Analysis of a Surface Congestion Management Technique at New York JFK Airport*

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Airport surface congestion can be a cause of significant increases in taxi times, fuel burn and emissions. Various surface congestion management techniques are being developed to help mitigate these issues at different airports, typically by holding aircraft at the gate or some other designated area during times of high congestion in order to reduce the number of aircraft on the active movement area. This paper describes the development and field testing of one such technique at New York John F. Kennedy airport. Impacts are quantified based on extensive analysis of operational data. Total annualized taxi-out time reductions of 14,800 hours were estimated at the airport, with annual fuel savings of 5.0 million US gallons ($10-15 million at $2-3/US gallon) and 48,000 metric tons of carbon dioxide emissions reductions.

I. Introduction

Air traffic is expected to continue to grow in the future and improved methods for dealing with the increased demand on the system need to be implemented. The airport surface is one area where system inefficiencies are especially evident in the form of congestion: at major airports in the United States in 2009 there was over 32 million minutes of departure taxi delay [1], translating to over 130 million US gallons of excess fuel burn at a typical taxi fuel burn rate of 4.1 US gallons/minute. One approach to mitigate the resulting monetary and environmental impacts is to employ surface congestion management techniques (also known as departure queue management or departure metering). Understanding the potential benefits of these techniques is important to help prioritize them relative to other capabilities which could be developed to help address future air transportation system needs.

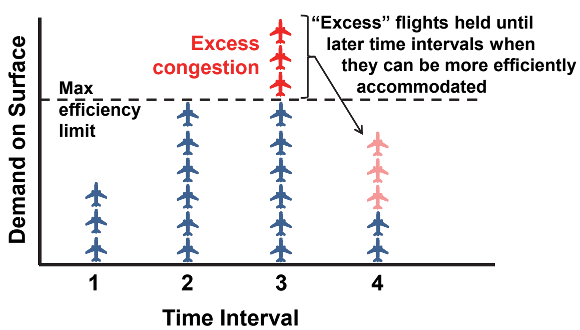

Figure 1: Surface Congestion Management Concept

Every airport has a limit to the number of aircraft it can efficiently handle as a function of characteristics such as runway configuration, weather conditions and demand. Surface congestion management techniques aim to keep the airport operating at this limit during periods of high demand when it would otherwise be above the limit, with "excess" flights being held at the gate or some other appropriate location with engines off until they can be released to the departure runway more efficiently, as shown in Figure 1. By restricting the number of aircraft on the surface in this way, "engines-on" taxi-out time, fuel burn and emissions can be reduced.

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A useful way of visualizing the performance of the airport is illustrated in Figure 2 in terms of the departure rate as a function of an appropriate surface traffic metric (such as the number of aircraft taxiing out or in the departure queue). For low levels of surface traffic, as more departing aircraft are pushed back from the gates onto the surface, the departure rate increases as more aircraft are available at the runways. However, as surface traffic increases further, the capacity limit of the airport is approached and the departure rate eventually saturates. At this point, any additional increase in surface traffic simply adds to congestion and does not achieve any additional departure rate (indeed, if surface traffic gets very high, the departure rate will start to decline as gridlock on the surface is approached). Archived operational data can be used to determine performance curves of this form for different airports under different runway configurations, weather and traffic (e.g., arrival rate) characteristics. They can then be used as a basis for surface congestion management at the airport under those conditions by holding aircraft off the surface when the airport is expected to operate above some control point on the curve. Typically the control point would be slightly higher than the expected saturation point so as to avoid risking loss in departure rate, but not so large as to lose significant benefits from the control strategy. The impacts of congestion management can then be assessed in terms of performance implications (e.g., taxi time and fuel burn) of moving the operating point of the airport from above the control point back to the control point, as shown in Figure 2. Note that, because the maximum departure rate should be maintained during effective surface congestion management, there should be no impact to a flight's wheels-off time or downstream performance implications.

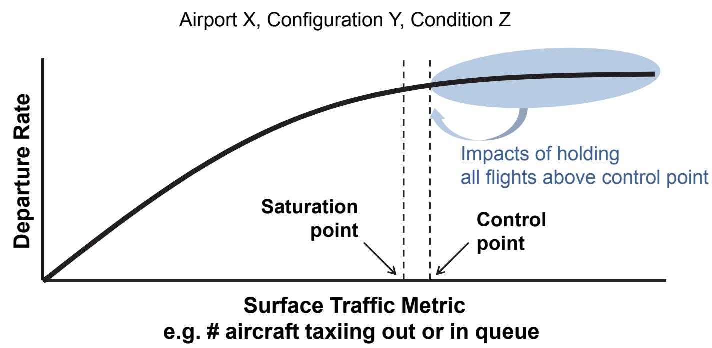


Figure 2: Airport Performance Curve

Although the principles of surface congestion management as described above are generally applicable across congested airports, the specifics of implementation at any given airport (e.g., how to determine when flights need to be held, coordination of which specific flights to then hold, where to hold them and what level of airline interaction is needed) depends on the airport/traffic characteristics and the level of sophistication desired. To illustrate this point, several specific implementations of surface congestion management have recently been tested in field trials or in simulation environments. For example, pushback rate control has been tested at Boston Logan Airport (BOS) which recommends a general pushback rate to tower controllers to limit the number of aircraft on the surface at peak times [2]. Collaborative Departure Queue Management (CDQM), tested at Memphis airport (MEM), allocates departure slots to different airlines at peak times to manage average departure delay to below a control value, and then the airlines determine which of their flights go into which allocated slot [3]. Another class of approach recommends when specific flights should leave from gate or spot to manage surface congestion [4]. This affords greatest control (and potentially greatest benefits), but requires significant real-time airline coordination for the congestion management system to know when flights want to push-back, as well as communication of and compliance to allocated slot times which may be later than the desired push time to better manage excess demand.

This paper describes the development, operational testing and benefits analysis of a surface congestion management technique of this last category (i.e., flight-specific) at New York John F. Kennedy International Airport (JFK) during 2010. Other studies have examined the potential impacts of congestion management at JFK through simulation [5,6], but this is the first study to base findings on the actual operational testing at the airport. The development and implementation of the surface congestion management approach is discussed in the next section, followed by a description of the assessment methodologies used to assess its impact. Results from the assessments are presented to quantify the impacts of the surface congestion management technique at the airport.

