A Methodology for Environmental and Energy Assessment of Operational Improvements


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Disclaimer: This work was sponsored by the Federal Aviation Administration (FAA) Office of Environment and Energy. Opinions, interpretations, conclusions, and recommendations are those of the authors and do not necessarily reflect the views of the FAA.
Agenda

+ Introduction
+ Analysis of EVA-CAVS
+ Results
+ Conclusions
+ Next Steps
Carbon Neutral Growth

- Aspirational climate goal in US - Carbon neutral growth, starting in 2020, relative to the 2005 emissions level.

- Given the current growth forecast, emissions reducing measures will be required to meet the carbon neutral growth target.
Solution set for achieving the desired level of improvement

- Climate Goal
- Solution Set
  - Airframe and engine improvements
  - Operational Improvements
  - Alternative Fuels
  - Market Based Measure
  - Improved scientific understanding, modeling and analysis
Operational Improvements have the highest potential for delivering E&E benefits in the near term

- Operational Improvements include development and integration of advanced operational procedures and infrastructure to foster airspace system operational capabilities that will function more efficiently and contribute to mitigating environmental impacts and improving energy efficiency.

- Operational Improvements have the highest potential for delivering E&E benefits in the near term
  - Higher Technology Readiness Level (TRL).
  - Faster time constant of implementation.

Focus of this research: Operational Improvements that can potentially improve terminal airspace operations and can affect noise exposure in areas surrounding the airport.
Need for Environmental Modeling

+ Previous research/studies have primarily focused on feasibility of implementation of Operational Improvements.
+ There is a need to develop a methodology to assess the E&E benefits and tradeoffs of Operational Improvements.
  – Improved operational performance vs. air quality emission and noise exposure.
+ Use of tools like Aviation Environmental Design Tool (AEDT)
  – Bypass costly flight trials or Human-in-the-Loop simulation (HITL)
Aviation Environmental Design Tool

+ AEDT is a software system developed by FAA that can model aircraft performance to produce fuel burn, emissions and noise metrics.

+ Used by the U.S. government to assess the interdependencies between aircraft-related fuel burn, noise and emissions at airports.

+ Data input format
  – XML file used to define airports, scenarios, cases, flights, tracks, and operations.

+ Can model both noise and emissions.

+ Can model standard and user-defined aircraft and flight profiles.

+ Website: https://aedt.faa.gov/
Generic Approach to Model Operational Improvements

- Climate Goal
- Solution Set
  - Airframe and engine improvements
  - Operational Improvements
  - Alternative Fuels
  - Market Based Measure
  - Improved scientific understanding, modeling and analysis
- AEDT
  - Pre-implementation. Baseline scenario Average Annual Day
  - Post-implementation. Modified scenario Average Annual Day

Energy and Environment Benefits and Tradeoff
Agenda

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Enhanced Visual Approach (EVA)

+ EVA is an operational improvement (OI) that can allow visual approaches in marginal meteorological conditions.

<table>
<thead>
<tr>
<th>Weather Minima</th>
<th>Visual</th>
<th>Marginal</th>
<th>Instrument</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visibility</td>
<td>at least 5 statute miles</td>
<td>below VMC but better than IMC</td>
<td>below 3 statute miles</td>
</tr>
<tr>
<td>Ceiling</td>
<td>at least 3,000 ft.</td>
<td>below VMC but better than IMC</td>
<td>below 1,000 ft.</td>
</tr>
</tbody>
</table>


- Flights appear to trombone more in the downwind leg during marginal condition compared to visual conditions.
- EVA is expected to improve the operational performance of terminal airspace by allowing visual approaches during marginal conditions.
Assumption:

- With EVA aircraft can consistently perform visual approaches during marginal conditions.
- The trajectories of arrival flows to a given runway during marginal conditions would be similar to the present day visual approaches.

+ The baseline scenario (pre-implementation)
- Represent average annual day for present day operations at an airport.

