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Analysis of Environmental Impact of Eliminating Arrival Hold Short Operations for Runway Crossings at Dallas/Ft. Worth Airport

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This paper analyzes the environmental impact of eliminating arrival aircraft stops at active runway crossings. As the air traffic demand increases, innovative operating procedures to either reduce or maintain environmental impact will be required. To improve surface operation efficiency, as well as potentially reduce environmental harm, eliminating arrival aircraft stops at active runway crossings is being explored. This paper describes an analysis of active runway crossing operations for arrival aircraft, as well as a comparison of the fuel and emissions environmental impact of maintaining current active runway crossing operations versus eliminating aircraft hold short operations at active runway crossings. Three previously developed software tools were used in the data analysis. The results indicate a decrease in both emissions exposure levels and fuel consumption prior to a runway crossing on the order of 30% with the implementation of the operating procedure that eliminates hold short operations and allows continual taxi for runway crossings.

I. Introduction

The airport surface is a limiting factor in meeting the future airport capacity requirements.[1] Currently, significant surface operations issues include the wait time that aircraft experience at the airport. These wait times are incurred at various points on the surface, including the spot location (the interface point between the movement area and the ramp area) after pushback before a clearance is given for taxiing. Extensive waiting may also occur in the runway queue before departure. Arrival aircraft may experience wait times and delays at runway crossings and in complex taxi routing, as well as in the ramp area when acquiring a gate. These points of delay impact surface environmental concerns that arise from operations today, and delays and adverse environmental impacts will increase as traffic levels increase. Future surface operations solutions must not only maintain safety and efficiency, but should address the reduction of emissions exposure, which corresponds to a decrease in fuel burn, resulting in cost savings. Future surface operations must also be consistent with environmental protection goals. For example, Eurocontrol has a target to reduce the environmental impact of flight operations by 10% by the year 2020.[2] While the U.S. has goals for conducting fuel and emissions analyses for the nation's top 100 airports, no specific emissions goals have been specified. Once specified, how the various components of surface operations contribute to emissions must be understood to identify the most efficient means to meet the overall goals.

Previous work in the area of environmental impact of aviation operations has generally addressed the need for modifications to the airport layout and to aircraft design.[3] More recently, Levy et al. has developed a method to estimate total and excess taxi times from Airport Surface Detection Equipment, model X (ASDE-X) surface surveillance data at various airports.[4] The study reported the additional fuel burn and costs associated with excess taxi time of aircraft. Other work has focused on the impact of environmental constraints more within the terminal

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airspace as opposed to the surface.[5] Previous studies have not examined emissions exposure as it relates to excess taxi time and have not explored fuel burn and fuel costs related to runway crossing operations.

This paper describes an initial evaluation of the environmental impact of a proposed change to current surface operations. The focus is on the assessment of the environmental impact, particularly emissions and fuel burn of arrival aircraft on hold short operations for runway crossings, and the implementation of a new procedure for managing these operations. The assessment provides a comparison of the environmental impact of the current process of holding arrival aircraft at active runway crossings and the proposed concept of eliminating such holding in favor of allowing continual taxi to the ramp area. Dallas-Fort Worth International Airport (DFW) was selected as the analysis airport for this environmental impact study, because it is ranked as one of the top three busiest airports in the nation and experiences a large number of runway crossings daily. DFW also has surveillance technologies such as the ASDE-X system and provides easy access for data collection through the NASA/FAA North Texas Research Station (NTX) facility.

The first section of this paper provides background information and the approach used in the analysis. The next section details the decision support, modeling, and simulation tools that were utilized for the analysis. After that, an overview of the data collection and data processing actions is provided. This overview is followed by the details of the environmental analysis that was conducted. Next, the analysis results and a summary are provided. Finally, potential future work is presented.

II. Background and Approach

Large airports are characterized by high-density surface traffic and complex geometry for taxiways and runways, making runway crossing events common for both departures and arrivals. For example, an arrival aircraft that has landed may have to cross an active departure runway parallel to the arrival runway in order to taxi into the designated ramp area. The Local Controller at the Air Traffic Control Tower (ATCT) actively controls the runway crossing operations to ensure safety. Currently, arrival aircraft land, exit from the runway, taxi, and hold short of active runways used for departures until arrival aircraft receive air traffic control (ATC) clearance to cross to ensure the safe departure operations on the runway. This hold short operation requires aircraft to move slowly and often stop altogether on the taxiway. These hold short events contribute to arrival delay, fuel usage, and airline operating costs. The effect of these operations will be even more evident with the predicted increase of future traffic, and will result in greater environmental impact. Therefore, new operational procedures are needed to address the issue and provide environmental relief to the air traffic system.

