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A Methodology for Environmental and Energy Assessment of Operational Improvements

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Abstract—**NextGen Operational Improvements (OIs) have the potential for delivering Environmental and Energy (E&E) benefits in the near term. To foster improved aviation environmental performance, it is important to assess the E&E impacts of NextGen OIs. This paper presents a methodology that uses the Federal Aviation Administration's (FAA) Aviation Environmental Design Tool (AEDT) to assess the E&E benefits and tradeoffs of OIs that can potentially improve terminal airspace operations and can affect noise exposure in areas surrounding the airport. The methodology is demonstrated in performing an E&E assessment of the Enhanced Visual Approach (EVA) concept across operational performance (i.e., track distance and time), energy (i.e., fuel savings), emissions and noise. The E&E assessment of EVA is performed at three airports: Denver International Airport (DEN), General Edward Lawrence Logan International Airport (BOS) and Los Angeles International Airport (LAX). The results indicate that at 100% equipage (i.e., all aircraft are equipped with EVA-CAVS capability) and traffic levels of year 2012-2013, EVA-CAVS can result in on average 0.4%, 0.3% and 1.2% improvement annually in terms of operational performance (distance) at DEN, BOS and LAX, respectively. This corresponds to 0.1%, 0.6% and 1.1% reduction in terms of fuel and CO_2 emissions. In addition, the potential reduction in trombones (i.e., stretched flight paths in the downwind leg of final approach) from use of EVA-CAVS can reduce noise exposure as well. The applicability of the methodology to assess the E&E benefits and tradeoffs of other NextGen OIs is also discussed.**

Keywords- NextGen, Operational Improvement, Enviromental and Energy Assesssment, Enhanced Visual Approach.

I. INTRODUCTION

The Federal Aviation Administration's (FAA) Environmental and Energy (E&E) policy statement has set goals for noise, air quality, climate, energy and water quality [1][2]. These goals have been set to foster sustainable aviation growth and can be achieved through the following means of improvement [3][4][5][6]:

1. Airframe and engine improvements.
2. Operational Improvements (OIs).
3. Alternative jet fuels development and deployment.
4. Policies, standards and market-based measures development.
5. Improved scientific understanding, modeling and analysis.

The first three means of improvement (i.e., airframe/engine, Operational Improvement [OIs] and alternative jet fuels) are directly tied to the various E&E goals, of which OIs have the highest potential for delivering E&E benefits in the near term as they generally have higher Technology Readiness Level (TRL). Also, OIs generally have a faster time constant of implementation as they can be applied across the fleet provided no additional equipage is required [7]. The fourth means of improvement, policy development and market-based measures, supplement and support efforts on airframe/engine technology, operations and alternative fuels in order to achieve the set goals [8]. Lastly, improved scientific understanding, modeling and analysis--which involves the use and development of state of the art modelling tools such as the Aviation Environmental Design Tool (AEDT) [9] and Aviation environmental Portfolio Management Tool (APMT) [8][10]—is essential to better understand and quantify the various E&E tradeoffs and interdependencies and help identify and prioritize the most effective mitigation options.

Operational Improvements are specific to phase of flight and range from improvements in surface movement at the airports to introduction of efficient procedures in the en-route and terminal airspace [11][12][13][14]. This paper presents a methodology that uses advanced AEDT-based modeling to assess the E&E benefits and tradeoffs of OIs that can potentially improve terminal airspace operations and can affect noise exposure in areas surrounding the airport. Specifically, this methodology is applied to assess the potential E&E impacts of Enhanced Visual Approach (EVA), which is an OI enabled by Cockpit Display of Traffic Information (CDTI) Assisted Visual Separation (CAVS). The EVA-CAVS OI is expected to improve the operational performance of terminal airspace approaches during marginal conditions by allowing pilots to safely perform visual approaches instead of instrument approaches (see Background section for details). Previous research related to EVA-CAVS is focused primarily on the feasibility of implementing the OI [15][16][17][18]. There is a need to develop a methodology to assess the E&E benefits and tradeoffs of such OIs that can result in changes in traffic flow patterns in the terminal airspace. Further, the availability of AEDT presents an opportunity to assess OIs that exhibit potential E&E tradeoffs (improved operational performance vs. noise exposure) without the need for costly flight trials or Human-in-the-Loop simulation (HITL)[17].

