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Advanced Air Transportation Technologies RTO-48

Tasks 2 & 3 Report:

Refined Benefits Assessment of Expedite Departure Path (EDP) Final Report

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Prepared For

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Executive Summary

The national-level benefits of NASA's Expedite Departure Path (EDP) tool were estimated for two different time horizons, 1999 and 2015. EDP is a controller decision support tool (DST) currently being researched as a part of NASA's Advance Air Transportation Technologies (AATT) Program. This report presents an EDP benefits assessment. As the concept of operations for EDP evolves, a more detailed and accurate assessment may be performed.

We determined that we could most accurately estimate EDP benefits in the required time frame by considering separately the potential benefits of the major EDP functions on the ground and in the terminal and regional airspace. EDP appears to generate both direct and indirect benefits:

- Direct Benefits: reduction of climb-out time due to unrestricted climbs into the en-route system and optimally merging multiple aircraft over a common fix or through a departure gate.

- Indirect Benefits: reduction of taxi-out delays due to providing advisories to the ground DSTs.

The national-level benefits of these functional enhancements are provided in the following table for the two time frames considered, 1999 and 2015. The net present value (1997) is also presented for both time frames. It is important to note that these benefits assume that implementation of EDP can eliminate the described delays in the system entirely; that is, these benefits provide the upper bound of potential dollar savings.

EDP National-Level Benefits

EDP Benefits	Crew Time Savings (millions)	Fuel Savings (millions)	Maintenance Savings (millions)	Passenger Time Savings (millions)	Total - Without Passenger Time (millions)	Total - With Passenger Time (millions)
1999						
Direct Benefits due to Unrestricted Climbs and Optimal Merging	$56	$95	$41	$493	$189	$682
NPV (1997)	**$49**	**$83**	**$36**	**$431**	**$168**	**$599**
Indirect Benefits due to Providing Advisories to Ground DSTs	$314	$171	$246	$2,773	$732	$3,505
NPV (1997)	**$274**	**$149**	**$215**	**$2,422**	**$639**	**$3,061**
2015						
Direct Benefits due to Unrestricted Climbs and Optimal Merging	$336	$564	$249	$2,963	$1,149	$4,112
NPV (1997)	**$114**	**$191**	**$84**	**$1,004**	**$389**	**$1,393**

1 Introduction

1.1 Purpose

As a part of their Advanced Air Transportation Technologies (AATT) Program, NASA is investigating concepts designed to improve the technical performance of the National Airspace System (NAS). The approach of the AATT Program has been to create prototype decision support tools (DSTs) to facilitate implementing these concepts. NASA develops these DSTs through the concept exploration and concept development phases after which those that merit further investments are transitioned to the NAS stakeholders. To optimally allocate the resources of the AATT program, NASA must assess the benefits of these candidate research projects throughout the concept exploration and concept development process. The Benefits and Safety Assessments (B&SA) sub element of AATT is challenged with performing an initial assessment of each of these proposed tools to help determine program investment priorities. The purpose of this report is to document a benefits assessment performed for NASA's candidate AATT decision support tool for the departure domain, Expedite Departure Path (EDP).

1.2 EDP Overview

The EDP network uses aircraft flight plans and position data from FAA computers, inputs from TRACON departure controllers, and current weather predictions, to produce advisories to assist controllers in managing departure traffic. TRACON departure controllers interact with EDP, both receiving advisories and providing inputs, through standard FAA hardware. FAA Air Route Traffic Control Center (Center) and Terminal Radar Approach Control (TRACON) Traffic Management Coordinators (TMCs) interact with EDP through a dedicated EDP display, although the Center Traffic Management Unit (TMU) provides no inputs to EDP.

1.3 EDP Operational Concept

EDP will address the capacity limitations inherent in current ATC departure procedures, such as giving priority to arriving traffic, suboptimal departure-arrival interactions, and delays at TRACON departure gates and en-route fixes caused by merging departure traffic. EDP will focus on interdependent traffic management of arrival and departure traffic and is expected to provide the following enhancements:

- Load management advisories for departing traffic
- Advisories for sequencing, pacing, and merging departing aircraft into the en-route stream
- Aids for scheduling and route planning of departure traffic from takeoff until the aircraft is merged with the en-route traffic stream or established on its preferred route

- Conflict-free four-dimensional trajectories for each departing aircraft
- Speed, altitude, and heading advisories for each departing aircraft
- Optimal release times for tower controllers at primary and satellite airports
- Transmitting pushback recommendations to airline operational control facilities

EDP will aid traffic management specialists in the Traffic Management Unit (TMU) as well as sector controllers in terminal, en-route, tower, and airline operational control facilities. Local facility procedures will be incorporated into EDP and its initial functionality will be departure management assistance

1.4 EDP Functions and Benefits

Table 1.4-1 provides a list of EDP functional contributions, benefit mechanisms and tool-level technical performance metrics. A more detailed overview of EDP functionality, along with module descriptions, can be found in [JO1].

EDP benefits will depend on air traffic volume, the dependencies between arrivals and departures at an airport, and the traffic flow between multiple airports within the TRACON and in the extended terminal area.

Expected Airspace User Benefits:

- Reduced aircraft fuel burn and block times due to improved departure trajectories and improved coordination of aircraft from satellite airports
- Reduced taxi delay

Expected Airspace Traffic Service Benefits:

- TRACON capacity improvements through more effective balancing and sequencing of arrival and departure traffic
- Improved runway system utilization
- Reduced tower-to-tower verbal communication

Expected Environmental Benefits:

- Noise and emissions reduction due to improved departure trajectories

It is understood that not all locations in the NAS may benefit from EDP. EDP is most likely to produce the greatest benefits in regions where pilots are currently requesting low-altitude departures (or "tunneling"), trading higher fuel burn for schedule integrity. Despite the added fuel costs, airline officials say the low-altitude routes allow them to complete more flights on time.

More than a year ago, the FAA gave airlines approval to operate some short flights of up to 500 miles at altitudes between 8,000 feet and 23,000 feet. Northwest Airlines, TWA, Delta, Continental and US Airways tested the routes for some city pairs this spring. At Chicago's O'Hare International Airport, United Airlines began rerouting some departing planes to underused, lower-altitude flight paths in June 2000.

Conversations with controllers from Washington Center confirmed that tunneling is actively used as a tool to alleviate delays. More airlines are willing to file for lower altitudes for their short-haul operations (less than 500 nm), realizing that it will allow their long-haul operations to fly at the resulting less-congested higher altitudes. Another area in the NAS where benefits of EDP show potential is in the airspace in which TRACONs must coordinate departures from multiple airports. Examples of such airspace can be found near Los Angeles, Chicago, New York, and Washington, DC.

Table 1.4-1EDP Functional Contributions and Benefit Mechanisms

Functional Contribution	Benefit Mechanisms	Tool-Specific Technical Performance Metrics [ST1]
1) Advisories regarding departing traffic: • Spacing • Speed, turn, altitude, and headings • Ascent trajectory maneuvering • Departure fix sequencing • Metering and/or clearances for aircraft that merge over a given fix • Initial set-up of departures to merge with en route streams • Managing loads	• Improved departure rate due to better knowledge of loads • Reduced spacing buffers along trajectories • Better coordination of departure traffic from multiple airports within a TRACON • Help with efficient merging of traffic streams in en route airspace • Increased ability to expedite departures that cross arrival routes • Increased loads on departure fixes (fewer missed slots) • Decreased departure delays for satellite airports	• Average number of departures per hour per runway during peak periods (for defined sets of airports) • Average number of aircraft over departure fix per hour during peak periods • Excess spacing buffers between departing aircraft pairs per runway • Average taxi-out time per flight during peak periods (for defined set of airports) • Emissions near airport
2) Aids for scheduling and initial route planning of departure traffic. This will help departures merge later with the en-route traffic stream.	• More efficient ground operations • Potential for controllers to handle more traffic with the same workload	
3) Determine when aircraft can make unrestricted climbs in en-route airspace to expedite departures that cross arrival routes	• Improved runway and terminal airspace utilization • Improved scheduling to departure fixes • More balanced arrivals and departures	
4) Provide departure gate balancing information to TRACON traffic management coordinators	• Improved departure rate due to better knowledge of loads • More accurately predict merging of traffic flows • Improved predictions of trajectories at departure fixes • Reduced variability in flight times from increased departure capacity per peak hour • Fewer corrective clearances required • Reduced interruptions to user preferred climb profiles	

2 Approach

2.1 Overview

In this section we outline our approach to evaluating EDP benefits. We are estimating benefits for two different time frames, 1999 and 2015. The 1999 benefits will equate to an estimate of the benefits attributable to EDP had EDP been fully operational in 1999. The 2015 benefits are the projected benefits that EDP will provide if fully implemented by that time, given that demand grows as forecasted in the FAA's Terminal Area Forecast [FA1] extrapolated to 2015. Benefits will consider the deployment of EDP across the NAS, as represented by 42 airports selected for use in previous AATT benefit assessments [CO1] and their airspace. These airports are listed in Table 2.1-1 and their locations are shown on Figure 2.1-1.

Table 2.1-1 NAS-Wide Deployment Strawman Airports

Airport Code	Airport	**Airport Code**	Airport	**Airport Code**	Airport
EWR	Newark	**ATL**	Atlanta	**COS**	Colo. Springs
LAX	Los Angeles	**SLC**	Salt Lake City	**IAD**	Wash Dulles
LGA	LaGuardia	**BWI**	Baltimore-Wash.	**BDL**	Bradley
MSP	Minneapolis	**CLT**	Charlotte	**DAB**	Daytona Beach
ORD	Chicago	**DFW**	Dallas	**DEN**	Denver
STL	Saint Louis	**DTW**	Detroit	**FLL**	Ft. Lauderdale
BOS	Boston	**DCA**	Wash. National	**HPN**	Westchester Co.
CLE	Cleveland	**JFK**	Kennedy	**IAH**	Houston G. Bush
CVG	Cincinnati	**LAS**	Las Vegas	**LGB**	Long Beach
MIA	Miami	**MCO**	Orlando	**HOU**	Houston Hobby
PHX	Phoenix	**MEM**	Memphis	**OAK**	Oakland
SEA	Seattle	**MDW**	Chicago Midway	**PIT**	Pittsburgh
SFO	San Francisco	**PDX**	Portland	**PHL**	Philadelphia
SAN	San Diego	**BNA**	Nashville	**TEB**	Teterboro

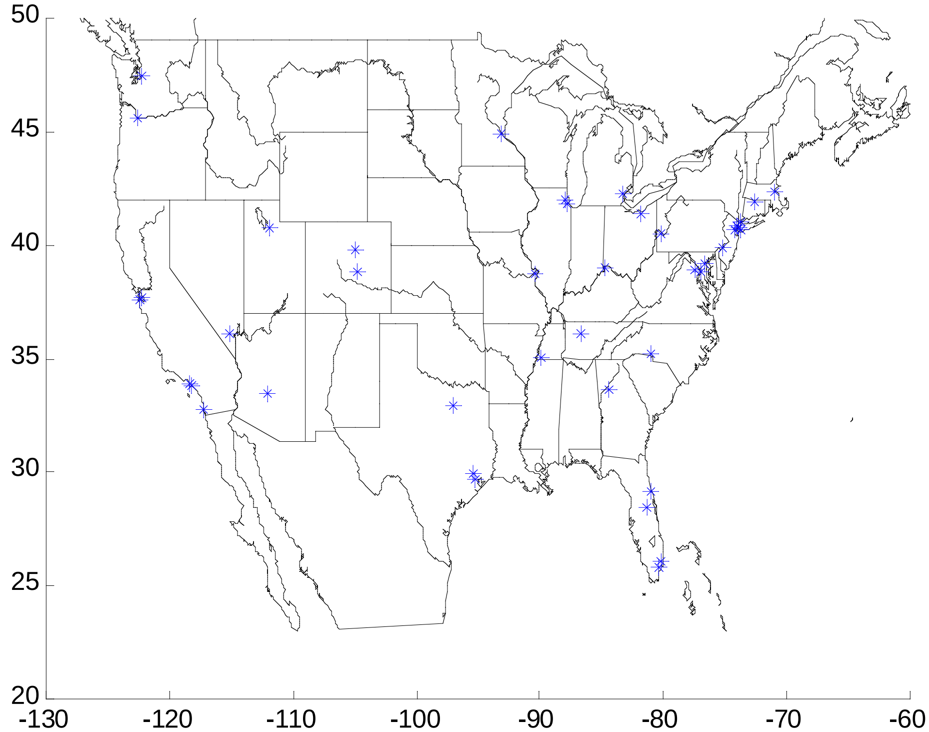


Figure 2.1-1 Proposed AATT Sites

As-flown flight data from the FAA's Enhanced Traffic Management System will be used to generate baseline demand. This data is generated from Departure (DZ), Arrival (AZ), and Position Update (TZ) messages extracted from ETMS data using National Resource Investment Model (NARIM) ETMS Parser [CS1]. In addition, Flight Plan (FZ) messages are extracted to identify departure gates and/or Standard Instrumental Departures (SIDs) and their demand.

We determined that we could most accurately estimate EDP benefits in the required time frame by considering separately the potential benefits of the major EDP functional contributions on the ground and in the terminal and regional airspace. EDP appears to generate both direct and indirect benefits:

- Direct Benefits: Reduction of climb-out time due to unrestricted climbs into the en-route system and optimally merging multiple aircraft over a common fix or through a departure gate.

- Indirect Benefits: Reduction of taxi-out delays due to providing advisories to the ground DSTs.

The methodology that we developed for assessing the aforementioned benefits is explained in the remainder of this section.

2.2 Reduction of Climb-out Time Due to Unrestricted Climbs into the En-route System and Optimally Merging Multiple Aircraft over a Common Fix or Through a Departure Gate

2.2.1 Methodology Discussion Using Operations at Washington Metropolitan Area Airports as an Example

To develop the methodology, we used data from the three major Washington, DC-area airports: Ronald Reagan Washington National Airport (DCA), Washington Dulles International Airport (IAD), and Baltimore-Washington International Airport (BWI).

The demand profiles for these airports for June 14, 1999, the day we used to illustrate our methodology, are shown on Figures 4.1-3 and 4.1-4.

Figure 2.2-1 depicts Washington departures over departure gate Linden (LDN). Flights departing IAD and DCA arrive as a single stream to LDN (35 nm and 54 nm respectively). Traffic from BWI arrives at higher altitude, because BWI is further out (75 nm) than DCA and IAD. IAD TRACON controls aircraft at altitudes up to 17,000 feet and at (or sometimes before) LDN aircraft are handed off to Washington Center's LDN Departure Sector, which controls the altitudes from 18,000 feet to 27,000 feet. Then both streams are merged as they climb to their assigned altitudes on jet route J134. About 20 nm east of COLNS fix, aircraft are handed off to the Moorefield High Altitude Sector (28,000 feet and above), allowing aircraft to further climb to their assigned altitudes. At COLNS (100 nm from DCA), two major jet routes cross: J134 with traffic from Washington and J6 with NYC traffic (which is in cruise by this time). At this point the controller has to merge the traffic, allowing aircraft to continue on their original routes or to turn onto J134 from J6, or vice versa.

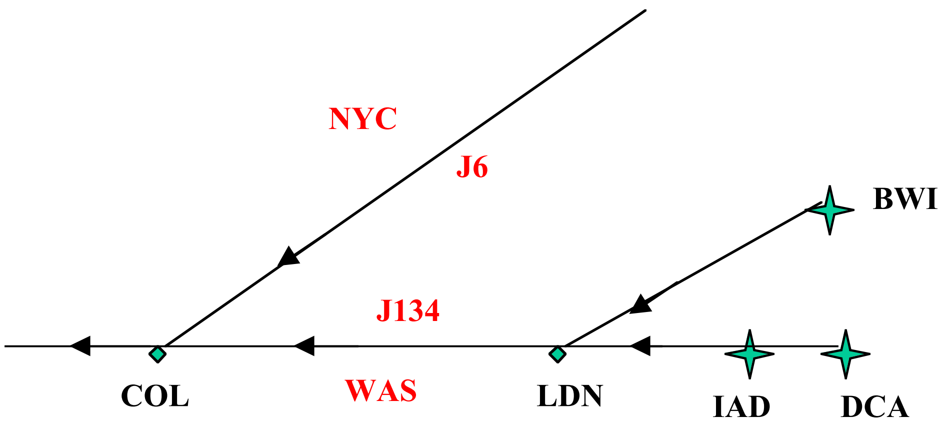


Figure 2.2.1-1 Washington Departures over LDN

Figures 2.2.1-2 and 2.2.1-3, plotted from as-flown data, show average speed and altitude vs. distance from the airport for aircraft departing over LDN. These figures demonstrate that the flights from IAD and BWI arrive at LDN as a single stream, while BWI traffic arrives at a higher altitude.

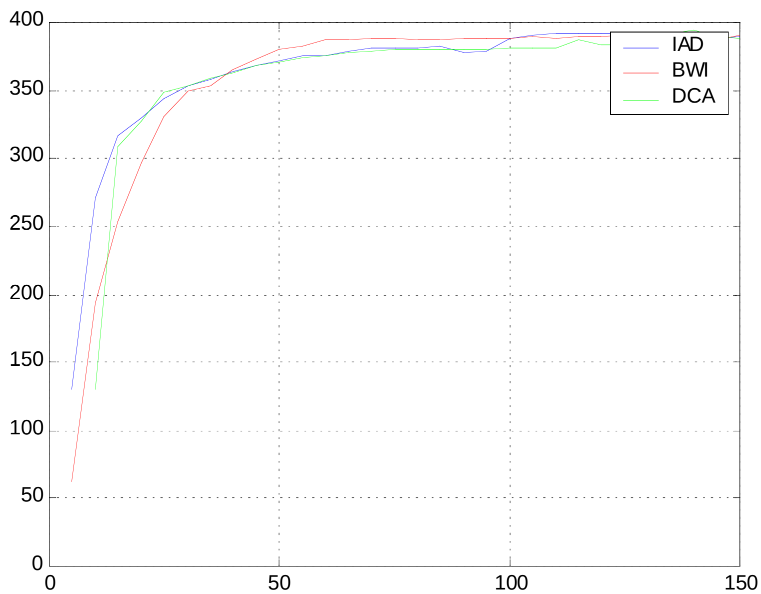


Figure 2.2.1-2 Aircraft Speed vs. Distance from the Airport

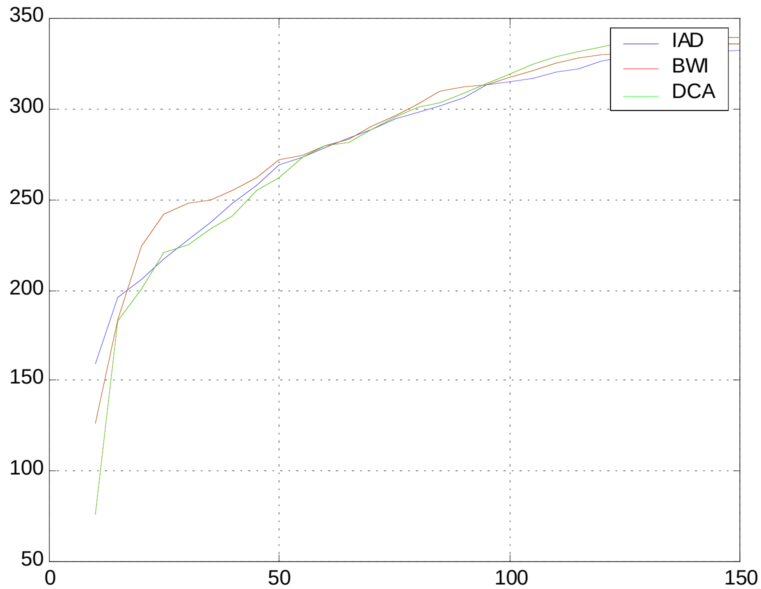


Figure 2.2.1-3 Aircraft Altitude vs. Distance from the Airport

The following example (shown in figures 2.2.1-4 and 2.2.1-5) is derived from as-flown ETMS data. It shows a comparison of two AAL flights. Both of these aircraft are Boeing 757-200s flying the same day (March 24, 1999) from DCA to DFW (stage length 1,035 nm), and both filed the same cruise altitude (FL 370).

The difference is that the 1st flight, AAL1081, departs during a non-peak time period (6:07 am local time) while the 2nd flight, AAL1821, departs during peak-hour period (12:41 pm local time).

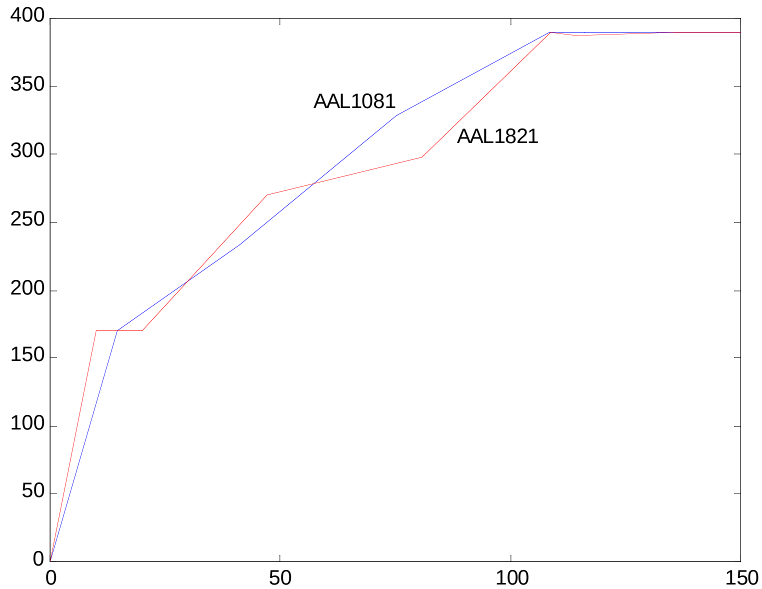


Figure 2.2.1-4 Altitude vs. Distance Profiles for AAL1081 and AAL1821

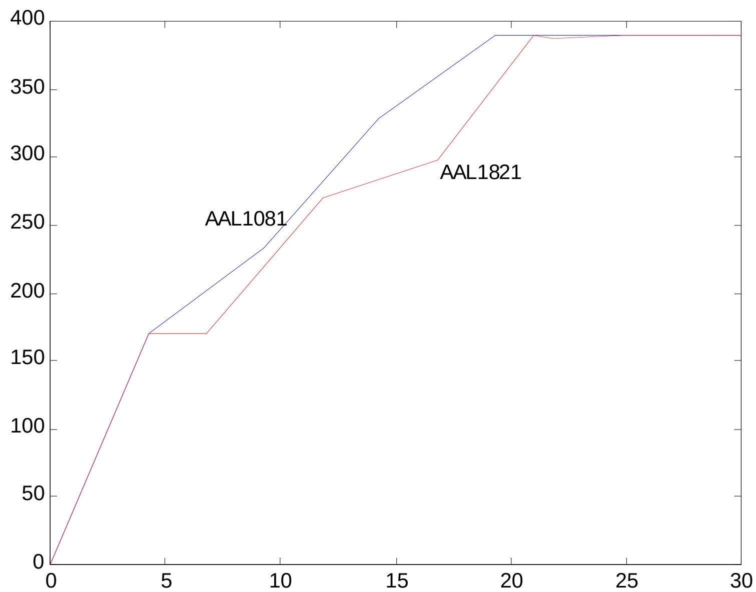


Figure 2.2.1-5 Altitude vs. Distance Profiles for AAL1081 and AAL1821

From figures 2.2.1-4 and 2.2.1-5 one can see that during the off-peak period AAL1081 is climbing practically uninterrupted to its assigned altitude at FL 390. During the peak period, AAL1821 is held at FL 170 waiting for hand-off from the TRACON to LDN Sector and then at FL 270 waiting for hand-off to Moorfield High Sector. It takes

AAL1081 about 43 minutes to fly 250 nm (time to fly 250 nm is taken from domain-specific technical performance metrics of EDP), while it takes AAL1821 roughly 45 minutes to fly the same distance. Flying the same distance AAL1821 burns roughly 300 more pounds of fuel (using BADA [EU1]).

