured over the web and transmits alerts via email or text messages to the cell phones of employees. Case studies are provided for: (1) alerts to adjust staffing at an airport food concession for forecast irregular operations (to generate an estimated $46K to $121K in additional annual profit), (2) alerts to investigate excessive taxi-in times and gate utilization compliance. Implications and limitations of the system are discussed.

INTRODUCTION

The air transportation system has a complex multi-level value chain. First tier and second tier suppliers, such as the airlines and air traffic control, are directly part of the air transportation system and have direct access to real-time data related to flight, airport and air traffic control status.

Other stakeholders, such as catering, airport concessions, airport taxis, off-airport shuttles, ... etc., are several layers removed and generally do not have access to real-time data related to flight, airport, and air traffic control status. The lack of access to the data does not reflect the importance of the information to these lower tier business operations whose costs of operation can be impacted by irregular operations. For example, when flights do not operate according to schedule, catering and fuel supply operations can be impacted when late arriving flights need to be serviced at the same time as previously scheduled on-time flights. This is also the case for stakeholders even further down the supply chain such as airport concessions, airport parking, rental cars, surface transportation, land-side and air-side construction and maintenance who may need to adjust staffing and/or inventories.

Despite the importance of the flight status to their business operations, the cost of purchasing access to a data feed may be prohibitive and the competencies required to develop and maintain hardware and software infrastructure may be beyond the capabilities of the organization. Further, in some cases, the need is seasonal and/or temporary (e.g., during period of construction, or airline market-share wars).

This paper describes a low-cost web-based software application that can be deployed to provide real-time alerts to stakeholders whose operations are directly impacted by flight status changes, but cannot afford and/or support this capability. The flight status alerts can be configured over the web and are transmitted via email or text messages to employees mobile phones. The employees will only receive the alerts when the appropriate situation exists (i.e. no need to monitor a website) and will then follow a pre-defined playbook for the situation.

Two case studies are provided. First a gate concourse food concession opportunistically takes advantage of a forecast of irregular operations to increase staff levels to service significantly higher numbers of customers waylaid on the concourse.

Revenue is estimated to increase between $46K and $121K per year. Second, an application of real-time alerting for an airport Airline Contracts department trying to understand issues with gate utilization and excess taxi-in times. The real-time alerts allowed the airport staff to go to the ramp and gate area to witness the events as they unfolded and gather information from supply chain personnel. Although technically not a “low tier” supplier the airport contracts department does not have access to the real-time data and needed real-time alerts texted when specific events were occurring (without having to monitor a display).

The paper is organized as follows: Section 2 describes the system design of the real-time alerting system. Section 3 describes the case study. Section 4 discusses implications, limitations and future work.

DESIGN OF A REAL-TIME ALERTING SYSTEM

The system architecture for the real-time alerting system is described in Figure 1. A flight status data feed provides the basis for the alerting. This data feed can be generated by radar surveillance track data (e.g. ASDI), ADS-B data (e.g. FlightAware, Radar24 …) or fused data sets (e.g. OAG, FlightAware, FlightStats …).

When the criteria for the alert is based on historic performance, this information is derived from a Historic Flight Performance data-base. There are also criteria and alert information associated with weather (e.g., METAR) data, and air traffic control status such as Traffic Flow Management (TFM) initiatives and Notice to Airmen (NOTAM). Parsed news feeds and estimates of passenger itineraries can also be used to supplement the alerts. Estimated passengers

