Project 011(A) Development of Rapid Fleet-Wide Environmental Assessment Capability Using a Response Surface Modeling Approach

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Project Lead Investigator

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- Period of Performance: Aug. 18, 2014 to Aug. 31, 2018 (year 4 as NCE)
- Task(s):
  1. Extend And Enhance Modeling Framework
  2. Extend Fleet Gauge Sample Problem To System Level
  3. Develop Multi-stakeholder Valuation Methods To Enable Comparison And Decisions About Preferred Strategies In The Environmental Output Space
  4. Apply Fast Modeling Framework To Additional Sample Problem

Project Funding Level

$670,000 FAA funding and $670,000 matching funds. Sources of match are approximately $279,000 from MIT, and $231,000 from Byogy Renewables, Inc. and $160,000 from Oliver Wyman Group.

Investigation Team

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Project Overview

The objective of the research is to continue development of an analytical framework for evaluating the environmental impact of air transportation and to use that framework on a variety of sample policy and operational problems. This framework will use fast models for aircraft-level performance, noise, and emissions, enabling broad scenario explorations and parametric analyses in environmental studies. Phase I of this research (2014-2015) consisted of general analysis framework development, sample problem selection, and surrogate model development. Phase II of this research (2015-2016) aimed to continue model development while demonstrating the capability of the modeling approach on a specific multi-dimensional sample problem involving fleet gauge modification. Phase III of this research (2016-2017) aimed to increase the ability to evaluate local noise impacts at the system level and develop additional multi-objective sample problems to demonstrate the flexibility and extensibility of the rapid environmental analysis framework. This phase refined the relationship between local and system-level impacts arising from specific advanced operational procedures and aircraft fleet evolution.

Task #1: Extend and Enhance Modeling Framework

Objective(s)

The modeling framework for rapid environmental impact assessment has been developed to include local and system wide impacts for noise, emissions, and fuel consumption at specific locations based on representative or generic airports. The first two years of this research highlighted the challenge of systematically evaluating local (e.g. noise and LTO emissions) which depend on location-specific elements such as procedure design, fleet mix, population density, etc. with global factors such as emissions and fuel consumption.

This task aimed to develop techniques that can capture key environmental characteristics at a system level that incorporates location-specific characteristics. In order to rapidly analyze individual airport performance, it is necessary to have a generic representation of the operating patterns and flight trajectories. This task leverages work that has been done on statistical clustering methods to identify common operations at individual airports, simplified generic profile definitions for some airports, and detailed procedure modeling for certain classes of advanced operational procedures.

Research Approach

- Expand the modeling framework and architecture developed in the initial phases of the research with greater detail on modules and interfaces to enable implementation of specific sample problems.
- Locate and incorporate data sources for procedure definition, fleet mix, and timetable to enable rapid system-level analysis without requiring extensive manual intervention on an airport-by-airport basis.

Major Accomplishments

- Extended the modeling framework with new simplifying assumptions to allow system wide noise analysis using simplifying straight-in and straight-out procedural assumptions
- Developed data processing architecture and capability for system-level analysis incorporating location-specific procedure definitions

Task #2: Extend Fleet Gauge Sample Problem To System Level

Objective(s)

In Year 2 of this effort, an initial fleet gauge sample problem was evaluated. The objective of this sample problem was to calculate the environmental impact of a 10% upgauge at a single example airport (DCA) using the 2015 operational fleet model. The aggregate noise, emissions, fuel consumption, and NOx impacts were calculated, along with potential effects on passenger throughput. In Year 3, this sample problem will be expanded to a broader system level using the results of Task 1, specifically incorporating local noise analysis at the OEP 35 airports. This allowed for continued development and refinement of the modeling framework, allowing for policy valuation and comparison across multiple stakeholders and impact scales.

