Airport Departure Flow Management System
(ADFMS)

Scenario Analysis

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1. Introduction

The results of the simulation model depict a situation in which the implementation of the Airport Departure Flow Management System (ADFMS) will reduce mean aircraft taxi time as well as the standard deviation of aircraft taxi times in Philadelphia. The reduction in mean aircraft taxi time is achieved as the actual taxi time approaches the unimpeded taxi time per aircraft, otherwise the time it would take the aircraft to taxi from its gate (actual pushback) to the departure runway and takeoff (wheels-up) without any conflicts or queuing on the airport surface areas.

With 46 percent of the airport traffic, or aircraft movements, US Airways and its code share carriers (Piedmont, Air Wisconsin, Chautauqua, et al) stand to gain the greatest benefits from the reduction in departure queues. However, all airlines that operate at PHL will stand to benefit from Departure Flow Management.

The implementation of ADFMS at PHL introduces two concepts that are foundational to the reduction in departure delays at PHL: the departure slot scheduling/assignment of airline flights [three or more months in advance], and centrally-controlled (queue-managed) aircraft movements on ramps, aprons, taxiways, and runways.

2. Background

Philadelphia International Airport (PHL) is rated the 11th business airport in the world and 8th busiest airport in the United States (RITA | BTS). Along with the positive rating in terms of airport volume is the correlated downside: PHL is rated 5th in terms of airport departure delays.

A non-scientific survey of Web-based forums for air travel passengers / consumers, with postings over the last few years, results in much consternation and disaffection for Philadelphia International Airport and its major tenant – US Airways. Airline passengers are more likely to complain than to praise when participating in on-line forums – and these postings are often the result of the lack of any other method of redress from airlines due to delays and other negative experiences during the course of air travel.

Airlines operating in and out of PHL need to take notice. While these complaints range from poor (and surly) customer service from flight attendants, gate attendants, and ticketing agents at PHL; poor food and beverage service; and lost, delayed, or damaged baggage; the common theme across the great majority of complaints is flight delays. Most commonly mentioned are delays departing PHL, including one commentary that spoke to the scenic route from the gate to the departure runway due to circuitous taxi routing.

3. Benefits of ADFMS

Departure slot scheduling / assignment (slot control) levels departure demand across airport capacity of ten aircraft departures per 15-minute window, effectively metered to a sustained departure rate of one take-off every 1.5 minutes. With a demand that does not exceed the capacity – or airport departure rate (ADR) – aircraft movements can be collectively sequenced into a departure queue with virtual and physical components that efficiently uses and conserves airport and airline resources.

Queue management sequences all aircraft movements on PHL surfaces to reduce conflicts at surface control points and minimize the physical queue. By holding aircraft at the gate as long as possible while still meeting departure slot times, excess taxi time is reduced, resulting in reductions in aircraft fuel consumption and aircraft emissions. Reduced fuel burn is one benefit and the source of immense cost savings to each airline. Reduced emissions are another benefit to the environment and the local community. Reducing mean excess taxi time via queue management will also reduce the uncertainty airlines face as to how long any one flight will be required to taxi. The corresponding reduction in standard deviation will allow airlines to reduce the "schedule padding" that all airlines do meet Official Airline Guide (OAG) departure and arrival times.

Trade brokering enables airlines to trade departure slots within the virtual queue in order to better meet airline needs. ADFMS uses a point system to facilitate departure slot trading on an equitable basis. If a specific flight needs an earlier departure slot for any reason, the airline's Station Manager can request a trade to an earlier departure slot; ADFMS displays the trade request and enables other Station Managers to accept the trade, subject to available time, and swap departure slots. A requesting Station Manager may also swap departure slots amongst its airlines' flights.