The methodology combines Aviation System Performance Metrics (ASPM) airport data with Performance Data Analysis and Reporting System (PDARS) track data to construct a baseline scenario and a modified scenario (see Methodology section for details). The Aviation Environmental Design Tool (AEDT) is used to model the flight tracks to compute the operational performance, energy, emissions and noise metrics for the two scenarios, with the EVA-CAVS benefits and tradeoffs calculated as the difference between the two scenarios' corresponding metrics. The EVA-CAVS E&E assessment is performed for arrivals at Denver International Airport (DEN), General Edward Lawrence Logan International Airport (BOS) and Los Angeles International Airport (LAX).

This paper first provides a background on AEDT and the EVA-CAVS OI, followed by the methodology section which describes in detail the modeling approach, followed by airport data analysis at DEN, BOS and LAX. Results are then described with the E&E tradeoffs of EVA-CAVS at these airports, and finally a conclusions section summarizes the paper and provides a discussion on the potential to generalize the methodology to assess the E&E tradeoffs of other similar OIs.

II. BACKGROUND

This section provides a brief description of AEDT and its capability for modeling the E&E impacts NextGen OIs, followed by a description of the EVA-CAVS OI.

A. Aviation Environment Design Tool

The Aviation Environment Design Tool (AEDT) is a software system developed by FAA that can model aircraft performance to produce fuel burn, emissions and noise metrics[19]. AEDT is currently used by the U.S. government to assess the interdependencies between aircraft-related fuel burn, noise and emissions at airports [20].

AEDT uses an Extensible Markup Language (XML) file called the AEDT Standard Input Format (ASIF) to import data and create studies. An ASIF can be used to create new AEDT studies and to update existing AEDT studies. The ASIF format allows users to import a complete AEDT study, including airports, scenarios, cases, flights, tracks, and operations [21].

AEDT can model standard flight profiles that are built-in its database as well as user-specified profiles, such as actual flight track data or simulated profiles. AEDT also allows users to specify operational configurations in the ratios appropriate to represent average annual airspace and runway usage at the airport [19]. These two key capabilities allows the use of AEDT to develop studies that are representative of the pre/post (i.e., pre-implementation and post implementation) scenarios associated with the OI and evaluate their E&E benefits and tradeoffs.

B. Enhanced Visual Approach

Visual Approach is an approach conducted on an instrument flight rules (IFR) flight plan which authorizes the pilot to proceed visually and clear of clouds to the airport. The pilot must, at all times, have either the airport or the preceding aircraft in sight. This approach must be authorized and under the control of the appropriate air traffic control (ATC) facility. ATC may authorize this type approach when it will be operationally beneficial [22].

The Enhanced Visual Approach (EVA) is a NextGen operational improvement (OI) that can allow visual approaches in marginal meteorological conditions. Marginal meteorological conditions refer to visibility criteria at the airport that are below visual meteorological conditions (VMC) but better than instrument meteorological conditions (IMC), as shown in Table 1.

TABLE 1. DEFINITIONS OF WEATHER MINIMA FOR VISUAL, MARGINAL AND INSTRUMENT CONDITION

		Meteorological Conditions		
		Visual	Marginal	Instrument
Weather Minima	Visibility	at least 5 statute miles	below VMC but better than IMC	below 3 statute miles
	Ceiling	at least 3,000 ft.	below VMC but better than IMC	below 1,000 ft.

The EVA OI is enabled by Cockpit Display of Traffic Information (CDTI) Assisted Visual Separation (CAVS) capability (an application of ADS-B In equipage) which displays surrounding target aircraft's position and trajectory information such that the pilots can visually acquire and safely follow the target lead aircraft without any controller assistance or having to look out the cockpit window (see Fig 1). Consequently, pilots can take responsibility of maintaining safe separation with the lead aircraft and request the controller for a visual approach clearance during marginal meteorological conditions. The controller may provide the requested visual approach clearance to the CAVS capable aircraft, allowing for tighter spacing between aircraft in the terminal airspace during marginal conditions[15][16][17].

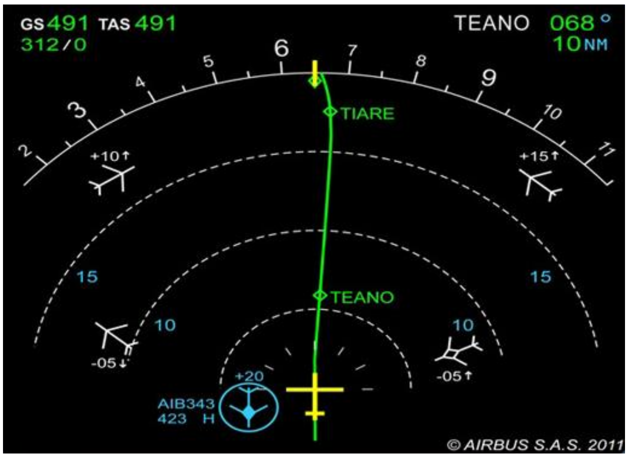

Figure 1. Cockpit Display of Traffic Information by Airbus.