II. JFK Surface Congestion Management Approach

JFK is one of the biggest and most congested airports in the US. The layout of the airport is shown in Figure 3. Early forms of surface congestion management have been used at the airport since 2002 to assist with deicing operations. In February 2010, a full-time implementation of prototype software and processes was put in place by PASSUR Aerospace for the Port Authority of New York and New Jersey (PANYNJ), initially to manage the disruption caused by a five month closure of one of the major runways (13R/31L) for maintenance, but its use was continued after the runway re-opened.

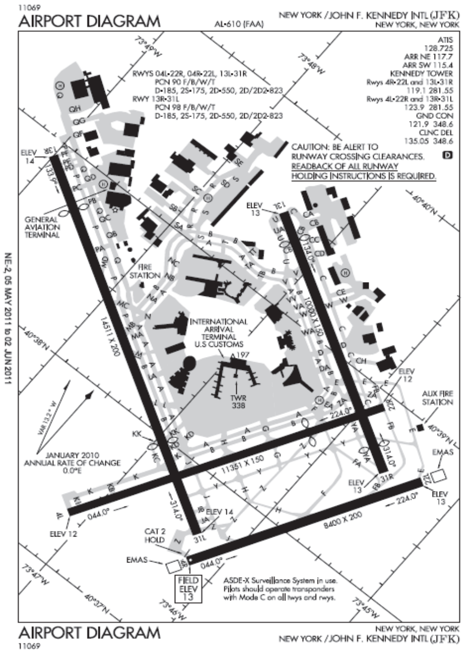


Figure 3: New York JFK Airport

A schematic of the implementation of the specific Surface Congestion Management (SCM) approach at JFK is shown in Figure 4. The development of the approach was based upon a collaborative process in which all carriers participated to ensure the maximum use of departure capacity, while ensuring the lowest amount of engines-on departure taxi time. One of the cornerstones of the development approach was the use of predictive analytics to accurately forecast up to eight hours in advance the expected departure and arrival capacity (in terms of departure and arrival "slot counts") of the airport based on the weather forecast and matching past airport performance under similar predicted weather conditions. This in turn was used with the demand information of flight-specific requested push-times sourced from (and updated by) the airlines to develop the initial allocation of flights to permitted taxi "slot times" over the forecast period. When the number of aircraft wanting to push-back was below what the airport could efficiently handle in a certain time period (e.g., 15 minute time bins), the slot times were the same as the desired push times. But when the number of flights wanting to push exceeded what the airport could efficiently handle, the excess flights were allocated slot times later than their desired push times into bins when the airport could more efficiently handle them, as illustrated in Figure 1. The initial allocation of flights to slot times used the concept of "ration by schedule" [7] in which the number of slots per hour was allocated to each operator based on their normal (unrestricted) percentage of the hourly volume. Slots were issued up to two hours in advance, to accommodate the longer planning horizon of international operations. Once the initial allocation of departure slots had occurred, the users had the opportunity to request swaps and substitutions within their allotment of departure slots, in order to better reflect their internal business priorities. These requests were received and processed electronically via a web interface managed by the "slot allocation manager": a neutral third-party established to run the program. All slot assignments could be seen by all program users, ensuring maximum transparency and trust that there was no gaming of the system. The central tenet of the above process is that users do not push-back until they have reached their assigned departure slot time rather than simply pushing back whenever they are ready (as happens when surface congestion management is not in effect). When a flight's slot time was later than the requested push time, the hold time was absorbed either at the gate or, if the gate was required by another aircraft, at a pre-assigned holding pad with engines off as much as possible.

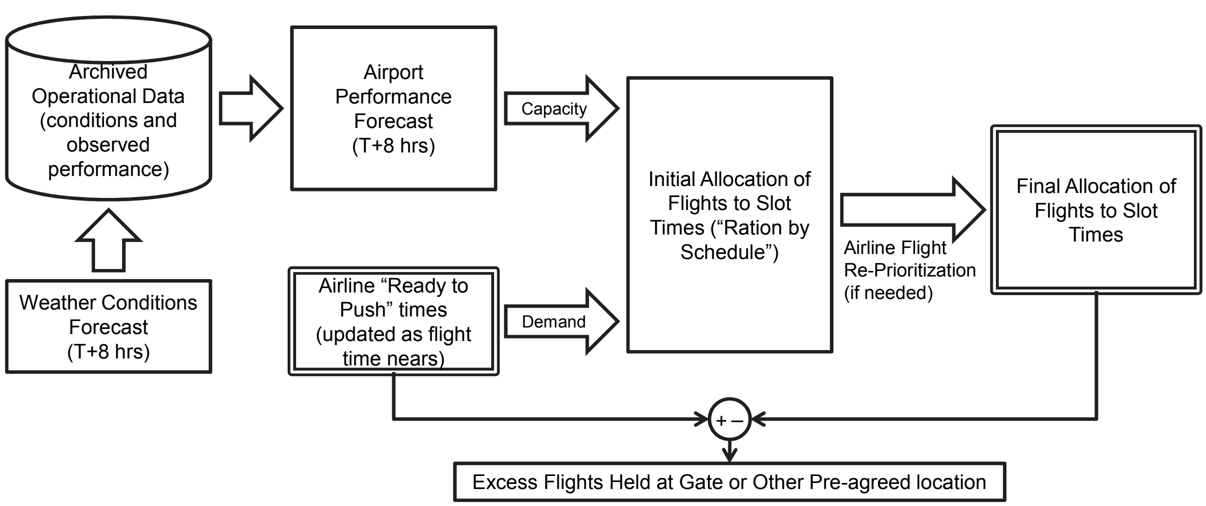
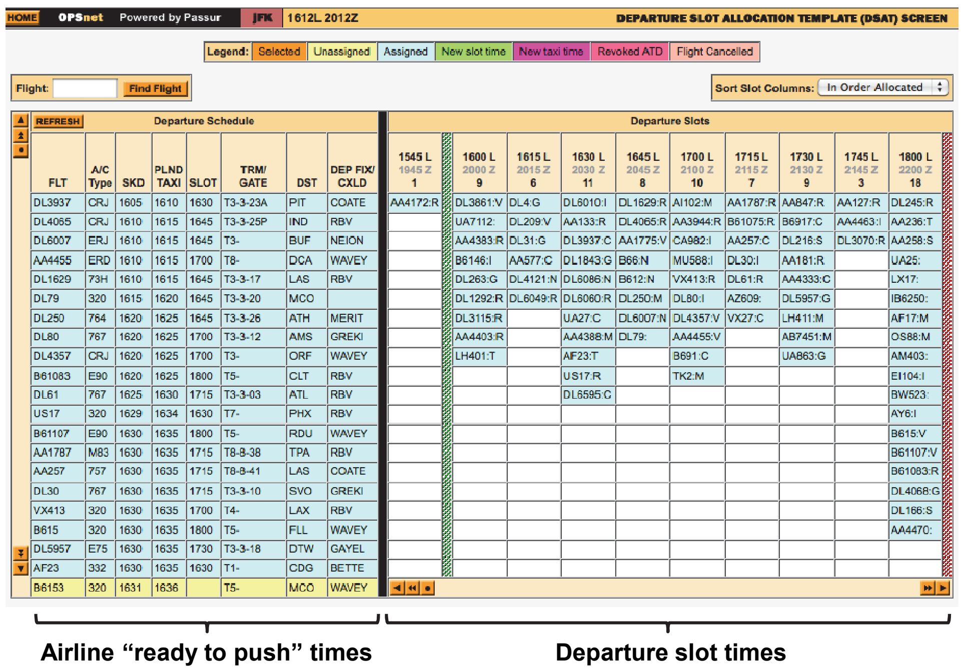