If a specific flight needs a later departure slot, due to delays for unscheduled maintenance, delayed arrivals, or ramp or gate operations issues, the airline's Station Manager it can offer its earlier departure slot for trade; ADFMS displays the trade request and enables other Station Managers to accept the trade, also subject to available time. Again, a requesting Station Manager can swap departure slots amongst its airline's flights. If a willing trading partner for a later departure slot does not materialize via ADFMS, an aircraft will be able to fall-back to a later departure as necessary; the ADFMS Queue Management function will re-sequence pushback times amongst the aircraft in the virtual queue in order to maintain the airport departure rate and limit the emergence of taxi delays within physical queue. The point system will track, but suspend, penalty points for these occurrences of unaccepted trades that result in bump-backs. Upon reaching a penalty point threshold, penalties will be assessed to discourage excessive delayed notification of anticipated missed pushback times to ADFMS. Point penalties may also address other root causes of departure delays, including intentional "overbooking" of departure slots, and flight cancellations.

Reducing both the mean taxi time and the standard deviation of taxi times are key points to all airlines: lower costs. Departure slot scheduling is the key enabler for achieving reductions in taxi times, for it establishes the virtual queue, which can then be managed by ADFMS for the benefit of all airlines at PHL. Trade brokering does not reduce airline costs per se, but it does better enable efficient use of airport capacity / airport departure rate. While it would be a challenge to place a monetary value on trade brokering, all airlines would stand to gain operational efficiencies and other intangible benefits with the flexibility established via structured departure slot trading within ADFMS.

4. Analysis

There are three baseline cases for the ADFMS comparison – all with non-optimized pushback and taxi from the gate to the departure runway. Each case is established at the airport capacity

(ADR) of 40 aircraft departures across a one-hour long departure window, but with different movement initiations.

- Scenario A is the situation in which ten aircraft request clearance from Ramp Control to pushback simultaneously in a 15-minute window, followed by three additional 15-minute windows of ten aircraft pushback requests and taxi initiations. This scenario utilizes the First Come First-Served (FCFS) queuing method, and most closely resembles the actual taxi times at PHL
- Scenario B simulates the FCFS queueing method with five aircraft entering the queue every 7.5 minutes, a 100 % improvement in metering.
- Scenario C simulates the Airport Departure Flow Management System (ADFMS) managed queue.
- Scenario X is the situation in which 20 aircraft request clearance from Ramp Control to pushback simultaneously in a 30-minute window, with another 20 aircraft pushing back in the second 30-minute window. Ramp Control authorizes these pushback requests with the same consideration for separation and safety as Scenario A and B.

There are also two baseline cases for ADFMS comparison that represent an overscheduling condition where demand exceeds the airport capacity of 40 aircraft departures within one hour. In both cases, these scenarios were selected for comparison due to the limitation of the academic version of the Arena software which reaches its maximum amount of concurrent events of 150.

- Scenario Y simulates the FCFS queuing method in which 21 aircraft simultaneously pushback within a single 30-minute window (42 attempted departures per hour).
- Scenario Z simulates the FCFS queuing method in which 11 aircraft simultaneously pushback in a single 15-minute window (44 attempted departures per hour).

The ADFMS comparison is the situation in which there are 40 aircraft assigned to 40 different departure slots across a one hour-long departure window, each with a known gate and therefore, known required pushback time and calculated expected pushback time that together minimize conflicts on the PHL surface areas between taxiing aircraft.

Each baseline case demonstrates the following: the more aircraft that pushback simultaneously, the more conflicts and the heavier the congestion on the taxiways that result in departure delays. Corralling aircraft push-backs into a 30-minute window, then a 15-minute window, and finally through a departure slot controlling mechanism that injects one moving aircraft into the physical queue every 1.5 minutes results in minimal, foreseeable, and therefore avoidable conflicts that reduce aircraft taxi time on the airport surfaces.