From our conversations with a recently retired United Airlines senior pilot, conversations with Washington Center controllers, and recent media reports, we learned that "tunneling"[WE1] evolved from instances when departing flights were held at a low altitude to avoid inbound traffic at higher altitudes. Now tunneling more frequently refers to a situation in which the pilot files for a lower-than-optimal but less busy altitude, trading higher fuel burn for schedule integrity. (The benefits of this are described more in section 4.1 of this report.) For example, it is now common for short-haul jet flights from Washington Center origins to Cleveland Center destinations to fly no higher than 22,000 feet, thus avoiding the more-congested altitudes of FL 310 and FL 350 used by long-range flights to West Coast.

By analyzing combinations of assigned altitudes filed before the departure (from DZ messages) and as-flown data (from TZ messages), we can identify the following three cases:

1. Aircraft filed altitude is optimal and aircraft was cleared to fly at that altitude

2. Aircraft filed altitude is optimal, but aircraft was not cleared to fly at that altitude or was delayed in reaching its optimal altitude

3. Aircraft filed lower than optimal altitude, trading fuel burn for schedule integrity

Case 2 is essentially the original definition of tunneling, while Case 3 is the more recent definition of tunneling.

The following table shows the percentage of user requests for altitude honored for departures from selected airports in Washington Center on March 24, 1999 (this data includes both props and jets):

Table 2.2.1-1 Percentage of Honored User Requests for Altitude

Airport	Jets	Props
IAD	88.1%	86.8%
DCA	81.7%	94.0%
BWI	93.6%	84.5%

Note that Table 2.2.1-1 does not take into account whether the aircraft was delayed in reaching its requested altitude, or if the filed altitude is not an optimal altitude. However, this data is a good indication of the potential magnitude of fuel saving should an aircraft be cleared to its optimal altitude.

To estimate the fuel saving due to EDP, in cases where an aircraft files for a less-than-optimal altitude, we will use the lowest altitude that this flight was most likely to file, given no other restrictions.

The following steps summarize the approach:

1. In cases where an aircraft filed for its optimal altitude and was delayed in its climb to that altitude, we will use the method described earlier in this section. That is, we will calculate the additional time it takes an aircraft to fly 250 nm during a peak period compared to the time it takes during a non-peak period and calculate the fuel savings.

2. In the cases where an aircraft was never cleared to its filed optimal altitude, we will calculate the fuel saving for the entire duration of the flight by comparing the as-flown flight to the same flight had it been cleared to its optimal altitude.

3. In the cases where an aircraft flies at a filed altitude that is below its optimal, we will calculate the fuel saving for the entire duration of the flight by comparing the as-flown flight to the same flight had it flown the lowest altitude that this flight was most likely to file, given no other restrictions.

Figure 2.2.1- 6shows major departure fixes used by the three major Washington, DC-area airports.

Some of the departures gates are used solely by jets or props, others by a combination of both. In the latter case, jets and props arriving at the departure gate are separated by altitude. Table 2.2.1-1 lists major departure gates and daily traffic going over these fixes on March 24, 1999. Results are shown separately for jets and props.

Table 2.2.1-1 Washington Area Major Departure Fixes (Daily Departures, March 24, 1999)

Fix	Jets				Props			
	IAD	DCA	BWI	**Total**	IAD	DCA	BWI	**Total**
BUFFR	13	24	20	**57**	4	3	0	**7**
CSN	0	0	0	**0**	52	17	0	**69**
DAILY	13	29	31	**73**	0	15	0	**15**
FLUKY	47	35	31	**113**	29	0	3	**32**
HAFNR	61	27	22	**110**	0	3	3	**6**
JERES	20	38	25	**83**	28	3	13	**44**
LDN	55	53	49	**157**	7	7	0	**14**
PALEO	2	15	13	**30**	0	24	28	**52**
SWANN	60	82	49	**191**	7	10	22	**39**

The problem of merging aircraft over the common departure fixes exists when aircraft from the different Washington-area airports arrive at the same departure gate not separated longitudinally or by altitude. Aircraft are already airborne, so delays related to merging will be accumulated in the airspace. Thus, benefits from optimally merging aircraft through departure gates will be included in the time savings for aircraft in reaching their assigned flight levels. From conversations with controllers at Washington Control Center, aircraft from different airports arrive at some fixes already separated by altitude, such as traffic from DCA, IAD, and BWI over LDN. This is mainly because controllers coordinate traffic from DCA and IAD as a single stream over LDN and BWI traffic arrives at LDN at a higher altitude. Thus, even though the total number of traffic over LDN is one of the highest from the Table 2.2.1-1, the problem of merging traffic is not significant. On the other hand, there are some delays due to merging traffic over SWANN going to the New York area. In this case, traffic from all three airports arrives at SWANN requiring additional controllers interference, thus causing delay to a flight.

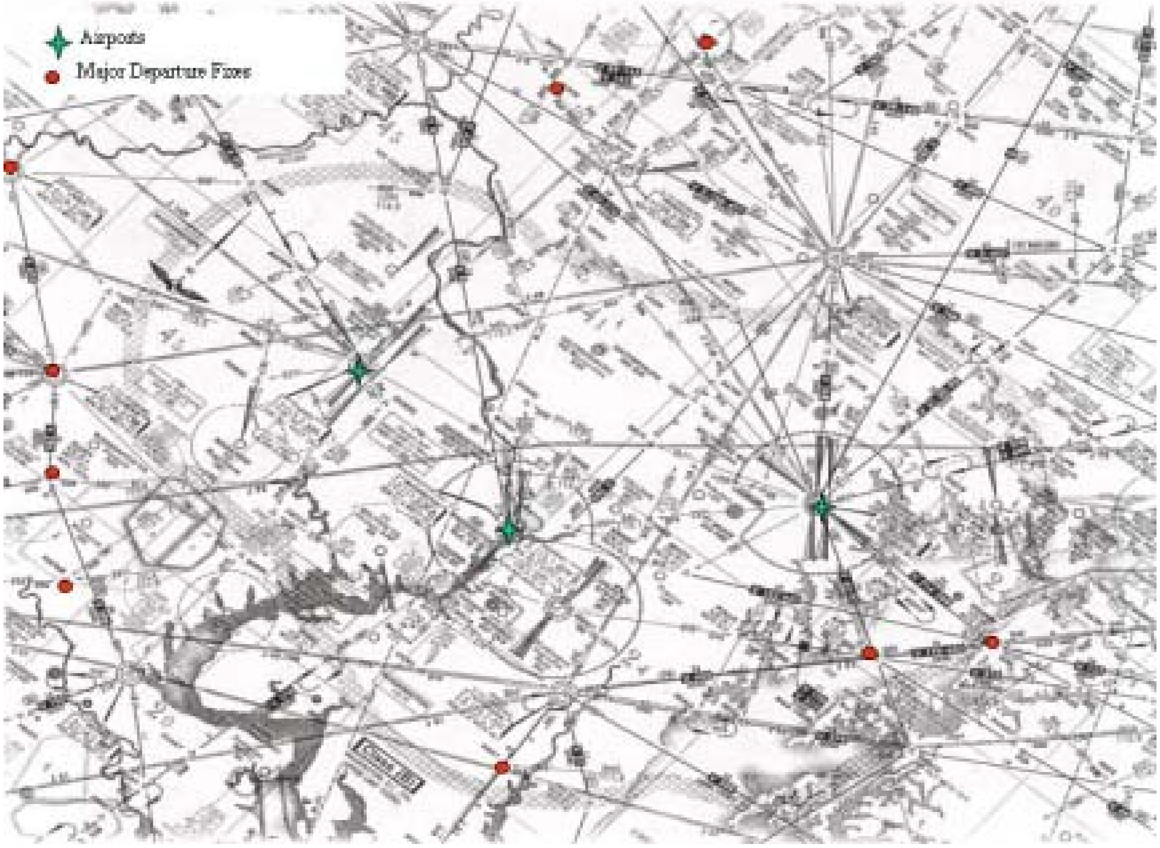


Figure 2.2.1-6 Washington Area Major Departure Fixes

2.2.2 Baseline Benefits Assessment

In assessing the EDP benefits due to unrestricted climbs and optimal merging, it should be noted that climb trajectories are very sensitive to errors in takeoff weight. An aircraft's gross weight determines its absolute altitude ceiling. Variation of aircraft weight for the aircraft of the same type serving the same city pair can be significant as well. The following table shows the data collected from Airline Operation Center (AOC) flight plans during March-April 1999 for operations departing from Dallas/Ft. Worth Airport and Denver International Airport. These results are taken from [CO3].

Takeoff weight estimates for about 8,000 operations were obtained. These results show maximum variations of up to 50% of mean takeoff weight for certain aircraft types.

Table 2.2.2-1 Takeoff Weight Variations

Aircraft Type	Mean Weight (lb)	Std. Dev. (% of mean)	Min. weight (% of mean)	Max. weight (% of mean)
B727	159,700	6.8	-22.9	+14.3
B737	118,500	4.5	-8.8	+9.6
B747	567,700	3.9	-4.0	+6.8
B757	192,500	6.4	-23.8	+37.2
B767	341,800	15.0	-26.8	+19.3
B777	424,400	5.2	-9.3	+8.6
DC10	448,100	20.1	-29.3	+36.6
A319	126,000	6.5	-11.4	+15.1
F100	87,400	5.8	-20.6	+34.4
MD11	416,500	3.4	-3.5	+3.1
MD80	129,900	7.1	-27.0	+51.6

Based on data listed in Table 2.2.2-1 we realize that our benefits assessment has a certain level of uncertainty due to the unavailability of aircraft takeoff weight data.

Based on the relationship between assigned flight level and actual flight level outlined in the Section 2.2.1, we can break down benefits due to unrestricted climbs into three components:

$$\ddot{A} = \ddot{A}_{\text{delayed}} + \ddot{A}_{\text{cleared lower}} + \ddot{A}_{\text{filed lower}} \qquad (2.2.2\text{-}1)$$

Where,

$\ddot{A}$	Total savings due to unrestricted climb ($)
$\ddot{A}_{\text{delayed}}$	Savings for the flights that are delayed to their assigned flight level ($)
$\ddot{A}_{\text{cleared lower}}$	Savings for the flights cleared to the flight level below their assigned flight level ($)
$\ddot{A}_{\text{filed lower}}$	Savings for the flights that had to file cruise flight level lower than their optimal in order to trade fuel burn for schedule integrity ($)

These three components of total savings due to unrestricted climbs are calculated differently and described in more details below. Before we discuss the approaches used to calculate the benefits of all three components, we have to identify the amount of traffic that falls under each three of these categories at all airports under study. In doing so it is important to further segregate traffic into two major categories: jet aircraft and turboprop aircraft, because their altitude profiles differ significantly due to aircraft performance. Piston engine aircraft comprise a very small portion of total traffic and we include them in the turboprop category in the analysis with the exception of converting time savings into dollar savings. In the latter case we will use different critical values for these aircraft. To distribute aircraft between these two categories we used our database of aircraft types (Appendix A) that contains over 400 aircraft types (including alias names, such as LJ35 and LR35, etc.). This database was compiled from different data sources, and was tuned (in terms of alias names) by using traffic information from all 42 facilities under study.

Once aircraft were distributed between the two categories, we continued our analysis by further segregating traffic into groups based on the relationship between aircraft assigned and actual cruise flight level. While doing so we realized that, from the existing format of ETMS data as well as from other relevant sources of data, it is very hard to identify cases when aircraft filed flight level is lower than preferred flight level for the flight (the nature of these instances is described in the Section 2.2.1 of this report). We assumed (based on real-life data) that these cases are not very frequent (even though this trend is changing—see Section 2.2.1) and include these cases in the category of the flight delayed to their assigned flight levels. Thus for further analysis we include $\ddot{A}_{\text{filed lower}}$ component of our benefit equation (2.2.2-1) into $\ddot{A}_{\text{delayed}}$.

Aircraft not cleared to their assigned flight levels

Table 2.2.2-2 shows the percentage of cases when jet or turboprop aircraft were cleared to their requested flight levels for June 14, 2000 for all 42 key AATT sites. In calculating these percentages we made sure that incomplete flights (for example, flights that had data records cut off before completing the climb phase, or aircraft that were already descending at the time when data records were extracted) were discarded.

Figures 2.2.2-1 and 2.2.2-2 show the average stage length for jet and turboprop and piston engine aircraft for flights both cleared and not cleared to their assigned flight level for each of 42 proposed AATT sites. These figures show that short-haul aircraft are most likely to accept a lower-than-filed flight level, supporting the current trend among airlines to make their short-haul operations to accept, if necessary, lower altitudes for their cruise to alleviate more congested higher flight levels used by long-haul aircraft.

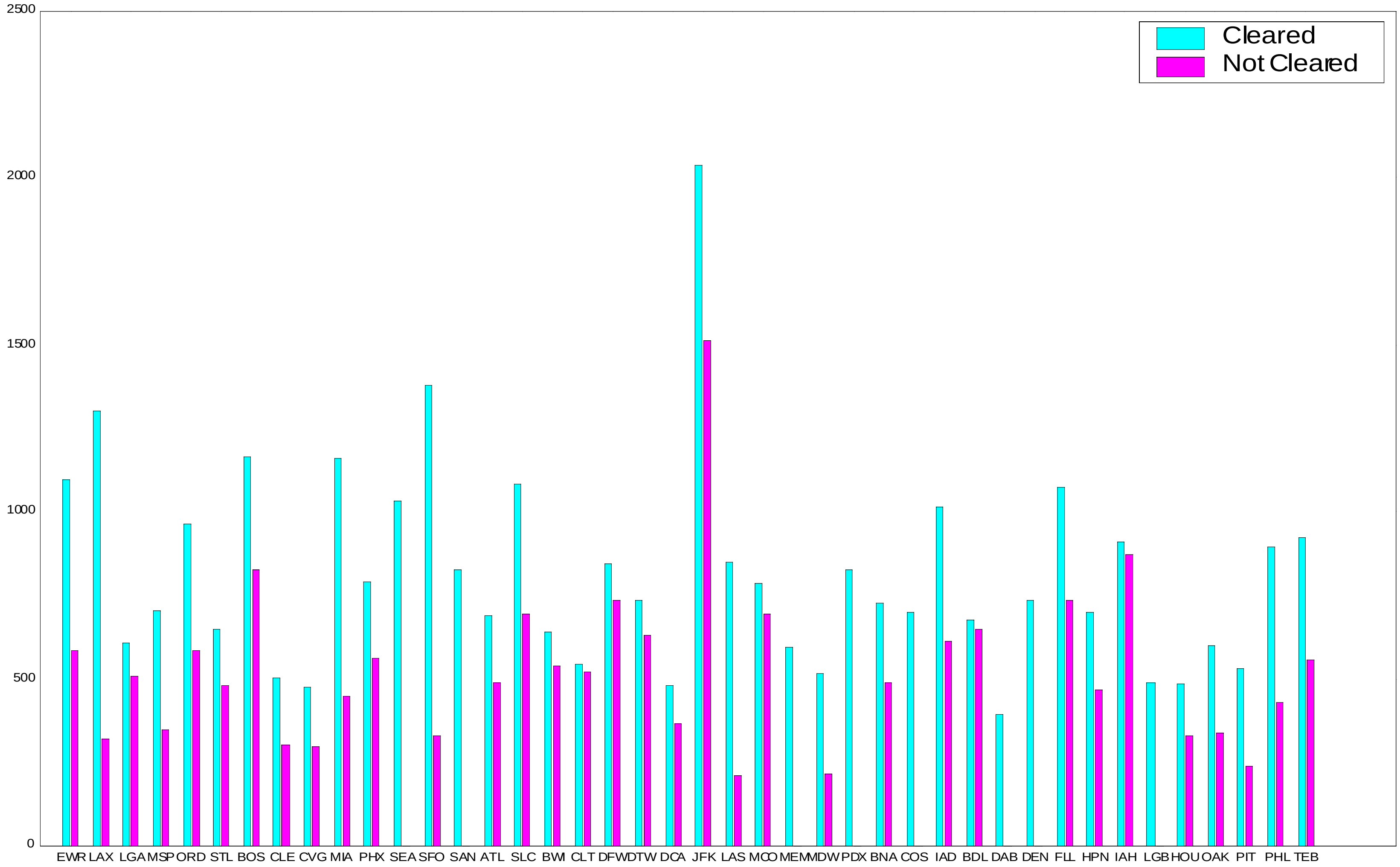


Figure 2.2.2-1 Jet Aircraft Average Stage Length

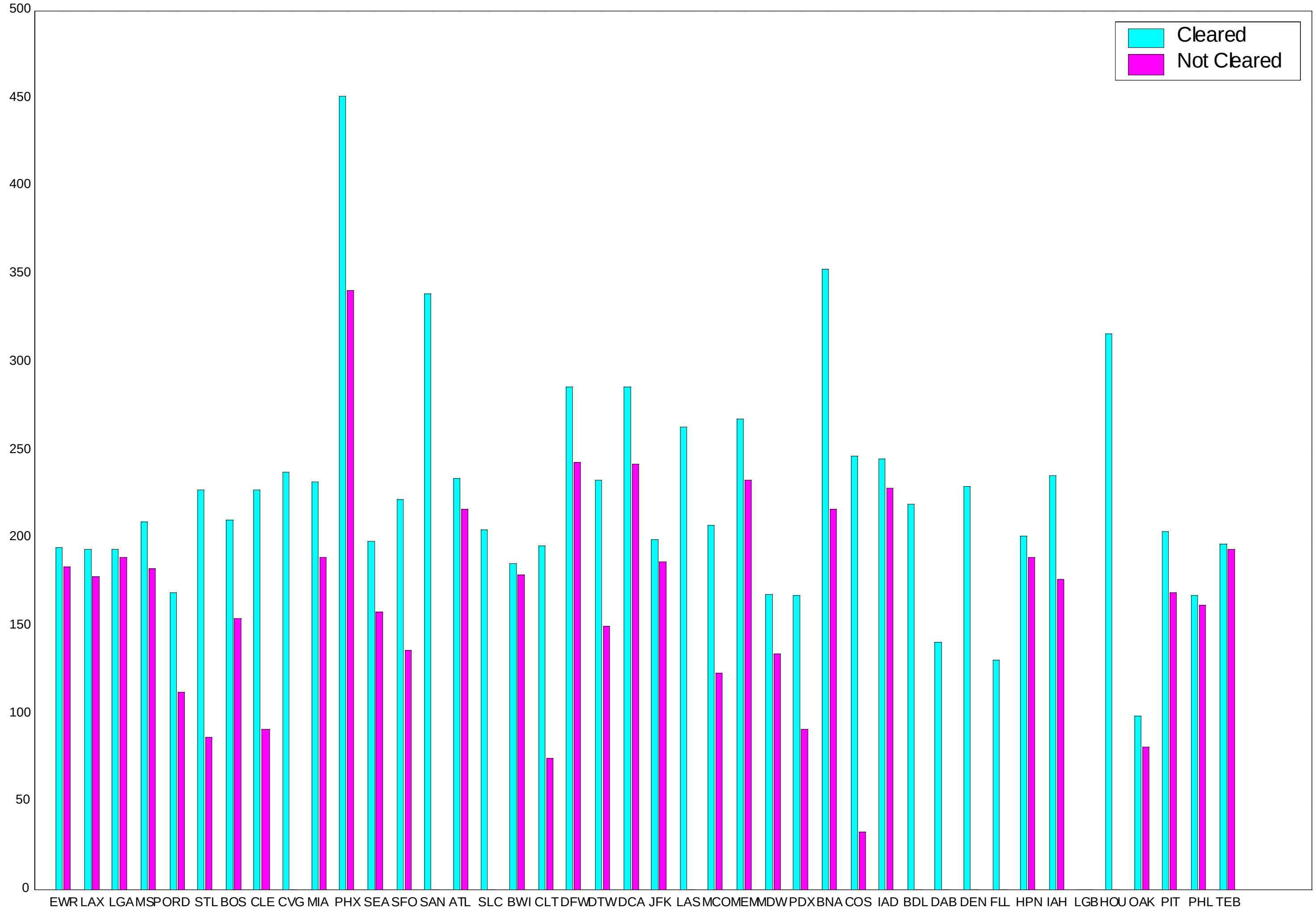


Figure 2.2.2-2 Turboprop and Piston Engine Aircraft Average Stage Length

Table 2.2.2-2 Percentage of Honored Requests for Cruise Altitude

Airport	Percentage of Honored Requests for Cruise Altitude	
	Jet Aircraft	Turboprop Aircraft
ATL	99.68	98.59
BDL	99.02	100.00
BNA	97.12	94.44
BOS	98.49	88.89
BWI	86.29	81.58
CLE	96.34	99.34
CLT	97.74	98.48
COS	100.00	80.00
CVG	96.20	100.00
DAB	100.00	100.00
DCA	82.88	88.14
DEN	100.00	98.97
DFW	99.09	99.64
DTW	97.47	94.94
EWR	89.33	70.97
FLL	98.89	100.00
HOU	97.06	100.00
HPN	74.14	83.67
IAD	85.02	91.42
IAH	97.57	96.83
JFK	96.97	90.24
LAS	98.57	100.00
LAX	99.83	97.84
LGA	86.65	76.84
LGB	100.00	100.00
MCO	99.05	98.59
MDW	99.44	91.49
MEM	100.00	96.04
MIA	99.10	96.27
MSP	96.30	93.87
OAK	96.00	69.39
ORD	97.86	97.97
PDX	100.00	98.56
PHL	84.91	82.07
PHX	99.57	97.44
PIT	97.01	98.32
SAN	100.00	100.00
SEA	100.00	98.91
SFO	96.39	96.00
SLC	99.48	100.00
STL	99.52	98.81
TEB	94.87	75.00

For flights that were never cleared to their assigned flight levels, the benefits of introducing the EDP tool were calculated based on the amount of fuel saved for the entire duration of the flight. This seems reasonable given that the airline policies (confirmed after conversations with our senior retired United Airlines pilot) are to readjust assigned cruise speeds for flights to meet their schedules. Thus no time-associated benefits were considered in these cases.