The EVA-CAVS OI is expected to improve the operational performance of terminal airspace by allowing visual approaches during marginal conditions, which are inherently more efficient than instrument approaches as pilots are able to visually acquire and efficiently follow the aircraft ahead while maintaining safe separation. The instrument approaches (during marginal and instrument meteorological conditions) in comparison are longer due to the vectors given out by the controllers (limited by the radar refresh rate) to sequence the arrivals on the final approach while maintaining safe separation. These vectors take the form of trombones (stretched flight paths in the downwind leg of approach, shown in Fig 2) and are a source of inefficiency in the terminal airspace.

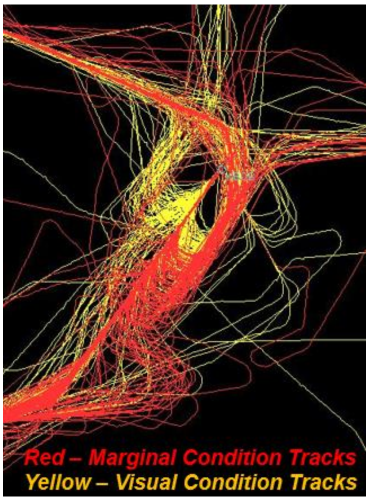

Figure 2. A Comparison of marginal condition flight tracks to visual condition flight tracks at Boston Logan airport (BOS) show that aircraft appear to trombone more in the downwind leg during marginal condition.

Previous research related to EVA-CAVS is focused primarily on the implementation feasibility in terms of pilots' willingness and the ability to use CAVS during marginal conditions to accept the responsibility of maintaining safe separation and perform visual approaches [15][16][17][18]. There is a need to develop a methodology to assess the E&E benefits and tradeoffs of OIs that can potentially result in changes in traffic flow patterns in the terminal airspace. This paper describes an AEDT based methodology to assess the E&E tradeoffs of EVA-CAVS across operational performance (i.e., track distance and time), energy (i.e., fuel savings), emissions and noise.

III. Data Sources

A. ASPM

The Aviation System Performance Metrics (ASPM) online access system provides detailed data on flights to and from the ASPM airports (currently 77) and all flights by the ASPM carriers (currently 22), including flights by those carriers to international and domestic non-ASPM airports. ASPM also includes airport weather, runway configuration, and arrival and departure rates [23].

In the methodology, the ASPM data is used to analyze airport runway configuration, meteorological conditions and estimate the count of arrivals corresponding to the meteorological conditions.

B. PDARS

The Performance Data Analysis and Reporting System (PDARS) manages and processes flight plan and radar track data collected from Air Route Traffic Control Centers (ARTCCs), the Terminal Radar Approach Control (TRACON) and the Air Traffic Control Tower (ATCT) facilities [24].

In the methodology, the PDARS track data is used to construct the average annual day scenarios which are input into AEDT to estimate E&E benefits and tradeoffs.

IV. Methodology

The underlying premise of the methodology is that with EVA-CAVS aircraft can consistently perform visual approaches during marginal conditions, and therefore the trajectories of arrival flows to a given runway during marginal conditions would be similar to the present day visual approaches. It is reasonable to make this assumption, as the trombones in the downwind leg of the final approach for instrument approaches are primarily due to lower visibility and less so due to other factors such as wind direction or magnitude.

The overview of the methodology is shown in Fig 3. The methodology leverages AEDT's modeling capabilities to estimate the potential benefits and tradeoffs (i.e., operational benefits and noise impact from tighter spacing) of EVA-CAVS in the airport's terminal airspace during marginal conditions. The analysis is conducted at the airport level by comparing the baseline scenario with the modified scenario

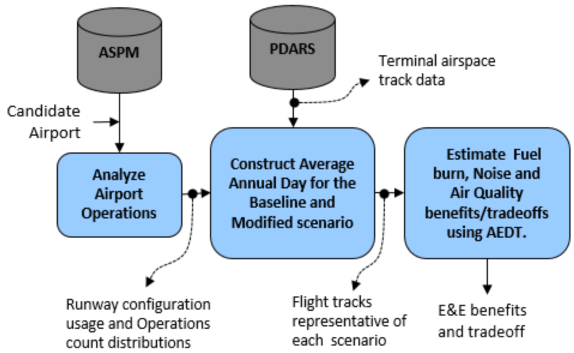

Figure 3. Methodology for Environmental Assessment of Operational Improvement - EVA-CAVS.