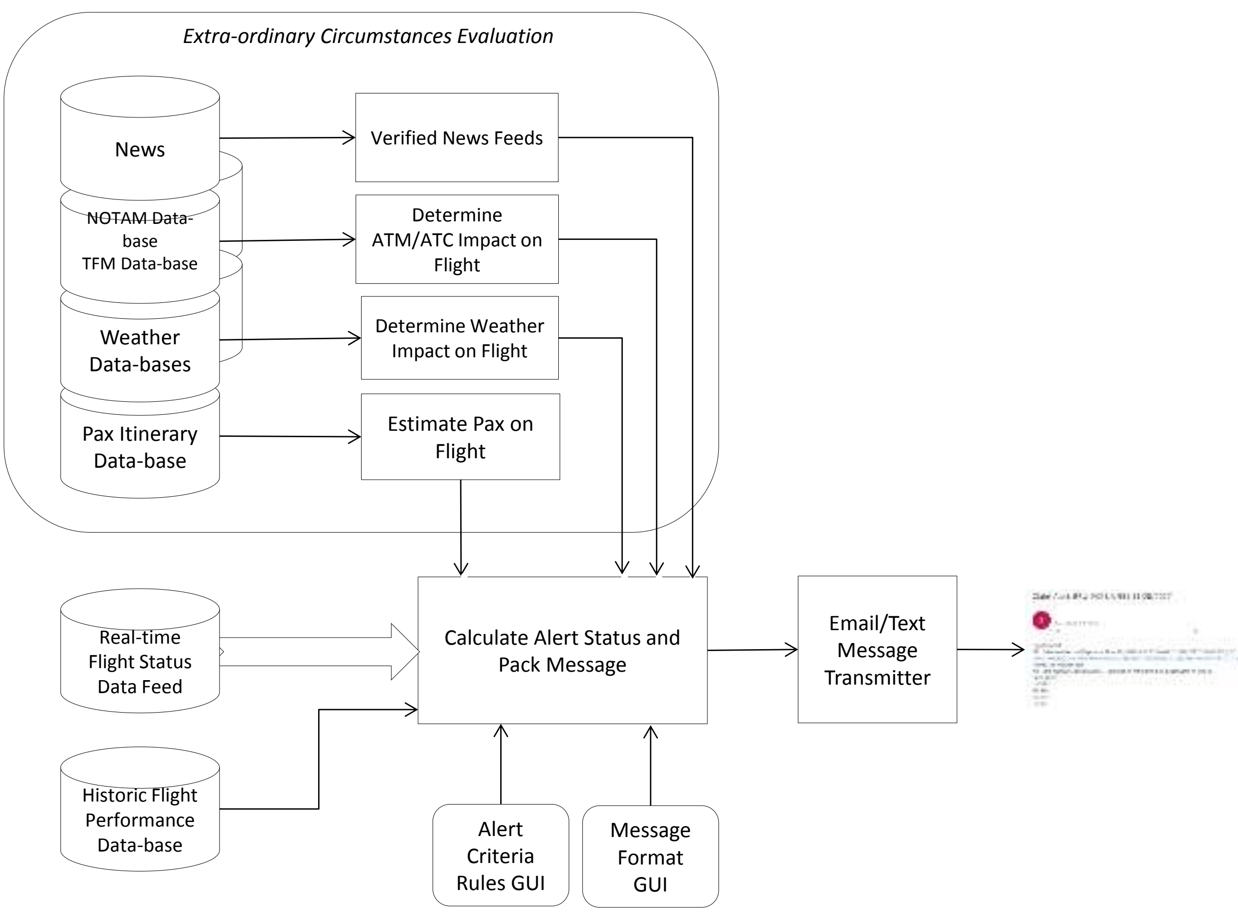

FIGURE 1: System Architecture for Real-time Flight Status Alerting System (RtFSAS).

counts and passenger itineraries can be added to the alerts.

Alert criteria can be set based on departure times (actual/scheduled), arrival times (actual/scheduled), block times, airborne times, taxi times, and/or flight status (e.g. Diverted, Cancelled).

The real-time alerting system shall transmit an email or text message when specific alert criteria are met on the specified set of flights. Flights are identified by their destination airport(s). The candidate flights can also be identified by departure time and by operating/ticketing airline.

For each of the considered case studies the data was interpreted and translated by the real-time alerting tool.

The core data for the alert is the Gate-Out, Wheels-Off, Wheels-On, and Gate-In times for each flight. The Gate-Out and Gate-In times provide the information about time when an aircraft has left from or arrived at the assigned gate respectively. The Wheels-Off specifies the time when an aircraft has taken off from a runway, and Wheels-On stands for the time when an aircraft has landed (i.e., landing gears touch a runway). The time difference between Gate-Out and Wheels-Off is called taxi-out time that describes how much time an aircraft has spent on a departure airport surface. Similarly, the time from Wheels-On and Gate-In is called taxi-in time in an arrival airport.