We used representative aircraft by user profiles presented in [FA3] and listed in Table 2.2.2-3. Corresponding fuel-burn data from [EU1] and [FA3] was used to calculate additional fuel burned by aircraft not cleared to their assigned flight levels. Fuel savings for this category of flights for each of 42 proposed AATT sites are summarized in table 5.1.2-2.

Table 2.2.2-3 Aircraft Classification and Representative Aircraft

FAR Category	Economic Value Class	Representative Aircraft by User Profile			
		Scheduled Commercial Service	Air Carrier w/o Commuters	Commuters	Air Taxi and General Aviation
FAR 25:					
Transport	Jet: 4-engine wide body	B747-400	B747-400		
	Jet: 4-engine narrow body	DC8-62	DC8-62		
	Jet: 3-engine wide body	DC10-30	DC10-30		
	Jet: 3-engine narrow body	B727-200	B727-200		
	Jet: 2-engine wide body	B767-332	B767-332		
	Jet: 2-engine narrow body	B737-300	B737-300		
	Jet: Regional under 40 seats	LR35-35		LR35-35	
	Jet: Regional 40-59 seats	CL600		CL600	
	Jet: Regional over 59 seats	F100-100		F100-100	
	Jet: Corporate				LR35-35
	Turboprop: 20+ seats	Saab 340		Saab 340	Saab 340
FAR 23:					
Commuter	Turboprop: under 20 seats	Metro III		Metro III	Metro III
Normal, Utility, & Aerobatics	Piston: Multi-Engine	Beech-B55		Beech-B55	Beech-B55
	Piston: Single Engine	Cessna-172		Cessna-172	Cessna-172

A fuel price of $0.08 per pound in 1999 [FA2] was used to calculate annual dollar savings for aircraft not cleared to requested flight levels. To express these annual savings in 1997 dollars we used an annual discount rate of 7% (see Appendix B).

Aircraft delayed to their assigned flight levels

Previous reports on EDP considered the benefits due to unrestricted climbs either by using artificially simulated data for a single facility and a limited number of aircraft [CO2] or by comparing climb-out times between "busy" and "non-busy" facilities over multiple sites [LE1]. The first approach, while using a high-fidelity simulation, did not take into account operational issues of the facility and real traffic flow at and around the airport. The second approach attempted to cover multiple facilities, but did not take into account operational differences between them. Comparing "busy" and "non-busy" facilities can create biased results using this approach. For example, an airport can have low local demand, but the overflight traffic can be significant, and vise versa. Given the time frame of this study and in an attempt to provide a reliable benefits estimate for all 42 proposed AATT sites, we developed the methodology outlined below.

We compared average climb-out times for jet and turboprop aircraft at an airport throughout the day using average climb-out times for the same facility during non-busy (usually night) hours that guaranteed not only a small number of operations at the airport (see Figures 4.1-1 through 4.1-6) but also a minimal number of overflights (see examples on Figure 2.2.2-3). Using operational data we obtained nominal (unrestricted) climb-out times that included specifics of each facility. Further analysis of the data revealed that the upper boundary for an aircraft delayed to its assigned flight level to reach top of the climb (TOC) varied from 250 nm of horizontal distance flown from the airport for jet aircraft to 100 nm for turboprop aircraft. Thus corresponding values of horizontal distance flown were used to calculate the climb-out times for jets and props. The following table summarizes the results of the unrestricted climb savings calculations for 42 airports.

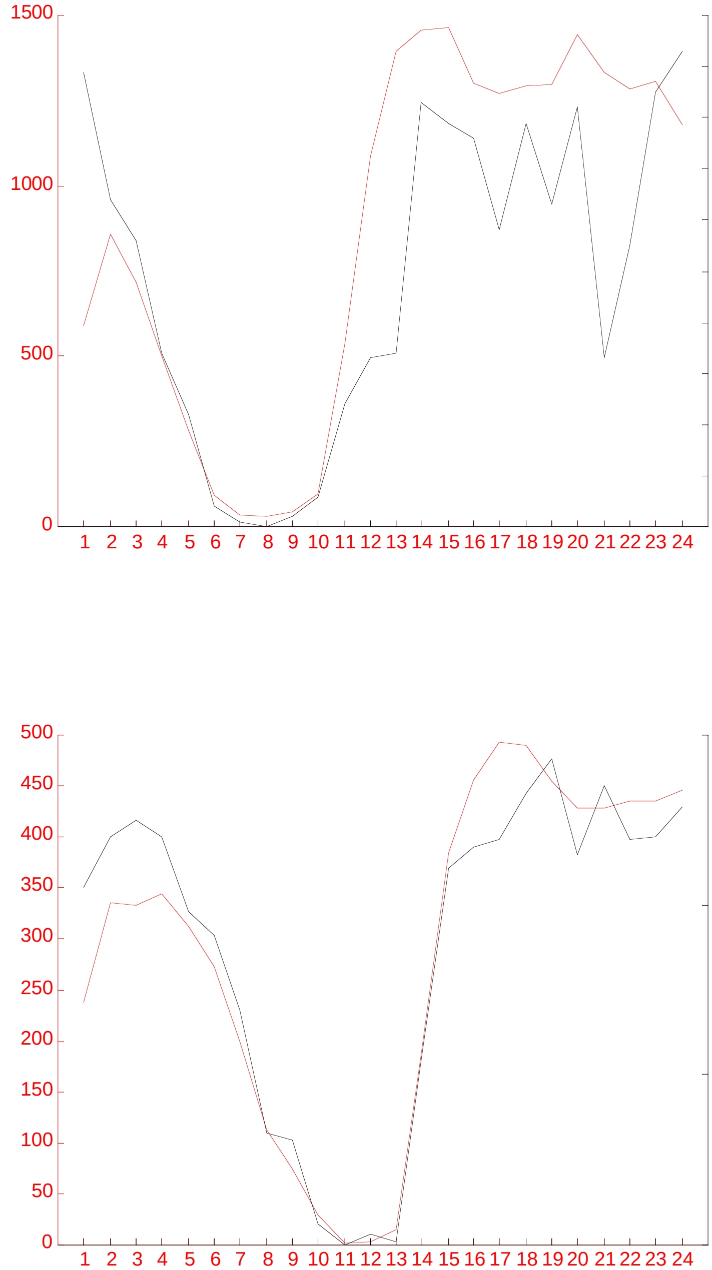


Figure 2.2.2-3 Traffic Demand at IAD, LAX and Their 250 nm Regional Airspace

Table 2.2.2-3 Average Unrestricted Climb Time Savings Per Departure (1999)

Airport	Time Savings per Aircraft (min)	
	Jet Aircraft	Turboprop Aircraft
EWR	1.26	0
LAX	0.96	0
LGA	1.03	0
MSP	0.51	0
ORD	1.02	0
STL	0	0
BOS	0.79	0
CLE	0	0
CVG	0	0
MIA	0.26	0
PHX	0	0
SEA	0.74	0
SFO	1.23	0
SAN	0.06	0
ATL	1.24	1.20
SLC	0.58	0
BWI	1.72	0.21
CLT	0.14	0.11
DFW	0.54	0
DTW	0.82	0.64
DCA	0.68	0.24
JFK	0.19	0
LAS	0.58	0
MCO	1.19	0
MEM	0	0
MDW	0	0
PDX	0.66	0
BNA	0	0
COS	0	0
IAD	0.24	0.16
BDL	0.57	0.17
DAB	0	0
DEN	1.04	0
FLL	0	0
HPN	1.03	0
IAH	0.36	0
LGB	0	0
HOU	0.47	0
OAK	0.54	0
PIT	1.47	0
PHL	1.00	0
TEB	0.60	0

From the table one can see that, even in baseline operations, the delays experienced by turboprop aircraft in reaching their assigned flight levels are much lower than the delays experienced by jet aircraft. This is explained by the fact that cruise altitudes for turboprop aircraft are lower than for jet aircraft and at less-congested flight levels. This trend was also confirmed with Washington Center controllers. Also, in the cases where turboprop aircraft are delayed to their assigned flight levels, they more frequently accept lower cruise flight levels to avoid delays. This is supported by the data listed in table 2.2.2-2. Given that turboprop flight stage length is rather short (compare to jet aircraft), the additional amount of fuel burned by these aircraft when they are cleared to lower cruise altitudes is not significant.

The delays listed in the Table 2.2.2-3 correspond well with information on potential delays for different phases of flight provided by Landrum & Brown, Inc. to the 1999 ACE Plan (Aviation Capacity Enhancement Plan, FAA 1999). The magnitude of the potential delays in the climb-out phase due to local and regional airspace congestion is estimated to range from 0 to 3 minutes.

Commonly used departure fixes

Our discussions with our retired senior United Airlines pilot, conversations with Washington Center controllers, and analysis of airport geographical locations identified the following potential departure conflicts due to multiple-airport metro areas among the 42 airports under study.

Table 2.2.2-4 Commonly Used Departure Fixes

Airport	Conflicts
BWI	DCA, IAD
COS	DEN
DCA	BWI, IAD
EWR	JFK, LGA
FLL	MIA
HOU	IAH
HPN	LGA, JFK
IAD	DCA, BWI
IAH	HOU
JFK	LGA, EWR
LGA	JFK, EWR
LGB	LAX
MDW	ORD
OAK	SFO
ORD	MDW
PHL	NY & Washington
SFO	OAK
LAX	LGB
DEN	COS
MIA	FLL
TEB	All NY

The corresponding departure fixes are listed in Appendix D. Daily traffic counts are for June 14, 1999 and listed separately for jets and props. As mentioned in Section 2.2.1, the time savings due to optimal merging will be included in the climb-out times reduction.

2.2.3 Time Savings Economic Conversion

Finally, to convert time savings into dollar savings, we use the economic conversion factors developed by FAA Office of Aviation Policy, Plans, and Management Analysis (APO) and listed in Appendix B. Further, we assume the cost of oil and fuel on the ground is 1/3 of the cost once the aircraft is airborne [CO2]. The aircraft types used in this conversion are identified in Appendix A. The final results are presented in Section 4 of this report.

To assign costs to delays, the weighted costs per block hour of the critical cost values were calculated based on aircraft type and mix for the 42 AATT key implementation airports. The following formulas were used:

$$\begin{aligned}\overline{C}_{\text{oil \& fuel}} = &(C^{\text{Jets(Com)}}_{\text{oil \& fuel}} \cdot \mu_{\text{Jets}} + C^{\text{Turboprops(Com)}}_{\text{oil \& fuel}} \cdot \mu_{\text{Turboprops}} + C^{\text{Pistons(Com)}}_{\text{oil \& fuel}} \cdot \mu_{\text{Pistons}}) \cdot \eta_{\text{Com}} + \\ &(C^{\text{Jets(GA)}}_{\text{oil \& fuel}} \cdot \mu_{\text{Jets}} + C^{\text{Turboprops(GA)}}_{\text{oil \& fuel}} \cdot \mu_{\text{Turboprops}} + C^{\text{Pistons(GA)}}_{\text{oil \& fuel}} \cdot \mu_{\text{Pistons}}) \cdot \eta_{\text{GA}} + \\ &(C^{\text{Jets(Mil)}}_{\text{oil \& fuel}} \cdot \mu_{\text{Jets}} + C^{\text{Turboprops(Mil)}}_{\text{oil \& fuel}} \cdot \mu_{\text{Turboprops}} + C^{\text{Pistons(Mil)}}_{\text{oil \& fuel}} \cdot \mu_{\text{Pistons}}) \cdot \eta_{\text{Mil}}\end{aligned} \qquad (2.2.3\text{-}1)$$

$$\begin{aligned}\overline{C}_{\text{crew}} = &(C^{\text{Jets(Com)}}_{\text{crew}} \cdot \mu_{\text{Jets}} + C^{\text{Turboprops(Com)}}_{\text{crew}} \cdot \mu_{\text{Turboprops}} + C^{\text{Pistons(Com)}}_{\text{crew}} \cdot \mu_{\text{Pistons}}) \cdot \eta_{\text{Com}} + \\ &(C^{\text{Jets(GA)}}_{\text{crew}} \cdot \mu_{\text{Jets}} + C^{\text{Turboprops(GA)}}_{\text{crew}} \cdot \mu_{\text{Turboprops}} + C^{\text{Pistons(GA)}}_{\text{crew}} \cdot \mu_{\text{Pistons}}) \cdot \eta_{\text{GA}} + \\ &(C^{\text{Jets(Mil)}}_{\text{crew}} \cdot \mu_{\text{Jets}} + C^{\text{Turboprops(Mil)}}_{\text{crew}} \cdot \mu_{\text{Turboprops}} + C^{\text{Pistons(Mil)}}_{\text{crew}} \cdot \mu_{\text{Pistons}}) \cdot \eta_{\text{Mil}}\end{aligned} \qquad (2.2.3\text{-}2)$$

$$\begin{aligned}\overline{C}_{\text{pass-time}} = &(C^{\text{Jets(Com)}}_{\text{pass-time}} \cdot \mu_{\text{Jets}} + C^{\text{Turboprops(Com)}}_{\text{pass-time}} \cdot \mu_{\text{Turboprops}} + C^{\text{Pistons(Com)}}_{\text{pass-time}} \cdot \mu_{\text{Pistons}}) \cdot \eta_{\text{Com}} + \\ &(C^{\text{Jets(GA)}}_{\text{pass-time}} \cdot \mu_{\text{Jets}} + C^{\text{Turboprops(GA)}}_{\text{pass-time}} \cdot \mu_{\text{Turboprops}} + C^{\text{Pistons(GA)}}_{\text{pass-time}} \cdot \mu_{\text{Pistons}}) \cdot \eta_{\text{GA}} + \\ &(C^{\text{Jets(Mil)}}_{\text{pass-time}} \cdot \mu_{\text{Jets}} + C^{\text{Turboprops(Mil)}}_{\text{pass-time}} \cdot \mu_{\text{Turboprops}} + C^{\text{Pistons(Mil)}}_{\text{pass-time}} \cdot \mu_{\text{Pistons}}) \cdot \eta_{\text{Mil}}\end{aligned} \qquad (2.2.3\text{-}3)$$

$$\begin{aligned}\overline{C}_{\text{maint}} = &(C^{\text{Jets(Com)}}_{\text{maint}} \cdot \mu_{\text{Jets}} + C^{\text{Turboprops(Com)}}_{\text{maint}} \cdot \mu_{\text{Turboprops}} + C^{\text{Pistons(Com)}}_{\text{maint}} \cdot \mu_{\text{Pistons}}) \cdot \eta_{\text{Com}} + \\ &(C^{\text{Jets(GA)}}_{\text{maint}} \cdot \mu_{\text{Jets}} + C^{\text{Turboprops(GA)}}_{\text{maint}} \cdot \mu_{\text{Turboprops}} + C^{\text{Pistons(GA)}}_{\text{maint}} \cdot \mu_{\text{Pistons}}) \cdot \eta_{\text{GA}} + \\ &(C^{\text{Jets(Mil)}}_{\text{maint}} \cdot \mu_{\text{Jets}} + C^{\text{Turboprops(Mil)}}_{\text{maint}} \cdot \mu_{\text{Turboprops}} + C^{\text{Pistons(Mil)}}_{\text{maint}} \cdot \mu_{\text{Pistons}}) \cdot \eta_{\text{Mil}}\end{aligned} \qquad (2.2.3\text{-}4)$$

$$\overline{C}_{\text{total}} = \overline{C}_{\text{oil \& fuel}} + \overline{C}_{\text{crew}} + \overline{C}_{\text{pass-time}} + \overline{C}_{\text{maint}} \qquad (2.2.3\text{-}5)$$

Where

$\overline{C}_{\text{oil \& fuel}}$ weighted cost of oil and fuel per block hour ($/hour)

$\overline{C}_{\text{crew}}$ weighted cost of crew time per block hour ($/hour)

$\overline{C}_{pass\text{-}time}$ weighted cost of passenger time per block hour ($/hour). This cost is calculated based on number of seats and load factor and considered the cost of 1 passenger-hour to be equal to 45 $/hour.

$\overline{C}_{maint}$ weighted cost of maintenance per block hour ($/hour)

$$\mu_{Jets} + \mu_{Turboprops} + \mu_{Pistons} = 1 \tag{2.2.3-6}$$

$$\eta_{Jets} + \eta_{Turboprops} + \eta_{Pistons} = 1 \tag{2.2.3-7}$$

2.2.4 Horizon Year Benefits Calculations

We understand that more traffic will be affected by taxi-out and climb-out delays in the future, provided the concept of operations remains unchanged. Also, the size of the average delay is likely to increase both in the air and on the ground due to more congested airspace and ground facilities. The gap acceptance model, described in Appendix F of this report, shows that climb-out delays are at least proportional to flight-level throughputs.

We know that there are multiple reasons for an aircraft to be delayed in its climb to its assigned flight level, but all of them are related to traffic volume. Given the duration and the scope of this project, in order to estimate benefits for all 42 proposed AATT sites, we assumed that the number of climb-out delays per number of honored altitude requests were proportional to the volume of traffic in the terminal and regional airspace near each airport. As mentioned above, the maximum horizontal distance an aircraft flies before reaching its assigned flight level is about 250 nm. We therefore considered the change in traffic volume within 250 nm from the airport. A weakness in this approach is that we cannot grow climb-out delays proportionately to the traffic volume when the baseline delays are zero. However, the majority of the airports under consideration are subject to this limitation only for turboprop aircraft operations that do not contribute significantly to the final benefits.

The corresponding traffic volume changes and adjusted climb-out delays are shown in the Table 2.2.4-1. Corresponding future traffic demands are described in Chapter 4 of this report. Finally, EDP benefits due to unrestricted climbs and optimal merging, as well as additional fuel savings for the aircraft not cleared to their assigned flight levels, are shown in Chapter 5 of this report.

It should be noted that some future alternatives, such as Reduced Vertical Separation Minima (RVSM), would make more flight levels available for NAS users. RVSM will decrease effective traffic density, thus (possibly) decreasing climb-out delays. In fact, we learned from our conversations with controllers at Washington Center that they expect this reduction in climb-out times due to an increased number of available flight levels resulting from the introduction of domestic RVSM.

Table 2.2.4-1 Adjusted Climb-Out Delays for 2015

Airport	Terminal and Regional Traffic Volume Change (2015 vs. 1999)	Adjusted Delays per Aircraft (min)	
		Jet Aircraft	Turboprop Aircraft
ATL	1.56	1.93	1.87
BDL	1.32	0.75	0.22
BNA	1.72	N/A	N/A
BOS	1.32	1.04	N/A
BWI	1.43	2.45	0.30
CLE	1.51	N/A	N/A
CLT	1.47	0.21	0.16
COS	1.77	N/A	N/A
CVG	1.64	N/A	N/A
DAB	1.55	N/A	N/A
DCA	1.44	0.98	0.35
DEN	1.70	1.77	N/A
DFW	1.74	0.94	N/A
DTW	1.56	1.28	1.00
EWR	1.42	1.78	N/A
FLL	1.59	N/A	N/A
HOU	1.78	0.84	N/A
HPN	1.37	1.41	N/A
IAD	1.43	0.34	0.23
IAH	1.77	0.64	N/A
JFK	1.39	0.26	N/A
LAS	2.05	1.19	N/A
LAX	2.00	1.92	N/A
LGA	1.37	1.41	N/A
LGB	1.99	N/A	N/A
MCO	1.57	1.87	N/A
MDW	1.73	N/A	N/A
MEM	1.68	N/A	N/A
MIA	1.59	0.41	N/A
MSP	1.53	0.78	N/A
OAK	1.79	0.97	N/A
ORD	1.70	1.73	N/A
PDX	1.29	0.85	N/A
PHL	1.43	1.43	N/A
PHX	1.90	N/A	N/A
PIT	1.49	2.19	N/A
SAN	2.02	0.12	N/A
SEA	1.28	0.94	N/A
SFO	1.79	2.20	N/A
SLC	1.86	1.08	N/A
STL	1.69	N/A	N/A
TEB	1.40	0.84	N/A

2.2.5 Benefits Annualization

Given the duration of this project and the need to evaluate EDP benefits at multiple sites, we used a demand scenario that reflected a single representative day. Annualizing EDP benefits from single day required that we consider the variation in demand between days of the week and between seasons. We used the ratio of the number of departures at the airport during the single day under study and the average number of departures at the same facility throughout the year. Corresponding demands are shown in Tables 4.1-1 and 4.1-2. The process for performing this annualization was simply to multiply the benefits for the single analysis day by the appropriate conversion factor determined by analyzing readily available flight data for the year in question and then multiplying by 365.

2.3 Reduction of Taxi-Out Delays Due to Interaction Between EDP and Ground DSTs

It is anticipated that EDP will be interoperable with surface DSTs, such as the National Surface Movement Tool (the current global name for the DSTs formerly known as SMA-1, the Passive Surface Movement Advisor; SMA-2, the Enhanced Surface Movement Advisor; and SMA-3, the Active Surface Movement Advisor) requiring an interface between surface DSTs and EDP. The surface DSTs will share information with EDP regarding the aircraft in the departure queue. EDP will use this information to calculate an aircraft departure time, which will be optimized given the airborne constraints. The surface DSTs will use this time to determine an optimal taxi scheme, and then send information to EDP as a revised departure queue. The two systems will iterate until an optimal solution is negotiated.

SMA-1 extracts data relevant to surface movements from several sources and distributes them to operational users.

SMA-2 will provide information from many sources – such as Automated Radar Terminal System (ARTS) data, airline schedule and gate data, flight plans, Aeronautical Radio Incorporated (ARINC) Communications Address and Reporting System (ACARS) data on flight status, runway status data – to optimize the use of surface movement resources, by means of collaborative decision-making among surface traffic managers and airlines. Specific benefits will include runway load balancing and managed competition for taxiway resources.

SMA-3 was added to the AATT product list development schedule behind SMA-1, paralleling the AFAST tool (Active Final Approach and Spacing Tool), which represents the 2nd version of PFAST (Passive Final Approach and Spacing Tool) and includes additional (harder to implement, and thus occurring later in the development plan) dynamic responses and active control of the problem domain. This includes prompting the controller when to tell the pilots to turn or change speed. The ASMA will suggest courses of action to ramp and air traffic controllers based on its status information and prediction capabilities. There isn't much direct information available on this original concept of the ASMA, but the name alone implies that it would have an "active" component to its makeup, similar to AFAST's enhancements over PFAST.

USA TODAY analyzed computer records of DOT data on 5.41 million flights at 200 airports to find out how long planes wait to take off after passengers have boarded. Some of its findings are listed in the Table 2.3-1. From this table one can see that causes of potential taxi-out delays can be both on the ground an in the air.