The baseline scenario, which is constructed to represent the average annual day for present day operations at an airport (i.e., pre-implementation scenario of EVA-CAVS), is modified by replacing all of the instrument approach trajectories corresponding to periods of marginal condition with visual approach trajectories. The modified scenario thus constructed is representative of the average annual day at an airport post EVA-CAVS implementation. The benefits and tradeoffs of EVA-CAVS is estimated as the difference between the two scenarios' corresponding metrics for operational performance, energy, emissions and noise, which are computed using AEDT.

The baseline scenario is constructed by first analyzing the distribution of arrival runway configuration and operations count for meteorological conditions (visual, marginal and instrument) at the candidate airport. The meteorological conditions are determined using the hourly ceiling and visibility information provided in the ASPM airport data and the criteria shown in Table 1. Next, a set of representative days are selected to cover all possible combinations of meteorological conditions and arrival runway configurations at the airport. The PDARS data is queried and the flight tracks are aggregated by runway configuration and meteorological condition for the selected representative days. The aggregate flight tracks thus serve as the population representative of the performance distribution (lateral and vertical) of the various arrival flows to runways for all meteorological conditions.

The baseline scenario average annual day is constructed by selecting a sample set of tracks from the aggregate population. This method of constructing the average annual day ensures that variance in arrival flow's operational performance (lateral and vertical) due to seasonal fluctuations, meteorological conditions, wind conditions, arrival rates and fleet mix distributions are captured, thus making the analysis robust.

The modified scenario average annual day is constructed by substituting all tracks corresponding to the marginal condition (i.e., instrument approaches) in the baseline scenario with an equal number of tracks corresponding to the visual condition (i.e., visual approaches) selected from the aggregate population. This is based on the premise that with EVA-CAVS aircraft can consistently perform visual approaches during marginal conditions, and therefore the trajectories of arrival flows to a given runway during marginal condition would mimic the present day visual approaches. The modified scenario thus consists of arrival flows that are representative of an average annual day at the airport when EVA-CAVS is in use. The methodology does not assume any implementation timeframe or equipage rate for EVA-CAVS. The methodology assumes that all aircraft are equipped with EVA-CAVS (100% equipage) and perform visual approaches in marginal conditions instead of instrument approaches.

The track data for each scenario is limited to within 40 nautical miles (NM) of the airport and converted to AEDT Standard Input Format (ASIF). The tracks are processed by AEDT which is used to compute the performance benefits and noise metric for the two scenarios, with the EVA-CAVS benefits and tradeoffs calculated as the difference between the two scenarios' corresponding metrics. The benefit of EVA-CAVS is measured in terms of average (averaged over all possible arrival flows and runway configurations at the airport) improvement per flight from performing visual approaches in marginal conditions instead of instrument approaches. The benefits are measured across operational performance (i.e., track distance and time), energy (i.e., fuel savings), and emissions (i.e., CO_2, CO, NO_X, SO_X and PM). The noise tradeoffs are measured in terms of population exposure to noise levels 45 dB (DNL) and above.

V. Data Analysis

A. Airport Selection

The benefits of EVA-CAVS at an airport is hypothesized to be proportional to the total annual duration of marginal condition occurrence at the airport (i.e., airports that have higher annual occurrence of marginal conditions are expected to have higher benefits). The analysis is conducted at three levels of annual duration of marginal condition occurrence, low (i.e., the 10^{th} percentile airport), medium (i.e., the 50^{th} percentile airport) and high (i.e., the 90^{th} percentile airport).

An analysis of the meteorological conditions at the Operational Evolution Partnership (OEP) 35 U.S. airports using the ASPM airport data for years 2012 and 2013 shows that DEN, BOS and LAX represent the 10^{th}, 50^{th} and 90^{th} percentile airports in terms of annual duration of marginal conditions occurrence, as shown in Fig 4. Discounting for the hours when the airports do not have any major operations (i.e., 12AM to 5AM), DEN has marginal conditions 2.6% of the time in a year affecting 7500 arrivals annually, BOS has marginal conditions 10% of the time in a year affecting 16,000 arrivals annually and LAX has marginal conditions 16% of the time in a year affecting 45,000 arrivals annually. The benefits of EVA-CAVS would come from performing visual approaches (instead of instrument approaches) on average 2.6% of the time at DEN, 10% of the time BOS and 16% of time at LAX.