The sequence of steps below describes how the modelled system works.

1. Connect to the real-time data feed
2. Achieve the data from the data feed
3. Filter the data
4. Group all codeshare flights by an operating carrier
5. Apply alerting criteria
6. Send out an alerting email or text message

Note:

The Real-Time Alerting tool interface is shown in Figure 2 for tracking the status of each arriving flight to San Francisco International Airport (IATA: SFO).

The programming language and framework are C# .Net.

Existing Airport Data and Alerting Tools

Airport Labs (airportlabs.com) has two products: VisionAirFIDS – provides airport-Flight Information Display (FIDS) data on a cloud based

FIGURE 2: Real-Time Alerting tool logging taxi-in time

information platform, and Airport Community App - cloud messaging and alerting platform designed for the needs of today's collaborative airport environments.

Springshot (springshot.com) is a generic app-based product for communicating across any enterprise. Alerts can be set-up and sent to emails or cell phones. The app has been applied to airport operations.

Several vendors provide Airport Operational Data Base (AODB) services that make operational data available to stakeholders across the airport enterprise (e.g. amadeuas.com, indracompany.com). These services typically require licenses to a tool suite.

Airport service providers have develop proprietary communication and alerting services (e.g. omni-serv.com)

CASE STUDIES

This section describes real-time alerting for: (1) an Airport Food Concession and, (2) an Airport Airline Contracts Department. Although the airline contracts department are technically not a low tier supplier, they: (i) do not have direct access to real-time data or a license for airport surface management tools, (ii) needed alerts sent to their cell phones when the events where occurring, and (iii) only have occasional need for the alerting service.

Gate Concourse Food Concession

Food concessions on the gate concourse are staffed based on the estimated customer demand based on "normal" operations of the scheduled flights. This staffing plans maximizes revenue for the "normal" days. However, when irregular operations are in effect for flight operations, there can be up to three times more passengers/customers in the gate concourse area demanding service. Without adjusting staffing, a significant number of passenger/customers go unserved resulting in a loss of revenue.

An east-coast, domestic flights-only, airport has a terminal that services airline operators: Delta Airlines, Delta Shuttle, Frontier Airlines, Spirit Airlines, and West jet.

An estimate of the cumulative number of Gate Concourse Passenger-Hours at this terminal, based on actual flight arrival and departure times from July 2015 to June 2017 and the passenger flow model described in the Appendix. The average daily passenger-hour count was 16,079, with a standard deviation of 5,340 (Figure 3). The Coefficient of Variation is 0.3 indicative of modest fluctuations that in part are the result of variations in seasonal scheduling. During this period there were 39 days in which the Gate Concourse Passenger-Hour count was above 2 sigma.

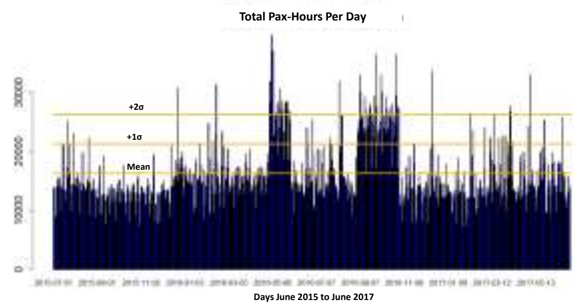

FIGURE 3: Estimated Daily Passenger-Hours in a Terminal at an east-coast domestic flight-only airport (July 2015 to June 2017)

The daily excess passenger-hours over and above the schedule is illustrated in Figure 4. The mean excess passenger-hour count is 630, with a standard deviation of 785. The coefficient of variation is 1.2 indicating significant fluctuations. During this period there were 39 days in which the estimated excess Gate Concourse Passenger-Hour count was above 2 sigma.

