# Reducing Aviation Emissions With MILP Optimization

## *2024 FAA Data Challenge — Contribute to Sustainable Aviation*

TEXAS A&M UNIVERSITY Engineering


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## Problem Definition

The aviation industry contributes significantly to global carbon emissions, accounting for 3.5% of human-induced climate change. While advancements in sustainable aviation fuel and next-generation aircraft offer long-term solutions, large-scale emissions reductions remain difficult due to technological and economic barriers. Addressing this requires optimizing airline operations to cut emissions while maintaining profitability and efficiency. This work presents an algorithm that optimizes historical flight schedules to reduce airline emissions by **5.1%**.

## Methodology

The optimization algorithm presented has 3 major components:

**Data Inputs (Figure 1)**

- Historic Flight Data (from BTS T-100 Database)
- Emissions Estimates (from Texas Transportation Institute)
- Revenue Data (from DB1B Market Database)

**Multiple Integer Linear Programming Model (Figure 4)**

- Reassigns aircraft types to minimize emissions
- Adjusts flight frequencies to improve efficiency
- Restructures routes to balance demand and revenue

**Key Constraints**

- Demand fulfillment (maximizing passenger capacity)
- Revenue floors (ensures operational profitability)
- Aircraft availability (respects fleet limitations)

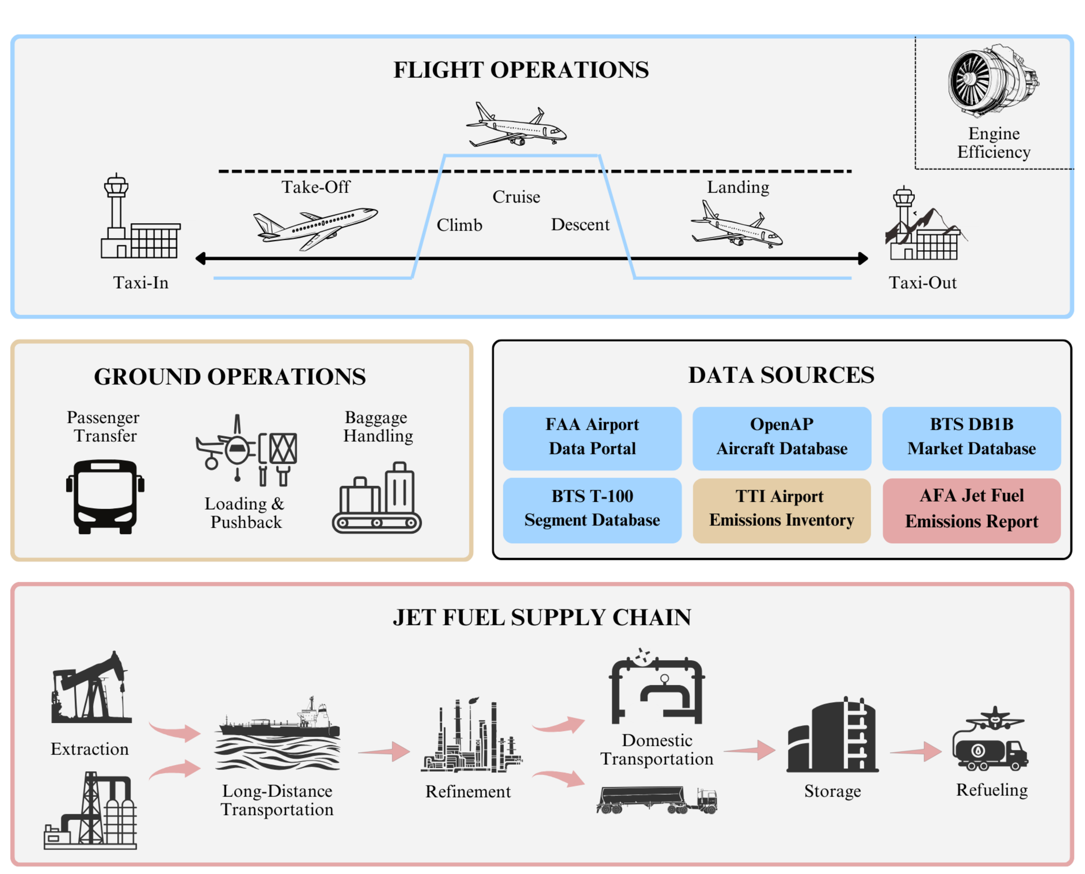


*Figure 1. Contributing sources of emissions and data inputs.*

## Emissions Analysis

After designing the algorithm based on historical data, a full suite of studies on the optimized flight schedule was conducted to showcase the efficacy of the results:

**A.** **Figure 2** — The average emissions contribution by flight phase highlights that in shorter flights, the relative impact of ground times can be noticeable.