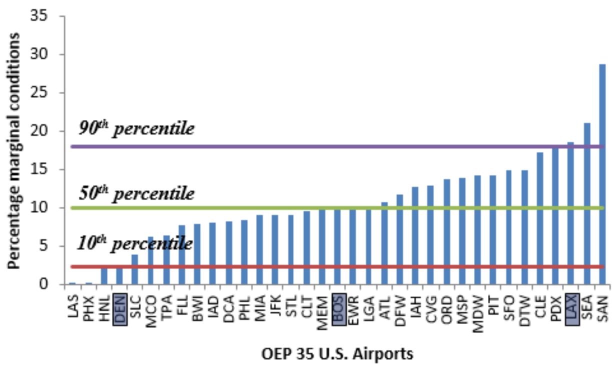

Figure 4. OEP 35 U.S. airports ranked based on the percentage annual occurrence of marginal conditions in 2012-2013

B. Airport Runway Usage Analysis

The ASPM airport data for years 2012 and 2013 is further analyzed to determine the average annual use of arrival runway configuration at DEN, BOS and LAX.

The distributions of arrival runway configuration and the corresponding number of arrivals for each configuration for DEN, BOS and LAX are shown in Fig 5, Fig 6 and Fig 7 respectively.

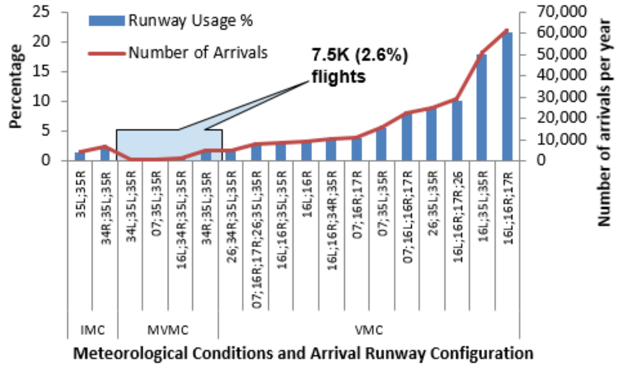

Figure 5. Distribution of arrival runway configuration usage at DEN and the total annual arrivals for each configuration.

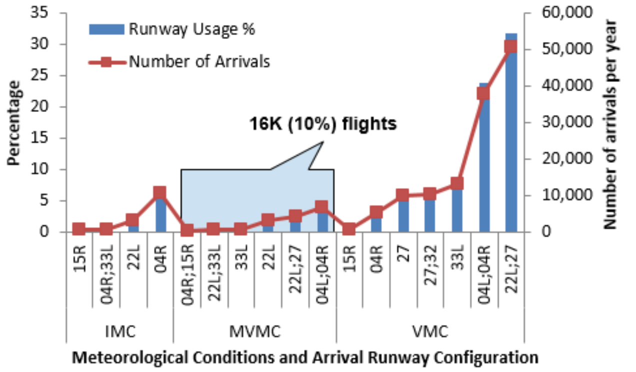

Figure 6. Distribution of arrival runway configuration usage at BOS and the total annual arrivals for each configuration.

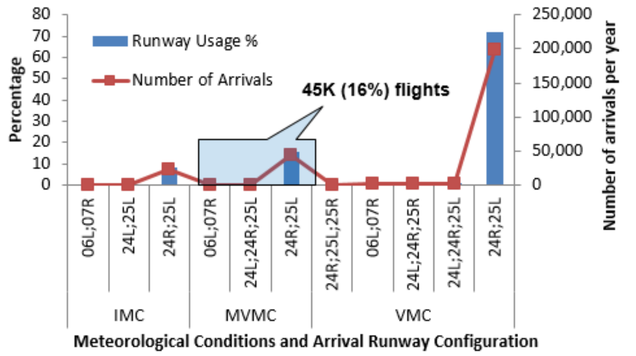

Figure 7. Distribution of arrival runway configuration usage at LAX and the total annual arrivals for each configuration.