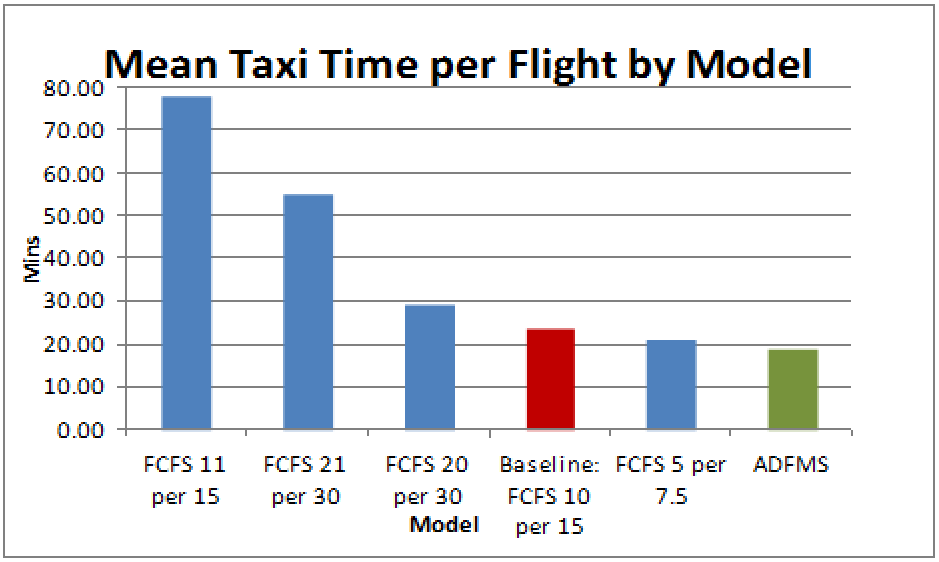

Figure 1 Mean Taxi Time per Departing Flight

The reduction of mean taxi time per aircraft flight, along with the reduction in variation (uncertainty) is the core component for the business value of ADFMS. Reduction and/or elimination of excess taxi time per flight can be converted into reduced operating costs for airlines, primarily in reduced fuel consumption, but also in reduced anticipated maintenance costs, as scheduled maintenance intervals are based upon aircraft operating hours. The ADFMS results for mean taxi time are the lowest of all the comparison cases, significantly lower than the FCFS queue at peak times (over-scheduling scenarios Y and Z), but also less than FCFS queue at demand equal to capacity where conflicts occur on airport surface areas.