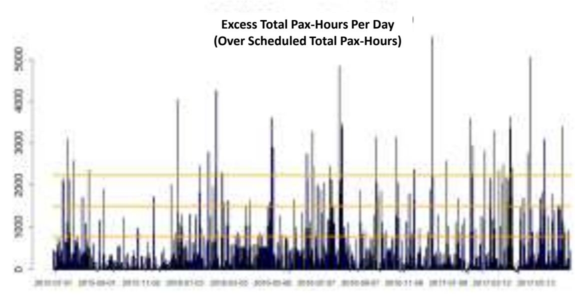

FIGURE 4: Estimated excess daily passenger-hours in airport Terminal (July 2015 to June 2017)

A probability density function of daily excess passenger-hours exhibits no left tail and a "fat" right tail indicating an asymmetric variance towards higher number of pax-hours only.

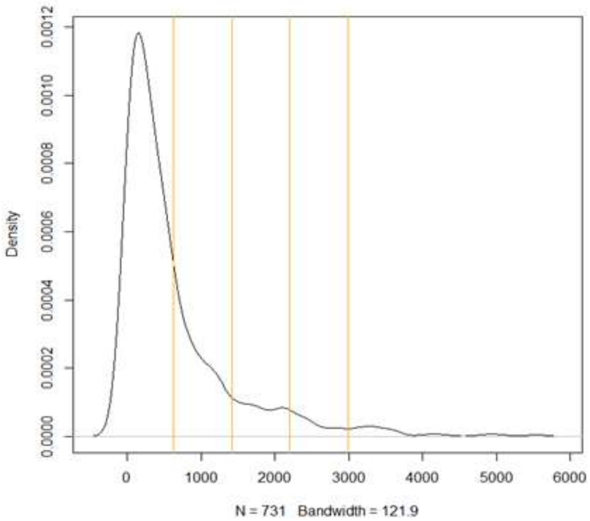

FIGURE 5: Probability density function of daily excess passenger-hours in terminal.

The specific days are listed in Table 1. Eleven of those days were in the Summer "convective storm season" (June- August), and 11 were in the Winter "snow season" (December – February).

TABLE 1: Daily Gate Concourse Passenger-Hour count and Excess Gate Concourse Passenger-Hour Count due to delays and cancellations (i.e. Pax Diff)

DATE	PAX DIFF	PAX	DATE	PAX DIFF	PAX	DATE	PAX DIFF	PAX	DATE	PAX DIFF	PAX
7/21/2015	3,111	25,243	5/4/2016	3,604	38,785	10/28/2016	3,151	36,520	3/22/2017	2,363	22,433
7/30/2015	2,602	23,045	5/6/2016	2,901	37,148	11/22/2016	2,381	21,178	3/28/2017	2,498	22,878
8/20/2015	2,375	22,333	6/23/2016	2,752	24,100	12/17/2016	3,539	33,795	4/6/2017	3,629	27,806
12/23/2015	4,044	30,898	7/1/2016	3,223	25,480	12/18/2016	2,231	21,388	4/7/2017	3,051	26,828
1/24/2016	2,466	21,454	7/2/2016	2,444	19,555	1/7/2017	2,584	17,853	4/9/2017	2,416	21,610
2/5/2016	2,788	24,826	7/25/2016	2,458	22,586	2/8/2017	3,593	26,613	5/1/2017	2,774	24,373
2/15/2016	2,334	23,050	8/6/2016	4,828	31,999	2/12/2017	2,271	19,369	5/5/2017	3,048	33,075
2/16/2016	4,260	31,430	8/11/2016	3,482	26,288	2/13/2017	2,959	23,704	5/25/2017	3,097	25,369
2/24/2016	2,514	22,998	8/12/2016	3,366	26,083	3/2/2017	2,826	24,138	6/19/2017	3,594	25,819
2/25/2016	2,291	23,618	8/28/2016	3,151	38,625	3/14/2017	3,297	26,383			

The estimated Excess Gate Concourse Passenger-Hour count by hour of day for the 2sigma vs the 50^{th}%-tile of the non-2 sigma days is shown in Figure 6. These charts illustrate general patterns in hourly excess passenger-hours over the course of the day. For example, when the Excess Passenger-Hour Count exceeds a threshold of 500 at 10am, this is an indicator of a +2 sigma day.