**B.** **Figure 3** — The Pareto Curve of emissions vs. revenue reduction demonstrates the trade-off of approx. **\$1 of lost revenue per kg of $CO_2$ saved.**

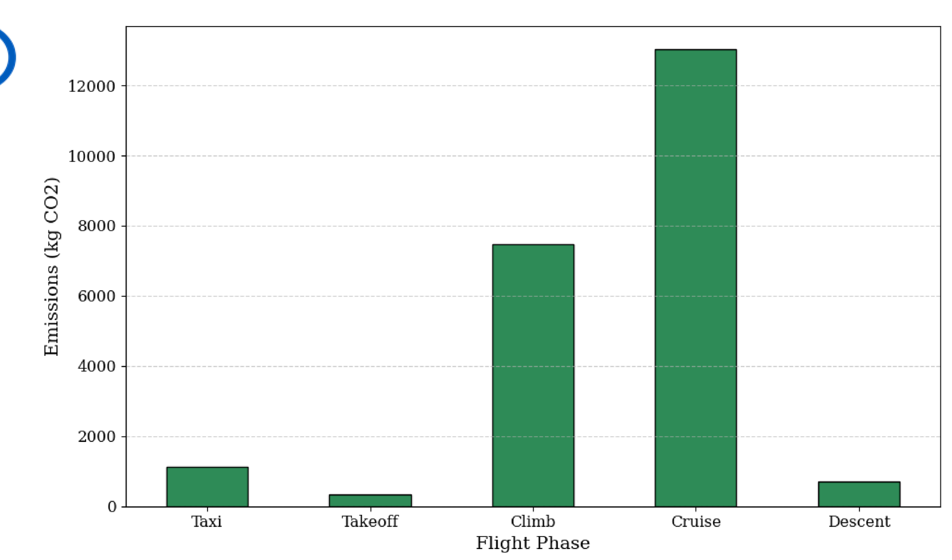


*Figure 2. Emissions Contribution by Flight Phase.*

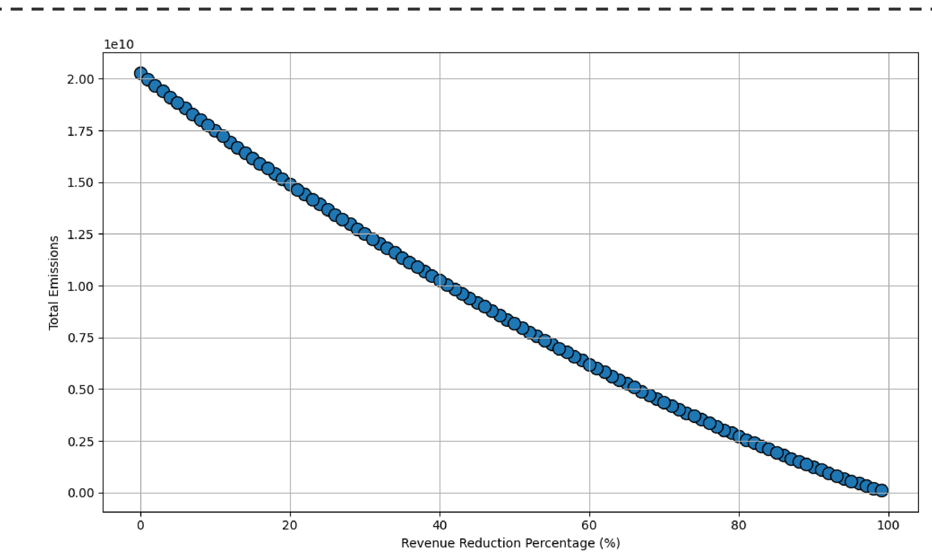


*Figure 3. Pareto Curve of Emissions vs. Revenue Reduction.*

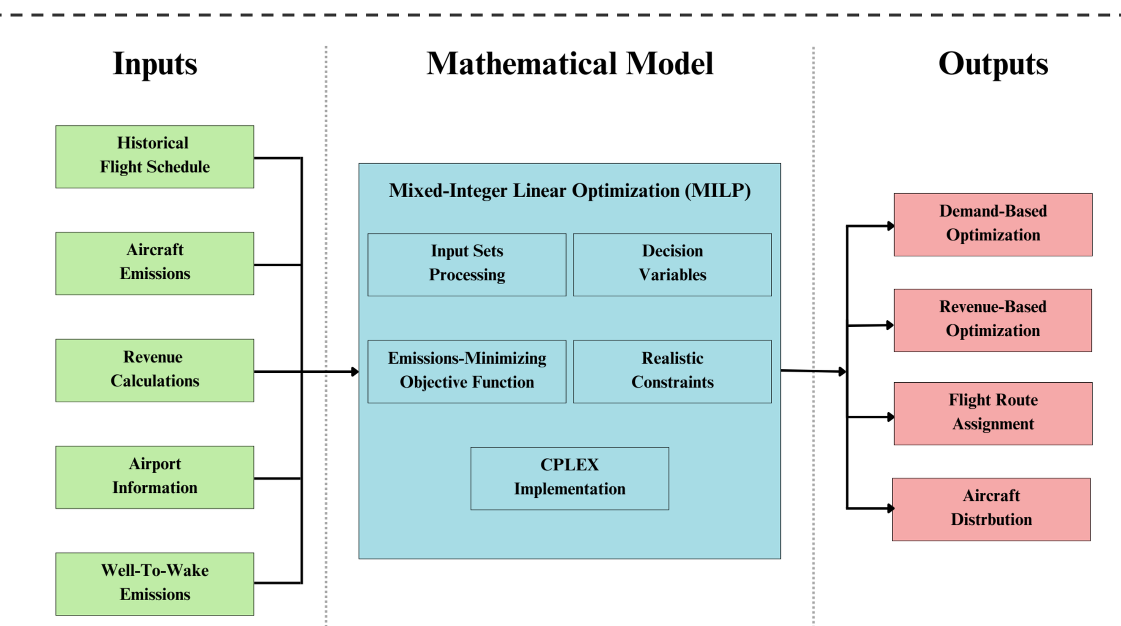


*Figure 4. Flowchart of the MILP model's architecture.*