One surface concept currently being researched involves reducing or eliminating arrival aircraft holding short for active runway crossings. Cheng et al. developed and evaluated a future surface automation concept called the Surface Operations Automation Research (SOAR), where aircraft 4-D trajectories (i.e., positions and time) are controlled by both a ground-based surface traffic management system and an aircraft-based advanced taxi control system.[6,7] One of the objectives of this concept is to tightly control crossing operations of both departures and arrivals via efficient surface traffic planning and precise control of taxi operations to meet 4-D taxi clearances. Another element of the operational concept, currently being pursued by Georgia Institute of Technology, is to eliminate, or reduce, hold short operations for arrival aircraft through the intricate coordination of departure and arrival events.[8] If arrival aircraft were able to proceed through a safe, continuous taxi process to their gates, fuel usage and emissions may be reduced. This would also decrease the wait time of the aircraft on the surface. The environmental impact, and efficiency benefits, of such operational concepts should be examined.

In order to study the environmental impact incurred by the hold short operations of arrival aircraft and, thereby, to assess the environmental benefit and airlines' operating cost savings by eliminating the need for hold short operations, a 24-hour surface traffic dataset from the DFW airport was obtained. The traffic data were examined to identify aircraft, within that data sample, that had runway crossing operations, which likely had hold short operations. Then, the excess taxi times, defined to be the elapsed time minus the nominal taxi time, were calculated and an environmental impact analysis was performed to assess the value of introducing this new concept. A detailed description regarding methodology, data analysis tools used, and processes are detailed in the following sections.

III. Decision Support, Modeling, and Simulation Tools

The following tools were utilized in this analysis: the Surface Management System (SMS), Surface Operations Data Analysis and Adaptation (SODAA), and the NAS-wide Environmental Impact Modeling (NASEIM) tools.

A. Surface Management System

SMS is a decision support tool developed jointly by NASA and the FAA. It provides decision support to air traffic personnel and is used to manage aircraft while on the surface of busy airports and within the terminal airspace. SMS primarily provides surface traffic predictions and advisories to assist in the management of surface operations and coordination between air carriers and ATC, but it also allows the exchange of data between its users and displays airport surface and flight plan information.[9] Figure 1 shows SMS tools that provide situation awareness, and are used in the tactical and strategic management of surface operations. Currently, SMS is not being used as a decision support tool at DFW, but is operational both in the UPS ramp facility at Louisville International Airport and in the FedEx ramp facility at Memphis International Airport. NASA is, however, using SMS for NextGen concept and technology development and at its North Texas (NTX) facility as a data collection system.

SMS receives flight information from various data sources, including Enhanced Traffic Management System/Aircraft Situation Display for Industry (ETMS/ASDI) data, airport operations database, airline data, Center-Tracon Automation System/Traffic Management Advisor (CTAS/TMA) data, and ASDE-X data. SMS uses real-time location and identity information about aircraft on the airport surface that it receives from its ASDE-X data source. SMS receives track data from the surface surveillance, which is updated every second, that gives location information for an aircraft at that instant.

SMS generates model data (or derived data) that are the results of modeling of surface traffic. The model data include predictions of surface event times, such as push-back (OUT), take-off (OFF), landing (ON), and gate arrival (IN) event of each aircraft. Each instance of data is captured and stored in the SMS log file which is typically used for playback capabilities and in post-analysis of the airport operations. For this particular analysis, the data in this log file will be used by the SODAA tool to conduct post-analysis.

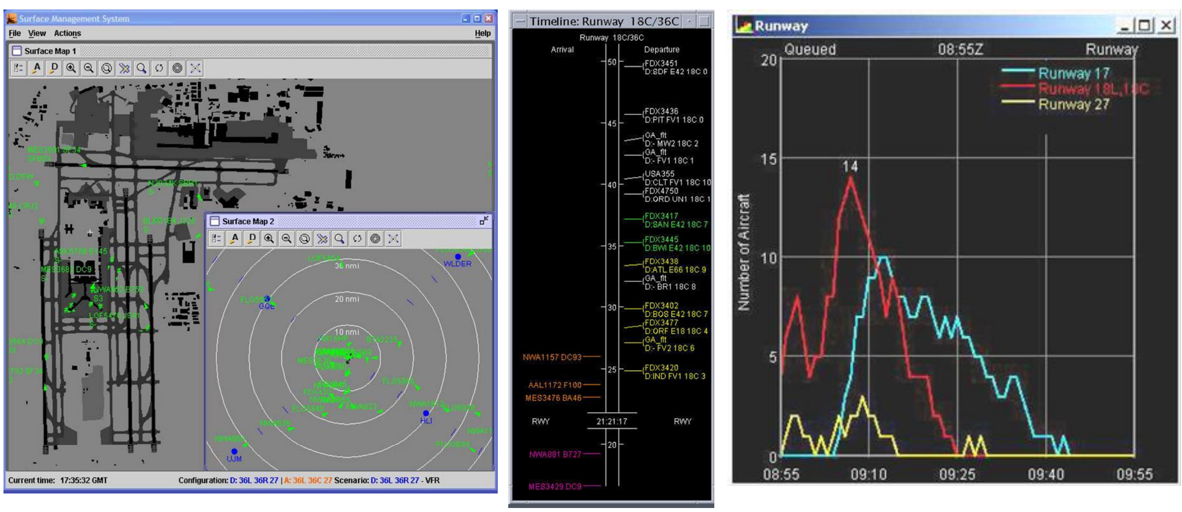

Figure 1. SMS Map Display, Timeline, and Load Graph.