A model of concession profits had the following characteristics:

- Employees work in groups of 3 (cashier, barista #1, barista #2)
- At most 3 groups can work at any one time
- Shifts last either 6 or 8 hours
- At most 3 distinct start times for shifts
- Wage = $25/hour (fully burdened)
- 1 cashier can service 30 customers per hour
- 1 in 16 pax in the terminal over 1 hour visits the concession
- Average sale is $16
- Overtime shifts last 2 hours, pay 50% more than regular-time
- Overtime shift includes a group of 3 employees

A linear regression model fit to estimate the additional profit generated by extending each shift an additional 2 hours to accommodate a forecast of excess Gate Concourse Passenger-Hours for +2 sigma day:

$$P2 = \beta_0 + (\beta_1 * CumHEPH) + \boldsymbol{\varepsilon}$$

Where:

P2 profit in next two hours

β_0 = -158

β_1 = 0.1

$CumHEPH$ = Cumulative Gate Concourse Hourly Excess Passenger-Hours

$\boldsymbol{\varepsilon}$ = Error term = 180

With a confidence interval of 70%, estimated additional profit by holding over a shift an additional 2 hours in anticipation of a +2sigma event, ranged from $46K to $141Kper year. [Side note: adjusting the staffing plan to match the flight schedule (not the traditional staffing plan), profit could be increased by $518K per year.

Gate Waiting and Airport Surface Congestion

Note: Although the Airline Contracts Department at an airport is not technically *a low tier supply chain vendor*, they do not have license to real-time data feeds (e.g. surface management tools) as they only need post-operations data on a monthly basis and do not need alerting. This case study shows how this department used real-time alerting to resolve gate lease contractual issues

Although airport operators are not responsible for the operation of airline flights or their on-time performance, increasingly they are taking

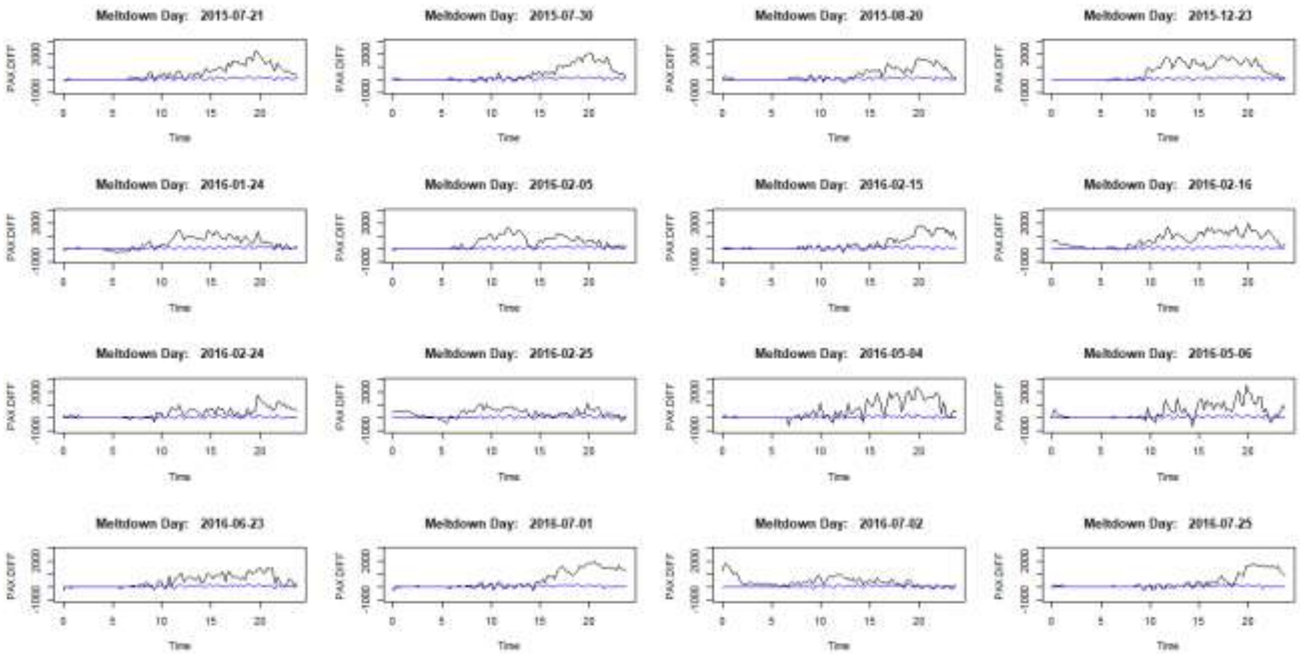

FIGURE 6: Sample of +2 Sigma Daily Excess Gate Concourse Passenger-Hour counts by time of day.

responsibility for the overall passenger travel experience and assisting all airport tenants to operate efficiently.