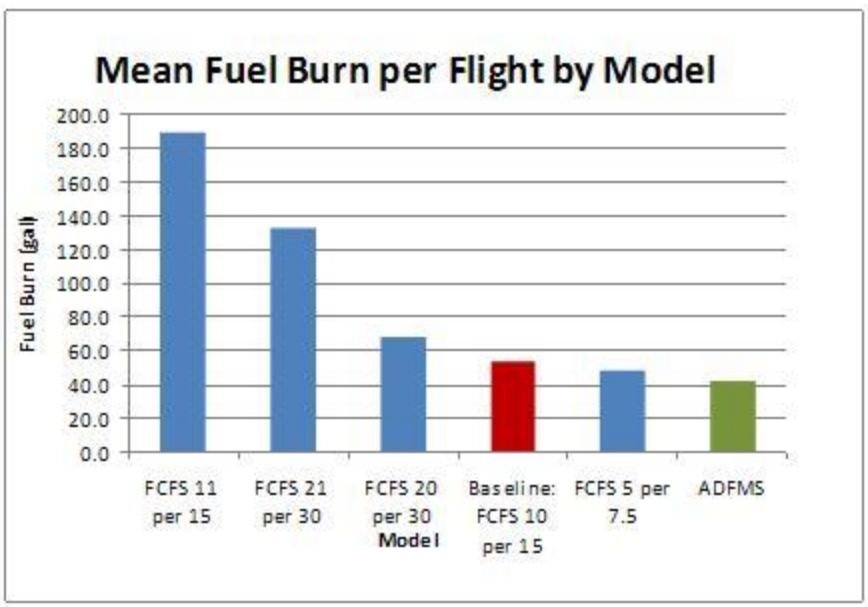

Figure 2 Mean Fuel Burn per Flight by Model

Taxi out times and aircraft tail numbers for flights were provided by On-Time Summary data through the Bureau of Transportation Statistics. The tail numbers were then used to find the aircraft manufacturer and type for each aircraft. With this information, the ADFMS team was able to map each aircraft to its corresponding Emission Index in the EDMS (Emission and Dispersion Modeling System) database, which provides rates of jet fuel burned in kg's per second of operation and grams of CO_2/ HC/ NO_x/ SO_x emissions per kg of jet fuel burned (EDMS 2010). The simulation input files contained the rates for each flight and calculated the average fuel burn by multiplying each rate by each flight's taxi time, summing over the entire schedule, and then dividing by the total number of flights for a per flight average. Average emissions were calculated in a similar manner.

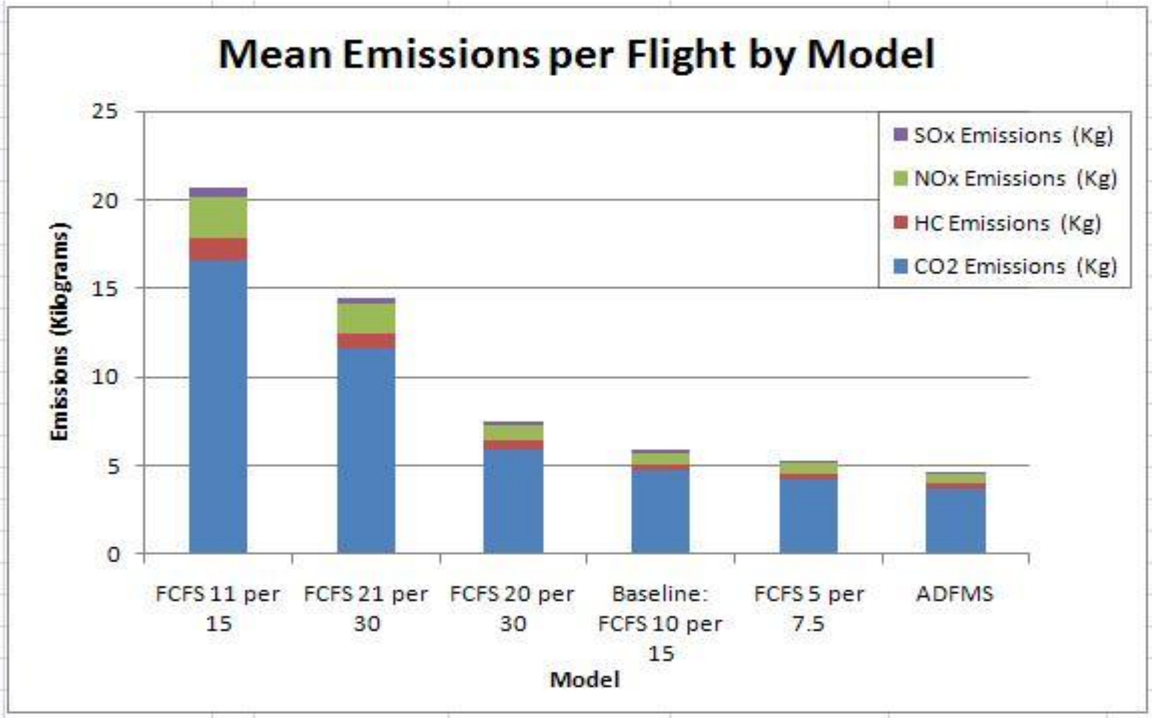

Figure 3 Mean Emissions per Flight by Model

Consistent with the reduction in fuel burn is a proportional reduction in emissions of greenhouse gases into the atmosphere due to the reduction and/or elimination of excess taxi time with the implementation of ADFMS. Greenhouse gas emissions produced during engine combustion processes are air pollutants. Reduction in emissions is a measurable and tangible result of ADFMS implementation for the local PHL community.