+ The modified scenario (post-implementation)
- Represent average annual day if EVA-CAVS is introduced.
- Constructed by replacing instrument approach trajectories in the baseline scenario corresponding to periods of marginal condition with visual approach trajectories.
Data Sources

+ Aviation System Performance Metrics (ASPM):
  – 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.
  – Includes airport weather, runway configuration, and arrival and departure rates.
  – In this analysis ASPM data is used to analyze airport runway configuration, meteorological conditions and estimate the count of arrivals corresponding to the meteorological conditions.

+ The Performance Data Analysis and Reporting System (PDARS).
  – Includes 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.
  – In this analysis PDARS is used to construct the average annual day scenarios which are input into AEDT to estimate E&E benefits and tradeoffs.
Selection of candidate airports

+ Hypothesis: The potential benefits of EVA-CAVS is proportional to the total annual duration of marginal condition occurrence at the airports.
  
  – Airports that have higher annual occurrence of marginal conditions are expected to have higher benefits.

+ DEN, BOS and LAX represent the 10th, 50th and 90th percentile airports in terms of annual duration of marginal conditions occurrence.
At DEN 2.6% (7.5K flights) of arrivals are affected by marginal condition on average annually.

Runways with final approach from the south (i.e. runways 34R, 35L, 35R) are predominantly used during marginal conditions.

Runway Configuration and Flight Count Distribution for arrivals

- Rwy Usage %
- # of Arrivals

IMC

2.6% (7.5K flights)

VMC

Meteorological Conditions and Arrival Runway Configurations

DEN – Runway Layout
At BOS 10% (16K flights) of arrivals are affected by marginal condition on average annually.

Runways with final approach from the northeast and southwest (i.e. runways 22L, 27 and 4L, 4R) are predominantly used during marginal conditions.
At LAX 16% (45K flights) of arrivals are affected by marginal condition on average annually.

Runways with final approach from the northeast (i.e. runways 24R and 25L) are predominantly used during marginal conditions.
Select representative days at the airport
  – Based on runway configuration and meteorological conditions

Aggregate PDARS data for the representative days.
  – 10,000 flight tracks for BOS
  – 20,000 flight tracks for DEN and LAX.

Construct Baseline scenario (Average annual day)
  – Sample size 2500 flights

Construct modified scenario
  – Substitute 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.

Truncate flight tracks
  – Track limited to within 40 nautical miles (NM) or 75 kilometers (km) of the airport.

Estimate AEDT scaling factor to normalize operations.
  – Scaling factor = average number of arrivals per day/2,500.
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Operational, Energy and Emission Benefits/Tradeoffs per flight

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.

In terms of CO$_2$, the corresponding savings are 25.5 kg, 51kg, and 61 kg at DEN, BOS and LAX, respectively.

<table>
<thead>
<tr>
<th>Airport</th>
<th>% Flights Affected</th>
<th>Total Annual Arrivals Affected</th>
<th>Operational Performance</th>
<th>Energy</th>
<th>Climate</th>
<th>Air Quality Emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Distance (km)</td>
<td>Duration (min)</td>
<td>Fuel (kg)</td>
<td>CO2(kg)</td>
</tr>
<tr>
<td>DEN</td>
<td>2.7</td>
<td>7K</td>
<td>16.2</td>
<td>2.8</td>
<td>8.1</td>
<td>25.5</td>
</tr>
<tr>
<td>BOS</td>
<td>9.8</td>
<td>15K</td>
<td>3.6</td>
<td>1.1</td>
<td>16.2</td>
<td>51.0</td>
</tr>
<tr>
<td>LAX</td>
<td>16.3</td>
<td>45K</td>
<td>6.6</td>
<td>0.5</td>
<td>19.2</td>
<td>60.7</td>
</tr>
</tbody>
</table>
### Annual benefits of EVA-CAVS at DEN, BOS, LAX:
- 0.4%, 0.3% and 1.2% improvement in terms of operational performance (track distance)
- 0.1%, 0.6% and 1.1% potential reduction in terms of fuel burn and CO₂ annually.
- Except for NOx at LAX there is reduction in other emissions too.