B. Surface Operations Data Analysis and Adaptation Tool

SODAA[10] is a surface and terminal analysis tool developed by Mosaic ATM, Inc. Designed as a data analysis companion to SMS, SODAA provides surface researchers with the capability to manage, query, and mine raw and derived data elements. SODAA can be used to analyze either basic surface surveillance data or SMS log files, which include data from a variety of surveillance sources, air carrier data feeds, and SMS derived values.

SODAA's data warehouse capabilities and tools for accessing and visualizing surface data enable the researcher to focus on higher-level analysis objectives rather than data parsing and validation. For this paper, SODAA provided query results for analysis parameters such as the total number of active runway crossings, the total time aircraft are held at active runway crossings, and the total number of operations for particular runways, taxiways, and runways over a specified period of time.

SODAA also has a plug-in feature that allows users to add new functionality to the tool. The capabilities of the plug-in feature include adding a new field to the tool's database, performing the necessary data processing to populate the new database field, and creating new, custom analyses and graph outputs.

C. NAS-wide Environmental Impact Modeling Tool

The NASEIM tool, developed by Metron Aviation, Inc., is used to advance the state-of-the-art in environmental modeling via development of a NAS-wide, integrated noise and emissions model. NASEIM was developed to address the increasingly important aspect of environmental modeling in the evaluation of both existing and proposed changes to airport and airspace operations. The tool is capable of computing associated noise and emissions impacts in both the airport area and the surrounding community.[11]

The tool provides a visual depiction of the results on a map display, as well as a list-format of the environmental impact of emissions for pollutants, such as carbon monoxide (CO), hydrocarbons (HC), nitrogen oxide (NOx), and sulfur oxide (SOx). In this study, NASEIM will be given flight data input taken from an operations analysis done with the SODAA tool and will provide environmental output related to fuel usage and emissions.

IV. Overview of Data Collection and Processing

Data were collected from one full day (24 hours) of surface operations at the DFW airport on March 20, 2008. The airport environment was a typical operations day, free of weather anomalies with a South flow airport configuration. Figure 2 shows an illustration of the DFW airport layout. In a South flow airport configuration, runways typically used for arrivals are 17L, 17C, 18R, and 13R. The runways typically used for departures are 17R and 18L. Sometimes, 13L is used for turbo-prop aircraft departures. In this study, hold short operations for runway crossing operations between two sets of parallel runways were examined (i.e., {17C, 17R} and {18R, 18L}).The data were captured in a SMS log file for post-processing by the SODAA tool. The SODAA tool then accessed the SMS log file data and provided analysis results for specified parameters. A brief discussion of data collection for ramp operations is also provided.