While there is more than one runway configuration that is in use during marginal conditions, DEN predominantly uses runways with final approach from the south (i.e. runways 34R, 35L, 35R), BOS predominantly uses runways with final approach from the northeast and southwest (i.e. runways 22L, 27 and 4L, 4R) and LAX predominantly uses runways with final approach from the northeast (i.e. runways 24R and 25L).

The runway configuration used during marginal conditions are also used to the same extent (proportionally) during visual conditions, indicating that variance in wind conditions (magnitude and direction) at these airports during marginal and visual conditions are similar. This supports the underlying premise of the methodology that with EVA-CAVS aircraft can consistently perform visual approaches during marginal conditions, and the trombones in final approach for instrument approaches during marginal condition are primarily due to lower visibility and less so due to other factors such as wind direction or magnitude.

C. *Average Annual Day*

As described in the methodology section, PDARS flight tracks are aggregated by runway configuration and meteorological conditions at the airports for the selected representative days. The total number of flight tracks in the aggregate population consisted of more than 10,000 flight tracks for BOS and more than 20,000 flight tracks for DEN and LAX.

The average annual day for the baseline scenarios is constructed by selecting a total of 2,500 arrival flight tracks from the aggregate population. The modified scenario to model potential operational changes from EVA-CAVS is constructed by substituting all marginal condition arrival tracks in the baseline scenario (i.e., instrument approaches) with an equal of number visual conditions arrival tracks (i.e., visual approaches) from the aggregate population.

The track data for each scenario is limited to within 40 nautical miles (NM) or 75 kilometers (km) of the airport, converted to AEDT Standard Input Format (ASIF) and processed in AEDT to estimate the E&E benefits and tradeoffs. A scaling factor (i.e., average number of arrivals per day/2,500) is used in AEDT to normalize the 2,500 flight tracks to the average number of operations at the airports.

VI. Results

A. *Operational, Energy and Emission Results*

The operational performance, energy and emissions metric for the two scenarios (baseline and modified – EVA-CAVS) is computed using AEDT, with the EVA-CAVS benefits and tradeoffs calculated as the difference between the two scenarios' corresponding metrics. The benefits represent the average (averaged over all possible arrival flows and runway configurations at the airport) improvement per flight from performing visual approaches in marginal conditions instead of instrument approaches (i.e., from use of EVA-CAVS). In the tables below, positive numbers indicate potential net savings (benefits) and negative numbers indicate net increase in the metric from use of EVA-CAVS.

The average operational and energy benefits are shown in Table 2 and emissions benefits are shown in Table 3. On average, visual approaches are 16.2 km, 3.6 km, and 6.6 km shorter than instrument approaches during marginal conditions at DEN, BOS and LAX, respectively. In terms of fuel burn, the corresponding savings are 8.1 kg, 16.2kg, and 19.2 kg at DEN, BOS and LAX, respectively.

TABLE 2. OPERATIONAL AND ENERGY BENEFITS PER FLIGHT FROM PERFORMING VISUAL APPROACHES IN MARGINAL CONDITIONS

Airport	% Flights Affected	Total Annual Arrivals Affected	Operational Performance		Energy
			Distance (km)	Duration (min)	Fuel (kg)
DEN	2.6	7.5K	16.2	2.8	8.1
BOS	9.8	15.6K	3.6	1.1	16.2
LAX	16.3	45.1K	6.6	0.5	19.2

The fuel savings at DEN is much less compared to its operational performance improvement. Further analysis is required to explain this discrepancy, however it is hypothesized that the flight level of the final approach at DEN is much higher compared to other airports due to DEN's field elevation (5433 ft. or 1656 m) and therefore yields a lower fuel burn.

The CO_2 emissions scale proportionally with the fuel savings. All other types of emissions have less than a tenth of kilogram in difference between the baseline and modified (EVA-CAVS) scenarios, except for NO_x in BOS which shows a difference of 0.174 kg.

TABLE 3. AIR QUALITY EMISSIONS BENEFITS PER FLIGHT OF PERFORMING VISUAL APPROACHES IN MARGINAL CONDITIONS

Airport	Air Quality Emissions				
	CO_2(kg)	CO(kg)	NOx(kg)	SOx(kg)	PM 2.5(kg)
DEN	25.5	0.3	0.045	0.010	0.026
BOS	51.0	4.4	0.174	0.021	0.014
LAX	60.7	0.8	-0.008	0.025	0.015

The total annual benefits of EVA-CAVS is obtained by multiplying the benefits per flight with the total annual arrivals affected by marginal conditions at the airports. These are shown in Table 4 for operational and energy performance and in Table 5 for emissions. The corresponding percentage savings are shown in Table 6 and Table 7.