### Reduction in trombones in the downwind leg of the final approach from use of EVA-CAVS can reduce noise exposure

### TOTAL ANNUAL SAVINGS FROM PERFORMING VISUAL APPROACHES IN MARGINAL CONDITIONS

<table>
<thead>
<tr>
<th>Airport</th>
<th>Operational Performance</th>
<th>Energy</th>
<th>Climate</th>
<th>Air Quality Emissions</th>
<th>Noise - Population Exposure DNL Noise Level (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Distance (km)</td>
<td>Duration (min)</td>
<td>CO2(kg)</td>
<td>CO(kg)</td>
<td>NOx(kg)</td>
</tr>
<tr>
<td>DEN</td>
<td>121K</td>
<td>20K</td>
<td>60K</td>
<td>190K</td>
<td>2K</td>
</tr>
<tr>
<td>BOS</td>
<td>56K</td>
<td>17K</td>
<td>252K</td>
<td>796K</td>
<td>68K</td>
</tr>
</tbody>
</table>

### PERCENTAGE IMPROVEMENT FROM PERFORMING VISUAL APPROACHES IN MARGINAL CONDITIONS

<table>
<thead>
<tr>
<th>Airport</th>
<th>Distance (km)</th>
<th>Duration (min)</th>
<th>CO2(kg)</th>
<th>CO(kg)</th>
<th>NOx(kg)</th>
<th>SOx(kg)</th>
<th>PM 2.5(kg)</th>
<th>40</th>
<th>45</th>
<th>50</th>
<th>55</th>
<th>60</th>
<th>65</th>
<th>70</th>
<th>75</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEN</td>
<td>0.4%</td>
<td>0.5%</td>
<td>0.1%</td>
<td>0.1%</td>
<td>0.3%</td>
<td>0.1%</td>
<td>0.1%</td>
<td>0.6%</td>
<td>2.8%</td>
<td>0.3%</td>
<td>No Change</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BOS</td>
<td>0.3%</td>
<td>0.6%</td>
<td>0.6%</td>
<td>0.6%</td>
<td>5.2%</td>
<td>0.9%</td>
<td>0.6%</td>
<td>0.9%</td>
<td>-11.6%</td>
<td>-9.2%</td>
<td>-27.1%</td>
<td>-37.8%</td>
<td>-9.4%</td>
<td>-4.8%</td>
<td>No Change</td>
</tr>
<tr>
<td>LAX</td>
<td>1.2%</td>
<td>0.6%</td>
<td>1.1%</td>
<td>1.1%</td>
<td>4.3%</td>
<td>-0.1%</td>
<td>1.1%</td>
<td>1.5%</td>
<td>-4.9%</td>
<td>-1.2%</td>
<td>-4.7%</td>
<td>-2.7%</td>
<td>-9.4%</td>
<td>-4.8%</td>
<td>No Change</td>
</tr>
</tbody>
</table>
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.

A linear function is used to estimate the fuel savings per flight based on the annual percentage occurrence of marginal conditions.

\[ y = 0.824x + 6.5754 \]

\[ R^2 = 0.9485 \]
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 major airports in the U.S.

At $3/gallon this amounts to $10.7 million in annual savings.
+ EVA-CAVS can have benefits across energy, emissions and noise.
  – 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 CO2.
  – The reduction in trombones in the downwind leg of the final approach from use of EVA-CAVS can reduce noise exposure as well.

+ The paper demonstrates the use of AEDT in performing:
  – pre/post (i.e., pre-implementation and post implementation) analysis to evaluate E&E benefits and tradeoffs of OIs
  – OIs that can potentially improve terminal airspace operations and can affect noise exposure in areas surrounding the airport.

+ Limitation
  – The results and analysis presented in this paper are limited to EVA-CAVS and do not capture the vast portfolio of OIs that are comprised in the NextGen.
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Generate distributions of operational performance based on actual radar based track data.

Perform parametric analysis to estimate CO₂ mitigation potential at various levels of operational performance.

- Analyze flights at various performance level percentile (i.e., 10th, 50th and 90th percentile) to estimate the lower, mean and upper bound for flight performance.
- Identify factors that influence level of operational performance.
- Estimate lower bound of NAS-wide operational performance

Scope

- NAS wide runway to runway operations.
- Regional airport level flow analysis.

Estimate Fuel burn and CO₂ reduction potential
Questions & Comments

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Acknowledgments:  
The authors thank Mr. Christopher Dorbian for his guidance.