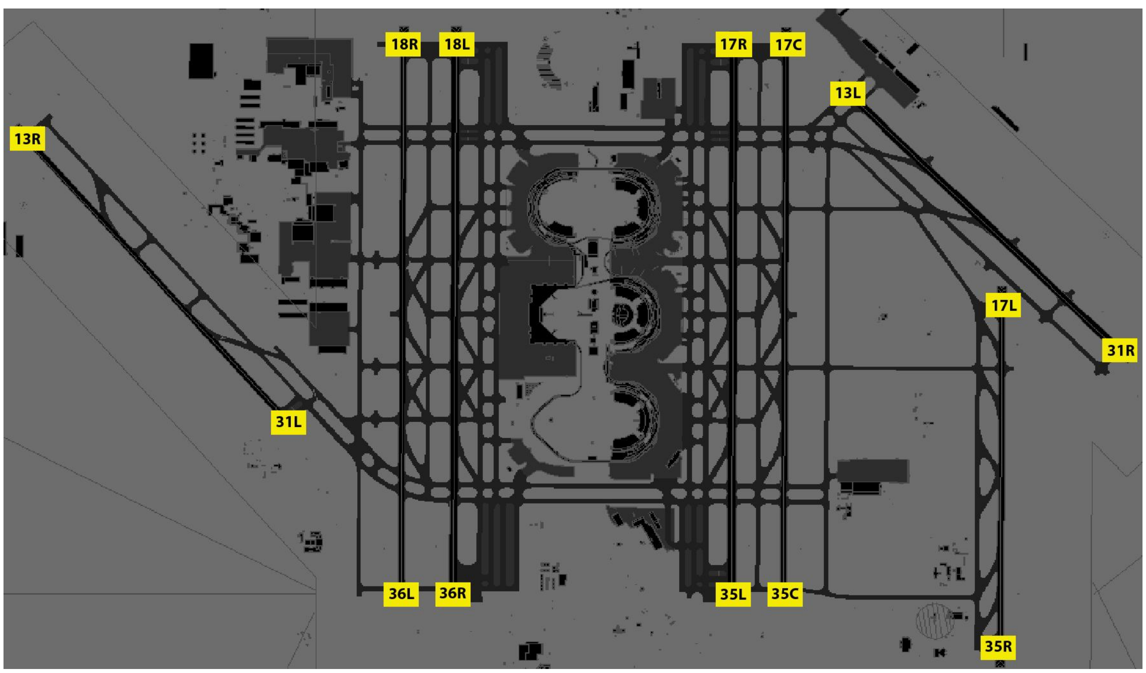

Figure 2. DFW airport layout.

A. Hold Short Operations

SMS was utilized as the primary data source for the hold short operations analysis. SMS provides state data for each aircraft, such as position, speed, and heading at a rate of 1 Hz both on the surface and in the airspace near the airport. The state data, compiled into an SMS log file, along with information pertaining to the flight, such as aircraft ID and type, as well as airport adaptation data (e.g., runway exit locations and runway crossing locations), provided necessary information required for the analysis of hold short operations for runway crossings.

The selected SMS log file was imported into the SODAA tool's database for data processing and analysis. For the hold short operations analysis, multiple geospatial regions were identified between the two aforementioned parallel runway sets. Each geospatial region is a rectangular shape and includes the corresponding high-speed runway exit location and runway crossing entry location. Figure 3 shows a diagram of such geospatial regions. For example, the region labeled R0 includes high-speed runway exit M3 and the runway crossing entry for 17R along the K8 taxiway. Next, the SODAA database was queried to identify flights that landed on the parallel arrival runways, 17C and 18R, and crossed active departure runways, 17R and 18L, respectively. SODAA was also used to calculate and output the elapsed time (runway cross entry time – arrival runway exit time) that aircraft spent on the corresponding high-speed exit taxiways. Table 1 shows the total count of arrival operations and the counts and percentage of arrivals on runways 17C and 18R in the dataset. A great majority of the arrival operations take place on these two runways due to the usual airport configuration when in a South flow. Most of these arrivals have crossed runways 17R and 18L, as specified in the geospatial regions, where possible wait times may contribute to excessive fuel use and emissions production.

Observations indicated that some arrivals did not cross the active runway in the same region in which they entered. Instead, the aircraft made a turn at the intersection of the high-speed exit taxiway and the taxiway parallel to the arrival runway. Figure 4 illustrates such a case, where the aircraft took the M3 exit and turned out of the region as opposed to taxiing straight through the region to cross runway 17R. Most of these flights taxied to the terminals located on the other side of the airport and likely crossed the active runway at far south end of the runway. Although these aircraft may significantly contribute to the overall excess taxi time in hold short operations, their excess taxi times were not included in this analysis. Utilizing single-region taxi in the analysis provided the most straightforward method for establishing a baseline case with the simplest conditions that are easiest to quantify. Observing and collecting a nominal taxi time for multi-region taxi aircraft is a complex task, provided the array of possible paths through multiple taxiway regions, and may be explored in future research efforts.

Table 2 shows the count of arrival aircraft on each high-speed exit taxiway region. The count in the second column (Single Region) lists arrival operations that entered and exited the same region before a runway crossing. The third column (Multiple Regions) lists the arrivals that entered one taxiway region but exited and entered into another taxiway region before a runway crossing. For example, out of 347 arrivals on runway 17C, 207 arrivals (60%) entered and exited the same taxiway region. The data reveals that, on both sides of the airport, the majority of arrival aircraft use one of the first two high-speed taxiway exits from their respective arrival runway. Observations also indicated that aircraft that taxi to the other side of the airport have a tendency to take a runway exit further down the runway in order to reduce the overall taxi time and fuel consumption. In general, however, use of multiple regions may mean longer taxi time, resulting in increased fuel use and emissions production. This is a finding that will be explored further in a future analysis.

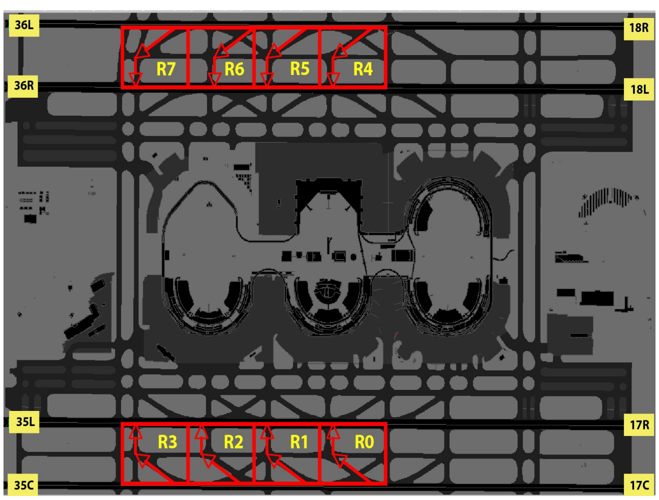

Figure 3. Geospatial regions of high-speed exit taxiways.