Per Flight	2005-2009 AVG	Baseline A: FCFS 10 per 15	ADFMS
Fuel Burned (gal)	55.3	54.2	42.4
Fuel Burn Reduction (gal) Using DFM	13.0	11.9	0.0
%Fuel Burn Reduction Using DFM	23.4%	21.9%	0.0%

Per Flight	2005-2009 AVG	Baseline A: FCFS 10 per 15	ADFMS
Emissions (Kg)	6.1	6.0	4.7
Emissions Reduction (Kg) Using DFM	1.5	1.3	0.0
% Emissions Reduction Using DFM	23.9%	22.2%	0.0%

Figure 4 Mean Fuel Burn and Emission Reduction per Flight Using ADFMS

5. Capital Investment and Operations Cost

The decision to undertake an effort such as ADFMS is one of initial capital investment as well as follow-on operational and sustainment costs. The return of the investment is measured through the estimated annual value realized by the airlines through a reduction in fuel consumption costs, in turn due to the reduced taxi time (elimination of excess taxi time). Using the Fuel Burn Reduction values from the simulation (at an initial cost of $2.05 per gallon of jet fuel (EIA 2010)), an estimated capital investment (non-recurring) cost of $5 million and annual operating expenses of $2 million, the investment realizes a net present value of $22 million on a 10-year service life at a 8 per cent rate of return. The payback period is within the second year of operations per Figure F-5 below.

				Return Rate	8.00%	
Year	Fuel Burn Reduction ADFMS	Annual O&M Costs	Capital Expenditures	Net Savings	Net Savings (NPV) at Return Rate	Cumulative Net Savings
0			**$5000**	-$5000	-$5000	-$5000
1	$5160	$2000		$3160	$2709	-$2291
2	$5631	$2000		$3631	$2882	$591
3	$6021	$2000		$4021	$2956	$3547
4	$6285	$2000		$4285	$2916	$6463
5	$6480	$2000		$4480	$2823	$9286
6	$6728	$2000		$4728	$2759	$12045
7	$6947	$2000		$4947	$2673	$14718
8	$7137	$2000		$5137	$2570	$17288
9	$7267	$2000		$5267	$2440	$19728
10	$7384	$2000		$5384	$2309	$22037
All figures in thousands (000's)					Total:	$22037

Figure 5 Incremental Savings / Net Present Value of ADFMS

The Fuel Burn Reduction values are the result of the comparison between mean taxi time for scenario A (FCFS queue with ten aircraft pushback every 15 minutes) compared to mean taxi time for scenario C (ADFMS queue with one aircraft pushback every 1.5 minutes). The team calculated an annual taxi cost savings per flight and multiplied that cost savings by the total number of departures at PHL annually for each of the past five calendar years (as reported by the RITA BTS Airline Data for PHL) to arrive an average fuel burn reduction cost for the next ten years. The average price of a gallon of jet fuel increases annually, based upon the U.S. Energy Information Administration's Annual Energy Outlook 2010. The overall fuel burn reduction assumes no increase in aircraft departures over the investment period, currently at 220,000 departures per annum.

Team ADFMS used an initial capital expenditure of $5 million for system development and implementation. This $5 million amount is a conservative estimate for this valuation in that expected capital investment should be much lower. Available comparisons for localized airport system implementations are the deployment and operations of Airport Collaborative Decision Making (CDM) in Europe (European Organisation for the Safety of Air Navigation "Airport CDM Cost Benefit Analysis v1.4")

Annual operating costs of $2 million per year are based upon estimates for additional Ramp Control staff required to operate ADFMS as well as operations and maintenance costs for the ADFMS information technology solution itself. This is a conservative estimate as costs should be much lower: Eurocontrol estimates operational costs of 7 million Euros (approximately $9.4 million) over a ten-year period per airport. Team AirportDFM uses a conservative $2 million operations and maintenance costs annually to further justify the return on investment for ADFMS.

Team AirportDFM used a return rate of eight percent for the valuation. Eight percent is a conservative estimate. A lower rate of return, which is much more likely, will result in a higher net present value (NPV), while a higher rate of return will result in lower NPV. Unless the rate of return is significantly high (higher than 40 %), the investment in ADFMS will pay off in the second year of operations.