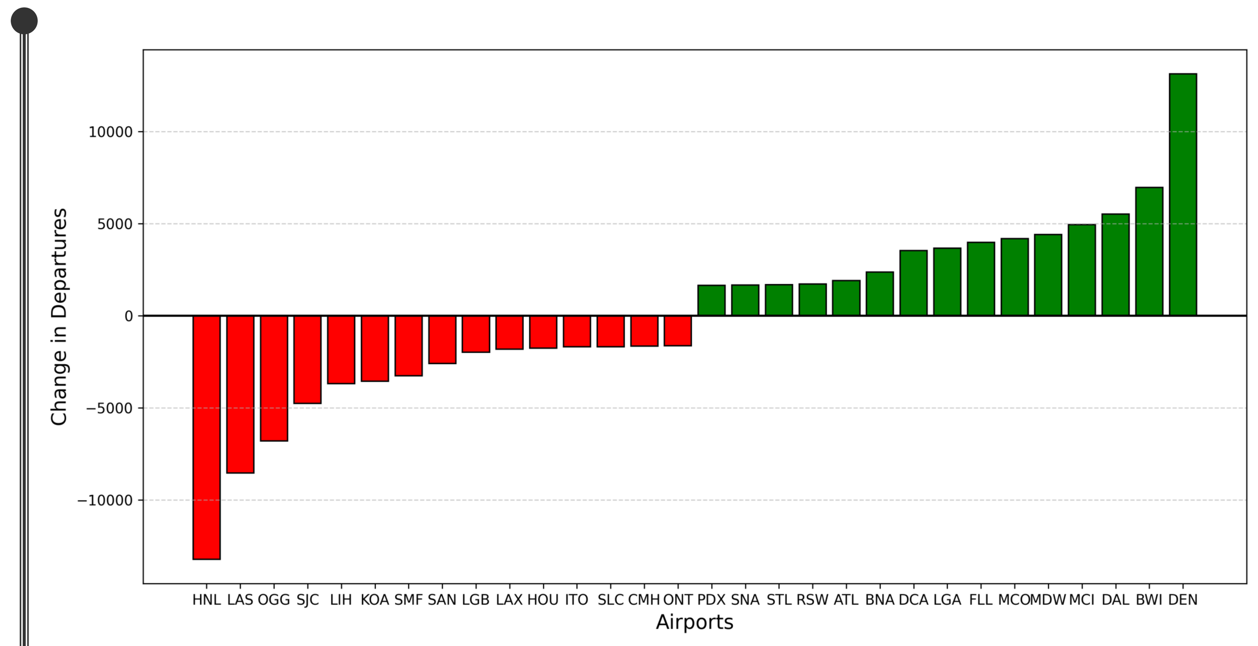


*Figure 5. New Distribution of the 737-8 Aircraft*

## Outcomes

The model demonstrated that adjusting aircraft assignments and flight frequencies can achieve at least **5.1% emissions reduction** without compromising demand or revenue. Among other variables that were changed, a major contributor to this reduction was reassigning aircraft to their most efficient route length (**Figure 5**).