Figure 4: JFK Surface Congestion Management (SCM) Approach

Figure 5 shows an example "Departure Slot Allocation" screen from the system employed at JFK capturing sample information from the double-lined boxes in Figure 4. The left side illustrates airline-sourced "ready to push" times by flight, while the right side shows the allocated departure slot times in 15 minute bins. The current time bin is delineated by the green vertical bar. Differences between the "ready to push" and "departure slot times" represent the hold time to manage surface congestion more efficiently. For example, DL3937 had a ready to push (planned taxi) time of 16:10 but a departure slot time of 16:30, so received a 20 minute gate hold time and shows as demand in the 16:30 time window. Note the ":C" after the flight number indicates the departure fix for this flight (COATE).



FLT	A/C Type	SKD	PLND TAXI	SLOT	TRM/ GATE	DST	DEP FIX/ CXLD
DL3937	CRJ	1605	1610	1630	T3-3-23A	PIT	COATE
DL4065	CRJ	1610	1615	1645	T3-3-25P	IND	RBV
DL6007	ERJ	1610	1615	1645	T3-	BUF	NEION
AA4455	ERD	1610	1615	1700	T8-	DCA	WAVEY
DL1629	73H	1610	1615	1645	T3-3-17	LAS	RBV
DL79	320	1615	1620	1645	T3-3-20	MCO	
DL250	764	1620	1625	1645	T3-3-26	ATH	MERIT
DL80	767	1620	1625	1700	T3-3-12	AMS	GREKI
DL4357	CRJ	1620	1625	1700	T3-	ORF	WAVEY
B61083	E90	1620	1625	1800	T5-	CLT	RBV
DL61	767	1625	1630	1715	T3-3-03	ATL	RBV
US17	320	1629	1634	1630	T7-	PHX	RBV
B61107	E90	1630	1635	1800	T5-	RDU	WAVEY
AA1787	M83	1630	1635	1715	T8-8-38	TPA	RBV
AA257	757	1630	1635	1715	T8-8-41	LAS	COATE
DL30	767	1630	1635	1715	T3-3-10	SVO	GREKI
VX413	320	1630	1635	1700	T4-	LAX	RBV
B615	320	1630	1635	1800	T5-	FLL	WAVEY
DL5957	E75	1630	1635	1730	T3-3-18	DTW	GAYEL
AF23	332	1630	1635	1630	T1-	CDG	BETTE
B6153	320	1631	1636		T5-	MCO	WAVEY

1545 L 1945 Z 1	1600 L 2000 Z 9	1615 L 2015 Z 6	1630 L 2030 Z 11	1645 L 2045 Z 8	1700 L 2100 Z 10	1715 L 2115 Z 7	1730 L 2130 Z 9	1745 L 2145 Z 3	1800 L 2200 Z 18
AA4172:R	DL3861:V	DL4:G	DL6010:I	DL1629:R	AI102:M	AA1787:R	AA847:R	AA127:R	DL245:R
	UA7112:	DL209:V	AA133:R	DL4065:R	AA3944:R	B61075:R	B6917:C	AA4463:I	AA236:T
	AA4383:R	DL31:G	DL3937:C	AA1775:V	CA982:I	AA257:C	DL216:S	DL3070:R	AA258:S
	B6146:I	AA577:C	DL1843:G	B66:N	MU588:I	DL30:I	AA181:R		UA25:
	DL263:G	DL4121:N	DL6086:N	B612:N	VX413:R	DL61:R	AA4333:C		LX17:
	DL1292:R	DL6049:R	DL6060:R	DL250:M	DL80:I	AZ609:	DL5957:G		IB6250:
	DL3115:R		UA27:C	DL6007:N	DL4357:V	VX27:C	LH411:M		AF17:M
	AA4403:R		AA4388:M	DL79:	AA4455:V		AB7451:M		OS88:M
	LH401:T		AF23:T		B691:C		UA863:G		AM403:
			US17:R		TK2:M				EI104:I
			DL6595:C						BW523:
									AY6:I
									B615:V
									B61107:V
									B61083:R
									DL4068:G
									DL166:S
									AA4470:

Figure 5: Airline Ready to Push and Departure Slot Allocation Example (FLT = flight number, SKD = scheduled time, PLND TAXI = ready to push time, SLOT = departure slot time, TRM/GATE = terminal/gate location, DST = destination, DEP FIX = departure fix)

III. Assessment Methodology

A. Background

There are many potential impacts of the surface congestion management approach, for example in terms of taxi-out time, fuel burn, emissions, throughput, gate usage, holding area usage, ground crew operations, passenger connectivity, bag connectivity, airport terminal occupancy, airport terminal revenues, etc. *The focus of the analysis reported here is in terms of a first order assessment of annualized impacts of the 2010 surface congestion management approach on taxi-out time, fuel burn and carbon dioxide (CO_2) emissions at JFK.* The general approach to achieve this was to compare taxi times, fuel burn & emissions pre/post congestion management implementation, with all other relevant operational factors being as equal as possible (hence the desire to avoid the runway closure period). It was possible to find a few days where the airport was operating under very similar conditions pre/post surface congestion management implementation, allowing example impacts of the technique to be observed. Figure 6 shows results for two similar days pre/post implementation. Surface congestion management reduced the number of aircraft on the airport surface between 17:00 and 21:00 (corresponding to the evening departure push at JFK) from a peak of 40 on the sample day before the technique was implemented, to about 25 after it was implemented, resulting in active taxi-out time savings of over 20 minutes for the average flight departing at

20:00. The surface traffic snapshot shown in Figure 7 reinforces the effect in terms of the reduced departure queue size and resultant reduced taxi-out times, with the "excess" aircraft being held off the active movement area.

