Arrival Metering Fuel Consumption Analysis

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Abstract—Arrival metering is a method of time-based traffic management that is used by the Federal Aviation Administration to plan and manage streams of arrival traffic during periods of high demand at busy airports. The Traffic Management Advisor is an automated scheduling and flow management tool that enables arrival metering. A study using the Federal Aviation Administration's Aviation Environmental Design Tool of the effects of implementing arrival metering via the Traffic Management Advisor at Newark International Airport showed a reduction of between 6 and 11% in fuel consumption for aircraft arriving during peak periods. The greatest benefit was seen by aircraft arriving from Europe.

***Keywords-** fuel consumption; arrival metering; traffic management advisor; environmental impacts; modeling*

I. Introduction

The Volpe National Transportation Systems Center (Volpe Center) supports the U.S. Federal Aviation Administration's (FAA) vision for the Next Generation Air Transportation (NextGen). NextGen is an integrated transition plan for the National Airspace System (NAS) to move from ground-based radar technology and voice communication to satellite-based operations, enhanced automation and communication systems, and improved weather and traffic flow management capabilities. Part of the NextGen plan includes examining and leveraging existing time-based flow management technologies and capabilities in support of system-wide transformation.

Traffic Management Advisor (TMA) is a scheduling and flow management tool created to assist the FAA in planning and managing air traffic into select airspace and airports. TMA has the potential to increase operational efficiency by improving arrival flows. TMA provides arrival traffic flow visualization as well as scheduling and time-based metering capabilities. When TMA is used across adjacent facilities, it can support metering of traffic in complex airspace where multiple facilities are responsible for delivering traffic to congested airports using interdependent flows.

While TMA has been implemented at several FAA air traffic facilities throughout the NAS, the effectiveness of TMA on reducing aircraft fuel consumption has not been quantified. This study represents the first quantification of fuel consumption reduction through the use of TMA.

II. Background

In late 2009, the FAA began an analysis to examine the relationship between arrival metering via TMA at Newark and changes in fuel consumption for the impacted flights being metered. To support the analysis, the FAA employed the Volpe Center to utilize a suite of software tools that enable a thorough assessment of the environmental effects of flight operations.

This suite of capabilities, known as the Aviation Environmental Design Tool (AEDT), consists of the integration and harmonization of existing analysis tools. These tools include the Integrated Noise Model (INM — local noise analysis), the Model for Assessing Global Exposure to the Noise of Transport Aircraft (MAGENTA — global noise analysis), the Emissions and Dispersion Modeling System (EDMS — local emissions analysis), and the System for Assessing Aviation's Global Emissions (SAGE — global emissions analysis).

AEDT is capable of dynamically modeling aircraft in 4-dimensional space, is scalable from a single flight to global analyses, handles inputs from radar and/or simulation tools, and allows for the assessment of interdependencies between aviation-related fuel consumption, noise, and emissions [1, 2]. A new method of calculating fuel consumption for aircraft operating in the terminal area was recently implemented [3]. The new method is based on using aircraft performance data from the aircraft manufacturers as input to a statistical program which calculates coefficients for empirical Thrust Specific Fuel Consumption (TSFC) models. The TSFC models are specific to either departure (high thrust conditions) or arrivals (low thrust). The aircraft performance methods of [4], with modifications by [5], are used below 10,000 feet Above Field Elevation (AFE). Above 10,000 feet AFE, the methods of EUROCONTROL's Base of Aircraft Data (BADA) are used [6].

For purposes of this analysis, inputs to the AEDT included radar data collected using the Performance Data Analysis and Reporting System (PDARS). PDARS integrates surveillance data from radars located within the en route and terminal areas into a single data stream. The Newark data used in this study was collected from August 1st to August 31st for both 2007 and 2008. Flight data were culled to retain only that part of the arrival track within 250 nautical miles (Great Circle distance) of the airport. Flights that departed within this radius were removed from the analysis.

III. TMA Usage at Newark Airport

The analysis examined fuel consumption per unit of distance and time for major airlines and aircraft types arriving at Newark. The study compared data sets for pre- and postimplementation of TMA while isolating the data sets for periods of documented metering activity.

A detailed examination of arrival profiles using AEDT for all B757 aircraft from the Northeast, beginning at a distance of 250 nm from the airport and ending at the runway, showed a reduction in fuel consumption of approximately 11% during periods of arrival metering. Analysis showed the primary benefit of metering for these arrivals was the reduction of flight time and distance during the level flight segment at 16,000 feet mean sea level (MSL), which occurs in the vicinity of the Barnes and Bradley VORs.

Additional analysis examined average fuel consumption for all narrow-body aircraft arrivals at Newark during similar periods. For the narrow-body aircraft arrivals, the 2008 implementation of metering showed an average reduction in fuel consumption of about 6%, though this average reduction was not evenly distributed across all aircraft types.

The analysis at Newark focused on the known times when metering was being used in 2008. For each of the days within the one-month period of 2008 under examination, the period of usage of metering was noted. In general, metering began around 1430Z and generally continued for five to seven hours. For 2008, we included only those flights when metering was implemented. For 2007, we included those flights during the average period (from 1430Z to 2100Z) when metering was implemented in 2008; that is, we assumed that Newark in 2007 was busy during the same periods it was busy in 2008 and compared the two years on this basis. Two days (August 15th and 27th) were dropped from the analysis for 2007 and one day dropped (August 14th) for 2008 due to lack of PDARS data.

A. *Continental Airlines B757 Trans-Atlantic Operations*

A major consideration at Newark was the impact of metering on Continental Airlines B757 flights inbound from Europe. These flights are close to the limits of their range and often have had to divert to other airports due to low fuel. As a result, these B757 arrivals were considered to be a potential primary beneficiary of arrival metering via TMA.