6. Investment Alternatives

Once the Philadelphia International Airport partners / community of interest recognizes that the cost of not doing anything to reduce departure delays exceeds the cost of implementing the Airport Departure Flow Management System (ADFMS), the question of financing and administering the system procurement and implementation arises. Alternative investment scenarios include investment and administration by the Federal Aviation Administration, airlines, and the Philadelphia Airport Authority.

6.1 FAA Investment and Administration

Capital investment and administration of ADFMS by the Federal Aviation Administration (FAA) would be a government acquisition. While the ADFMS concept of operations characterizes the FAA as a stakeholder in ADFMS, neither the Air Traffic Control Tower nor the PHL Terminal Radar Approach Control (TRACON) facility is a primary user of ADFMS. The primary users are airline AOCs, Station Managers, and PHL Ramp Control.

Perhaps the greatest pro to an FAA-driven investment scenario is that the airlines would realize the benefits of an unbiased arbiter for limited airport resources.

The FAA would realize benefits of ADFMS implementation, to include: improved departure queue operations that are part of the supply chain for National Airspace System flight operations; government-sponsored reduction in emissions / air pollutants; and better fuel efficiency in an energy-conscious national context. However, the FAA would not realize the direct benefits of the fuel burn reductions that reduce airline operating costs.

Also, it’s unlikely that the FAA would invest and administer a system that would not fall under their operational control. FAA investment and administration of ADFMS would require redevelopment of the ADFMS concept of operations, either eliminating or significantly reducing the role of PHL Ramp Control in the PHL airport surface operations. Increasing the scope of FAA responsibility at PHL would require additional staff and/or additional training for Air Traffic Control Tower personnel, and would also make the FAA subject to liability claims by airlines and passengers for airport surface area mishaps and other issues. These conditions and risks are unlikely to be undertaken by the FAA for an inherently local issue which would set a precedent for NAS boundary expansion from the departure and arrival runways at each airport and instead encroach upon airport surface areas.

6.2 Airline Investment and Administration

Capital investment and administration of ADFMS by the airlines would require organization and governance to acquire and oversee the system. While the primary benefit of ADFMS is reduced operating costs due to reduced fuel burn, collective and fair governance and operations amongst hypercompetitive airlines in a consolidating industry that is highly susceptible to economic and other external conditions would be a tremendous challenge. While efficient use of airport resources and surface areas is a worthy endeavor, airlines would not be likely to pay for this benefit through a direct capital investment structure compared with other competing strategic investment needs. The airlines would still require an unbiased arbitrator to the allocation of PHL resources (departure slots and airport surface areas), a role best filled by the local airport authority.

6.3 PHL Airport Authority Investment and Administration

Capital investment and administration of ADFMS by the Philadelphia Airport Authority would be a local government acquisition, similar to other airport-specific enhancements such as terminal construction and improvements, runway and taxiway expansion, or other facility improvements, such as the AeroTrain people mover system recently opened at Washington-Dulles International Airport. While PHL would not realize the direct benefit of dollar cost savings due to reduced fuel burn, it benefit is many other ways. Unlike the FAA or airlines, PHL has direct operational control over the current departure queue through its Ramp Control responsibility, and would retain that responsibility with ADFMS. PHL would oversee ADFMS development and direct its implementation, and retain its status as an unbiased arbiter of PHL resources. PHL would also stand to recoup some or all initial investment or annual operational costs through a pass-through charge to the airlines and/or through alternatives to include increased gate fees or possibly passenger facility charges (PFCs) at PHL.

Although one of the two Ramp Control Towers at PHL is operated by US Airways Airlines, PHL would take on the responsibility to implement ADFMS is an appropriately administered methodology that eliminates the perception of bias. PHL would also hire the required additional staff to operate and maintain ADFMS for PHL.

The city of Philadelphia would stand to benefit from the intangibles associated with this kind of investment, to include increased satisfaction amongst passengers for the reduction in departure delays.