Table 2.3-1 Taxi-Out Delays, Their Causes and Remedies

Airport	Average Gate to Takeoff Time (min)	Special Problems	Remedy
Newark International	25.3	Congested airspace because Newark is one of four busy airports in the New York metro area. Also, Newark's two main runways for departure and arrival are just 800 feet apart. (The FAA requires runways to be 4,300 feet apart for simultaneous landings and takeoffs during bad weather.)	Newark's main departure runway is being extended to accommodate more departures by bigger jets. Completion: 1999
Honolulu International	19.2	Four runways are located on a reef three-quarters of a mile from the airport gates to reduce noise in the city of Honolulu.	
La Guardia	20.5	Congested airspace. Just 15 miles from Newark and 10 miles from Kennedy. La Guardia's two 7,000-foot runways intersect, so arriving and departing traffic cross.	The FAA has proposed redirecting air traffic at the New York-area airports.
JFK International	24.8	Congested airspace and heavy international traffic on its four runways.	The FAA has proposed redirecting air traffic at the New York- area airports.
Lambert St. Louis International	18.0	Five runways, but they are close together, making simultaneous landings and takeoffs difficult in bad weather	Waiting for FAA approval for a sixth runway that would increase capacity during bad weather.
San Francisco International	16.7	Two sets of parallel runways (two for departure and two for takeoff) are just 750 feet apart, the closest runways at a major U.S. airport. During bad weather, the maximum number of landings and takeoffs is cut from 60 an hour to 30.	Plans being made for another runway. Construction expected to start in three to five years.
San Diego International Lindberg Field	11.7	Has one runway, which the San Diego airport says is the busiest single runway in the USA.	Studying plans to build a second runway.
SLC International	15.9	Terminal and ramp areas not designed for airline hub-and-spoke system, which typically has large banks of flights departing or arriving at the same time. Just one plane at a time can move from the ramp area onto the taxiway.	Building a new terminal and concourse that should ease congestion on the ramp area. Completion date: 2003.

Table 2.3-2 and Figure 2.3-1 show percentage of operations (separately departures and arrivals) delayed over 15 minutes at 42 proposed AATT sites in June 1999. This data was derived from Air Travel Consumer Report)

Table 2.3-2 Percentage of Delayed Operations (June 1999)

Airport	Percentage of Delayed Operations	
	Arrivals	Departures
EWR	35.30	25.30
LAX	30.80	21.70
LGA	35.00	24.00
MSP	25.40	23.90
ORD	35.40	31.20
STL	28.70	31.30
BOS	31.00	22.50
CLE	28.80	20.00
CVG	23.40	18.50
MIA	40.20	30.90
PHX	25.10	25.20
SEA	31.50	23.30
SFO	30.70	20.10
SAN	26.90	18.10
ATL	31.90	27.00
SLC	21.50	16.10
BWI	29.80	26.50
CLT	25.60	26.70
DFW	28.10	27.20
DTW	21.50	22.10
DCA	29.10	19.70
JFK	28.50	17.70
LAS	25.50	24.60
MCO	29.70	21.20
MEM	19.00	15.80
MDW	27.30	31.30
PDX	24.10	15.30
BNA	24.70	20.40
COS	35.90	15.70
IAD	35.20	26.60
BDL	29.80	18.10
DAB	23.30	21.10
DEN	27.30	23.10
FLL	36.50	23.00
HPN	43.30	27.80
IAH	31.70	26.90
LGB	29.30	7.90
HOU	26.60	29.40
OAK	20.00	18.50
PIT	26.10	27.10
PHL	34.80	30.30
TEB	N/A	N/A

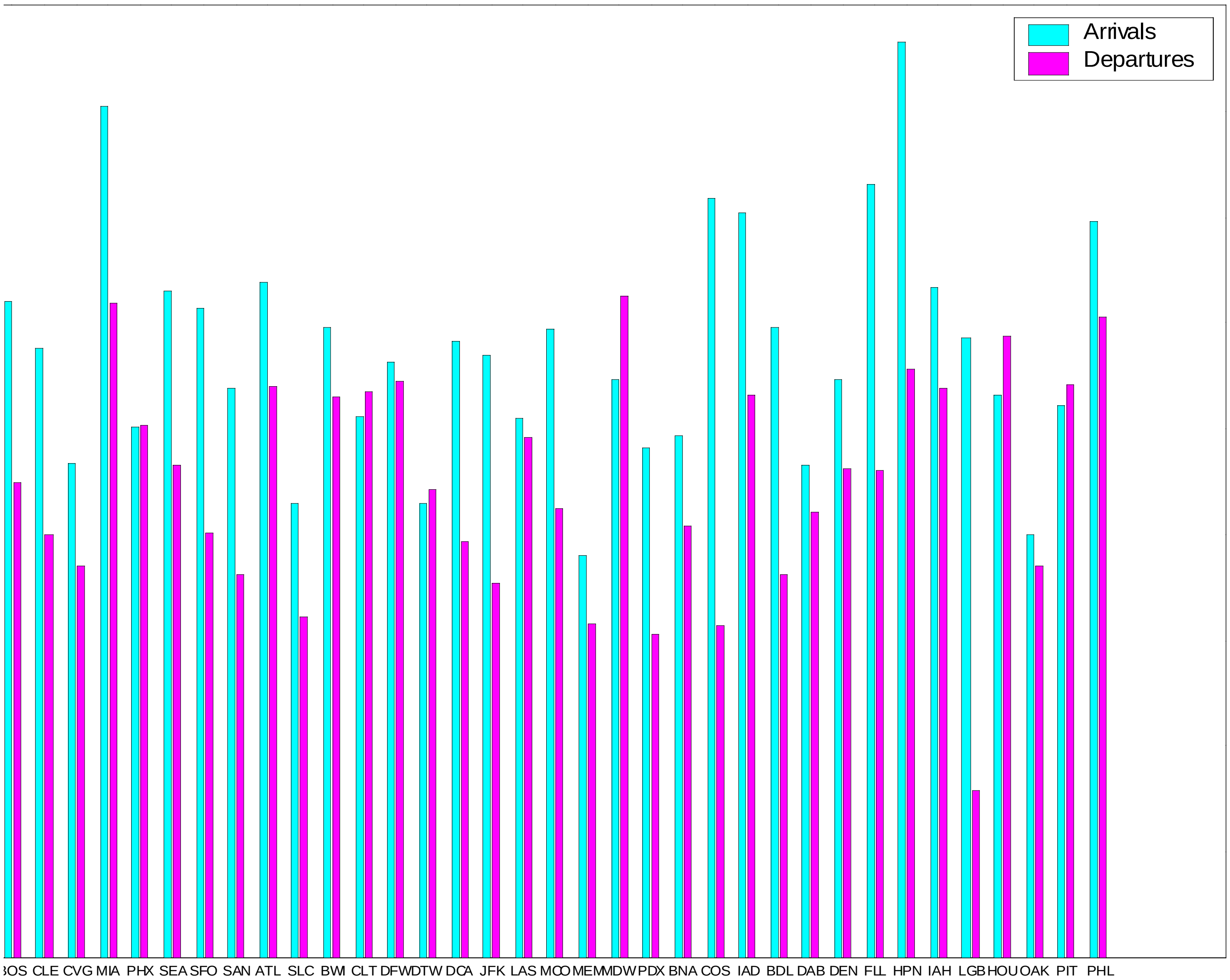


Figure 2.3-1 Percentage of Delayed Operations (June 1999)

Delay, the difference between actual travel time and unimpeded travel time, is the traditional measure of NAS performance. FAA's 1999 ACE plan outlines the four basic causes of delay:

- Weather
- Terminal traffic volume
- Equipment outage
- Runway closure

Weather and terminal traffic volume were cited as the primary causes of taxi-out delays. Below are several examples of airport demand-capacity issues causing some of these delays even under perfect weather conditions:

- At Dallas/Fort Worth International Airport, airlines schedule 57 operations in a 10-minute period around the 6 pm peak. Airport capacity is 35 operations. Thus, even if the weather is perfect across the United States and there are no equipment problems, 22 flights will be automatically delayed during this 10-minute period.

- At Minneapolis/St.Paul International, 44 operations are scheduled in a 15-minute period. Because airport capacity is 30 operations, 14 of these planes will be delayed under perfect conditions.

- At Atlanta the runways are overbooked nearly one-third of the time. Specifically, 22 of the 72 10-minute segments in a 12-hour period are over capacity.

In acknowledging that delays are inevitable from over scheduling at peak times, airlines pad their schedules to maintain their on-time performance. For example, a flight from Washington, D.C. to Atlanta takes a little over an hour in actual flight time. But, airlines schedule the flight to last two hours because they know the runways will be overbooked on departure and/or arrival.

To achieve a competitive advantage and reduce costs, airlines have increased the number of smaller jet aircraft with frequently scheduled flights. This has resulted in crowded airports and increased en-route congestion. These aircraft use the same airspace as larger jets but fly at a slower pace.

Consolidated Operations and Delay Analysis System (CODAS) data, along with data from an ongoing CSSI weather-related delays study and CSSI airport capacity data, has being utilized to obtain the average taxi-out delays that occur as a result of terminal and regional airspace congestion. The process of obtaining this data is outlined in the following steps:

1. Use CODAS traffic data to obtain actual and scheduled arrival and departure counts on a 15-minute basis.

2. Use CODAS delays data to extract cumulative taxi-out delays for each 15-minute interval.

3. Use CODAS weather data to obtain meteorological conditions on a 15-minute basis to identify times of instrument flight rules (IFR) and visual flight rules (VFR) operations at the facility.

4. Exclude the times when departure demand exceeded corresponding capacity (IFR or VFR), taking into account arrival demand.

5. Identify ground delay programs, equipment outage and runway closures using FAA's Operations Network (OPSNET) data to eliminate delays that resulted from them. (This data was not readily available to us for June 14, 1999. However, given the overall impact of these causes, according to FAA's ACE 1999 Plan, is insignificant compare to weather and volume, we can assume that our final results are not impacted significantly by the absence of this data).

6. Steps 1-5 enable us to the certain extend to extract taxi-out delays due to airspace congestion, discounting those due to weather and airport congestion. Table 2.3-2 described airport meteorological conditions (in percent of IFR and VFR during the day) and demand-capacity relationship (percent of time during the day when demand exceeded capacity at the airport).

Table 2.3-2 Airport Meteorological Conditions and Demand-Capacity Relationship (June 14, 1999) from CODAS

Airport	VFR (%)	IFR (%)	Demand>Capacity (%)
ATL	96.88	3.13	14.58
BDL	43.75	56.25	0
BNA	70.83	29.17	0
BOS	75.00	25.00	5.21
BWI	76.04	23.96	7.29
CLE	64.58	35.42	16.67
CLT	100.00	0	0
COS	66.67	33.33	0
CVG	21.88	78.13	16.67
DAB*	N/A	N/A	N/A
DCA	76.04	23.96	6.25
DEN	98.96	1.04	0
DFW	76.04	23.96	3.13
DTW	38.54	61.46	8.33
EWR	40.63	59.38	13.54
FLL	95.83	4.17	0
HOU	100.00	0	0
HPN*	N/A	N/A	N/A
IAD	50.00	50.00	10.42
IAH	100.00	0	10.42
JFK	59.38	40.63	6.25
LAS	100.00	0	0
LAX	89.58	10.42	5.21
LGA	52.08	47.92	14.58
LGB*	N/A	N/A	N/A
MCO	100.00	0	0
MDW	81.25	18.75	7.29
MEM	59.38	40.63	3.13
MIA	95.83	4.17	2.08
MSP	91.67	8.33	10.42
OAK	100.00	0	0
ORD	100.00	0	22.92
PDX	100.00	0	0
PHL	48.96	51.04	20.83
PHX	100.00	0	10.42
PIT	83.33	16.67	4.17
SAN	51.04	48.96	0
SEA	100.00	0	4.17
SFO	31.25	68.75	9.38
SLC	95.83	4.17	0
STL	100.00	0	14.58
TEB*	N/A	N/A	N/A

* Not in CODAS data

Finally, the results are presented in Table 2.3- 2 in terms of average minutes of taxi-out delay per flight for all 42 proposed AATT sites.

Table 2.3-2 Average Taxi-Out Delays

Airport	Total Average Taxi Out Delay (min)	Average Taxi-Out Delay Due to Airspace Congestion (min)
ATL	11.81	3.68
BDL	3.52	3.52
BNA	2.47	2.47
BOS	7.07	5.48
BWI	4.49	2.54
CLE	2.97	0.63
CLT	2.94	2.94
COS	2.72	2.72
CVG	5.74	1.43
DAB*	1.18	1.18
DCA	6.19	4.20
DEN	5.12	5.12
DFW	8.35	8.03
DTW	12.18	6.71
EWR	8.90	3.31
FLL	1.81	1.81
HOU	1.45	1.45
HPN*	4.04	4.04
IAD	5.63	3.20
IAH	4.30	1.73
JFK	8.10	4.22
LAS	5.24	5.24
LAX	4.61	3.41
LGA	12.99	5.74
LGB*	1.11	1.11
MCO	1.77	1.77
MDW	3.56	2.73
MEM	4.13	2.57
MIA	1.57	1.16
MSP	6.46	2.12
OAK	2.09	2.09
ORD	6.63	1.58
PDX	2.32	2.32
PHL	11.27	3.56
PHX	4.84	2.29
PIT	4.02	2.65
SAN	1.81	1.81
SEA	2.86	2.49
SFO	4.74	2.65
SLC	3.20	3.20
STL	6.08	1.96
TEB*	3.80	3.80

* From our weather study data, nearest airport weather observations, and traffic counts from ETMS data.

These delays correlate well with information on potential delays for different phases of flight provided by Landrum & Brown, Inc. for the 1999 ACE Plan. The magnitude of potential taxi-out delays is estimated to be in the range of 0 to 60 minutes.

The cost savings of ameliorating these delays using EDP advisories to the ground DSTs, described in Chapter 2.2.3, are shown in Chapter 5 for a baseline year.

3 Environmental Impacts and Constraints of EDP

3.1 Overview

This section describes the environmental impacts that need to be addressed in order to implement EDP. The following discussion is mainly an overview of three European reports [SO1, SO2, and SO3]. These reports are the summary of the over than 2 years long effort of various European Agencies in studying of optimization procedures for decreasing the impacts of noise and emissions around the airports with primary concentration on the noise abatement procedures.

Increasing the distance flown in climb increases fuel consumption and therefore increases carbon dioxide, water vapor and nitrogen oxide emissions.

The balance in engine emissions has to be taken into account not only for environmental assessments but also for possible economical impacts. In Europe, for example, many airports will use financial incentives based on gaseous emissions. Currently these airports use engine certification standards that do not take actual procedures into account.

While aircraft have become much cleaner over the last 20 years, air quality around airports is still a valid concern. The new Stage 3 aircraft have much higher nitrous oxides (NOx) emissions. This can be a problem for airports with long departure delays and queue times.

Using cutback power and/or delaying acceleration and/or climb at takeoff reduce fuel consumption at low altitudes and CO_2, H_2O and NO_x emissions. Maintaining the highest slope for climb generally, depending on aircraft performance, reduces fuel consumption and therefore the amount of fuel that needs to be carried. This reduces the aircraft weight during operation and thus the noise projected on the ground.

Some noise-abatement procedures increase flight time and fuel consumption because the flight plan is extended to avoid a noise-sensitive area. For example, the new SID at Madrid Barajas used by aircraft bound for America was extended by 12 miles in order to avoid flying over high-cost residential areas. The cost increase for the airlines was estimated to be $20 million a year. Another example is Ontario, California, where nearby upscale communities require special noise-abatement departure procedures that require flights to fly longer at lower altitudes with lower power settings, thus keeping them in their departure stage longer.

3.2 Parameters Allowing Faster Climbs and Reduction of Noise on the Ground

1. Takeoff configuration: a cleaner configuration has a better climb gradient. A lower flap setting enhances the climb gradient and thus quickly increases the distance between the aircraft and sensitive areas.

2. Takeoff speed: a higher takeoff speed allows using a cleaner takeoff configuration but the roll length increases as well. For a given configuration, the lower speed allows the higher climb gradient. On the other hand, a higher speed reduces the acceleration segment later. For noise-abatement purposes, the airspeed should be the one that provides the maximum altitude in the minimum distance (the maximum angle speed), giving the highest distance increase between the aircraft and sensitive areas.

3. Reduction height: height at which the thrust is reduced from takeoff to climb thrust. The higher this parameter is, the higher the climb segment ends. At 1,000 or 1,500 feet, depending on the procedure, thrust is reduced to decrease noise emission. New FAA procedures distinguish between aircraft equipped with and without thrust-restoration system. Aircraft with a thrust restoration system can achieve a higher reduction under the assumption of quick system response in case of engine failure to provide the necessary thrust reduction to continue climbing.

4. Climb thrust: reducing climb thrust decreases the slope as well as the noise level generated by the engine. Noise produced by thrust changes proportionally with the eighth power of the exhaust gas speed.

5. Acceleration height: at this height, usually 1,500 ft to 3,000 ft, aircraft accelerate to en-route climb speed and retract flaps on schedule. At acceleration height, the noise should be lowered to a pitch attitude slightly higher than one-half the takeoff value. This will provide a suitable climb gradient while allowing the speed to increase for flap reduction. Acceleration should be continuous through the flap retraction to provide an adequate maneuvering margin.

3.3 Noise-Abatement Concepts for Departure Operations

The following solutions may improve departure procedures from a noise standpoint:

- Optimization of the noise-abatement takeoff procedures for a particular airport or runway, with respect to thrust-reduction altitude and/or flap-retraction schedule

- Use of full takeoff compared to currently often-derated takeoff thrust. Successful application of this procedure depends on a detailed examination and cost study of the potential for increased maintenance, engine wear, and fuel consumption when continuously using full takeoff thrust.

- Optimization of takeoff flap settings with respect to noise

- Optimization of horizontal SID routings to avoid noise-sensitive areas, based on current technology (RNAV) or based on coming area-navigation capabilities (such as advanced curved RNAV procedures)

- Reductions of average track dispersion to better avoid the areas affected by takeoff noise

- For noise-sensitive areas farther away from the airport, introducing speed restrictions during climb-out (below 10,000'), which could increase the climb gradient instead of acceleration to 250 knots

- Optimized and segregated departure routes for turboprop and jet aircraft.

- Better and more consistent use of FMS for departure routing (However, FMS is not yet certified for use in terminal areas.)

4 Scenario Descriptions

All demand scenarios used for this study were constructed using the scenario generation capabilities of National Airspace Resource Investment Model (NARIM) [CS1], specifically NARIM's ETMS Parser and OPGEN components. Year 2015 demand was developed using the FAA's Future Demand Generator (FDG). The FDG uses ETMS data for the baseline day (June 14, 1996) and the Terminal Area Forecast (TAF) [FA1], generated by the FAA's Office of Aviation Policy and Plans (APO), as input. Since the TAF forecasts to 2013 only, we extrapolated linearly to generate the scheduled demand growth and the GA/military demand growth for 2015. The FDG creates demand schedules for modeled airports subject to their VFR capacity. Because changes such as planned airport improvements or procedural changes will impact airport capacity, the impacts of these changes anticipated to take place by 2015 were considered for the airports modeled in the FDG. Projecting these changes in airport capacity reflects work previously done by CSSI and is provided in Appendix A of [CO1]. Corresponding capacities are listed in Appendix E.

4.1 Baseline

The baseline scenario day used in our study was Monday, June 14, 1999. According to NOAA data, the winds for this day were nearly calm with some thunderstorms in the Ohio Valley. There were no EDCT programs in place. This day was selected to generate the most representative EDP benefits, benefits that would not be skewed by significantly bad weather at any of the analysis locations. The as-flown version of the baseline demand was used to perform this analysis. This version of the baseline demand is generated from departure (DZ) messages, arrival (AZ) messages and position update (TZ) messages extracted from ETMS data using NARIM's ETMS Parser. Because this demand scenario is generated using TZ messages, the resultant 4-D trajectory reflects controller intervention actions taken for a variety of reasons (such as conflict resolution and flow management).

This version of the baseline demand is generated from Departure (DZ) messages, Arrival (AZ) messages and Position Update (TZ) messages extracted from ETMS data using NARIM's ETMS Parser. Since this demand scenario is generated using TZ messages, the resultant 4-D trajectory reflects controller intervention actions taken for a variety of reasons (such as conflict resolution, flow management).

Figures 4.1-1 through 4.1-6 show daily demand for all 42 proposed AATT sites derived from ETMS data and thus reflecting only IFR flights.