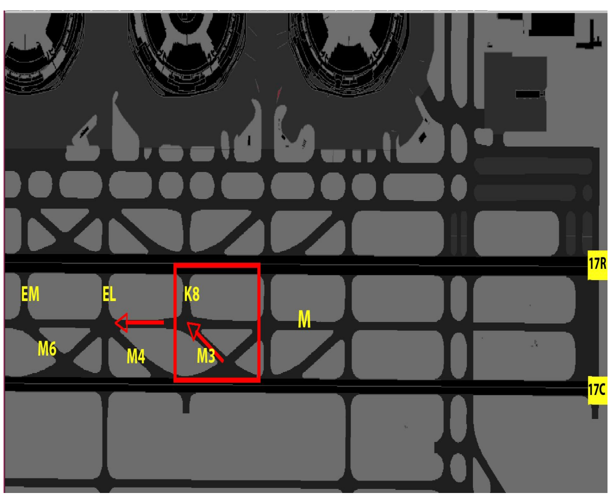

Figure 4. Example of aircraft multi-region use.

Table 1. Count of arrival operations at DFW from the dataset.

DFW	
Total Arrival Operations	923
Arrivals on 17C	347
Percentage of Arrivals on 17C	38%
Arrivals on 18R	345
Percentage of Arrivals on 18R	37%
Arrivals on 17C and 18R	692
Percentage of Arrivals on 17C and 18R	75%

Table 2. Count of arrival aircraft per exit region for single region and multiple regions taxi.

Region	Single Region	Multiple Regions
Region 0 / Taxiways M3 - K8	84	54
Region 1 / Taxiways M4 - EL	92	40
Region 2 / Taxiways M6 - EM	14	22
Region 3 / Taxiways M7 - B	17	3
Region 4 / Taxiways E3 - G8	63	6
Region 5 / Taxiways E4 - WL	84	18
Region 6 / Taxiways E6 - WM	28	20
Region 7 / Taxiways E7 - B	12	0

A concept of threshold elapsed taxi time was developed to determine which aircraft, among those that had runway crossing operations, had a hold short operation, and the excess taxi time incurred due to the hold short was computed. In this concept, an aircraft with an elapsed time longer than the pre-determined threshold elapsed time is assumed to have held short before crossing an active runway. The threshold for elapsed taxiway times for hold short operations was established by analyzing a small sample dataset consisting of three hours of surface traffic plus voice communications between ATCT Local Controllers and pilots. In this threshold analysis, elapsed times were measured both for aircraft that were required to hold short at a runway crossing and for aircraft that were given clearances to proceed through a runway crossing without a hold short operation.

For those aircraft required to hold short at a runway crossing by the controller, the distribution of elapsed times from this observation was examined and the minimum, maximum, average taxi times, and standard deviation were calculated for aircraft within the high-speed taxiway regions. In the threshold analysis, the observed minimum time equaled 68 seconds, the average time equaled 122 seconds, the maximum time equaled 274 seconds, and the standard deviation equaled 46 seconds. Table 3 lists the observed elapsed taxi times for both stopped and non-stop taxi aircraft. Three observed times, minimum, average, and average minus standard deviation, were used for the actual dataset for the arrival operations on runways 17C and 18R to identify aircraft that might have likely had a hold short operation. Figure 5 shows the frequency of aircraft from the 24-hour dataset with elapsed taxiway times that are at least the minimum observed taxiway time, the average observed taxiway time, and the average-standard deviation observed taxiway time.

The same threshold analysis was applied to aircraft that proceeded non-stop through a runway crossing and the elapsed times were obtained from the observation. The observed minimum, average, maximum, and standard deviation of taxi times for aircraft within the high-speed taxiway regions were 25, 43, 73, and 12 seconds, respectively. Since the tail ends of the distributions of elapsed times in two conditions (stopped and non-stop) overlap for 5 seconds (i.e., 68 to 73 seconds), either value can be used for further analysis. Simply, both elapsed times were used as the threshold for excessive elapsed taxi times prior to a runway crossing in the dataset for the environmental analysis. Therefore, all aircraft in the dataset with an elapsed taxiway time greater than or equal to either 68 seconds or 73 seconds were considered in the subsequent environmental analysis.

Table 3. Observed elapsed taxi times.