Examination of these aircraft operations in 2007 and 2008 showed significant changes in their operations. In 2007, the level segment distance at 16,000 feet MSL in the vicinity of the Barnes and Bradley VORs was about 90 nm. In 2008, this level segment distance was considerably shorter at 45 nm. The 2008 has more track distance *before* this level segment, but this is where the aircraft are operating most efficiently from a fuel burn standpoint. The total distance flown was also considerably shortened; the distance flown from the radius point of 250 nm to the airport was 357 nm in 2007 and was reduced by 26 nm to 331 nm in 2008.

Subject matter experts at New York TRACON (N90) and Boston Center (ZBW) attribute these improvements to the use of the TMA system in conjunction with the removal of a daily miles-in-trail (MIT) restriction at Newark. Prior to TMA implementation, it was common for N90 to place a 15 MIT restriction on the northeast arrival fix (SHAFF) to delay flows coming from ZBW. In order to meet the MIT restriction, en route controllers would descend flights from the upper level streams to prepare them for blending with flights already in the lower stratum. This descent would begin approximately 100 miles upstream from the arrival fix. This would enable a single merged stream to meet the crossing restriction at ACOVE at FL160 with 15 miles of separation.

Controllers managing the merged flow in the lower sector(s) needed flights to descend sooner in order to work the flights to meet the restriction. Once TMA was implemented, the MIT restriction at the arrival fix was removed, and controllers no longer had to manually blend streams to meet the restriction. Flights could stay at altitude longer and absorb delay as assigned by TMA. Today, flights still need to meet the crossing restriction at ACOVE, but the descent no longer begins early to accommodate the stream merge. TMA addresses the necessary stream merge by assigning targeted delays to flights in all arrival streams.

The combination of keeping the aircraft higher for longer periods of time and shortening the distance flown reduced the total fuel consumption by about 11% in this region. The information is given in Table I and Figure 1. In Figure 1, the solid blue line represents the nominal profile of a B757 arrival during 2007; the dashed red line shows a nominal profile observed in 2008. The key difference is the 2008 profile has half the distance of 2007 profile at the 16,000 ft level segment.

TABLE I. CHANGES IN B757 DISTANCES FLOWN FOR NEWARK NORTHEAST ARRIVALS

Segment	2007	2008
38,000 ft. level	67 nm	71 nm
38,000 ft.– 16,000 ft. descent	80	100
16,000 level	90	45
16,000 ft. – 10,000 ft. descent	30	35
10,000 level	47	38
10,000 ft. – Airport descent	43	42
Total distance	357 nm	331 nm

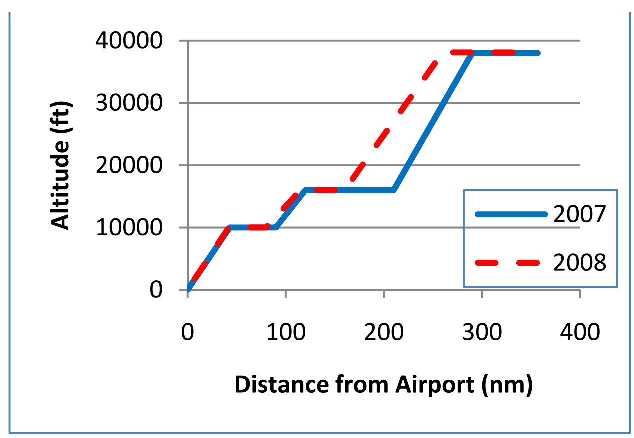

Figure 1. Nominal altitude profile of COA B757 Newark arrivals from the Northeast

B. Other Operations

In addition to the B757 arrivals, the other aircraft arriving at Newark during periods of metering also experienced benefits.

Table II below shows the average fuel consumption per flight for the major types of aircraft arriving at Newark during the analysis period. The average reduction in fuel consumption for this mixed fleet between the two years is roughly 6%.

TABLE II. AVERAGE NEWARK ARRIVAL FUEL CONSUMPTION IN 2007 & 2008 (FOR MAJOR AIRCRAFT TYPES)

Aircraft	2007	2008	Difference
A320	2115 kg	2170 kg	+2.6%
B737-300	2057	1891	-8.1%
B737-500	2142	2100	-2.0%
B737-700	2293	2120	-7.6%
B737-800	2493	2318	-7.0%
EMB135/145	1411	1327	-6.0%

Note that during the measurement period in 2007, Newark generally operated in north flow, while in 2008 the flow was generally to the south. The primary A320 operator had a majority of flights arriving from the south in both periods. This meant that in 2008, most A320 arrivals had to fly north of the airport on a downwind leg before turning back to the airport, while in 2007 they could fly directly to the airport. This increase in track length for the A320 increased the fuel consumption for these aircraft in 2008 relative to 2007. The other aircraft types shown in Table II primarily arrived from the west, so this flow bias was not as important.

IV. CONCLUSIONS

This paper presents the results of using the FAA's AEDT to determine the fuel consumption impacts of operational changes via TMA at a major airport. The authors believe the model shows sufficient fidelity to accurately capture the effects of these operational changes on airplane fuel consumption. The usage of TMA showed benefits of 6% to 11% fuel consumption reduction in the flight region under consideration. This ability to accurately model fuel consumption changes due to advanced procedures will be important as policy makers seek to improve the efficiency of the national and international airspace system while considering the associated environmental impacts. These are important objectives of the FAA's NextGen and of EUROCONTROL's Single European Sky initiative.

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