Figure 4.1-1 Daily Traffic Demand (EWR, LAX, LGA, MSP, ORD, STL, BOS, CLE)

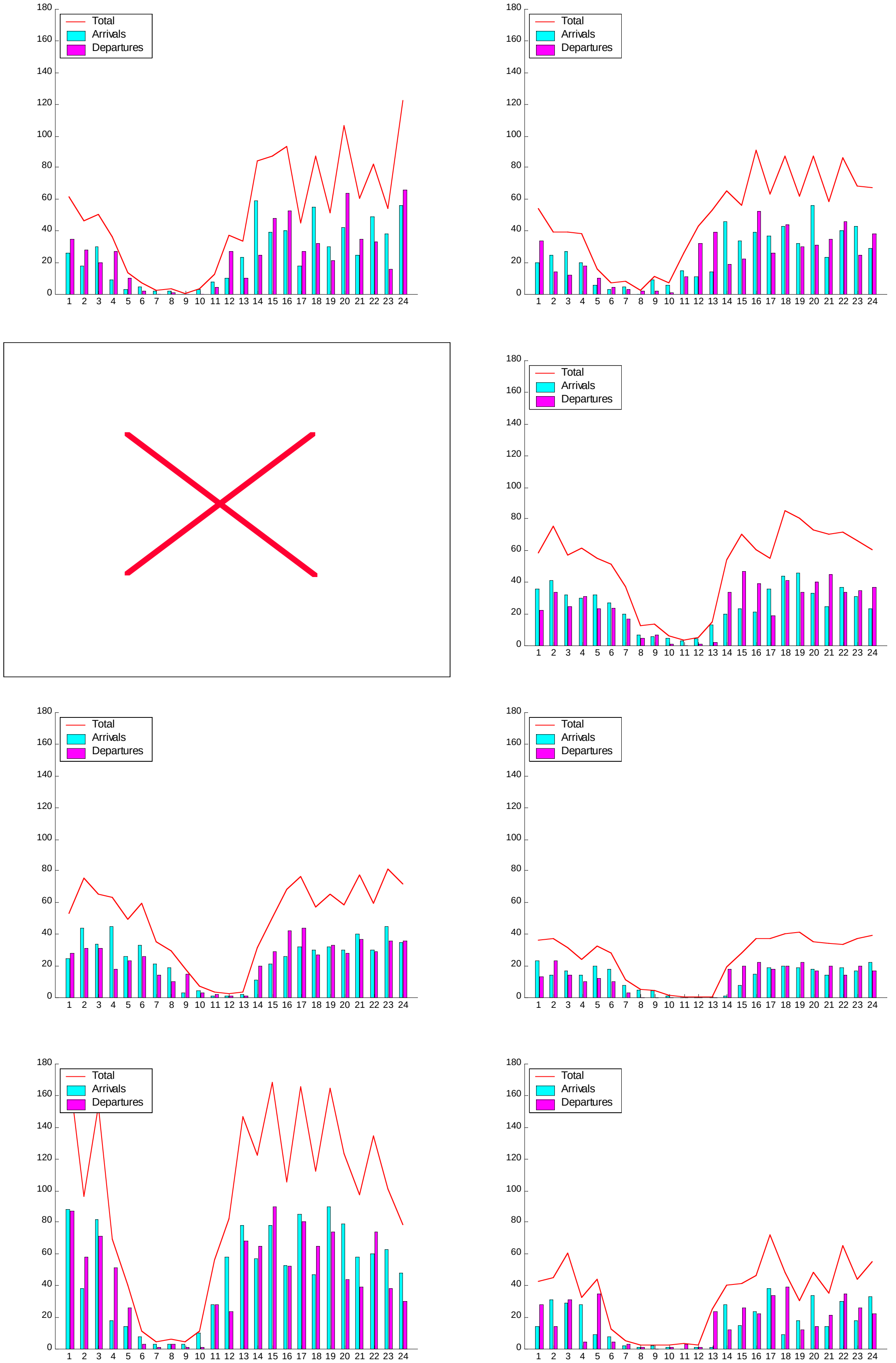


Figure 4.1-2 **Daily Traffic Demand (CVG, MIA, PHX, SEA, SFO, SAN, ATL, SLC)**

Figure 4.1-3 **Daily Traffic Demand (BWI, CLT, DFW, DTW, DCA, JFK, LAS, MCO)**

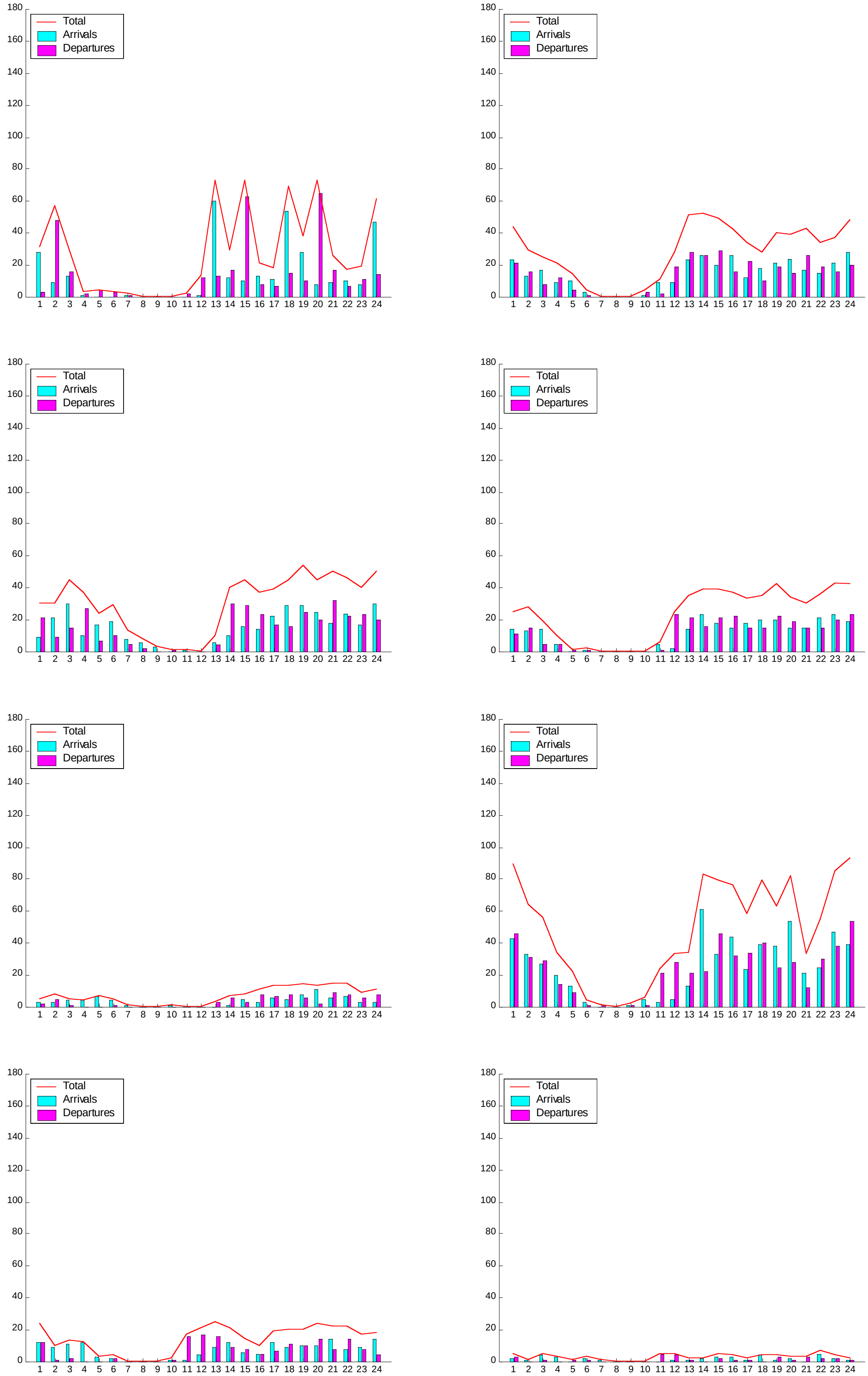


Figure 4.1-4 **Daily Traffic Demand (MEM, MDW, PDX, BNA, COS, IAD, BDL, DAB)**

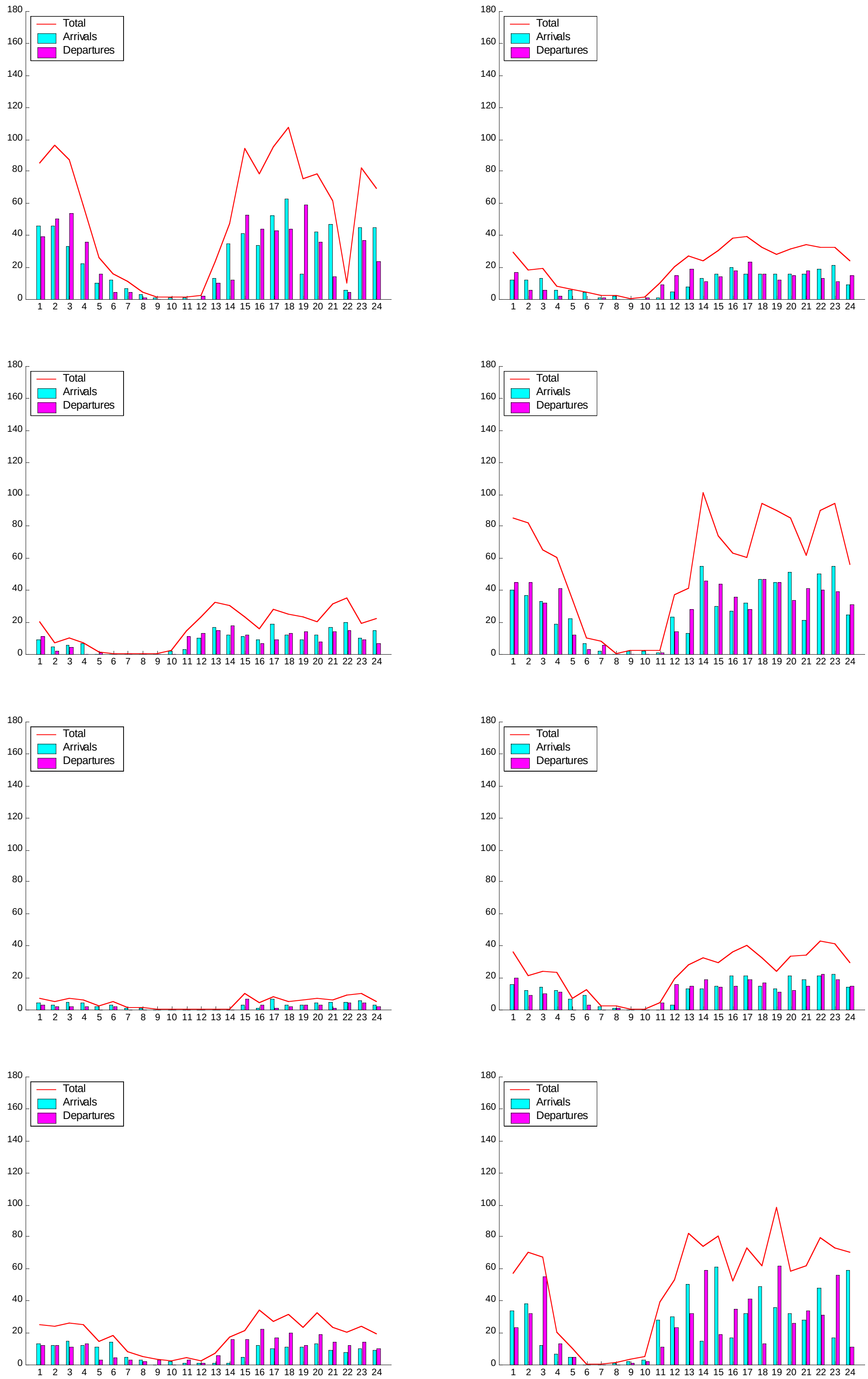
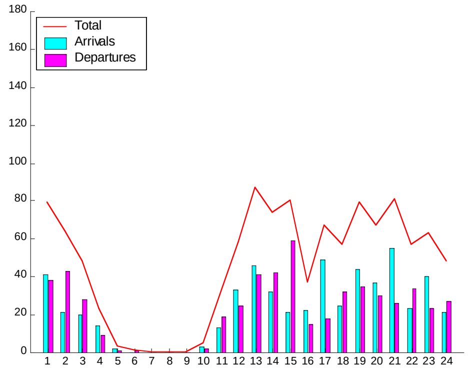


Figure 4.1-5 **Daily Traffic Demand (DEN, FLL, HPN, IAH, LGB, HOU, OAK, PIT)**



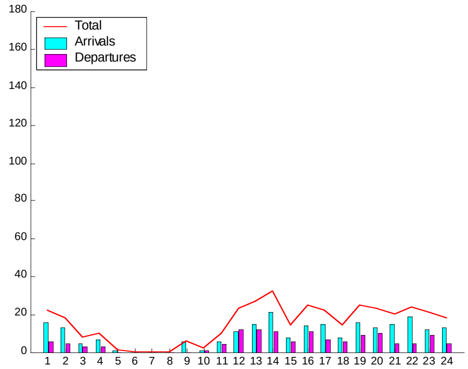


Figure 4.1-6 **Daily Traffic Demand (PHL, TEB)**

The following table shows demand for all 42 airports for June14, 1999. The number of annual departures is derived from ETMS data, thus reflecting only controlled flights.

Table 4.1-1 Baseline Demand

Airport	Annual Departures	June 14, 1999 Daily Demand		
		Arrivals	Departures	Total
ATL	429483	1149	1073	2222
BDL	65638	173	165	338
BNA	99038	275	286	561
BOS	230561	735	690	1425
BWI	133384	373	342	715
CLE	146756	428	401	829
CLT	204180	545	553	1098
COS	30013	85	83	168
CVG	217835	590	584	1174
DAB	11776	39	32	71
DCA	138694	392	361	753
DEN	234625	621	586	1207
DFW	398828	1090	1122	2212
DTW	239367	728	703	1431
EWR	216337	606	576	1182
FLL	97194	248	242	490
HOU	90669	284	267	551
HPN	67344	205	183	388
IAD	211196	591	564	1155
IAH	211883	639	658	1297
JFK	162908	461	429	890
LAS	176203	513	468	981
LAX	364056	1062	1035	2097
LGA	173594	536	505	1041
LGB	15088	63	41	104
MCO	156327	446	434	880
MDW	114857	345	332	677
MEM	167549	323	338	661
MIA	215305	583	550	1133
MSP	234524	688	695	1383
OAK	86823	189	245	434
ORD	426409	1228	1226	2454
PDX	140151	364	358	722
PHL	214395	562	548	1110
PHX	228943	616	613	1229
PIT	202856	604	584	1188
SAN	104694	296	293	589
SEA	198708	595	597	1192
SFO	205963	590	564	1154
SLC	147954	388	412	800
STL	234636	729	688	1417
TEB	47840	235	130	365

Table 4.1-2 Baseline and Future Demands

Airport	1999 Annual Departures			2015 Annual Departures
	All (TAF) [1]	IFR (ETMS) [2]	All/IFR	All (TAF) [1]
ATL	439653	429483	1.02	657255
BDL	89765	65638	1.37	128000
BNA	115870	99038	1.17	156669
BOS	258183	230561	1.12	293891
BWI	146392	133384	1.1	200485
CLE	163859	146756	1.12	250684
CLT	225884	204180	1.11	278104
COS	56552	30013	1.88	69047
CVG	229527	217835	1.05	369717
DAB	123762	11776	10.51	162919
DCA	165069	138694	1.19	175727
DEN	249070	234625	1.06	360853
DFW	437700	398828	1.1	660256
DTW	271172	239367	1.13	411043
EWR	231251	216337	1.07	303217
FLL	134357	97194	1.38	177938
HOU	128411	90669	1.42	150204
HPN	80234	67344	1.19	99350
IAD	219130	211196	1.04	288406
IAH	229371	211883	1.08	378996
JFK	177731	162908	1.09	207075
LAS	247160	176203	1.4	420666
LAX	381414	364056	1.05	585763
LGA	182589	173594	1.05	206459
LGB	127265	15088	8.43	158642
MCO	182670	156327	1.17	307499
MDW	143626	114857	1.25	191675
MEM	183578	167549	1.1	284221
MIA	265142	215305	1.23	367742
MSP	248545	234524	1.06	391190
OAK	193499	86823	2.23	242711
ORD	449663	426409	1.05	575662
PDX	153768	140151	1.1	233479
PHL	239572	214395	1.12	350400
PHX	263119	228943	1.15	439974
PIT	229081	202856	1.13	284348
SAN	111649	104694	1.07	170754
SEA	205663	198708	1.04	280876
SFO	217316	205963	1.06	328015
SLC	184277	147954	1.25	299290
STL	251662	234636	1.07	344573
TEB	122312	47840	2.56	163396

[1] Calculated from the total number of operations (excluding over flights) in TAF assuming 50/50 split of departures and arrivals throughout the year

[2] Annual number of departures from CODAS calculated from ETMS data

High values of ALL/IFR ratios in the Table 4.1-2 indicates heavy general aviation traffic at corresponding airports. This is the case for DAB, LGB, and several other airports.

Table 4.1-3 IFR (ETMS) Aircraft Fleet Mix in % (June 14, 1999)

Airport	Engine Type			Aircraft Weight			Aircraft Category		
	Jet	Turb	Piston	Heavy	Large	Small	Comm	GA	Mil
ATL	85.65	13.70	0.65	12.02	76.51	11.46	97.95	2.05	0
BDL	69.09	26.67	4.24	1.82	78.18	20.00	84.85	15.15	0
BNA	69.93	16.43	13.29	0	66.08	33.92	75.17	22.73	2.10
BOS	55.94	34.49	9.57	8.12	68.26	23.62	96.81	2.90	0.29
BWI	70.18	27.19	2.63	1.75	83.04	14.91	91.52	8.48	0
CLE	61.60	37.16	1.25	0.75	49.88	49.38	96.51	3.24	0.25
CLT	69.08	27.67	3.25	2.71	79.39	17.90	91.32	8.68	0
COS	81.93	10.84	7.23	0	69.88	30.12	69.88	20.48	9.64
CVG	86.47	12.67	0.86	4.11	82.36	13.53	97.60	2.40	0
DAB	46.88	3.13	46.88	0	21.88	78.13	15.63	81.25	3.13
DCA	77.56	20.50	1.94	1.11	82.83	16.07	82.83	16.90	0.28
DEN	75.09	23.38	1.54	7.85	72.53	19.62	98.63	1.37	0
DFW	73.08	26.83	0.09	3.83	86.90	9.27	99.38	0.62	0
DTW	78.66	19.77	1.56	4.69	90.04	5.26	95.45	4.55	0
EWR	86.11	13.89	0	9.90	78.82	11.28	98.09	1.74	0.17
FLL	74.38	20.25	5.37	5.37	68.18	26.45	86.78	13.22	0
HOU	88.39	7.49	4.12	0	77.15	22.85	79.03	19.48	1.50
HPN	55.19	36.07	8.74	0	43.72	56.28	46.99	52.46	0.55
IAD	56.03	43.26	0.71	8.16	49.11	42.55	92.02	7.98	0
IAH	81.00	18.54	0.46	2.28	80.40	17.33	96.20	3.80	0
JFK	68.76	31.24	0	42.66	41.03	16.08	98.83	1.17	0
LAS	92.95	6.84	0.21	5.13	86.32	8.55	89.10	10.68	0.21
LAX	70.72	29.18	0.10	18.07	59.03	22.90	98.16	1.74	0.10
LGA	76.04	23.17	0.79	3.96	87.72	8.32	96.63	3.17	0.20
LGB	75.61	12.20	12.20	2.44	60.98	36.59	58.54	39.02	2.44
MCO	80.41	18.89	0.69	7.60	73.96	18.43	95.85	4.15	0
MDW	82.83	11.75	5.12	0.30	71.69	28.01	80.42	19.28	0.30
MEM	61.83	32.25	5.92	2.07	74.26	23.37	83.14	16.27	0.59
MIA	72.18	26.91	0.91	18.36	70.00	11.64	96.36	3.09	0.55
MSP	76.12	22.88	1.01	2.73	88.35	8.92	92.09	7.48	0.43
OAK	74.29	4.49	21.22	2.45	67.76	29.80	76.73	22.86	0.41
ORD	89.31	10.44	0.16	11.50	76.59	11.75	97.80	2.04	0.16
PDX	58.94	37.43	3.63	3.35	74.86	21.51	94.13	5.03	0.84
PHL	70.07	28.83	1.09	3.83	81.39	14.78	93.25	6.75	0
PHX	86.79	12.72	0.49	1.47	89.89	8.65	96.57	3.10	0.33
PIT	55.82	43.66	0.51	2.05	76.03	21.92	96.23	3.42	0.34
SAN	72.01	26.62	1.37	3.75	73.04	23.21	94.88	5.12	0
SEA	66.67	33.17	0.17	7.04	81.74	11.22	99.50	0.50	0
SFO	83.87	15.60	0.53	17.91	64.89	17.02	96.45	3.55	0
SLC	74.27	21.36	4.37	7.04	62.86	30.10	88.59	10.68	0.73
STL	77.03	22.24	0.73	0.73	78.20	21.08	97.38	2.62	0
TEB	73.85	12.31	13.85	0	30.00	70.00	10.00	87.69	2.31

4.2 Future

The demand scenario for the future time horizon is 2015 Baseline scenario. Departure times for future flights came from the FDG and en-route times were based on current flights with the same aircraft type between that O/D pair. Arrival times were derived from the departure time and time en route as opposed to being obtained from the FDG. Flight tracks for future flights were randomly assigned from existing flight tracks for similar aircraft between that origin and destination.

Since the aircraft fleet will change between 1999 and 2015, we used a fleet forecast for 2015 developed by the FAA's Systems Engineering Technical Assistance (SETA) Contractor based on APO's fleet forecast. This forecast was used by the FAA's Office of System Architecture and Investment Analysis to perform a study of the emissions reductions attributable to Version 3.0 of the NAS Architecture. The required fleet mix for the future scenario was obtained by allocating model types to future flights (by stage length) to the maximum extent possible. Where this was not sufficient, the aircraft type of existing flights was revised to achieve the proper fleet mix for that stage length.

5 Results and Discussion

This section presents analysis results for both EDP primary contributions. Aggregate benefits are presented in Section 6.

5.1 Reduction of Climb-Out Time Due to Unrestricted Climbs into the En-route System and Optimally Merging Multiple Aircraft over a Common Fix or Through a Departure Gate

5.1.1 National-Level Benefits

The benefits of climb-out time reduction due to unrestricted climbs into the en-route system and optimally merging multiple aircraft over a common fix or through a departure gate are summarized in the Table 5.1.1-1 for baseline and horizon years.

Table 5.1.1-1 EDP National Benefits of Reduction of Climb-Out Time

EDP Benefits	Crew Time Savings (millions)	Fuel Savings (millions)	Maintenance Savings (millions)	Passenger Time Savings (millions)	Total - Without Passenger Time (millions)	Total - With Passenger Time (millions)
1999						
Benefits Due to Unrestricted Climbs and Optimal Merging	$56	$92	$41	$493	$186	$679
NPV (1997)	**$49**	**$80**	**$36**	**$431**	**$165**	**$596**
Additional Benefits Due to Fuel Savings of Aircraft Not Cleared to Their Assigned FL		$3.4				$3.4
NPV (1997)		**$3**				**$3**
2015						
Benefits Due to Unrestricted Climbs and Optimal Merging	$336	$557	$249	$2,963	$1,142	$4,105
NPV (1997)	**$114**	**$185**	**$84**	**$1,004**	**$383**	**$1,387**
Additional Benefits Due to Fuel Savings of Aircraft Not Cleared to Their Assigned FL		$6.9				$6.9
NPV (1997)		**$6**				**$6**

5.1.2 Airport-Specific Benefits

Focusing on the 42 key AATT implementation airports, Tables 5.1.2-1 through 5.1.2-4 summarize the benefits of climb-out time reduction due to unrestricted climbs into the en-route system and optimally merging multiple aircraft over a common fix or through a departure gate.