	Observed Taxi Time (Seconds)			
	Minimum	**Maximum**	**Average**	**Standard Deviation**
Non-stop Aircraft	25	**73**	43	12
Stopped Aircraft	**68**	274	122	46

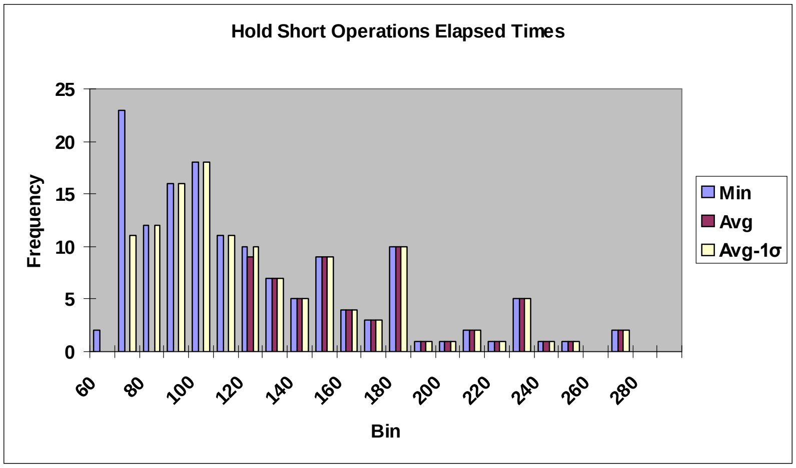

Figure 5. Frequency of hold short operations based on min, avg, and avg-1σ elapsed times in 24-hour dataset.

V. Environmental Analysis

The data outputs from the SODAA tool analysis, described in the previous section, served as inputs into the NASEIM system. NASEIM computed the environmental impact for aircraft engine emissions, as well as fuel usage on the airport surface area. The arrivals on runways 17C and 18R that exited on high-speed exits and crossed active runways through the specified runway crossing entry point of runways 17R and 18L were considered in the analysis. These high-speed exit taxiway segments were identified as eight separate regions as described in the previous section of this paper, and aircraft taxi times spent within these regions were captured.

NASEIM calculations were based on the taxiway elapsed time provided. With the assumption that all aircraft have all engines operating, NASEIM calculates emissions and fuel usage accordingly. The emissions and fuel use of each aircraft were calculated for three categories: 1. for all aircraft in the dataset with their corresponding elapsed taxiway times, which established a baseline dataset, 2. for all aircraft in the dataset, where those determined to have had a hold short operation, their elapsed times were replaced with the observed minimum elapsed time of 68 seconds, with the rest of the aircraft elapsed times unchanged, and 3. for all aircraft in the dataset, where those determined to have had a hold short operation, their elapsed times were replaced with the observed maximum elapsed time of 73 seconds (from observed non-hold shorts), with the rest of the aircraft elapsed times unchanged. These three categories provide both a data baseline with the current nature of runway crossing wait time and two data alternatives that suggest the nature of possible runway crossing procedures that eliminate aircraft wait time.

The 24 hour period of data was annualized for emissions exposure and fuel burn. NASEIM computed the total of the pollutants and fuel used from the three categories, baseline, elapsed time of 68 seconds, and elapsed time of 73 seconds for a full day. The modeling tool multiplied the pollutants and fuel values by 365 to calculate the total emissions inventory and fuel burn for an entire year.

The NASEIM output provides the collective emissions inventory, defined as the aggregation of pollutants generated at an airport due to aircraft activity, and fuel burn for these operations. For example, during taxi mode, the CF6-45A engine burns 0.16 kilograms of fuel per second, and for each kilogram of fuel burned, 23.04 grams of carbon monoxide is released into the atmosphere. A comparison of the three categories mentioned above was also conducted.

VI. Results

This analysis sought to examine the environmental impact of implementing a new operational concept as the solution to runway crossings for arrival aircraft. The results of this analysis will show the potential environmental benefits of successfully implementing new operating procedures in future increased capacity operations. The results of the environmental analysis are detailed below.

A. Emissions

Aircraft ground emissions exposure is a significant contributor to environmental impact on the airport surface. The emissions inventory below details the pollutants CO, HC, NOx, and SOx in kilograms for the DFW airport.

Table 3 shows the total emissions inventory for runway crossing operations within the dataset. The table lists the emissions output for all runway crossings, all runway crossings where those with an elapsed taxi time greater than or equal to 68 seconds are set to equal 68 seconds, and all runway crossings where those with an elapsed taxi time greater than or equal to 73 seconds are set to equal 73 seconds. Because there is only a five second difference between the two threshold values (68 and 73), resulting values are close.

The output reveals a clear excess of emissions for the 24 hour dataset, as well as a full year of operations, when compared to the two revised datasets. By applying either the 68 second threshold or the 73 second threshold, it is evident that a decrease in elapsed taxiway time for arrivals aircraft yields a decrease in total emissions exposure for CO, HC, NOx, and SOx pollutants by approximately 30% and 28%, respectively.

Table 3. Total and excess emissions inventory for the 3 dataset categories.