Research Approach

- Develop modeling capability at a specific airport (DCA) that is representative of the types of results desired for each airport in a broader system-level analysis.
- Extend the modeling capability developed for the specific airport to a small subset of the NAS to evaluate potential data and analysis implementation challenges.
- Extent modeling capability to full airport sample set of interest (initially the OEP 35 airports)

Major Accomplishments

- Developed operation modeling method using ASPM data for DCA case study that can be applied at any other airport in NAS
- Calculated DNL contours for OEP35 airports using simplified framework
- Compared ASPM runway use results to official FAA runway use assumptions for straight-in and straight-out system level analysis
- Began development of system wide trajectory modeling of RNAV procedures (SIDs and STARs) to capture realistic flight patterns rather than earlier straight-in and straight-out assumption

Task #3: Develop Multi-stakeholder Valuation Methods to Enable Comparison and Decisions about Preferred Strategies in the Environmental Output Space

Objective(s)

Environmental impacts from air transportation activities are felt across multiple stakeholders, geographic scales, and timescales. As a result, different stakeholders have different priorities and perceived valuations of possible policies and procedures. The focus of the first two years in this research effort was to generate system outputs in terms of raw environmental metrics (for noise, emissions, fuel burn, etc.). These metrics do not translate directly to a stakeholder preference structure or an improved understanding of community welfare on local and system wide scales. In this phase of the research effort, multi-stakeholder valuation methods were investigated with specific emphasis placed on an evaluation of different noise metrics to capture annoyance beyond traditional "significant" noise level definitions.

Research Approach

- Evaluate methods and metrics for assessing impact from environmental variables, particularly noise.
- Analyze and compare results using the rapid system-level analysis framework using appropriate metrics of choice.

Major Accomplishments

- Generated fuel results for a sample network using surrogate model version of TASOPT
- Developed fuel burn model for departures to compare effects of speed and configuration modification on fuel/emissions from modified procedures.
- Developed method for rapid population impact analysis in terms of DNL and Nabove noise metrics.

Task #4: Apply Fast Modeling Framework To Additional Sample Problem

Objective(s)

In this task, the fast modeling architecture for local and system wide environmental analysis was applied to an additional sample problem to evaluate system-level applications for location-specific procedural changes. The objective of this task was to exercise modeling capabilities with scenarios that are relevant for multiple stakeholders, including local communities, operators, airports, and regulators.

Research Approach

- Identify methods to model flight operations in the vicinity of airports using representative trajectories based on historical radar data and published procedures
- Integrate schedule, fleet, and runway utilization data from external sources to allow calculation of noise contours at airports of interest
- Analyze noise impacts at a system level that would arise from implementing a specific advanced operational procedure of interest, or modifying procedure design criteria for specific types of PBN procedures.

Major Accomplishments

- Developed concept for additional sample problems at DCA including fleet replacement strategies and minimum-gauge strategies
- Completed analysis on 3 sample problems at DCA, including emissions, fuel, and noise results.
- Develop estimation method for finding noise benefits from advanced operational procedures, including:
    - Shortened final approach segments
    - Steep descents
    - Reduced-speed departures

Publications

"Development of Rapid Fleet-Wide Environmental Assessment Capability," *AIAA AVIATION Forum*, 2017.
DOI: 10.2514/6.2017-3339

Outreach Efforts

1/25/2017: Briefing to FAA Joint University Program research update meeting
4/17/2017: Joint briefing to FAA and MITRE to discuss tool development pathway
4/18/2017: Briefing to ASCENT Advisory Board
6/5/2017: Presentation at AIAA Aviation Conference in Denver, CO.
In-person outreach and collaboration with TASOPT aircraft performance model development team at MIT.
In-person outreach and collaboration with Volpe noise tool development team.

Awards

None

Student Involvement

Graduate students have been involved in all aspects of this research in terms of analysis, documentation, and presentation.

Plans for Next Period

The next phase of this project is a no-cost extension of the Year 3 effort. This Year 4 effort will involve three primary areas of focus:

1. Continued development of a system-level modeling approach with a focus on noise analysis incorporating advanced operational procedures. Specifically, this will involve development of a procedure-based track generation method to supplement straight-in and straight-out procedures at airports with defined SIDs. This will increase the fidelity of noise modeling at airports where straight-in and straight-out assumptions do not capture prevailing traffic flows. This will be accomplished by parsing the FAA Coded Instrument Flight Procedures (CIFP) dataset to automatically generate published ground tracks on a NAS-wide basis and applying a set of standardized climb profiles (altitude/thrust/speed) to the CIFP-derived lateral tracks based on fleet-specific ASDE-X analysis (same method presented in the past).
2. Development of an updated codebase and user interface for noise analysis workflow to simplify analysis flexibility, data sources, and profile assignment and noise contour post-processing workflow.
3. Improved population impact assessment to evaluate sensitivity of system-level noise exposure to specific operational and policy questions such as final approach leg length criteria, final approach intercept angles, and RNAV leg length requirements.