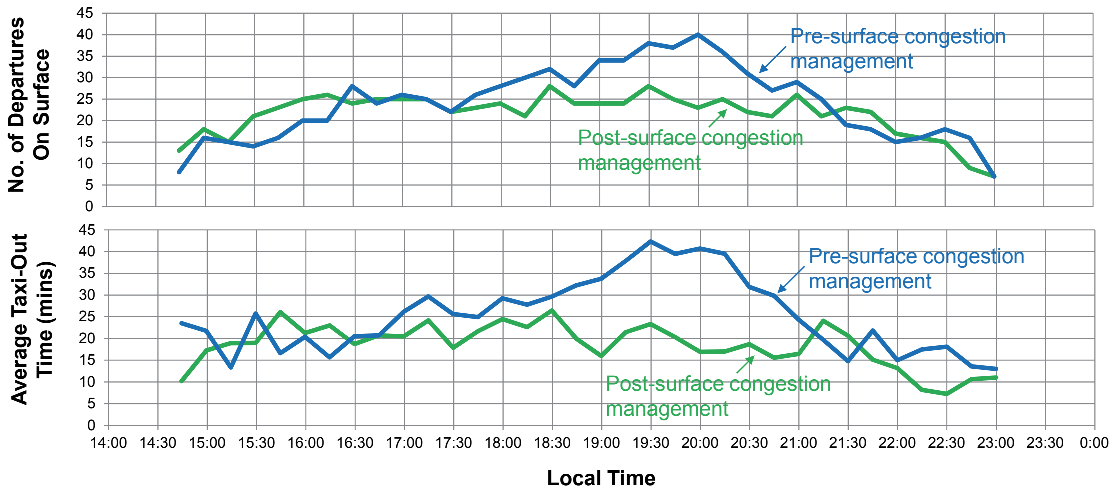


Figure 6: Comparison of Taxi-out Times Pre/Post Surface Congestion Management for Sample Days

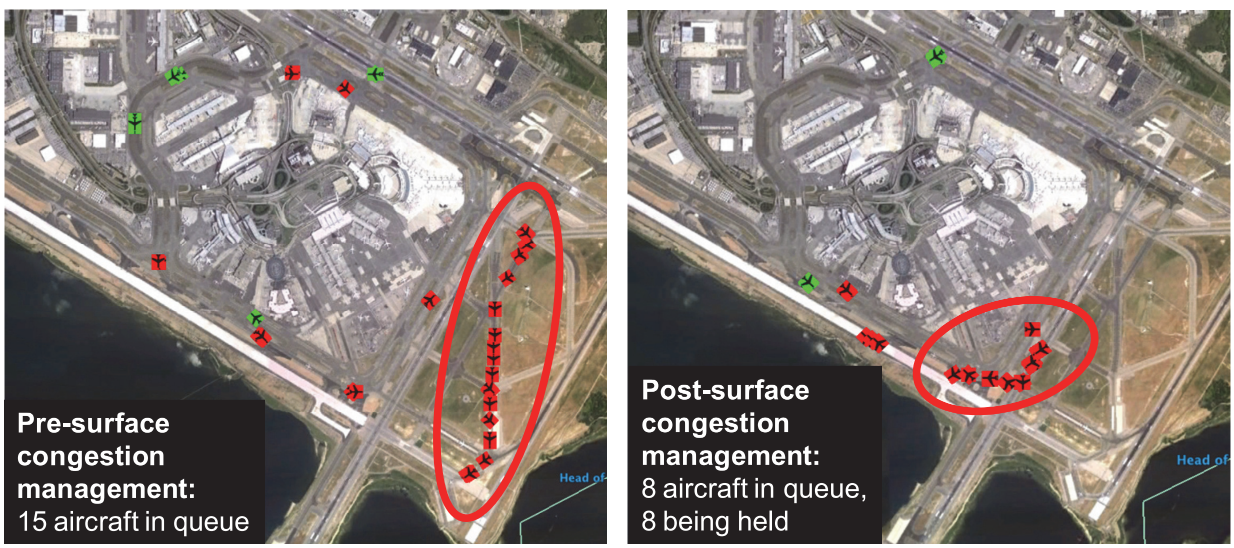


Figure 7: Comparison of Airport Traffic and Departure Queues Pre/Post Surface Congestion Management (red icons = departure aircraft, green icons = arrival aircraft)

Although these observations provide insights into the effect of surface congestion management, data across numerous days was required to estimate annualized impacts. However, the large number of factors that influence airport operations (e.g., demand, capacity, airport configuration, weather, air traffic control constraints, equipment status, etc.) and the complexity of operations specifically at JFK, made finding a large enough sample of comparable days pre/post-implementation very difficult. Therefore, an analysis approach was developed which found relationships between surface congestion management and taxi time impacts in each major airport runway configuration and then applied the identified relationships to the full set of data to determine the annualized impacts of the congestion management technique, as described in the next section.

B. Analysis Methodology

The analysis methodology is presented in Figure 8, with the general sequence of steps presented along the top and more detail on how the steps were executed below. Each of the steps is discussed in detail in this section.