Airport	**DFW (March 20, 2008)**				
Mode	**Taxi IN**				
Emissions (1 Day)					
	Baseline	**68 seconds**	**Excess**	**73 seconds**	**Excess**
CO (kg)	113	79	**34**	82	**31**
HC (kg)	18	12	**6**	13	**5**
NOx (kg)	26	18	**8**	19	**7**
SOx (kg)	7	5	**2**	5	**2**
Emissions (1 Year)					
	Baseline	**68 seconds**	**Excess**	**73 seconds**	**Excess**
CO (kg)	41,100	28,800	**12,300**	29,800	**11,300**
HC (kg)	6,600	4,500	**2,100**	4,700	**1,900**
NOx (kg)	9,400	6,600	**2,800**	6,800	**2,600**
SOx (kg)	2,400	1,700	**700**	1,700	**700**

B. Fuel Burn

Fuel efficiency is also of great importance in ground operations. The fuel burn calculations below detail the taxiway fuel usage in kilograms for all aircraft and aircraft types for the DFW airport.

Table 4 shows the total fuel burn for runway crossing operations within the dataset. The table lists the fuel burn output for all runway crossings, all runway crossings where those with an elapsed taxi time greater than or equal to 68 seconds are set to equal 68 seconds, and all runway crossings where those with an elapsed taxi time greater than or equal to 73 seconds are set to equal 73 seconds.

The output clearly reveals an excess of fuel consumption for the 24 hour dataset, as well as a full year of operations, when compared to the two revised datasets. By applying either the 68 second threshold or the 73 second threshold, it is evident that a decrease in elapsed taxiway time for arrival aircraft yields a decrease in aircraft fuel usage by approximately 30% and 28%, respectively.

Table 4. Total and excess fuel burn for the 3 dataset categories.

Airport	**DFW (March 20, 2008)**				
Mode	**Taxi IN**				
Fuel Burn (1 Day)					
	Baseline	**68 seconds**	**Excess**	**73 seconds**	**Excess**
Fuel (kg)	6,500	4,600	**1,900**	4,700	**1,800**
Fuel Burn (1 Year)					
	Baseline	**68 seconds**	**Excess**	**73 seconds**	**Excess**
Fuel (kg)	2,390,000	1,660,000	**730,000**	1,720,000	**670,000**

C. Fuel Costs

Fuel costs, at any stage of aircraft flight, are of high interest to airlines. Given both the total and excess fuel burn values for the various datasets, the corresponding fuel costs for the analysis were calculated.

Table 5 illustrates a $3,125 savings in fuel costs if all aircraft have an elapsed taxi time no longer than 68 seconds prior to a runway crossing operation. There is also a $2,876 savings in fuel costs if all aircraft have an elapsed taxi time no longer than 73 seconds prior to a runway crossing operation.

The result show that fuel cost savings may result from aircraft decreasing elapsed taxi time prior to runway crossing operations by approximately 30% and 28%, respectively. For example, in the context of a single aircraft, a flight with an MD82 aircraft type with a Pratt & Whitney JT8D-209 engine type, expels 0.13kg of fuel per second according to the NASEIM database. The aircraft's total taxi time, from runway arrival to gate arrival, was 10 minutes, or 600 seconds, resulting in taxi fuel costs of $245. From the threshold analysis, the aircraft's elapsed time on the taxiway prior to a runway crossing can be reduced from 156 seconds to 68 seconds. By decreasing this elapsed time by 88 seconds, there is a total taxi time fuel cost savings of $36. This single flight reduces airline fuel costs by approximately 15% for arrival taxi operations.

These cost values were based on the nation-wide average of Jet A fuel types at $5.93 per gallon ($1.56 per kg) on July 6, 2008.

Table 5. Total fuel cost and fuel cost savings for the 3 dataset categories.

Airport	**DFW (March 20, 2008)**				
Mode	**Taxi IN**				
Fuel Burn (1 Day)					
	Baseline	**68 seconds**	**Savings**	**73 seconds**	**Savings**
Fuel (kg)	6,500	4,600	**1,900**	4,700	**1,800**
Cost (dol)	$10,300	$7,100	**$3,100**	$7,400	**$2,900**
Fuel Burn (1 Year)					
	Baseline	**68 seconds**	**Savings**	**73 seconds**	**Savings**
Fuel (kg)	2,390,000	1,660,000	**730,000**	1,720,000	**670,000**
Cost (dol)	$3,740,000	$2600000	**$1,140,000**	$2,690,000	**$1,050,000**

VII. Conclusions

The future of air traffic management calls for new, innovative procedures and operations to ensure a safe and efficient surface environment. This paper illustrates the impact of implementing procedures that eliminate hold short operations for arrival aircraft. This analysis presents the total emissions and fuel burn that aircraft use in current day runway crossing operations and reveals the emissions and fuel reduction, as well as fuel costs in the event of non-stop taxi operations through runway crossings. The results of the analysis provide significant insight into the effect of implementing a new operating procedure that may impact air traffic operations throughout the NAS.