Prolonged taxi-in time is a phenomenon airport staff are paying closer attention to. Although a flight may land on schedule there can be circumstances in which the flight does not gate-in on time [1], [2]. In some cases, gates may not be available when a previous late arriving flight has not yet departed. In other cases, an airline may have scheduled flights in excess of their leased gate capacity. Gate waiting delays have a knock-on effect of creating surface congestion that prevents other flights (perhaps from other airlines) from departing or arriving at their gates. This is particularly true at airports with small surface footprint.

A case study application of real-time alerting for a hypothetical scenario at a major west coast airport is described. This international airport, situated on small parcel of land adjacent a body of water, has limited taxiway and ramp areas. Any congestion on the surface can have impact on a large number of flights.

Hypothetical Scenario

In the Fall of 2017, flights arriving at the airport abruptly started experiencing long taxi-in times (e.g. greater than 45 minutes) across multiple carriers. Airport management became aware of the issue of extended gate waiting through social media, traditional media, and their own post-operations analysis from ATC provided data. Airport management decided to investigate and quickly realized analysis of surface surveillance track data was not sufficient to identify the true causes of the delays. To better understand the causes of the delays and their mitigation steps, personnel with knowledge of the airline gate leasing contracts needed to be in the gate area and on the ramp as the scenarios unfold. This way discussions airline and supply chain personnel as the situation unfolded to get a better sense of airline and supply chain constraints and needs.

The gate waiting events did not occur consistently at the same time so waiting in the gate area was not a productive use of time. Although sophisticated airport surface management tools can provide alerts it would require installing a license and then monitoring the tool display. What they needed was a real-time alert sent to email (or cell phone text) for each flight when it exceeded a 45 minute taxi-in time threshold with specific flight and gate information.

Real-time Alerts

The real-time alerting, function provides the means to alert airport operations managers to the occurrence of taxi-in times in excess of 45 minutes so they could proceed to the gate area to investigate the source of delays first hand.

The alerting criteria for real-time alerting tool for identifying exceeding taxi-in time is shown below.

1. Find all flights with arrival status “Wheels-On” and “Gate-In”
2. When the system finds a new flight with status “Wheels-On”, assign its time
3. Save the flight details to Wheel-On array
4. Update the data every 5 minutes from the data feed and calculate taxi-in time for each flight
5. If the arrival status of the flight has not been changed to “Gate-In” longer than a threshold (e.g., 45 minutes), send an alert

A sample email message is shown in Figure 3 for flight from LAX that arrived 43 minutes late. By the time it arrived at XXX it’s assigned gate was in use by an on-time scheduled flight. The airline did not have another gate available that could accommodate that aircraft.

SUBJECT: Taxi-in Time Alert UAL 1294

- Flight UAL 1294
- From LAX to XXX
- Scheduled Arrival 12/2/17 10:22:00AM Local Time
- Actual Arrival 12/2/17 11:05:13AM Local Time
- Current Taxi Time 45 minutes and counting
- Scheduled Gate 73 (Terminal 3)
- Weather at XXX 999nm, 100OVC
- Codeshares: NZ 9282

FIGURE 7: Example Real-time alert email message for flight with taxi-in time of 45 minutes and counting

Analysis

In September 2017, five Legacy Network Carriers (LNC) operated domestic flights at the airport along with six Low Cost Carriers (LCC). There were on average 496 domestic arrivals per day, with 14,906 arrivals in the month. The LNCs operated 69% of the arriving flights, the LCCs 31% of the arriving flights. LNC2 and it’s regional operator, LNC2-Regional, accounted for 54% of the total arriving flights (i.e. hub operation). LNC2 and LNC2-Regional had on average 271 arrivals per day. These statistics are summarized in Table 2.