Table 5.1.2-1 Annual Savings due to Unrestricted Climbs and Optimal Merging (1999)

Airport	Annual $ Savings for 1999 (in 1997 $Millions)											
	Jet Aircraft						Turboprop Aircraft					
	Crew	O+F	M	Pass	Ó$_{\text{w/o pass}}$	Ó$_{\text{w pass}}$	Crew	O+F	M	Pass	Ó$_{\text{w/o pass}}$	Ó$_{\text{w pass}}$
ATL	6.61	10.47	4.68	57.99	**21.76**	**79.74**	0.16	0.27	0.23	0.99	**0.67**	**1.65**
BDL	0.25	0.43	0.21	2.28	**0.88**	**3.16**	0.01	0.01	0.01	0.05	**0.02**	**0.08**
BNA	0	0	0	0	**0**	**0**	0	0	0	0	**0**	**0**
BOS	1.21	1.92	0.84	10.40	**3.97**	**14.36**	0	0	0	0	**0**	**0**
BWI	1.85	3.00	1.39	16.71	**6.25**	**22.95**	0.01	0.03	0.03	0.14	**0.05**	**0.20**
CLE	0	0	0	0	**0**	**0**	0	0	0	0	**0**	**0**
CLT	0.32	0.52	0.24	2.93	**1.07**	**4.00**	0.02	0.03	0.03	0.14	**0.06**	**0.20**
COS	0	0	0	0	**0**	**0**	0	0	0	0	**0**	**0**
CVG	0	0	0	0	**0**	**0**	0	0	0	0	**0**	**0**
DAB	0	0	0	0	**0**	**0**	0	0	0	0	**0**	**0**
DCA	0.66	1.13	0.50	5.75	**2.30**	**8.04**	0.01	0.01	0.02	0.12	**0.05**	**0.17**
DEN	3.77	5.86	2.57	32.05	**12.20**	**44.25**	0	0	0	0	**0**	**0**
DFW	2.42	3.84	1.74	21.55	**8.00**	**29.54**	0	0	0	0	**0**	**0**
DTW	2.32	3.73	1.69	20.53	**7.74**	**28.27**	0.07	0.09	0.12	0.83	**0.30**	**1.13**
EWR	2.36	3.86	1.79	20.74	**8.01**	**28.73**	0	0	0	0	**0**	**0**
FLL	0	0	0	0	**0**	**0**	0	0	0	0	**0**	**0**
HOU	0.67	1.18	0.57	6.20	**2.41**	**8.62**	0	0	0	0	**0**	**0**
HPN	0.16	0.49	0.25	1.26	**0.90**	**2.18**	0	0	0	0	**0**	**0**
IAD	0.27	0.45	0.21	2.40	**0.91**	**3.31**	0.02	0.05	0.03	0.13	**0.10**	**0.24**
IAH	0.85	1.39	0.64	7.58	**2.90**	**10.47**	0	0	0	0	**0**	**0**
JFK	0.25	0.43	0.18	2.07	**0.84**	**2.91**	0	0	0	0	**0**	**0**
LAS	1.44	2.38	1.10	13.02	**4.92**	**17.94**	0	0	0	0	**0**	**0**
LAX	3.47	5.84	2.61	31.26	**11.91**	**43.17**	0	0	0	0	**0**	**0**
LGA	1.29	2.03	0.90	11.16	**4.22**	**15.39**	0	0	0	0	**0**	**0**
LGB	0	0	0	0	**0**	**0**	0	0	0	0	**0**	**0**
MCO	1.74	2.80	1.27	15.50	**5.80**	**21.30**	0	0	0	0	**0**	**0**
MDW	0	0	0	0	**0**	**0**	0	0	0	0	**0**	**0**
MEM	0	0	0	0	**0**	**0**	0	0	0	0	**0**	**0**
MIA	0.47	0.76	0.31	3.83	**1.55**	**5.38**	0	0	0	0	**0**	**0**
MSP	1.29	2.10	0.95	11.15	**4.35**	**15.49**	0	0	0	0	**0**	**0**
OAK	0.47	0.80	0.37	4.43	**1.64**	**6.08**	0	0	0	0	**0**	**0**
ORD	5.12	8.24	3.68	43.35	**17.05**	**60.40**	0	0	0	0	**0**	**0**
PDX	0.61	1.01	0.49	5.66	**2.11**	**7.77**	0	0	0	0	**0**	**0**
PHL	1.61	2.63	1.21	14.60	**5.44**	**20.06**	0	0	0	0	**0**	**0**
PHX	0	0	0	0	**0**	**0**	0	0	0	0	**0**	**0**
PIT	2.19	3.53	1.66	20.06	**7.38**	**27.44**	0	0	0	0	**0**	**0**
SAN	0.09	0.12	0.05	0.72	**0.26**	**0.98**	0	0	0	0	**0**	**0**
SEA	1.26	2.06	0.95	11.71	**4.28**	**15.99**	0	0	0	0	**0**	**0**
SFO	2.65	4.39	1.97	23.65	**9.01**	**32.65**	0	0	0	0	**0**	**0**
SLC	0.92	1.47	0.66	7.92	**3.05**	**10.98**	0	0	0	0	**0**	**0**
STL	0	0	0	0	**0**	**0**	0	0	0	0	**0**	**0**
TEB	0.02	0.33	0.18	0.07	**0.52**	**0.58**	0	0	0	0	**0**	**0**
TOTAL	**48.57**	**79.17**	**35.88**	**428.53**	**163.64**	**592.13**	**0.31**	**0.49**	**0.48**	**2.40**	**1.26**	**3.68**

Table 5.1.2-2 Additional Annual Fuel Savings for Aircraft not Cleared to Requested FL (1999)

Airport	Annual Fuel Savings (Millions lbs)			Annual Fuel Savings (1997 $Millions)		
	Jet Aircraft	Turboprop Aircraft	**Total**	Jet Aircraft	Turboprop Aircraft	**Total**
ATL	0.25	0.03	**0.27**	0.02	0.00	**0.02**
BDL	0.08	0	**0.08**	0.01	0	**0.01**
BNA	1.27	0.34	**1.61**	0.09	0.02	**0.11**
BOS	0.83	0.29	**1.12**	0.06	0.02	**0.08**
BWI	2.45	0.32	**2.77**	0.17	0.02	**0.19**
CLE	0.14	0.01	**0.15**	0.01	0.00	**0.01**
CLT	0.55	0	**0.55**	0.04	0	**0.04**
COS	0	0	**0**	0	0	**0**
CVG	1.00	0	**1.00**	0.07	0	**0.07**
DAB	0	0	**0**	0	0	**0**
DCA	2.37	0.61	**2.98**	0.17	0.04	**0.21**
DEN	0	0	**0**	0	0	**0**
DFW	1.25	0	**1.26**	0.09	0	**0.09**
DTW	0.67	0	**0.67**	0.05	0	**0.05**
EWR	3.48	0.34	**3.82**	0.24	0.02	**0.27**
FLL	0.88	0	**0.88**	0.06	0	**0.06**
HOU	0.24	0	**0.24**	0.02	0	**0.02**
HPN	1.70	0.06	**1.77**	0.12	0.00	**0.12**
IAD	3.10	0.36	**3.45**	0.22	0.03	**0.24**
IAH	1.10	0.06	**1.16**	0.08	0.00	**0.08**
JFK	0.65	0.31	**0.98**	0.05	0.02	**0.07**
LAS	0.08	0	**0.08**	0.01	0	**0.01**
LAX	0.04	0.12	**0.16**	0.00	0.01	**0.01**
LGA	4.50	0.49	**5.00**	0.31	0.03	**0.35**
LGB	0	0	**0**	0	0	**0**
MCO	0.39	0	**0.39**	0.03	0	**0.03**
MDW	0.08	0.02	**0.09**	0.01	0.00	**0.01**
MEM	0	0.90	**0.90**	0	0.06	**0.06**
MIA	0.14	0.13	**0.28**	0.01	0.01	**0.02**
MSP	0.59	0.40	**1.01**	0.04	0.03	**0.07**
OAK	0.44	0.01	**0.44**	0.03	0.00	**0.03**
ORD	2.33	0.14	**2.47**	0.16	0.01	**0.17**
PDX	0	0.03	**0.03**	0	0.00	**0.00**
PHL	2.71	0.76	**3.48**	0.19	0.05	**0.24**
PHX	0.32	0.17	**0.49**	0.02	0.01	**0.03**
PIT	0.11	0.23	**0.33**	0.01	0.02	**0.02**
SAN	0	0	**0**	0	0	**0**
SEA	0	0	**0**	0	0	**0**
SFO	0.61	0	**0.61**	0.04	0	**0.04**
SLC	0.06	0	**0.06**	0.00	0	**0.00**
STL	0.02	0	**0.02**	0.00	0	**0.00**
TEB	0.07	0.04	**0.13**	0.01	0.00	**0.01**
TOTAL	**34.49**	**6.19**	**40.72**	**2.41**	**0.43**	**2.85**

Table 5.1.2-3 Annual Savings due to Unrestricted Climbs and Optimal Merging (2015)

Airport	Annual $ Savings for 2015 (in 1997 $Millions)											
	Jet Aircraft						Turboprop Aircraft					
	Crew	O+F	M	Pass	Ó w/o pass	Ó w pass	Crew	O+F	M	Pass	Ó w/o pass	Ó w pass
ATL	15.42	24.42	10.91	135.24	**50.75**	**185.96**	0.37	0.63	0.54	2.31	**1.56**	**3.85**
BDL	0.47	0.81	0.40	4.29	**1.66**	**5.95**	0.02	0.02	0.02	0.09	**0.04**	**0.15**
BNA	0	0	0	0	**0**	**0**	0	0	0	0	**0**	**0**
BOS	1.82	2.88	1.26	15.63	**5.97**	**21.58**	0	0	0	0	**0**	**0**
BWI	3.62	5.88	2.72	32.72	**12.24**	**44.95**	0.02	0.06	0.06	0.27	**0.10**	**0.39**
CLE	0	0	0	0	**0**	**0**	0	0	0	0	**0**	**0**
CLT	0.58	0.94	0.43	5.30	**1.94**	**7.24**	0.04	0.05	0.05	0.25	**0.11**	**0.36**
COS	0	0	0	0	**0**	**0**	0	0	0	0	**0**	**0**
CVG	0	0	0	0	**0**	**0**	0	0	0	0	**0**	**0**
DAB	0	0	0	0	**0**	**0**	0	0	0	0	**0**	**0**
DCA	1.01	1.73	0.77	8.81	**3.53**	**12.33**	0.02	0.02	0.03	0.18	**0.08**	**0.26**
DEN	9.29	14.43	6.33	78.94	**30.05**	**108.99**	0	0	0	0	**0**	**0**
DFW	6.35	10.08	4.57	56.56	**21.00**	**77.53**	0	0	0	0	**0**	**0**
DTW	5.49	8.82	4.00	48.55	**18.30**	**66.85**	0.17	0.21	0.28	1.96	**0.71**	**2.67**
EWR	4.39	7.19	3.33	38.62	**14.91**	**53.49**	0	0	0	0	**0**	**0**
FLL	0	0	0	0	**0**	**0**	0	0	0	0	**0**	**0**
HOU	1.39	2.46	1.19	12.91	**5.02**	**17.95**	0	0	0	0	**0**	**0**
HPN	0.27	0.83	0.42	2.14	**1.53**	**3.70**	0	0	0	0	**0**	**0**
IAD	0.51	0.85	0.40	4.52	**1.71**	**6.23**	0.04	0.09	0.06	0.24	**0.19**	**0.45**
IAH	2.49	4.07	1.87	22.17	**8.48**	**30.62**	0	0	0	0	**0**	**0**
JFK	0.40	0.70	0.29	3.35	**1.36**	**4.71**	0	0	0	0	**0**	**0**
LAS	5.02	8.30	3.84	45.43	**17.17**	**62.59**	0	0	0	0	**0**	**0**
LAX	10.66	17.94	8.02	96.02	**36.58**	**132.60**	0	0	0	0	**0**	**0**
LGA	2.00	3.14	1.39	17.29	**6.54**	**23.84**	0	0	0	0	**0**	**0**
LGB	0	0	0	0	**0**	**0**	0	0	0	0	**0**	**0**
MCO	4.60	7.40	3.36	40.96	**15.33**	**56.29**	0	0	0	0	**0**	**0**
MDW	0	0	0	0	**0**	**0**	0	0	0	0	**0**	**0**
MEM	0	0	0	0	**0**	**0**	0	0	0	0	**0**	**0**
MIA	1.04	1.68	0.68	8.45	**3.42**	**11.86**	0	0	0	0	**0**	**0**
MSP	3.11	5.06	2.29	26.85	**10.48**	**37.30**	0	0	0	0	**0**	**0**
OAK	1.06	1.80	0.83	9.95	**3.68**	**13.65**	0	0	0	0	**0**	**0**
ORD	11.14	17.93	8.01	94.34	**37.11**	**131.45**	0	0	0	0	**0**	**0**
PDX	1.19	1.98	0.96	11.09	**4.13**	**15.22**	0	0	0	0	**0**	**0**
PHL	3.37	5.50	2.53	30.54	**11.38**	**41.96**	0	0	0	0	**0**	**0**
PHX	0	0	0	0	**0**	**0**	0	0	0	0	**0**	**0**
PIT	4.05	6.53	3.07	37.10	**13.65**	**50.75**	0	0	0	0	**0**	**0**
SAN	0.28	0.37	0.15	2.22	**0.80**	**3.03**	0	0	0	0	**0**	**0**
SEA	2.20	3.60	1.66	20.47	**7.48**	**27.95**	0	0	0	0	**0**	**0**
SFO	7.16	11.86	5.32	63.90	**24.34**	**88.21**	0	0	0	0	**0**	**0**
SLC	2.78	4.44	1.99	23.93	**9.21**	**33.17**	0	0	0	0	**0**	**0**
STL	0	0	0	0	**0**	**0**	0	0	0	0	**0**	**0**
TEB	0.04	0.62	0.34	0.13	**0.97**	**1.08**	0	0	0	0	**0**	**0**
TOTAL	**113.19**	**184.22**	**83.34**	**998.40**	**380.70**	**1379.04**	**0.67**	**1.08**	**1.04**	**5.32**	**2.78**	**8.14**

Table 5.1.2-4 Additional Annual Fuel Savings for Aircraft not Cleared to Requested FL (2015)

Airport	Annual Fuel Savings (Millions lbs)			Annual Fuel Savings (1997 $Millions)		
	Jet Aircraft	Turboprop Aircraft	**Total**	Jet Aircraft	Turboprop Aircraft	**Total**
ATL	0.58	0.07	**0.63**	0.05	0	**0.05**
BDL	0.15	0	**0.15**	0.02	0	**0.02**
BNA	2.95	0.79	**3.74**	0.21	0	**0.26**
BOS	1.25	0.44	**1.68**	0.09	0	**0.12**
BWI	4.80	0.63	**5.42**	0.33	0	**0.37**
CLE	0.32	0.02	**0.35**	0.02	0	**0.02**
CLT	1.00	0	**1.00**	0.07	0	**0.07**
COS	0	0	**0**	0	0	**0**
CVG	2.64	0	**2.64**	0.18	0.04	**0.18**
DAB	0	0	**0**	0	0.06	**0**
DCA	3.63	0.94	**4.57**	0.26	0.10	**0.32**
DEN	0	0	**0**	0	0	**0**
DFW	3.28	0	**3.31**	0.24	0	**0.24**
DTW	1.58	0	**1.58**	0.12	0	**0.12**
EWR	6.48	0.63	**7.11**	0.45	0.04	**0.50**
FLL	1.85	0	**1.85**	0.13	0.16	**0.13**
HOU	0.50	0	**0.50**	0.04	0	**0.04**
HPN	2.88	0.10	**3.00**	0.20	0	**0.20**
IAD	5.83	0.68	**6.49**	0.41	0.04	**0.45**
IAH	3.22	0.18	**3.39**	0.23	0	**0.23**
JFK	1.05	0.50	**1.59**	0.08	0.04	**0.11**
LAS	0.28	0	**0.28**	0.03	0.05	**0.03**
LAX	0.12	0.37	**0.49**	0	0.05	**0.03**
LGA	6.97	0.76	**7.75**	0.48	0.02	**0.54**
LGB	0	0	**0**	0	0	**0**
MCO	1.03	0	**1.03**	0.08	0.02	**0.08**
MDW	0.18	0.05	**0.21**	0.02	0	**0.02**
MEM	0	2.34	**2.34**	0	0.03	**0.16**
MIA	0.31	0.29	**0.62**	0.02	0	**0.04**
MSP	1.42	0.96	**2.43**	0.10	0.03	**0.17**
OAK	0.99	0.02	**0.99**	0.07	0	**0.07**
ORD	5.07	0.30	**5.38**	0.35	0	**0.37**
PDX	0	0.06	**0.06**	0	0.03	**0**
PHL	5.67	1.59	**7.28**	0.40	0	**0.50**
PHX	1.02	0.54	**1.56**	0.06	0.06	**0.10**
PIT	0.20	0.43	**0.61**	0.02	0	**0.04**
SAN	0	0	**0**	0	0	**0**
SEA	0	0	**0**	0	0	**0**
SFO	1.65	0	**1.65**	0.11	0.16	**0.11**
SLC	0.18	0	**0.18**	0	0	**0**
STL	0.05	0	**0.05**	0	0.03	**0**
TEB	0.13	0.07	**0.24**	0.02	0.10	**0.02**
TOTAL	**69.28**	**12.75**	**82.15**	**4.90**	**0.83**	**5.72**

5.2 Reduction of Taxi-Out Delays Due to Providing Advisories to the Ground DSTs

5.2.1 National-Level Benefits

The benefits of reducing taxi-out delays by providing advisories to the ground DSTs are summarized in the Table 5.2.1-1 for both the baseline and horizon years.

Table 5.2.1-1 National EDP Benefits of Reducing Taxi-Out Delays

EDP Benefits	Crew Time Savings (millions)	Fuel Savings (millions)	Maintenance Savings (millions)	Passenger Time Savings (millions)	Total - Without Passenger Time (millions)	Total - With Passenger Time (millions)
1999						
Benefits Due to Providing Advisories to Ground DSTs	$314	$171	$246	$2,773	$732	$3,505
NPV (1997)	**$274**	**$149**	**$215**	**$2,422**	**$639**	**$3,061**

5.2.2 Airport-Specific Benefits

Focusing on the 42 key AATT implementation airports, Table 5.2.2-1 summarizes the benefits of reducing taxi-out delays by providing advisories to the ground DSTs.

Table 5.2.2-1 Potential Annual Taxi-Out Delay Savings Due to Airspace Congestion (1999)

Airport	Potential Annual Taxi Out Delay Savings (1997 $Millions)											
	Jet Aircraft						Turboprop Aircraft					
	Crew	O+F	M	Pass	Ó w/o pass	Ó w pass	Crew	O+F	M	Pass	Ó w/o pass	Ó w pass
ATL	19.66	10.39	13.93	172.66	43.99	216.65	0.51	0.29	0.73	3.06	1.51	4.58
BDL	1.54	0.90	1.27	14.21	3.71	17.92	0.12	0.05	0.18	1.09	0.36	1.45
BNA	3.16	1.78	2.48	29.00	7.44	36.42	0.09	0.11	0.32	0.51	0.53	1.02
BOS	8.50	4.49	5.97	73.24	18.97	92.20	1.15	0.49	1.54	8.34	3.18	11.52
BWI	3.16	1.72	2.39	28.60	7.26	35.86	0.22	0.09	0.32	2.08	0.65	2.74
CLE	0.65	0.37	0.52	5.56	1.54	7.10	0.07	0.05	0.10	0.35	0.22	0.57
CLT	6.73	3.69	5.18	62.93	15.60	78.52	0.47	0.22	0.69	3.92	1.39	5.31
COS	0.73	0.48	0.76	6.48	1.97	8.45	0.01	0.01	0.05	0.11	0.10	0.20
CVG	3.70	1.96	2.69	33.26	8.34	41.61	0.09	0.05	0.13	0.48	0.26	0.74
DAB	0.03	0.03	0.05	0.32	0.12	0.43	0	0	0.01	0.01	0.03	0.03
DCA	4.91	2.81	3.79	42.82	11.52	54.33	0.25	0.12	0.41	2.43	0.77	3.20
DEN	18.56	9.63	12.68	157.74	40.86	198.60	1.02	0.56	1.36	5.44	2.93	8.37
DFW	36.18	19.19	26.25	323.39	81.60	404.99	2.36	0.97	3.21	21.19	6.55	27.73
DTW	19.43	10.43	14.28	172.29	44.14	216.41	0.89	0.36	1.29	9.19	2.54	11.73
EWR	6.93	3.79	5.26	60.98	15.96	76.94	0.20	0.09	0.28	1.88	0.58	2.45
FLL	1.52	0.85	1.16	13.60	3.52	17.13	0.08	0.05	0.14	0.52	0.27	0.80
HOU	2.10	1.26	1.83	19.69	5.18	24.87	0.02	0.02	0.06	0.26	0.10	0.35
HPN	0.80	0.87	1.37	6.70	3.04	9.75	0.21	0.16	0.41	1.64	0.77	2.41
IAD	4.16	2.34	3.22	37.60	9.72	47.33	0.58	0.34	0.79	2.85	1.70	4.55
IAH	4.18	2.30	3.18	37.35	9.66	46.99	0.17	0.08	0.24	1.31	0.49	1.80
JFK	5.55	3.22	4.01	47.29	12.79	60.08	0.44	0.20	0.60	3.30	1.24	4.54
LAS	13.23	7.27	10.09	119.38	30.59	149.99	0.15	0.10	0.28	1.28	0.52	1.80
LAX	12.35	6.92	9.26	111.22	28.54	139.75	0.86	0.46	1.13	4.86	2.45	7.31
LGA	8.31	4.35	5.79	71.82	18.45	90.27	0.48	0.20	0.65	4.24	1.32	5.56
LGB	0.15	0.10	0.15	1.38	0.40	1.79	0	0	0.01	0.01	0.01	0.03
MCO	2.60	1.40	1.90	23.28	5.91	29.18	0.10	0.06	0.14	0.60	0.31	0.91
MDW	3.60	2.09	2.95	32.64	8.64	41.30	0.09	0.06	0.17	0.39	0.33	0.71
MEM	3.45	1.95	2.70	29.44	8.11	37.55	0.34	0.16	0.57	3.42	1.07	4.50
MIA	2.14	1.14	1.42	17.27	4.70	21.96	0.14	0.06	0.22	1.28	0.43	1.71
MSP	5.60	3.03	4.07	48.12	12.70	60.82	0.33	0.14	0.50	3.23	0.95	4.18
OAK	1.91	1.06	1.51	17.88	4.49	22.37	0.03	0.03	0.10	0.10	0.15	0.25
ORD	8.10	4.35	5.82	68.63	18.28	86.91	0.17	0.08	0.24	1.47	0.49	1.97
PDX	2.16	1.19	1.70	19.90	5.05	24.95	0.26	0.11	0.36	1.93	0.72	2.66
PHL	6.75	3.67	5.07	61.26	15.50	76.75	0.51	0.23	0.71	4.41	1.44	5.85
PHX	9.06	4.82	6.68	83.35	20.56	103.91	0.21	0.11	0.32	1.54	0.65	2.21
PIT	4.06	2.19	3.07	37.29	9.33	46.61	0.57	0.27	0.78	4.48	1.60	6.08
SAN	2.35	1.27	1.76	21.69	5.38	27.07	0.15	0.09	0.21	0.93	0.45	1.37
SEA	4.27	2.31	3.19	39.42	9.77	49.19	0.37	0.15	0.49	3.07	1.02	4.10
SFO	5.90	3.28	4.39	52.85	13.59	66.43	0.18	0.11	0.25	0.72	0.54	1.26
SLC	5.07	2.74	3.65	43.92	11.46	55.38	0.24	0.17	0.41	0.92	0.83	1.73
STL	7.03	3.75	5.19	64.35	15.97	80.32	0.33	0.18	0.44	1.71	0.96	2.67
TEB	0.13	0.70	1.21	0.45	2.04	2.47	0.02	0.05	0.14	0.11	0.20	0.33
TOTAL	260	142	194	2311	596	2908	14	7	21	111	43	153

6 Summary of Benefits

Benefits for 1999 and 2015 are summarized in Table 6-1. This table identifies the EDP functional contribution responsible for the benefits in addition to the element incurring the savings (such as fuel and passenger time). Benefits are summed both with and without passenger value of time. Since the passenger time savings will be incurred in small increments over many passengers, it is doubtful that the benefits will materialize as stated. In fact, in its cost-benefit analysis for passenger value of time, the FAA considers only delays of over 15 minutes.