As expected, the results of this environmental impact analysis show an apparent reduction in both emissions exposure and fuel consumption at the DFW airport when minimizing the taxi time of arrival aircraft at runway crossings. With the reduction of this wait time prior to runway crossings, the reduction of emissions and fuel use is inevitable. Therefore, the employment of the concept of eliminating hold short operations appears to have a positive environmental impact on the surface.

The environmental effect of this operational concept is exhibited in several ways: decreases in emissions, fuel consumption, and fuel costs. For both the 68 second and 73 second thresholds for continual taxi, noteworthy excess emissions inventory and fuel use were evidenced. Also, the results show a significant decline in emissions exposure and fuel burn by levels of 30% and 28%, respectively, prior to a runway crossing. The demonstrated improvements may greatly benefit U.S. emissions goals in the future. This is especially important considering the anticipated future growth of air traffic, which will result in increased environmental impact to the surface.

This analysis reveals only preliminary results of environmental impact of this operational concept. Further investigation of wait times throughout the multitude of surface operations will need to be explored.

VIII. Future Work

A. Full Airport Wait Times

In the future, not only will environmental reductions need to be addressed in one location of the airport surface, but on the airport as a whole. As the examination of the environmental impact of runway crossing wait times reveals an excess of emissions exposure and fuel consumption, there are other points on the surface that may have the same environmental impact. The environmental impact of wait times during operations such as spot wait time, departure runway queue wait time, all arrival hold short wait times and ramp arrival wait time should be explored.

B. Data Processing of Ramp Operations

Ramp area operations can also contribute to surface environmental issues. Sometimes arrival aircraft that have to wait for a gate or for ground crew availability add to environmental impact caused by engine emissions. The excess taxi times, or wait times, of arrival aircraft can be measured in a similar way as the hold short operations. The nominal taxi time (i.e., unimpeded taxi time within a ramp area) can be measured for various pairs of spots and gates, and subtracted from actual taxi times to obtain excess taxi time. SMS has the capability to detect spot time and gate arrival time of arrival aircraft provided air carrier data is available and the aircraft transponder remains activated until the aircraft has reached the gate. This allows the multilateration sensors around the ramp area to send the aircraft position to the ASDE-X system. However, because tracking aircraft with ASDE-X surface surveillance in the ramp area at DFW airport proves difficult because the system was optimized for use in the movement area rather than for ramp coverage, we were unable to collect and process quality data for aircraft from the spot location to the gate.

In the future, to improve SMS data integrity in the ramp area, and ultimately examine environmental impact, better surveillance will be needed. This may be possible through a combination of improved surveillance systems and mandatory transponder activation through gate arrival. A future ramp operations analysis may also involve the use of both surveillance data and airline data to provide quality data for aircraft from the spot location to the gate.

C. Speed as Hold Short Identifier

Speed values may also be used in a threshold methodology for hold short operations. Speed can be used to identify which aircraft actually stopped (speed = 0) for a hold short operation and which aircraft did not stop (speed > 0) for a hold short operation. One thing to consider in such a methodology is the noise in the data with regard to speed values. Because of this noise, simply taking the minimum speed of aircraft may not provide the most accurate data value. Also, it should be considered that, although aircraft may receive a hold short command for a runway crossing, not all are required to come to a complete stop. A hold short analysis using speed is plausible given additional information that includes enhanced aircraft speed estimates compared to raw data.

D. Baseline for Taxi Algorithms

Current research being performed with the SMS system will look to minimize excess taxi time for both departure and arrival aircraft. Algorithms being developed will provide the optimal taxi routes for aircraft to achieve this reduction in excess taxi time. The methodology for identifying excess wait time thresholds utilized in this environmental analysis may possibly provide a baseline for the taxi algorithm development being conducted in this research effort.

E. Runway Status Lights

The FAA has a research and development project that involves the use of runway status lights (RWSL) to indicate to pilots that a runway is unsafe. By using these RWSL, along with some form of status light activation recording system, actual hold short events can be determined more easily. The automatic recording of this information could provide a more enhanced, accurate method of collected aircraft wait times during hold short operations. An installation effort of the RWSL system is underway at the DFW airport and could possibly be a test site for such a methodology with the system.

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Acronyms

ATC	=	Air Traffic Control
SMS	=	Surface Management System
SODAA	=	Surface Operations Data Analysis and Adaptation
NASEIM	=	NAS-wide Environmental Impact Modeling
NASA	=	National Aeronautics and Space Administration
FAA	=	Federal Aviation Administration
ASDE-X	=	Airport Surface Detection Equipment, model X
CO	=	carbon monoxide
HC	=	hydrocarbons
NOx	=	nitrogen oxide
SOx	=	sulfur oxide
DFW	=	Dallas-Ft. Worth International Airport
SOAR	=	Surface Operations Automation Research
RWSL	=	Runway Status Lights
NTX	=	NASA/FAA North Texas Research Station
ETMS	=	Enhanced Traffic Management System
ASDI	=	Aircraft Situation Display for Industry
CTAS	=	Center-Tracon Automation System
TMA	=	Traffic Management Advisor