LNC1 had 25 (2.3%) arriving flights with taxi-in time in excess of 45 minutes in the month. 21% of the arriving flights had a taxi-in time over 15 minutes. LNC2/LNC-Regional had a combined 99 flights with taxi-in time in excess of 45 minutes, and a combined 1112 (14%) of the arriving flights with taxi-in time greater than 15 minutes. LCC5 had 46 (2.47%) arriving flights with taxi-in time greater than 45 minutes.

In October 2017, there were on average 502 domestic arrivals per day, with 15,583 arrivals in the month (Table 3). The LNCs operated 70% of the arriving flights, the LCCs 30% of the arriving flights. LNC2 and it’s regional operator, LNC2-Regional, accounted for 55% of the total arriving flights (i.e. hub operation). LNC2 and LNC2-Regional has on average 275 arrivals per day.

LNC1 had 17% of the arrivals with taxi-in time between 16 minutes and 45 minutes, and 15 flights (1.32%) of arriving flights with taxi-in time greater than 45 minutes (Table 2). LNC2/LNC2-Regional had 11% of the arrivals with taxi-in time between 16 minutes and 45 minutes, and 82 flights (1 %) of arriving flights with taxi-in time greater than 45 minutes. LCC5 had 7% of the arrivals with taxi-in time between 16 minutes and 45 minutes, and 18 flights (~1%) of arriving flights with taxi-in time greater than 45 minutes.

These aggregate monthly statistics do not tell the whole story (see Table 4). LNC2/LNC2-Regional had 22 days with at least one arriving flight with a taxi-in time greater than 45 minutes in September and 20 days in October. There were 10 days when there were 3 or more arriving flights with taxi-in time greater than 45 minutes in September and 8 in October. The NLC distributed the gate-waiting flights over 12 different arriving

TABLE 2: Summary statistics for arrivals in September 2017.

					< 15 mins		16 - 45 mins		> 45 mins		
Carrier	Total	Avg Arrs per Day	Cancelled	Div	Count	%	Count	%	Count	%	Terminal
LNC1	1096	36.5	0	3	874	79.74	194	17.70	*25*	*2.28*	1
LCC1	60	2.0	0	0	52	86.67	8	13.33	0	0.00	1
LCC2	557	18.6	9	2	475	85.28	70	12.57	1	0.18	Intl
LCC3	451	15.0	1	6	408	90.47	30	6.65	6	1.33	1
LNC2-Regi	3001	100.0	38	13	2618	87.24	313	10.43	19	0.63	1,3
LNC2	5150	171.7	45	17	4298	83.46	710	13.79	80	1.55	1,3, Intl
LCC4	1476	49.2	56	5	1285	87.06	129	8.74	1	0.07	1
LCC5	1861	62.0	16	3	1657	89.04	139	7.47	*46*	*2.47*	2
LCC6	182	6.1	3	0	139	76.37	34	18.68	6	3.30	1
LNC3	1072	35.7	18	7	968	90.30	75	7.00	4	0.37	2
ALL	**14906**	**480.8**	**186**	**56**	**12774**	**85.70**	**1702**	**11.42**	**188**	**1.26**	

flights so the same flight was not impacted every day.

LNC1 and LCC5 had 9 and 7 days respectively with at least one arriving flight with a taxi-in time greater than 45 minutes. These days were correlated with irregular operations in the NAS on the east-coat or in the mid-west.

Over or Tight Gate Scheduling

In September 2017 LNC2/LNC-Regional, operating a hub at the airport, engaged in a "market-share" war with a newly merged "low cost carrier" (LCC5) competitor. The LNC increased the frequency of flights and tightened the turn-around schedule of flights. The airline did not lease additional gates from the airport. Although some airport gate lease agreements require submission of schedules it is not clear that the schedule analysis by the airport raised any concerns. By observing the operations in-person, airport management was better able to understand the issues, and could seek to alleviate these delays by making additional gates available (if possible).