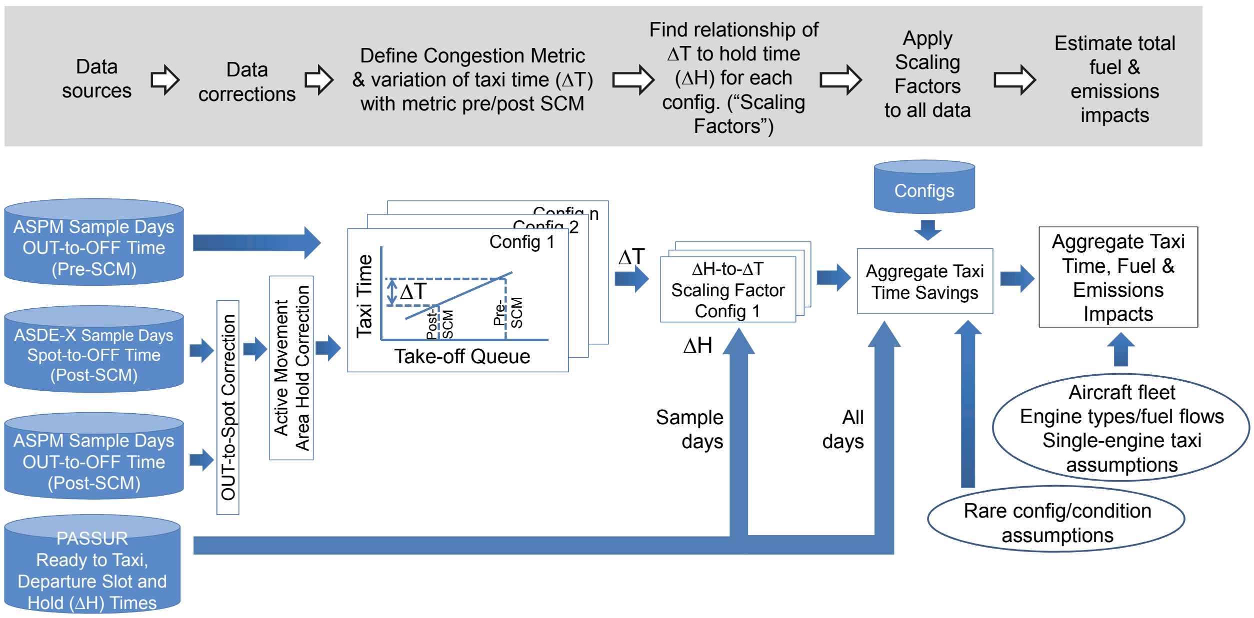


Figure 8: Analysis Methodology

1. Data Sources

This analysis used the following data sources:

- FAA Aviation System Performance Metrics (ASPM) database which provides flight-specific OOOI (gate OUT, wheels OFF (take-off), wheels ON (landing), gate IN) times and airport throughput in 15 minute intervals.
- Airport Surface Detection Equipment-X (ASDE-X) data which provides position in the active movement area (not ramp) at 1 second updates.
- PASSUR surface congestion management data which provides flight-specific ready to push, departure slot and resulting hold times (if any).

The pre-implementation analysis period was selected to be January 1, 2009 - December 31, 2009. The initiation of the surface congestion management process coincided with the closure of runway 13R/31L, but the impacts during the runway closure were not analyzed because the airport was not in its normal state (i.e., there was no pre-implementation data corresponding to JFK without runway 13R/31L). Therefore, the post-implementation analysis period was selected to be July 1, 2010 - December 31, 2010 corresponding to the day runway 13R/31L re-opened through the last day for which all of the data sources discussed above were available for this analysis.

2. Data Corrections

The data sources identified above provided the key analysis events illustrated in Figure 9. The difference between the ASPM OUT and OFF times provided a good measure of the taxi-out time in the pre-surface congestion management environment. However, it was not suitable in the post-surface congestion management environment due to the fact that a large number of the flights which were given slot times after their ready to push times were held “off-gate”. In those cases, the ASPM OUT time was not an accurate reflection of when the aircraft actually started taxiing to its departure runway, but rather when it left the gate to be held elsewhere (as would happen if the gate was needed for an inbound arrival). Therefore, the post-surface congestion management taxi-out times were determined from the ASDE-X data. Given that the ASDE-X tracks were generally picked up at the spots (the interface between the ramp and active movement areas), the tracks needed to be corrected back to an equivalent OUT time so they could be directly compared to the pre-implementation taxi-out times based on the ASPM OUT-to-OFF events.

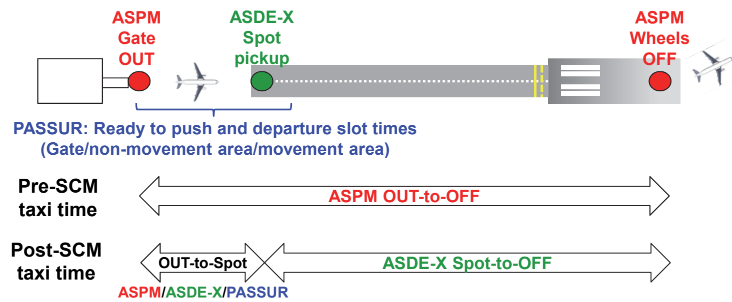


Figure 9: Key Analysis Events

To determine the appropriate "OUT-to-spot" correction factor, distributions of the differences between ASPM OUT times and ASDE-X pickup times were calculated for pre- and post-surface congestion management days. For the pre-implementation case, only 9 weeks of ASDE-X data were available, whereas 6 months of data were available for the post-implementation period. The pre- and post-implementation distributions were subtracted from each other resulting in the left side of Figure 10, which shows a spike above the horizontal axis and a trailing tail below it. The positive spike represents additional flights pre-congestion management implementation with small differences between their OUT and pickup times, while the trailing tail represented additional flights post-surface congestion management implementation with large differences. Because the number of flights in the negative tail and positive spike is approximately equal, it was hypothesized that the trailing tail represent flights that, pre-implementation, pushed back normally but post-implementation were held off-gate (resulting in a long period of time between their OUT and spot times). The positive spike therefore represents a distribution of typical OUT-to-spot times. This subsequently had a Normal distribution fitted to it as shown on the right side of Figure 10, with a resulting mean of 7 minutes and a standard deviation of 2 minutes. This can be interpreted as the distribution of times it takes a typical flight at JFK to reach the spot once the parking brake has been released at the gate, accounting for tug push-back, engine start and checklist completion times.