Table 6-1 assumes that EDP would only be deployed at each of 42 AATT deployment sites. The net present value (NPV in 1997) of the savings is presented in 1997 dollars for each cost source.

Table 6-1 EDP National Benefits

EDP Benefits	Crew Time Savings (millions)	Fuel Savings (millions)	Maintenance Savings (millions)	Passenger Time Savings (millions)	Total - Without Passenger Time (millions)	Total - With Passenger Time (millions)
1999						
Direct Benefits Due to Unrestricted Climbs and Optimal Merging	$56	$95	$41	$493	$189	$682
NPV (1997)	**$49**	**$83**	**$36**	**$431**	**$168**	**$599**
Indirect Benefits Due to Providing Advisories to Ground DSTs [1]	$314	$171	$246	$2,773	$732	$3,505
NPV (1997)	**$274**	**$149**	**$215**	**$2,422**	**$639**	**$3,061**
2015						
Direct Benefits Due to Unrestricted Climbs and Optimal Merging [2]	$336	$564	$249	$2,963	$1,149	$4,112
NPV (1997)	**$114**	**$191**	**$84**	**$1,004**	**$389**	**$1,393**

Table 6-2 EDP Direct Benefits at AATT Key Implementation Airports in 1999 (in 1997 $)

Airport	Annual Savings for 1999 (1997 $Millions)											
	Jet Aircraft						Turboprop Aircraft					
	Crew	O+F	M	Pass	Ó w/o pass	Ó w pass	Crew	O+F	M	Pass	Ó w/o pass	Ó w pass
ATL	6.61	10.49	4.68	57.99	**21.78**	**79.77**	0.16	0.27	0.23	0.99	**0.66**	**1.65**
BDL	0.25	0.44	0.21	2.28	**0.90**	**3.18**	0.01	0.01	0.01	0.05	**0.03**	**0.08**
BNA	0	0.09	0	0	**0.09**	**0.09**	0	0.02	0	0	**0.02**	**0.02**
BOS	1.21	1.98	0.84	10.40	**4.03**	**14.43**	0	0.02	0	0	**0.02**	**0.02**
BWI	1.85	3.17	1.39	16.71	**6.41**	**23.12**	0.01	0.05	0.03	0.14	**0.09**	**0.23**
CLE	0	0.01	0	0	**0.01**	**0.01**	0	0	0	0	**0**	**0**
CLT	0.32	0.56	0.24	2.93	**1.12**	**4.05**	0.02	0.03	0.03	0.14	**0.08**	**0.22**
COS	0	0	0	0	**0**	**0**	0	0	0	0	**0**	**0**
CVG	0	0.07	0	0	**0.07**	**0.07**	0	0	0	0	**0**	**0**
DAB	0	0	0	0	**0**	**0**	0	0	0	0	**0**	**0**
DCA	0.66	1.30	0.50	5.75	**2.46**	**8.21**	0.01	0.05	0.02	0.12	**0.08**	**0.20**
DEN	3.77	5.86	2.57	32.05	**12.20**	**44.25**	0	0	0	0	**0**	**0**
DFW	2.42	3.93	1.74	21.55	**8.09**	**29.64**	0	0	0	0	**0**	**0**
DTW	2.32	3.78	1.69	20.53	**7.79**	**28.32**	0.07	0.09	0.12	0.83	**0.28**	**1.11**
EWR	2.36	4.10	1.79	20.74	**8.25**	**28.99**	0	0.02	0	0	**0.02**	**0.02**
FLL	0	0.06	0	0	**0.06**	**0.06**	0	0	0	0	**0**	**0**
HOU	0.67	1.20	0.57	6.20	**2.44**	**8.64**	0	0	0	0	**0**	**0**
HPN	0.16	0.61	0.25	1.26	**1.02**	**2.28**	0	0	0	0	**0**	**0**
IAD	0.27	0.67	0.21	2.40	**1.15**	**3.55**	0.02	0.08	0.03	0.13	**0.13**	**0.26**
IAH	0.85	1.47	0.64	7.58	**2.96**	**10.54**	0	0	0	0	**0**	**0**
JFK	0.25	0.48	0.18	2.07	**0.91**	**2.98**	0	0.02	0	0	**0.02**	**0.02**
LAS	1.44	2.39	1.10	13.02	**4.93**	**17.95**	0	0	0	0	**0**	**0**
LAX	3.47	5.84	2.61	31.26	**11.92**	**43.18**	0	0.01	0	0	**0.01**	**0.01**
LGA	1.29	2.34	0.90	11.16	**4.53**	**15.69**	0	0.03	0	0	**0.03**	**0.03**
LGB	0	0	0	0	**0**	**0**	0	0	0	0	**0**	**0**
MCO	1.74	2.83	1.27	15.50	**5.84**	**21.34**	0	0	0	0	**0**	**0**
MDW	0	0.01	0	0	**0.01**	**0.01**	0	0	0	0	**0**	**0**
MEM	0	0	0	0	**0**	**0**	0	0.06	0	0	**0.06**	**0.06**
MIA	0.47	0.77	0.31	3.83	**1.55**	**5.38**	0	0.01	0	0	**0.01**	**0.01**
MSP	1.29	2.14	0.95	11.15	**4.38**	**15.53**	0	0.03	0	0	**0.03**	**0.03**
OAK	0.47	0.83	0.37	4.43	**1.67**	**6.10**	0	0	0	0	**0**	**0**
ORD	5.12	8.40	3.68	43.35	**17.20**	**60.55**	0	0.01	0	0	**0.01**	**0.01**
PDX	0.61	1.01	0.49	5.66	**2.11**	**7.77**	0	0	0	0	**0**	**0**
PHL	1.61	2.82	1.21	14.60	**5.64**	**20.24**	0	0.05	0	0	**0.05**	**0.05**
PHX	0	0.02	0	0	**0.02**	**0.02**	0	0.01	0	0	**0.01**	**0.01**
PIT	2.19	3.54	1.66	20.06	**7.39**	**27.45**	0	0.02	0	0	**0.02**	**0.02**
SAN	0.09	0.12	0.05	0.72	**0.26**	**0.98**	0	0	0	0	**0**	**0**
SEA	1.26	2.06	0.95	11.71	**4.27**	**15.98**	0	0	0	0	**0**	**0**
SFO	2.65	4.43	1.97	23.65	**9.05**	**32.70**	0	0	0	0	**0**	**0**
SLC	0.92	1.47	0.66	7.92	**3.05**	**10.97**	0	0	0	0	**0**	**0**
STL	0	0	0	0	**0**	**0**	0	0	0	0	**0**	**0**
TEB	0.02	0.34	0.18	0.07	**0.54**	**0.61**	0	0	0	0	**0**	**0**
TOTAL	**48.61**	**81.63**	**35.86**	**428.53**	**166.10**	**594.63**	**0.30**	**0.89**	**0.47**	**2.40**	**1.66**	**4.06**

Table 6-3 EDP Direct Benefits at AATT Key Implementation Airports in 2015 (in 1997 $)

Airport	Annual Savings for 2015 (1997 $Millions)											
	Jet Aircraft						Turboprop Aircraft					
	Crew	O+F	M	Pass	$Ó_{w/o\ pass}$	$Ó_{w\ pass}$	Crew	O+F	M	Pass	$Ó_{w/o\ pass}$	$Ó_{w\ pass}$
ATL	15.42	24.46	10.91	135.24	**50.79**	**186.03**	0.37	0.63	0.54	2.31	**1.54**	**3.85**
BDL	0.47	0.83	0.40	4.29	**1.69**	**5.99**	0.02	0.02	0.02	0.09	**0.06**	**0.15**
BNA	0	0.21	0	0	**0.21**	**0.21**	0	0.05	0	0	**0.05**	**0.05**
BOS	1.82	2.98	1.26	15.63	**6.06**	**21.68**	0	0.03	0	0	**0.03**	**0.03**
BWI	3.62	6.21	2.72	32.72	**12.55**	**45.28**	0.02	0.10	0.06	0.27	**0.18**	**0.45**
CLE	0	0.02	0	0	**0.02**	**0.02**	0	0	0	0	**0**	**0**
CLT	0.58	1.01	0.43	5.30	**2.03**	**7.33**	0.04	0.05	0.05	0.25	**0.14**	**0.40**
COS	0	0	0	0	**0**	**0**	0	0	0	0	**0**	**0**
CVG	0	0.18	0	0	**0.18**	**0.18**	0	0	0	0	**0**	**0**
DAB	0	0	0	0	**0**	**0**	0	0	0	0	**0**	**0**
DCA	1.01	1.99	0.77	8.81	**3.77**	**12.59**	0.02	0.08	0.03	0.18	**0.12**	**0.31**
DEN	9.29	14.43	6.33	78.94	**30.05**	**108.99**	0	0	0	0	**0**	**0**
DFW	6.35	10.32	4.57	56.56	**21.23**	**77.80**	0	0	0	0	**0**	**0**
DTW	5.49	8.94	4.00	48.55	**18.42**	**66.97**	0.17	0.21	0.28	1.96	**0.66**	**2.62**
EWR	4.39	7.63	3.33	38.62	**15.36**	**53.98**	0	0.04	0	0	**0.04**	**0.04**
FLL	0	0.13	0	0	**0.13**	**0.13**	0	0	0	0	**0**	**0**
HOU	1.39	2.50	1.19	12.91	**5.08**	**17.99**	0	0	0	0	**0**	**0**
HPN	0.27	1.03	0.42	2.14	**1.73**	**3.87**	0	0	0	0	**0**	**0**
IAD	0.51	1.26	0.40	4.52	**2.16**	**6.68**	0.04	0.15	0.06	0.24	**0.24**	**0.49**
IAH	2.49	4.30	1.87	22.17	**8.66**	**30.83**	0	0	0	0	**0**	**0**
JFK	0.40	0.78	0.29	3.35	**1.47**	**4.83**	0	0.03	0	0	**0.03**	**0.03**
LAS	5.02	8.34	3.84	45.43	**17.20**	**62.63**	0	0	0	0	**0**	**0**
LAX	10.66	17.94	8.02	96.02	**36.61**	**132.63**	0	0.03	0	0	**0.03**	**0.03**
LGA	2.00	3.62	1.39	17.29	**7.02**	**24.31**	0	0.05	0	0	**0.05**	**0.05**
LGB	0	0	0	0	**0**	**0**	0	0	0	0	**0**	**0**
MCO	4.60	7.48	3.36	40.96	**15.43**	**56.40**	0	0	0	0	**0**	**0**
MDW	0	0.02	0	0	**0.02**	**0.02**	0	0	0	0	**0**	**0**
MEM	0	0	0	0	**0**	**0**	0	0.16	0	0	**0.16**	**0.16**
MIA	1.04	1.70	0.68	8.45	**3.42**	**11.86**	0	0.02	0	0	**0.02**	**0.02**
MSP	3.11	5.15	2.29	26.85	**10.55**	**37.40**	0	0.07	0	0	**0.07**	**0.07**
OAK	1.06	1.86	0.83	9.95	**3.75**	**13.70**	0	0	0	0	**0**	**0**
ORD	11.14	18.28	8.01	94.34	**37.43**	**131.78**	0	0.02	0	0	**0.02**	**0.02**
PDX	1.19	1.98	0.96	11.09	**4.13**	**15.22**	0	0	0	0	**0**	**0**
PHL	3.37	5.90	2.53	30.54	**11.80**	**42.33**	0	0.10	0	0	**0.10**	**0.10**
PHX	0	0.06	0	0	**0.06**	**0.06**	0	0.03	0	0	**0.03**	**0.03**
PIT	4.05	6.55	3.07	37.10	**13.67**	**50.77**	0	0.04	0	0	**0.04**	**0.04**
SAN	0.28	0.37	0.15	2.22	**0.80**	**3.03**	0	0	0	0	**0**	**0**
SEA	2.20	3.60	1.66	20.47	**7.46**	**27.93**	0	0	0	0	**0**	**0**
SFO	7.16	11.97	5.32	63.90	**24.45**	**88.35**	0	0	0	0	**0**	**0**
SLC	2.78	4.44	1.99	23.93	**9.21**	**33.14**	0	0	0	0	**0**	**0**
STL	0	0	0	0	**0**	**0**	0	0	0	0	**0**	**0**
TEB	0.04	0.64	0.34	0.13	**1.01**	**1.14**	0	0	0	0	**0**	**0**
TOTAL	**113.9**	**189.12**	**83.34**	**998.40**	**385.65**	**1384.05**	**0.67**	**1.91**	**1.04**	**5.32**	**3.61**	**8.94**

Table 6-4 EDP Indirect Benefits at AATT Key Implementation Airports in 1999 (in 1997 $)

Airport	Potential Annual Taxi Out Delay Savings in 1999 (1997 $Millions)											
	Jet Aircraft						Turboprop Aircraft					
	Crew	O+F	M	Pass	Ó w/o pass	Ó w pass	Crew	O+F	M	Pass	Ó w/o pass	Ó w pass
ATL	19.66	10.39	13.93	172.66	**43.99**	**216.65**	0.51	0.29	0.73	3.06	**1.51**	**4.58**
BDL	1.54	0.90	1.27	14.21	**3.71**	**17.92**	0.12	0.05	0.18	1.09	**0.36**	**1.45**
BNA	3.16	1.78	2.48	29.00	**7.44**	**36.42**	0.09	0.11	0.32	0.51	**0.53**	**1.02**
BOS	8.50	4.49	5.97	73.24	**18.97**	**92.20**	1.15	0.49	1.54	8.34	**3.18**	**11.52**
BWI	3.16	1.72	2.39	28.60	**7.26**	**35.86**	0.22	0.09	0.32	2.08	**0.65**	**2.74**
CLE	0.65	0.37	0.52	5.56	**1.54**	**7.10**	0.07	0.05	0.10	0.35	**0.22**	**0.57**
CLT	6.73	3.69	5.18	62.93	**15.60**	**78.52**	0.47	0.22	0.69	3.92	**1.39**	**5.31**
COS	0.73	0.48	0.76	6.48	**1.97**	**8.45**	0.01	0.01	0.05	0.11	**0.10**	**0.20**
CVG	3.70	1.96	2.69	33.26	**8.34**	**41.61**	0.09	0.05	0.13	0.48	**0.26**	**0.74**
DAB	0.03	0.03	0.05	0.32	**0.12**	**0.43**	0	0	0.01	0.01	**0.03**	**0.03**
DCA	4.91	2.81	3.79	42.82	**11.52**	**54.33**	0.25	0.12	0.41	2.43	**0.77**	**3.20**
DEN	18.56	9.63	12.68	157.74	**40.86**	**198.60**	1.02	0.56	1.36	5.44	**2.93**	**8.37**
DFW	36.18	19.19	26.25	323.39	**81.60**	**404.99**	2.36	0.97	3.21	21.19	**6.55**	**27.73**
DTW	19.43	10.43	14.28	172.29	**44.14**	**216.41**	0.89	0.36	1.29	9.19	**2.54**	**11.73**
EWR	6.93	3.79	5.26	60.98	**15.96**	**76.94**	0.20	0.09	0.28	1.88	**0.58**	**2.45**
FLL	1.52	0.85	1.16	13.60	**3.52**	**17.13**	0.08	0.05	0.14	0.52	**0.27**	**0.80**
HOU	2.10	1.26	1.83	19.69	**5.18**	**24.87**	0.02	0.02	0.06	0.26	**0.10**	**0.35**
HPN	0.80	0.87	1.37	6.70	**3.04**	**9.75**	0.21	0.16	0.41	1.64	**0.77**	**2.41**
IAD	4.16	2.34	3.22	37.60	**9.72**	**47.33**	0.58	0.34	0.79	2.85	**1.70**	**4.55**
IAH	4.18	2.30	3.18	37.35	**9.66**	**46.99**	0.17	0.08	0.24	1.31	**0.49**	**1.80**
JFK	5.55	3.22	4.01	47.29	**12.79**	**60.08**	0.44	0.20	0.60	3.30	**1.24**	**4.54**
LAS	13.23	7.27	10.09	119.38	**30.59**	**149.99**	0.15	0.10	0.28	1.28	**0.52**	**1.80**
LAX	12.35	6.92	9.26	111.22	**28.54**	**139.75**	0.86	0.46	1.13	4.86	**2.45**	**7.31**
LGA	8.31	4.35	5.79	71.82	**18.45**	**90.27**	0.48	0.20	0.65	4.24	**1.32**	**5.56**
LGB	0.15	0.10	0.15	1.38	**0.40**	**1.79**	0	0	0.01	0.01	**0.01**	**0.03**
MCO	2.60	1.40	1.90	23.28	**5.91**	**29.18**	0.10	0.06	0.14	0.60	**0.31**	**0.91**
MDW	3.60	2.09	2.95	32.64	**8.64**	**41.30**	0.09	0.06	0.17	0.39	**0.33**	**0.71**
MEM	3.45	1.95	2.70	29.44	**8.11**	**37.55**	0.34	0.16	0.57	3.42	**1.07**	**4.50**
MIA	2.14	1.14	1.42	17.27	**4.70**	**21.96**	0.14	0.06	0.22	1.28	**0.43**	**1.71**
MSP	5.60	3.03	4.07	48.12	**12.70**	**60.82**	0.33	0.14	0.50	3.23	**0.95**	**4.18**
OAK	1.91	1.06	1.51	17.88	**4.49**	**22.37**	0.03	0.03	0.10	0.10	**0.15**	**0.25**
ORD	8.10	4.35	5.82	68.63	**18.28**	**86.91**	0.17	0.08	0.24	1.47	**0.49**	**1.97**
PDX	2.16	1.19	1.70	19.90	**5.05**	**24.95**	0.26	0.11	0.36	1.93	**0.72**	**2.66**
PHL	6.75	3.67	5.07	61.26	**15.50**	**76.75**	0.51	0.23	0.71	4.41	**1.44**	**5.85**
PHX	9.06	4.82	6.68	83.35	**20.56**	**103.91**	0.21	0.11	0.32	1.54	**0.65**	**2.21**
PIT	4.06	2.19	3.07	37.29	**9.33**	**46.61**	0.57	0.27	0.78	4.48	**1.60**	**6.08**
SAN	2.35	1.27	1.76	21.69	**5.38**	**27.07**	0.15	0.09	0.21	0.93	**0.45**	**1.37**
SEA	4.27	2.31	3.19	39.42	**9.77**	**49.19**	0.37	0.15	0.49	3.07	**1.02**	**4.10**
SFO	5.90	3.28	4.39	52.85	**13.59**	**66.43**	0.18	0.11	0.25	0.72	**0.54**	**1.26**
SLC	5.07	2.74	3.65	43.92	**11.46**	**55.38**	0.24	0.17	0.41	0.92	**0.83**	**1.73**
STL	7.03	3.75	5.19	64.35	**15.97**	**80.32**	0.33	0.18	0.44	1.71	**0.96**	**2.67**
TEB	0.13	0.70	1.21	0.45	**2.04**	**2.47**	0.02	0.05	0.14	0.11	**0.20**	**0.33**
TOTAL	**260**	**142**	**194**	**2311**	**596**	**2908**	**14**	**7**	**21**	**111**	**43**	**153**

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Appendix A Aircraft Types

Type	Engines	Class	Category
A10	2	J	L
A109	2	T	S
A3	2	J	L
A300	2	J	H
A306	2	J	H
A310	2	J	H
A319	2	J	H
A320	2	J	LH
A330	2	J	H
A340	4	J	H
A36	1	J	S
A4	1	J	L
A6	2	J	L
AA1	1	P	S
AA5	1	P	S
AC11	2	P	S
AC50	2	P	S
AC56	2	P	S
AC60	2	P	S
AC68	2	P	S
AC69	2	P	S
AC70	2	P	S
AC90	2	P	S
AC95	2	P	S
AC6L	2	P	S
AC6T	2	T	S
AEST	2	P	S
AJ25	2	T	L
AN24RW	2	T	L
AS50	1	T	S
ASTR	2	J	S+
ATP	2	T	L
AT43	2	T	L
AT42	2	T	L
AT45	2	T	L
AT72	2	T	L
ATR	2	T	L
B06	1	T	S
B12	2	T	S
B14A	1	P	S
B17	4	P	L
B190	2	T	S+
B222	2	T	S
B26	2	P	L
B2A	4	J	H
B350	2	T	S+
B52	8	J	H

B707	4	J	H
B720	4	J	H
B727	3	J	L
B721	3	J	L
B722	3	J	L
B72Q	3	J	L
B73A	2	J	L
B73B	2	J	L
B73C	2	J	L
B731	2	J	L
B732	2	J	L
B733	2	J	L
B734	2	J	L
B735	2	J	L
B737	2	J	L
B738	2	J	L
B73Q	2	J	L
B73S	2	J	L
B74A	4	J	H
B74S	4	J	H
B74B	4	J	H
B741	4	J	H
B742	4	J	H
B743	4	J	H
B744	4	J	H
B747	4	J	H
B757	2	J	LH
B752	2	J	LH
B762	2	J	H
B763	2	J	H
B767	2	J	H
B777	2	J	H
B772	2	J	H
BA10	2	J	L
BA11	2	J	L
BA46	4	J	L
BASS	2	P	S
BE10	2	T	S
BE17	1	P	S
BE18	2	P	S
BE19	1	P	S
BE20	2	T	S
BE23	1	P	S
BE24	1	P	S
BE30	2	T	S+
BE33	1	P	S
BE35	1	P	S
BE36	1	P	S
BE40	2	P	S
BE50	2	P	S

BE55	2	P	S
BE56	2	P	S
BE58	2	P	S
BE60	2	P	S
BE65	2	P	S
BE76	2	P	S
BE77	1	P	S
BE80	2	P	S
BE90	2	P	S
BE95	2	P	S
BE99	2	T	S
BE9L	2	T	S
BE9T	2	T	S
BE8T	2	T	S
BK17	2	T	S
BL17	1	P	S
BL8	1	P	S
BN2P	2	P	S
C120	1	P	S
C130	4	T	L
C135	4	J	H
C141	4	J	H
C150	1	P	S
C152	1	P	S
C160	2	T	L
C17	4	J	H
C170	1	P	S
C172	1	P	S
C175	1	P	S
C177	1	P	S
C180	1	P	S
C182	1	P	S
C185	1	P	S
C188	1	P	S
C195	1	P	S
C2	2	T	L
C205	1	P	S
C206	1	P	S
C207	1	P	S
C208	1	T	S
C210	1	P	S
C212	2	T	S+
C26	2	T	S+
C303	2	P	S
C310	2	P	S
C320	2	P	S
C335	2	P	S
C336	2	P	S
C340	2	P	S
C401	2	P	S