Propagation of NAS-wide Irregular Operations

The LNC was not alone in increasing

TABLE 3: Summary Statistics for arrivals in October 2017

					< 15 mins		16 - 45 mins		> 45 mins		
Carrier	Total	Avg Arrs per Day	Cancelled	Div	Count	%	Count	%	Count	%	Terminal
LNC1	1140	36.8	0	0	937	82.19	188	16.49	15	1.32	1
LCC1	62	2.0	0	2	54	87.10	6	9.68	0	0.00	1
LCC2	569	18.4	8	2	500	87.87	58	10.19	1	0.18	Intl
LCC3	462	14.9	2	15	414	89.61	30	6.49	1	0.22	1
LNC2-Regional	3113	100.4	204	9	2588	83.14	277	8.90	35	1.12	1,3
LNC2	5428	175.1	24	5	4679	86.20	673	12.40	47	0.87	1,3, Intl
LCC4	1526	49.2	80	0	1346	88.20	99	6.49	1	0.07	1
LCC5	2000	64.5	43	9	1786	89.30	144	7.20	18	0.90	2
LCC6	132	4.3	0	0	114	86.36	17	12.88	1	0.76	1
LNC3	1151	37.1	3	4	1065	92.53	75	6.52	4	0.35	2
ALL	15583	502.7	364	46	13483	86.52	1567	10.06	123	0.79	

TABLE 4: Number of days per month with taxi-in time greater than 45 minutes

Carrier	Sept			Oct		
	1 or More Arrivals per Day	3 or More Arrivals per Day	5 or More Arrivals per Day	1 or More Arrivals per Day	3 or More Arrivals per Day	5 or More Arrivals per Day
LNC1	10	3	2	11	1	0
LCC1	0	0	0	0	0	0
LCC2	1	0	0	1	0	0
LCC3	2	1	0	1	0	0
LNC2-Regional	13	1	0	17	5	1
LNC2	22	10	8	20	8	2
LCC4	1	0	0	1	0	0
LCC5	7	4	4	9	2	1
LCC6	5	0	0	1	0	0
LNC3	3	0	0	4	0	0
All	**29**	**20**	**13**	**28**	**16**	**11**

frequency. The newly merged LCCs (LCC5) also increased frequency of flights. As a trans-continental operator, LCC5's gate schedule has more slack than LNC2's. Although this airline could support the additional flights with their existing leased gates, on days when NAS-wide delays resulted in late arriving flights, temporary demand for gates in excess of gate capacity could occur when a bank of late flights (e.g. from east-coats) coincided with on-time flights (e.g. from west-coast only). The same phenomenon occurred with LNC1. This issue could be alleviated by making "spare" gates available on an as-needed basis for this type of irregular operation.

This case study illustrates the value of real-time alerting to understanding operational issues that cannot be understood by looking at the data alone post-operations. It was necessary for management to get down to the airport gates and collect additional data when the situation was taking place.

5 CONCLUSIONS

This paper describes an inexpensive method for alerting enterprise staff in all tiers of the air transportation system on the status of flights that affect their operations. These staff may not have access to the flight status information or may be located in remote locations. The flight status information is transmitted via email or text message in real-time.

Case studies demonstrate the range of applications for an alerting tool from contract compliance to customer service. When the alerts generate additional revenue, the low cost of the alerting service generally facilitates a profitable return.

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Acknowledgements

Authors acknowledge the contributions of John Shortle, George Donohue, Seungwon Noh (GMU), Mark Klopfenstein (AvMet), Terry Thompson (The Climate Service Group), Michael Garcia (Aerion), Jack Loop (LocusLabs), Gregg Wollard (MWAA).

Email Addresses

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Appendix

Algorithm for Estimated Hourly Passenger Gate Concourse Counts

The hourly passenger count is based on the following rules:

Departing passengers on operating flights (i.e. not cancelled) are present on the Gate Concourse as follows:

- 10% arrive 2 hours prior to boarding
- 30% arrive 1.5 hours prior
- 40% arrive 1 hour prior
- 20% arrive 0.5 hours prior

Departing passengers on Cancelled flights are present on the Gate Concourse as follows::

- 50% leave the terminal after 2 hours
- 25% leave after 3 hours
- 25% leaves after 4 hours

Arriving passengers are present on the Gate Concourse as follows:

- 90% depart the terminal 30 minutes after deplaning
- 25% stay in the terminal for 2 hours to catch a connecting flight

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