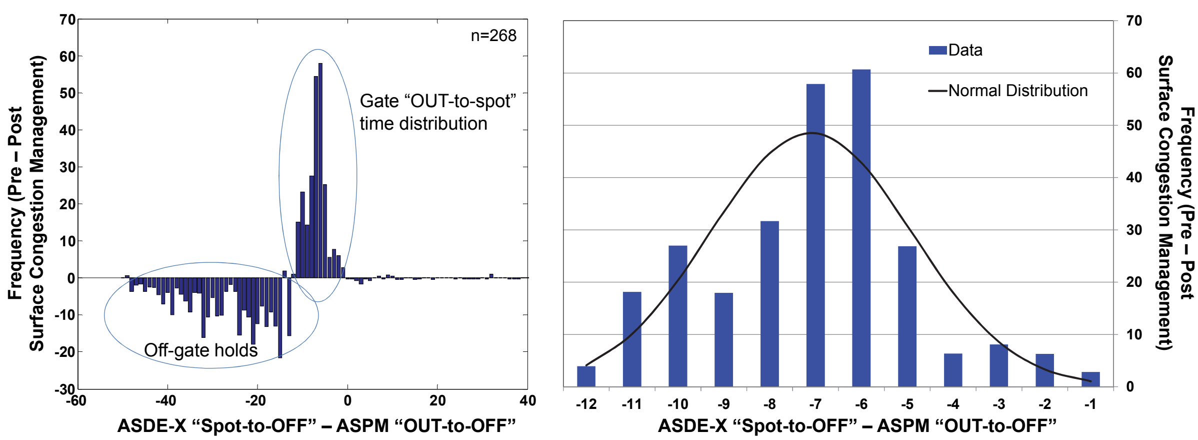


Figure 10: "OUT-to-spot" Correction Factor Data

Another correction factor was required to account for those flights that held in the active movement area at pre-designated hold locations until their slot time; i.e., their ASDE-X pick-up time was not a true reflection of their start of taxi time (similar to the reason why ASPM data was not appropriate for any flight with an off-gate hold). To correct for the fact that these flights were in fact holding in the active movement area (most likely with engines off), all flights which appeared in ASDE-X data 7 minutes or more before their scheduled slot time (5 minute PASSUR allowance + 2 minute grace period) had their spot times moved forward to their scheduled slot time. This approach was validated by examining ASDE-X tracks for individual flights that fit the criteria and verifying that those flights stayed in their assigned hold area until their slot time, then began taxiing to their departure runway.

3. Define Congestion Metric & Variation of Taxi Time with Metric Pre/Post SCM

The key congestion metric used in this analysis was the "take-off queue", which for a given flight *i* is defined as the number of other take-offs which occur between the pushback and take-off time of aircraft *i*. Other metrics were also tested, including number of departing aircraft on the airport surface and the number of aircraft in physical departure queues at the runways, but they were found to be less suitable for JFK analysis. Prior work has shown that the taxi time of a flight is often related to the take-off queue that it faces [8]. To convert the change in take-off queues into a change in taxi time at JFK with surface congestion management, a regression was calculated using taxi time versus take-off queue data as shown in Figure 11. The slope of the regression can be interpreted as the incremental taxi time for every additional aircraft in the take-off queue. The slopes of the regression pre- and post-surface congestion management are very similar, indicating the dynamics of the airport are unaffected by the procedure, but the airport is operating at much lower average take-off queue counts (i.e., more often on the left side of the regression line compared to the right) when surface congestion management is in operation. Regression lines like this were calculated for the top six most common configurations that experienced holds at JFK and the regression line slopes of all but one of the configurations were very similar pre- and post-implementation, but did vary between configurations as expected given their different capacities.

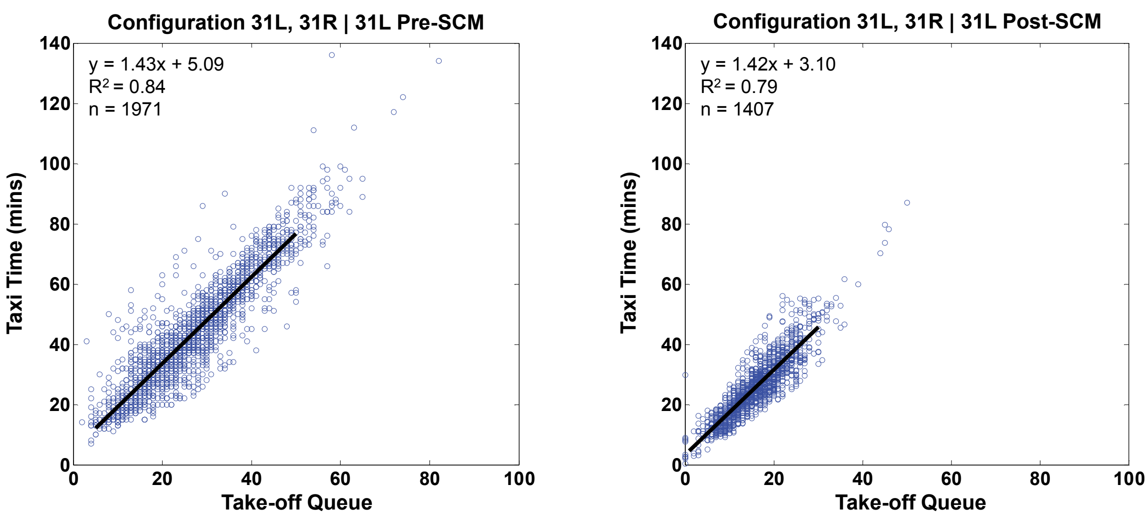


Figure 11: Relationship of Taxi Time to Take-off Queue

To alleviate the problem highlighted earlier with identifying similar days pre- and post-surface congestion management implementation, multiple "sample days" were found for each of the top 6 configurations. These days were chosen by looking at the peak departure period (17:00-21:00 in most cases) and finding days when the airport stayed in the same configuration for the duration of the period. This eliminated instances where the configuration was changed midway through the period, which could affect the results. By looking at a group of days and averaging the traffic over them, the variations in operation from day to day were accounted for to first order. The average takeoff queue across the group of sample days was calculated in 15 minute bins (e.g., 17:00-17:15) pre- and post-surface congestion management implementation, and using the regression lines for each configuration, the taxi time impact of the technique was determined in those 15 minute time bins. This was then summed over all time periods in the sample days to determine a total amount of taxi time saved in each major configuration.