C402	2	P	S
C404	2	P	S
C411	2	P	S
C414	2	P	S
C421	2	P	S
C425	2	T	S
C441	2	T	S
C5	4	J	H
C500	2	J	S
C501	2	J	S
C525	2	J	S
C550	2	J	S
C551	2	J	S
C560	2	J	S+
C56X	2	J	S+
C650	2	J	S+
C750	2	J	S+
C72R	1	P	S
C9	2	J	L
CARJ	2	J	L
CL60	2	J	L
CL64	2	J	L
CL65	2	J	L
CM11	1	P	S
CN35	2	T	S+
CONI	4	P	L
CONC	4	J	L
COUR	1	P	S
CVLP	2	P	L
CVLT	2	T	L
D228	2	T	S+
D328	2	T	L
DC10	3	J	H
DC3	2	P	S+
DC4	4	P	L
DC6	4	P	L
DC8	4	J	L
DC85	4	J	L
DC86	4	J	L
DC87	4	J	L
DC8Q	4	J	L
DC8S	4	J	L
DC9	2	J	L
DC9Q	2	J	L
DG15	1	P	S
DHC2	1	P	S
DH2T	1	T	S
DHC3	1	P	S
DHC4	2	P	S+
DHC5	2	T	L

DHC6	2	T	S
DHC7	4	T	L
DHC8	2	T	L
DH8A	2	T	L
DH8B	2	T	L
DH8C	2	T	L
DH8	2	T	L
DO28	2	P	S
DO82	2	T	S+
EA32	2	J	LH
E110	2	T	S
E120	2	T	S+
E145	2	T	S+
E2	2	T	L
E3	4	J	H
E6A	4	J	H
E9A	2	T	S+
F100	2	J	L
F111	2	J	L
F117	2	J	L
F14	2	J	L
F15	2	J	L
F16	1	J	L
F18	2	J	L
F26T	1	T	S
F27	2	T	L
F28	2	J	L
F2TH	3	J	L
F4	2	J	L
F406	2	T	S
F4G	2	J	L
F5	2	J	S+
F70	2	J	L
F86	1	J	L
F90	1	J	L
F900	3	J	L
FA10	2	J	S+
FA18	2	J	S+
FA20	2	J	S+
FA22	2	J	S+
FA50	3	J	S+
G159	2	T	S+
G21	2	P	S+
G222	2	P	L
G44	2	P	S+
G520	1	T	S
G73	2	P	S+
GA7	2	P	S
GC1	1	P	S
GULF	2	J	L

GLF	2	J	L
G2B	2	J	L
G2	2	J	L
G3	2	J	L
G4	2	J	L
GLF2	2	J	L
GLF3	2	J	L
GLF4	2	J	L
GLF5	2	J	L
H2	2	T	L
H25A	2	J	S+
H25B	2	J	S+
H25C	2	J	S+
H46	2	T	L
H47	2	T	L
H53	2	T	L
H60	2	T	L
H64	2	T	L
HAR	1	J	L
HF20	2	J	S+
HS25A	2	J	S+
HS25	2	J	S+
HUCO	1	T	S
HUSK	1	P	S
IL18	4	T	L
IL62	4	J	H
IL76	4	J	H
IL96	4	J	H
J2	1	P	S
JCOM	2	J	S+
JSTA	2	T	S+
JS31	2	T	S+
JS32	2	T	S+
JS41	2	T	S+
JSTB	2	T	S+
L101	3	J	H
L18	2	P	L
L188	4	T	L
L29A	4	J	L
L29B	4	J	L
LA25	1	P	S
LA4	1	P	S
LJ23	2	J	S
LJ24	2	J	S+
LJ25	2	J	S+
LJ28	2	J	S+
LJ31	2	J	S+
LJ35	2	J	S+
LJ36	2	J	S+
LR36	2	J	S+

LJ55	2	J	S+
LJ60	2	J	S+
LR23	2	J	S
LR24	2	J	S
LR25	2	J	S+
LR31	2	J	S+
LR35	2	J	S+
LR45	2	J	S+
LR55	2	J	S+
LR60	2	J	S+
M20	1	P	S
MO20	1	P	S
M20P	1	P	S
M20J	1	P	S
M200	1	P	S
M22	1	P	S
M404	2	P	L
M5	1	P	S
M6	1	P	S
M7	1	P	S
M7T	1	T	S
MD11	3	J	H
MD80	2	J	L
MD82	2	J	L
MD83	2	J	L
MD87	2	J	L
MD90	2	J	L
MRC	2	J	L
MU2	2	T	S
MU30	2	J	S+
N262	2	T	S+
P136	2	P	S
P180	2	P	S
P210	2	P	S
P31T	2	T	S
P337	2	P	S
P68	2	P	S
PA18	1	P	S
PA20	1	P	S
PA22	1	P	S
PA23	2	P	S
PA24	1	P	S
PA27	2	P	S
PA28	1	P	S
P28A	1	P	S
PA28R	1	P	S
PA28T	1	P	S
PA30	2	P	S
PA31	2	P	S
PA32	1	P	S

P32R	1	P	S
PA34	2	P	S
PA36	1	P	S
PA38	1	P	S
PA42	2	T	S
PA44	2	P	S
PA46	1	P	S
PA60	1	P	S
PAY1	1	P	S
PAY2	1	P	S
PAY3	1	P	S
PAYE	1	P	S
PC12	1	T	S
PC6T	1	T	S
PC7	1	T	S
R44	1	P	S
R82	1	P	S
RANG	1	P	S
S3	2	J	L
S360	1	T	S
S601	2	J	S+
S61	2	T	L
S65C	2	T	S
S76	2	T	S
SBR1	2	J	S+
SBR2	2	J	S+
SBR	2	J	S+
SC7	2	T	S
SF34	2	T	L
SH33	2	T	S+
SH36	2	T	S+
SSAB	1	J	L
ST75	1	P	S
STAR	2	T	S+
SW2	2	T	S
SW3	2	T	S+
SW4	2	T	S
T2	2	J	L
T28	1	P	S
T33	2	J	L
T34P	1	P	S
T34T	1	T	S
T37	2	J	S
T38	2	J	S+
T39	2	J	S+
TAMP	1	P	S
TBM7	1	T	S
TOBA	1	P	S
TRIN	1	P	S
TRIS	3	P	S

TU54	3	J	L
U2	1	J	S+
U21	2	T	S
UH1	1	T	S
V1	2	T	S
V10	2	T	S
VC10	4	J	H
WW23	2	J	S+
WW24	2	J	S+
YK40	3	J	S+
YK42	3	J	L
YS11	2	T	L

Number of Engines:

1, 2, 3, or 4

Engine Type:

J – jet
T- turboprop
P-piston

Aircraft Weight:

Heavy (H)	over 255,000 pounds takeoff weight
Large (L, LH)	41,000-255,000 pounds takeoff weight
Small (S, S+)	under 41,000 pounds takeoff weight

Appendix B Economic Conversion Factors

Table B-1 Discount Rate, and Value of Travelers Time (1997 dollars)

Element	Value
Discount Rate	7%
Travelers Time	$45 per hour

Table B-2 Air Carrier Critical Values (1997 dollars)

Aircraft Type	Cost/Block Hour (in $ per hour)			Number of Available Seats	Load Factor (percent)
	Crew	Oil & Fuel	Maint		
1. Turbofan 4-eng wide	1107	2551	966	369.2	63.5
2. Turbofan/Jet 4-eng reg	680	963	454	168.6	65.1
3. Turbofan 3-eng wide	882	1670	840	278.4	66.2
4. Turbofan 3-eng reg	628	917	301	148.8	61.4
5. Turbofan 2-eng wide	683	1099	518	220.3	65.6
6. Turbofan 2-eng reg	447	596	255	126.6	59.5
7. Turboprop 4-eng	203	196	529	86.0	64.0
8. Turboprop 2-eng	117	124	159	47.8	57.2
9. Piston	52	60	63	10.4	25.2

Table B-3 Air Taxi Critical Values (1997 dollars)

Aircraft Type	Cost/Block Hour (in $ per hour)			Number of Available Seats	Load Factor (in percent)
	Crew	Oil & Fuel	Maint		
1. Piston 1-eng	57	26	29	3.3	31.9
2. Piston 2-eng < 12500	76	67	83	5.1	31.2
3. Piston 2-eng >12500	76	78	90	5.9	15.1
4. Piston Multi > 12500	76	78	90	5.9	15.1
5. Turboprop 2-eng < 12500	104	167	135	8.7	20.9
6. Turboprop 2-eng > 12500	104	189	135	18.5	48.7
7. Turbojet 2-eng < 20000	199	507	277	5.9	16.3
8. Turbojet 2-eng > 20000	199	507	277	5.9	16.3
9. Turbojet Multi < 20000	199	507	277	5.9	16.3
10. Turbojet Multi > 20000	199	507	277	5.9	16.3

Table B-4 General Aviation Critical Values (1997 dollars)

Aircraft Type	Cost/Block Hour (in $ per hour)			Number of Available Seats	Load Factor (in percent)
	Crew	Oil & Fuel	Maint		
1. Piston 1-eng		26	29	3.3	31.9
2. Piston 2-eng < 12500		67	83	5.1	31.2
3. Piston 2-eng >12500		78	90	5.9	15.1
4. Piston Multi > 12500		78	90	5.9	15.1
5. Turboprop 2-eng < 12500		167	135	8.7	20.9
6. Turboprop 2-eng > 12500		189	135	18.5	48.7
7. Turbojet 2-eng < 20000		507	277	5.9	16.3
8. Turbojet 2-eng > 20000		507	277	5.9	16.3
9. Turbojet Multi < 20000		507	277	5.9	16.3
10. Turbojet Multi > 20000		507	277	5.9	16.3

Appendix C Aircraft Data Structure

Aircraft data structure illustrated on Figure C.1 was used in conducted analysis. An example flight data and the source of it are shown on the same diagram in Italic.

Aircraft[i] ----ID *AAL1119 – from DZ & FZ messages*
Type *B722 – from FZ messages*
Class *J - from AC Database (Appendix A)*
Category *H - from AC Database (Appendix A)*
Number of Engines *3 - from AC Database (Appendix A)*
Origin *IAD – from DZ messages*
Destination *DFW – from DZ messages*
Assigned Speed *464 (knots) – from FZ messages*
Assigned Altitude *310 (100 ft) – from FZ messages*
Departure Time *1064 (min from 12:00 AM GMT) –from DZ messages*
Departure Fix *LDN – from FZ messages*
Stage Length *1,015 (nm) calculated from O-D pair (see Equation C.1)*
Trajectory Data------Time (min from 12:00 AM GMT)
-from TZ messages
Ground Speed (knots)
-from TZ messages
True Airspeed (knots)
-calculated from combination of winds data and TZ data
Flight Level (100 ft)
-from TZ messages
Latitude (deg)
-from TZ messages
Longitude (deg)
-from TZ messages
Distance from Origin (nmi)
-calculated from the Origin to the current position (see Equation C.1)

Figure C-1 Aircraft Data Structure

The distance between two points given their longitude and latitude position is calculated using the following formula:

$$l = \sum ?\ \tan^{-1} \frac{\sqrt{1-\text{È}^{2}}}{\text{È}} ? + \partial ? \frac{\text{È} - \text{abs}(\Theta)}{2 ?\text{È}} ? \qquad \text{(C-1)}$$

$$\text{È} = \sin\text{ë}_1 ?\sin\text{ë}_2 + \cos\text{ë}_1 ?\cos\text{ë}_2 ?\cos(\text{ì}_2 - \text{ì}_1)$$

Where,

(ë$_1$, ì$_1$) and (ë$_2$, ì$_2$) are coordinates (latitude, longitude) of the two points in radians.
$\Sigma = 3437$ (nmi) is the radius of the Earth

Appendix D Departure Fixes

BWI	Jets	Props	DCA	Jets	Props	IAD	Jets	Pro
AML	31	0	AML	40	0	AML	43	4
BAL	6	10	BAL	0	1	AML091	9	12
BAL130	0	4	BUFFR	19	0	BLUES	2	0
BUFFR	12	1	CSN	0	17	BUFFR	8	8
DAILY	36	0	DAILY	21	14	CSN	0	42
EMI	0	2	FLUKY	37	0	DAILY	8	0
FLUKY	26	0	HAFNR	18	1	FLUKY	45	25
HAFNR	15	3	JERES	29	4	HAFNR	56	2
JERES	23	8	KRANT	2	3	HANEY	0	23
KROLL	1	6	LDN	32	8	JERES	19	18
LDN	40	0	OTT	0	1	KROLL	0	1
PALEO	0	5	PALEO	18	18	LDN	60	9
PALEO2	9	15	POLLA	4	12	LISON	0	6
SWANN	0	3	SWANN	60	5	MRB	2	54
SWANN2	44	9				PALEO	2	0
V44	0	6				SWANN	80	6
V93	0	29				TOMAC	0	3
						WOOLY	1	42

DEN	Jets	Props	COS	Jets	Props
BRK	0	3	BRK110045	27	1
DCBEL1	15	0	BRK135R	32	4
DEN	31	0	FQF	12	6
GLL	2	16	LAA	0	1
LUFSE	9	7	PUB	0	2
PIKES2	75	15	V108	2	2
PLAIN2	152	16			
ROCKI3	84	48			
YELLO1	71	42			

EWR	Jets	Props
BDR	1	0
BDR248	1	0
BIGGY	44	11
BREZY	0	22
COATE	44	4
COL	1	0
DIXIE	14	1
ELIOT	88	13
GAYEL	31	0
GREKI	25	0
HAAYS	0	18
HFD	1	0
IGN	1	0
LANNA	41	2
MERIT	49	0
NEION	23	0
PARKE	40	0
WHITE	82	1

JFK	Jets	Props
BDR	0	29
BETTE	5	0
BETTE2	22	0
COATE	3	0
COL	2	0
DIXIE	2	12
ELIOT	1	0
ETX	2	0
GAYEL	25	20
GREKI	6	1
GREKI2	5	0
HAAYS	0	2
HAPIE	1	0
JFK	4	0
JFK060	1	0
LANNA	1	0
MERIT	11	25
MERIT2	32	0
NEION	4	0
RBV	70	13
SHIPP	30	0
WAVEY	43	0
WHITE	3	29

LGA	Jets	Prop
BDR	2	19
BIGGY	52	2
CMK	1	2
COATE	34	3
ELIOT	63	8
GAYEL	34	0
GREKI	13	0
HAAYS	0	21
LANNA	36	0
MERIT	33	39
NEION	16	0
NYACK	1	0
PARKE	33	0
SAX	0	5
SHIPP	1	0
V475	0	1
WHITE	63	1

FLL	Jets	Props
3552/07847	2	0
ARKES	94	7
ARKS	0	2
BEECH	7	22
BR70V	0	4
DHP	0	1
FLL	2	4
MNATE	1	6
PBI	1	0
PHK	0	1
PREDA	8	2
THNDR	45	13
ZAPPA	23	1

MIA	Jets	Props
DHP	2	1
EONNS	44	2
FLL	1	0
HEDLY	87	32
MNATE	59	28
PADUS	10	13
PBI	1	0
SKIPS	83	32
VALLY	43	0
VKZ	1	0
WINCO	67	50
ZBV	1	0

HOU	**Jets**	**Props**
IAH2	182	28
J86	1	0
PRARI	0	1
V548	1	0
VUH6	53	0

IAH	**Jets**	**Props**
IAH2	485	115
IDU	0	1
J86	2	0
KRABB2	18	0
PLAYA1	10	0
V13	0	4
V477	2	7
VUH6	23	0

LAX	**Jets**	**Props**
BSR	1	0
GMN2	93	54
LAXL12	0	9
LAXL16	0	71
LAXL21	0	7
LAXL22	0	35
LAXL3	0	10
LAXL9	0	11
LAXX3	287	0
LOOP2	145	0
MZB	7	1
OCN	1	0
PRCH7	31	0
SLI3	0	40
V165	0	6
VTU2	125	53

LGB	**Jets**	**Props**
CSTL1	2	0
CSTL12	0	1
CSTL34	0	1
CSTL35	0	2
CSTL4	1	0
LAX	2	1
OCN	0	2
SLI	25	2
SXC	1	0
VTU	2	0

ORD	Jets	Props
BDF	7	12
ELX	197	25
EON	127	8
GIJ	162	31
GUIDO	33	0
HRK	2	0
IOW	93	0
MUSKY	3	0
MZV	122	0
NEWTT	0	13
OBK	2	6
PETTY	64	26
PLL	66	12
RBS	97	11
SIMMN	5	7

MDW	Jets	Props
BAE	21	0
BDF	6	0
ELX	9	6
EON	41	13
GIJ	96	12
GUIDO	11	0
IOW	24	3
LAIRD	0	1
MZV	29	0
NEWTT	0	2
OXI	2	0
PETTY	1	1
PLL	2	4
RBS	38	1
SIMMN	0	4
TALOR	0	6
WHETT	1	0

SFO	Jets	Props
CCR	0	17
CUIT2	15	0
EUGEN5	2	18
GAPP3	15	0
MOD	1	0
MOLEN3	17	0
OAK	0	26
OFFSH4	44	0
PORTE3	113	0
REBAS3	0	25
SAU	1	1
SFO8	255	1

OAK	Jets	Props
CCR	0	1
COAST5	22	0
COLLI	0	5
NUEVO5	0	2
OAK	1	22
OAK5	62	1
OSI	2	0
SABLO	0	7
SAU	0	1
SKYL3	79	0
SLNT7	3	0
V6	0	7

Appendix E Airport Capacities

Table E-1 Airport Capacities

Airport	Maximum VFR Capacity		Maximum IFR Capacity	
	1999	2015	1999	2015
EWR	100	100	77	84
LAX	159	229	143	205
LGA	76	77	71	72
MSP	117	137	78	98
ORD	162	198	153	190
STL	116	130	74	93
BOS	115	115	69	75
CLE	63	121	60	120
CVG	104	136	97	119
MIA	119	140	95	99
PHX	102	126	76	94
SEA	96	107	46	87
SFO	106	106	74	74
SAN	64	64	53	53
ATL	190	258	141	191
SLC	119	119	78	82
BWI	78	96	45	76
CLT	140	175	108	127
DFW	320	367	164	205
DTW	150	183	113	160
DCA	80	80	51	52
JFK	92	92	73	79
LAS	86	86	57	75
MCO	111	182	77	137
MEM	114	121	90	117
MDW	82	83	43	43
PDX	112	112	87	92
BNA	112	112	89	89
COS	97	97	50	89
IAD	120	152	93	110
BDL	90	90	46	46
DAB	124	124	50	50
DEN	210	238	207	207
FLL	90	98	45	96
HPN	66	66	43	43
IAH	119	119	114	114
LGB	131	131	112	112
HOU	92	92	74	74
OAK	176	176	73	73
PIT	162	211	102	161
PHL	90	148	52	124
TEB	73	73	49	49

Appendix F Gap Acceptance Model

To describe this model we can use either negative exponential distribution or Poisson distribution. Both will produce the same results because of the following relationship:

If the distribution of random events x, in some interval T conforms to Poisson distribution:

$$p(x) = \frac{m^x}{x!} e^{-m}; \; x = 0,1,2,... \qquad \text{(F-1)}$$

Then the distribution of times t, between the occurrences of these events corresponds to a negative exponential distribution with probability density function (PDF):

$$f(t) = be^{-bt}; \; 0 \le t < \times$$
$$b = \frac{m}{T} \qquad \text{(F-2)}$$

Where m is the mean of Poisson distribution, and T is the time interval.

<u>Problem:</u> Find the probability that a gap t is greater than ô in a traffic stream.

1. Using negative exponential distribution

$$p(t > \hat{o}) = {}_{\hat{o}}^{\times}\; be^{-bt}dt = e^{-b\hat{o}}$$
$$b = \frac{1}{T} \qquad \text{(F-3)}$$

2. Using Poisson distribution (that is, no arrivals during ô)

$$p(x) = \frac{m^x}{x!} e^{-m}$$
$$p(x = 0) = e^{-m} = e^{-b\hat{o}} \qquad \text{(F-4)}$$

In our case, we are looking at a probability of aircraft being cleared by a controller without delays to its assigned flight level. This probability can be obtained by multiplying the probabilities of aircraft being cleared through all flight levels below and including the assigned flight level.

Let n_{fl}^{B}, and n_{fl}^{F} designate number of flight levels that aircraft needs to be cleared through to reach it's assigned flight level in baseline (1999) and future (2015) scenarios correspondingly. Since we chose RVSM scenario of operations for the future, the number of flight levels that aircraft needs to be cleared through is likely to increase, i.e. $n_{fl}^{F}\ ?\ n_{fl}^{B}$.

Let m_i^B, and m_i^F designate average traffic demand for a corresponding flight level respectively in a baseline scenario and future scenario.

Let $\bar{\ddot{a}}$, and $\ddot{a}$ designate required minimum (5 nm, or 3 nm in terminal area) and average minimum (7-8 nm [EM1], [BR1], 3 nm in terminal area) separation used by the controllers to separate aircraft longitudinally. Then, for aircraft to be cleared through a flight level, a corresponding gap should be at least $2\ddot{a}$. Value of $\bar{\ddot{a}}$ is used to make sure that applied distribution yields probability of 100% of the minimum gap between two aircraft being equal to required minimum longitudinal separation (rather than 0 nm). After some algebraic manipulations, the probability of the gap of at least $2\ddot{a}$ on the i^{th} flight level (or, alternatively using Poisson distribution, the probability of no aircraft on a $2\ddot{a}$ stretch) can be calculated using the following formulas:

$$p_i^B(x=0) = e^{-\frac{m_i^B}{\bar{V}_i}(2\ddot{a}-\bar{\ddot{a}})}$$
$$p_i^F(x=0) = e^{-\frac{m_i^F}{\bar{V}_i}(2\ddot{a}-\bar{\ddot{a}})} \qquad \text{(F-5)}$$

Where, $\bar{V}_i$ is an average aircraft speed at i^{th} flight level.

Finally, considering probabilities of aircraft being cleared through all flight level including assigned flight level, the probability of the aircraft to be cleared to its assigned flight level is calculated using the following formulas:

$$P^B = \mathop{\subseteq}_{i=1}^{n_{fl}^B} p_i^B(x=0) = e^{-(2\ddot{a}-\bar{\ddot{a}}) \mathop{}_{i=1}^{n_{fl}^B} \frac{m_i^B}{\bar{V}_i}}$$
$$P^F = \mathop{\subseteq}_{i=1}^{n_{fl}^F} p_i^F(x=0) = e^{-(2\ddot{a}-\bar{\ddot{a}}) \mathop{}_{i=1}^{n_{fl}^F} \frac{m_i^F}{\bar{V}_i}} \qquad \text{(F-6)}$$

The ratio of above listed probabilities can be an indication of increasing of the traffic volume that controller needs to consider in clearing aircraft to it's assigned flight level.

$$\Delta = \frac{P^F}{P^B} = e^{-(2\ddot{a}-\bar{\ddot{a}}) \mathop{}_{i=1}^{n_{fl}^F} \frac{m_i^F}{\bar{V}_i} - \mathop{}_{i=1}^{n_{fl}^B} \frac{m_i^B}{\bar{V}_i} ?} \qquad \text{(F-7)}$$

From this formula one can see that this ratio, provided that separation standards remain unchanged in the future, is a function of the change in throughput of each flight level.