TABLE 4. TOTAL ANNUAL OPERATIONAL AND ENERGY SAVINGS FROM PERFORMING VISUAL APPROACHES IN MARGINAL CONDITIONS

Airport	Operational Performance		Energy
	Distance (km)	Duration(min)	Fuel (kg)
DEN	121K	21K	60K
BOS	56K	17K	252K
LAX	297K	22K	868K

TABLE 5. TOTAL ANNUAL EMISSIONS SAVINGS FROM PERFORMING VISUAL APPROACHES IN MARGINAL CONDITIONS

Airport	Air Quality Emissions				
	CO2(kg)	CO(kg)	NOx(kg)	SOx(kg)	PM 2.5(kg)
DEN	190K	1.9K	0.34K	0.08K	0.19K
BOS	796K	68K	2.7K	0.33K	0.22K
LAX	2,738K	34K	-0.37K	1.1K	0.68K

At 100% equipage and traffic levels of year 2012-2013, EVA-CAVS can result in on average 0.4%, 0.3% and 1.2% improvement in terms of operational performance (distance) annually at DEN, BOS and LAX, respectively. This corresponds to 0.1%, 0.6% and 1.1% potential reduction in terms of fuel and CO_2 annually.

TABLE 6. PERCENTAGE IMPROVEMENT IN OPERATIONAL AND ENERGY PERFORMANCE FROM PERFORMING VISUAL APPROACHES IN MARGINAL CONDITIONS

Airport	Operational Performance		Energy
	Distance (km)	Duration(min)	Fuel (kg)
DEN	0.4%	0.5%	0.1%
BOS	0.3%	0.6%	0.6%
LAX	1.2%	0.6%	1.1%

TABLE 7. PERCENTAGE IMPROVEMENT IN AIR QUALITY EMISSIONS FROM PERFORMING VISUAL APPROACHES IN MARGINAL CONDITIONS

Airport	Air Quality Emissions				
	CO_2(kg)	CO(kg)	NOx(kg)	SOx(kg)	PM 2.5(kg)
DEN	0.1%	0.3%	0.1%	0.1%	0.6%
BOS	0.6%	5.2%	0.9%	0.6%	0.9%
LAX	1.1%	4.3%	-0.1%	1.1%	1.5%

B. Assessment of EVA-CAVS on Noise Exposure

The noise tradeoffs are measured in terms of population exposure to noise levels 45 dB (DNL) and above. In the tables below positive numbers indicate an increase in population exposure and negative numbers indicate a decrease in population exposure.

At DEN EVA-CAVS can result in a 0.3% increase in the population exposure for noise level 45 dB DNL and below (see Table 8). There is no change in population exposure for noise level 50 dB DNL and above. At DEN, the marginal condition tracks constitute 2.6% of the arrival tracks, therefore the annual benefits accrued from use of EVA-CAVS is too low to have any significant impact across all the metrics.

TABLE 8. POPULATION EXPOSURE TO NOISE LEVELS 45 DB (DNL) AND ABOVE AT DEN

Scenario	Population Exposure DNL Noise Level (DB)			
	45	50	55	>60
Baseline	3,738	608	79	0
EVA CAVS	3,750	608	79	0
Δ Change	12	No Change		
Δ Change (%)	0.3%	No Change		

At BOS and LAX the use of EVA-CAVS has potential noise benefits. The results indicate that the reduction in trombones in the downwind leg of the final approach from use of EVA-CAVS can reduce noise exposure as shown in Table 9 and Table 10.

TABLE 9. POPULATION EXPOSURE TO NOISE LEVELS 45 DB (DNL) AND ABOVE AT BOS

Scenario	Population Exposure DNL Noise Level (DB)				
	45	50	55	60	>65
Baseline	138,386	56,205	9,140	1,719	0
EVA-CAVS	125,624	40,994	5,681	394	0
Δ Change	(12,762)	(15,211)	(3,459)	(1,325)	No Change
Δ Change (%)	-9%	-27%	-38%	-77%	No Change

TABLE 10. POPULATION EXPOSURE TO NOISE LEVELS 45 DB (DNL) AND ABOVE AT LAX

Scenario	Population Exposure DNL Noise Level (DB)					
	45	50	55	60	65	>70
Baseline	1,043K	549K	253K	83K	41K	0
EVA-CAVS	1,031K	524K	246K	75K	39K	0
Δ Change	(12K)	(25K)	(6K)	(7K)	(2K)	No Change
Δ Change (%)	-1%	-5%	-3%	-9%	-5%	No Change

C. NAS-wide Energy Savings

In order to derive a first-order estimate of the potential NAS-wide benefits from EVA-CAVS, the fuel saving estimates from this analysis for DEN, BOS and LAX airports are used to determine the relationship between percentage marginal condition and fuel savings per flight, shown in Fig 8.