4. Find Relationship of Taxi Time to Hold Time for Each Major Configuration ("Scaling Factors")

The difference in taxi time observed from the previous step was compared to the hold time due to the surface congestion management technique to determine configuration-specific "Scaling Factors": see Figure 12. The Scaling Factors can be considered as representing the observed taxi time reduction of each minute of hold time. Notice the sensitivity of the scaling factors (represented by the whiskers) to the gate-to-spot correction factor described earlier. Differences in scaling factors show that the benefits of metering differ by configuration, with benefits appearing to be greatest for configurations with lowest declared capacity (i.e., expected to have the most congestion due to a given demand level). The reasons for these differences are complex and are a subject of on-going investigation.

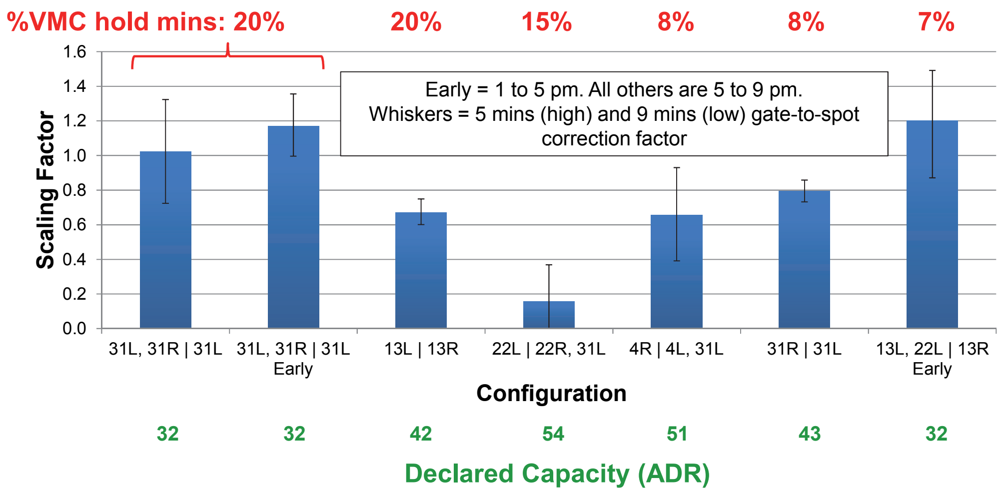


Figure 12: Scaling Factors Relating Taxi Time Reduction to Hold Time by Configuration

5. Apply Scaling Factors to All Data

Once scaling factors for the main configurations were calculated, they were generalized to the other configurations in use at JFK by comparing the number of runways in use as well as the specific runways (resultant average 0.79). Ideally, a separate analysis would be conducted for IMC conditions. However, because IMC conditions occur infrequently (< 10%) at JFK, there was not enough data to perform a valid analysis. Therefore, the conservative assumption was made that the scaling factors were the same for VMC as IMC for a given configuration. This is conservative because capacities are generally lower in IMC and hence the benefits of surface congestion management would be larger at these times. This full list of scaling factors was then applied to ALL the gate holds in the six month analysis period to estimate the aggregate taxi time impacts of surface congestion management. This number was doubled to estimate the annualized impacts.

6. Estimate Total Fuel & Emissions Impacts

To convert from taxi time savings into fuel and emissions savings, an average fuel burn index was calculated for each month of the study period. The PASSUR data included the tail number of all aircraft. A fleet database was used to match tail numbers to engine types, and then ICAO ground idle fuel flow certification data [9] was used to estimate the taxi fuel flow rate for each aircraft accounting for the number of engines of each type it possessed and APU/single-engine taxi assumptions. Fuel burn savings from surface congestion management were determined by multiplying this fuel flow rate by the taxi time savings determined from the previous steps and summing over all flights. Fuel burn savings were converted to carbon dioxide emissions savings by using the standard CO_2 emissions index of 3.16 kg CO_2/kg fuel burnt.

IV. Surface Congestion Management Impact Results

A. Annualized Taxi-out Time, Fuel Burn and Carbon Dioxide Emissions Impacts

Table 1 presents the calculated impacts of surface congestion management at JFK once the methodology discussed above had been applied. Total annualized taxi time reductions of 14,800 hours translate into annual savings of 5.0 million US gallons of fuel and 48,000 metric tons of carbon dioxide from surface congestion management at JFK. The total taxi time reduction results are within the range of estimates from *simulation* studies in the open literature [5, 6], but the results shown in Table 1 are based on the actual *operational* data.

Table 1: Calculated Surface Congestion Management Impacts

Configuration	Proportion of Hold Mins	Hold Time (hours)	Scaling Factor	Taxi-out Time Reduction (hours)	Fuel Reduction (US gallons)	Carbon Dioxide Reduction (metric tons)
31L, 31R | 31L	20%	1970	1.17 & 1.02	2160	730,000	6,990
13L | 13R	18%	1730	0.67	1160	391,000	3,750
22L | 22R, 31L	13%	1250	0.16	200	66,200	630
4R | 4L, 31L	9%	870	0.66	570	191,000	1,830
31R | 31L	7%	720	0.79	570	187,000	1,790
13L, 22L | 13R	6%	580	1.2	700	239,000	2,290
Others	27%	2580	0.79	2040	690,000	6,600
Totals (6 months)		**9700**	**0.76**	**7400**	**2,490,000**	**23,900**
Totals (annual)				**14,800**	**4,980,000**	**47,800**

Figure 13 shows how the resulting fuel cost savings of surface congestion management at JFK vary as a function of assumed fuel price and percent use of single engine taxi (a taxi procedure where one engine is turned off during taxi-out and started about 5 minutes before take-off: the fuel burn of a single-engine taxi was estimated to be 60% of the equivalent "all engine" taxi for a two-engine aircraft). At the typical 2010 fuel price range of $2-3/US gallon [10], fuel costs savings through surface congestion management are estimated to be $10-15 million per year at JFK if it is assumed no flights are performing single-engine taxi, and $7.5-12.5 million if half of the flights are assumed to be performing single-engine taxi.