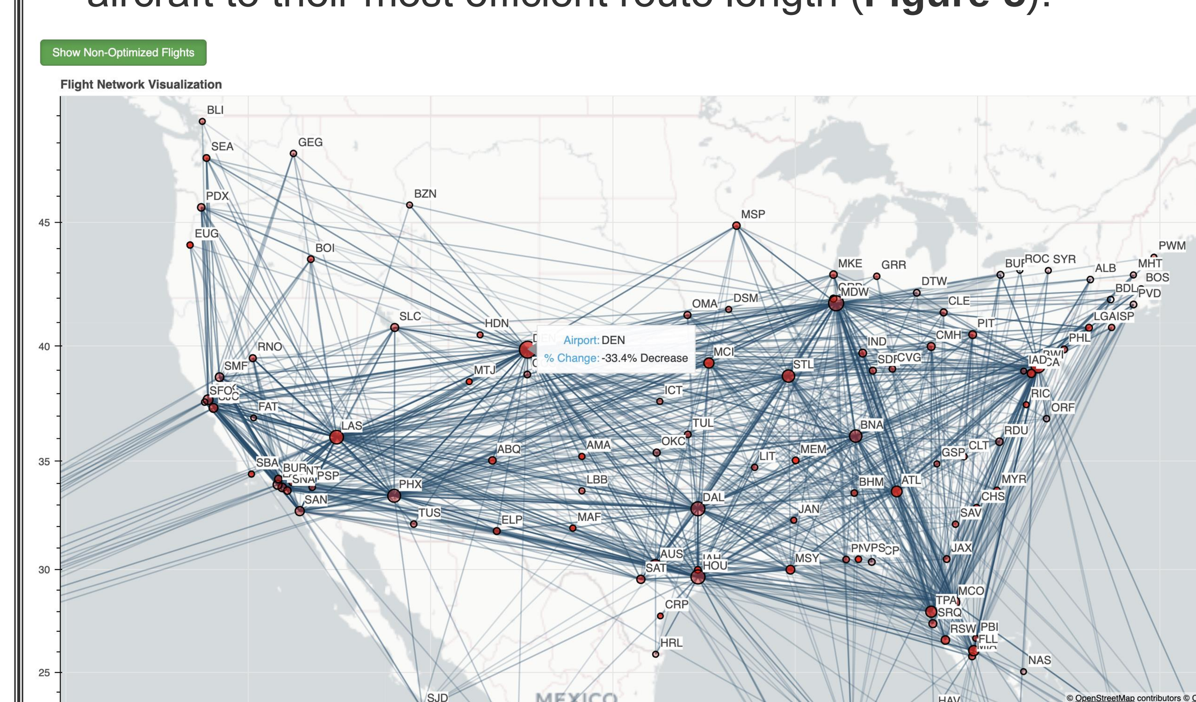


*Figure 6. Interactive map of flight network.*

### Building the Model with the End-User in Mind

The model was designed to be accessible for airline operations managers, so we worked extensively with Southwest Airlines to determine clear visualizations. An interactive map was developed (**Figure 6**) to visualize the optimized network, showing shifts in aircraft deployment and route structures, highlighting airports with the most significant changes, and providing a data-driven framework for emissions-conscious scheduling decisions.

*Table 1. Actual vs. Optimized System-Wide Network Performance*

| | Actual Network | Optimized Network | Percentage Reduction |
|---|---|---|---|
| Total $CO_2$ Emissions (MT) | 24,873,759 | 23,607,420 | -5.1% |
| Total Flights Operated | 1,459,427 | 1,073,214 | -26.3% |
| Total Passenger Demand | 176,107,136 | 176,107,136 | 0% |
| Total Seats Offered | 231,009,746 | ~176,107,136 | -23.7% |

The new optimized network meets demand while reducing the number of flights and seats offered (**Table 1**). While inefficiencies due to weather and mechanical issues are not considered, future work will include these factors.

## Impact

The optimization algorithm presented provides a realistic and implementable strategy for reducing airline emissions without requiring new technology or major infrastructure changes.

- **Emissions Reduction:** Optimized schedules lower $CO_2$ emissions by at least **5.1%** through improved aircraft allocation and flight frequency adjustments.
- **Operational Feasibility:** The model works within existing airline constraints, ensuring realistic implementation without disrupting operations.
- **Financial Viability:** The financial loss is quantified, giving operations manager clarity on how to best balance sustainability with profitability.
- **Scalability:** This approach can be applied across different airlines and networks, making emissions reduction a viable industry-wide strategy.

## References


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3. J. Sun, J. M. Hoekstra, and J. Ellerbroek, "OpenAP: An open-source aircraft performance model for air transportation studies and simulations"
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## Acknowledgements


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