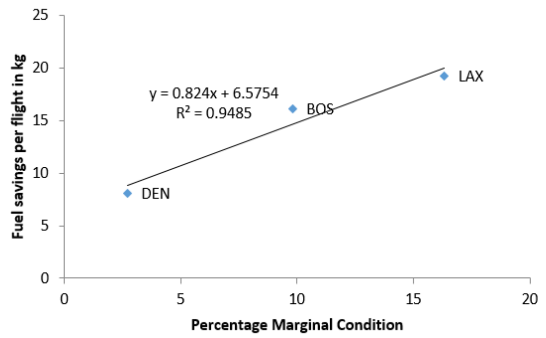

Figure 8. Relationship between percentage time in marginal condition and fuel savings per flight.

Assuming that from first principles the benefits from EVA-CAVS are proportional to percentage of time the airport is in marginal condition, a linear function is used to estimate the fuel savings per flight based on the annual percentage occurrence of marginal conditions. The total annual fuel savings is estimated based on the savings per flight and the total annual arrivals during the marginal condition instances at the OEP 35 U.S. airports, shown in Fig 9.

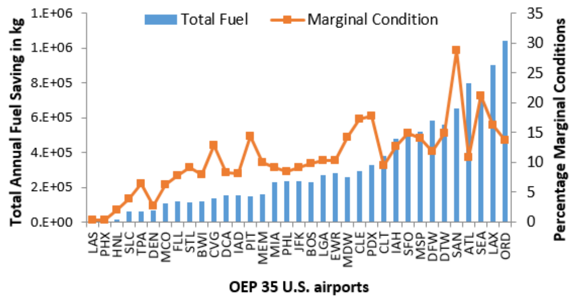

Figure 9. Annual fuel savings of EVA-CAVS at OEP 35 U.S. airports.

Analysis shows that EVA-CAVS has the potential for reducing fuel consumption in the terminal airspace (i.e., within 75 km of the airport) by 10.9 million kg annually for arrivals at OEP 35 airports based on average number of arrivals for years 2012 and 2013. At $3/gallon this amounts to $10.7 million in annual savings.

VII. CONCLUSIONS

This paper presented a methodology and analysis demonstrating E&E assessment of Enhanced Visual Approach (EVA), which is an OI for continuing visual approaches during marginal conditions. The E&E assessment of EVA-CAVS is performed at DEN, BOS and LAX. The results indicate that at 100% equipage and traffic levels of year 2012-2013, EVA-CAVS can result in on average 0.4%, 0.3% and 1.2% improvement annually in terms operations performance (distance) at DEN, BOS and LAX, respectively. This corresponds to 0.1%, 0.6% and 1.1% reduction in terms of fuel and CO2. Further, the reduction in trombones in the downwind leg of the final approach from use of EVA-CAVS can reduce noise exposure as well.

The results and analysis presented in this paper are limited to EVA-CAVS and do not capture the vast portfolio of OIs that have potential benefits in the terminal airspace. However, the methodology and analysis presented in this paper demonstrates the use of AEDT in performing a pre/post (i.e., pre-implementation and post implementation) analysis to evaluate E&E benefits and tradeoffs of OIs, specifically OIs that can potentially improve terminal airspace operations and can affect noise exposure in areas surrounding the airport. The pre/post analysis is performed by constructing a baseline scenario that is representative of airport's operations prior to implementation of the OI. A modified scenario is constructed to model the potential change in operations from implementation of the OI. The Aviation Environmental Design Tool (AEDT) is used to model the flight tracks to compute the operational performance, energy, emissions and noise metrics for the two scenarios and the benefits and tradeoffs of the OI is calculated as the difference between the two scenarios' corresponding metrics. This methodology can be generalized to model the E&E tradeoffs of any OI or a group of OIs, provided a track-based baseline (pre-implementation) and modified (post–implementation) scenario can be developed.

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DISCLAIMER

Any opinions, findings, and conclusions or recommendations expressed in this paper are those of the authors and do not necessarily reflect the views of the U.S. Federal Aviation Administration (FAA).

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