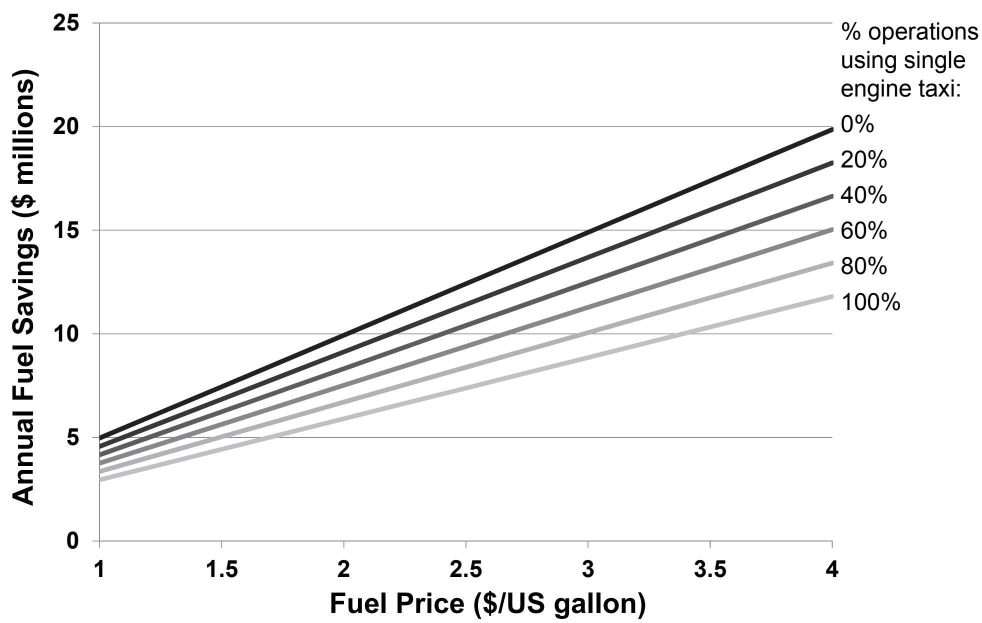


Figure 13: Annual Monetized Fuel Benefits of JFK Surface Congestion Management

B. Taxi-in Times

One possible side effect of surface congestion management can be an increase in taxi-in times for arriving aircraft if the procedure for holding departure aircraft is not sufficiently well planned. For example, if there are multiple aircraft being held at their gates past their desired departure times, there might not be enough gates available for arriving aircraft, resulting in the arriving aircraft having to wait on the surface and delaying their IN times. Figure 14 shows average taxi-in times by hour for six month periods in four different years: three before implementation of surface congestion management and one after. The change in average taxi time for the 17:00-21:00 local time period from 2009 pre-SCM to 2010 post-SCM is within the normal year-to-year variation, indicating surface congestion management has had no systematic impact (beneficial or adverse) on taxi-in times to first order. Closer inspection of the hourly comparisons shows some significant differences, but this could be due to a variety of other reasons (such as changes in schedule) and is the subject of on-going investigation.

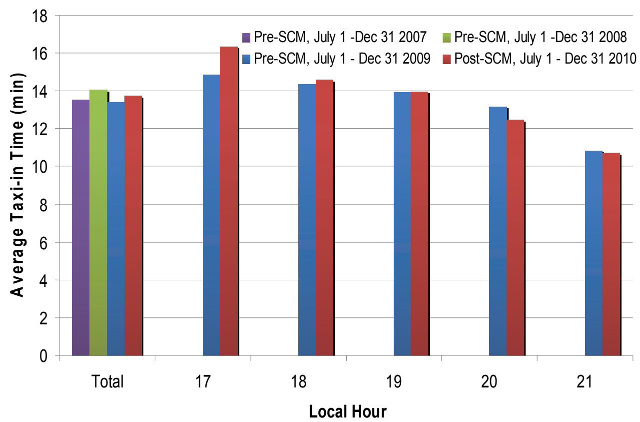


Figure 14: JFK Taxi-in Time Analysis

C. Throughput and Wheels-off Times

Another possible side effect of surface congestion management can be reduced throughput if too many aircraft are held back for too long. Figure 15 shows a comparison of airport throughput before and after surface congestion management by configuration for the sample days used in the analysis and airport-wide for the July-December periods. To first order there has been no systematic change in airport throughput before and after the implementation of surface congestion management. However, as in the case of taxi-in times, there are some differences observed on closer inspection which deserve special attention, especially with respect to how the congestion management technique employed at JFK could be refined in the future. This, too, is a subject of on-going investigation.

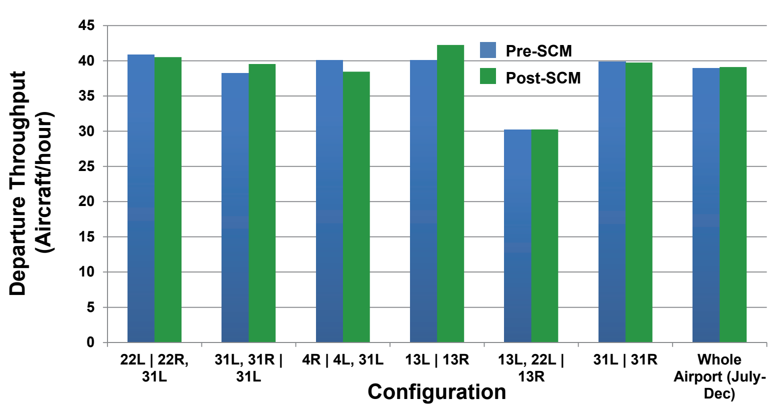


Figure 15: JFK Throughput Analysis

V. Conclusions

Surface congestion management is an important method for improving the efficiency of airport operations. The principles and various implementation options for the method have been described in this paper, and the operational impacts of the specific technique used at New York JFK airport during 2010 have been analysed in detail. Significant taxi time, fuel burn and emissions reductions have been observed in actual operations at JFK airport: total annualized taxi-out time reductions of 14,800 hours were estimated at the airport, with annual fuel savings of 5.0 million US gallons ($10-15 million at $2-3/US gallon) and 48,000 metric tons of carbon dioxide emissions reductions. These results point to significant potential benefits from surface congestion management more broadly at congested airports. However, it is important to also ensure any approach that is adopted does not introduce any adverse operational consequences, such as undesirable impacts to taxi-in times and airport throughput.

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