Research Pathways for Sustainable Aviation

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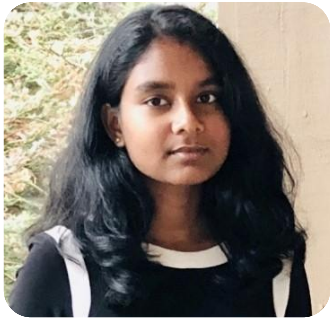

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Agenda

- Problems
- Potential solutions
- Impacts
- Future directions
- Acknowledgements
- Questions

Scheduling

Fuel

Scheduling

Schedule Making

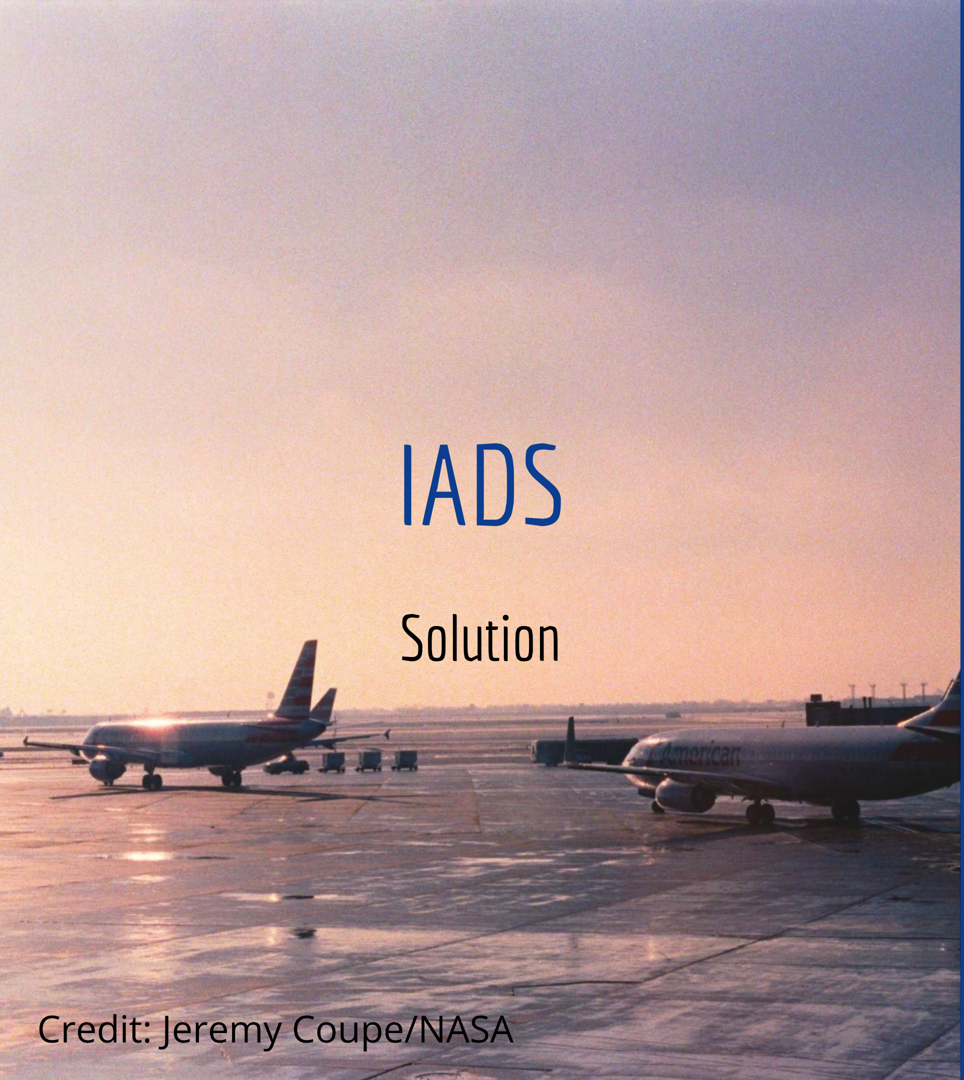
Problem

- Scheduling importance
- Scheduling process
    - Network design
        - Hub-and-spoke
        - Point-to-point
    - Frequency assignment
    - Flight schedule
- Issues
    - Complexity
    - Communication

Delays

Problem

- Why do some delays occur?
    - Staffing
    - Weather
    - Maintenance
- Problems that arise from delays
    - Fuel wastage
    - Aviation noise



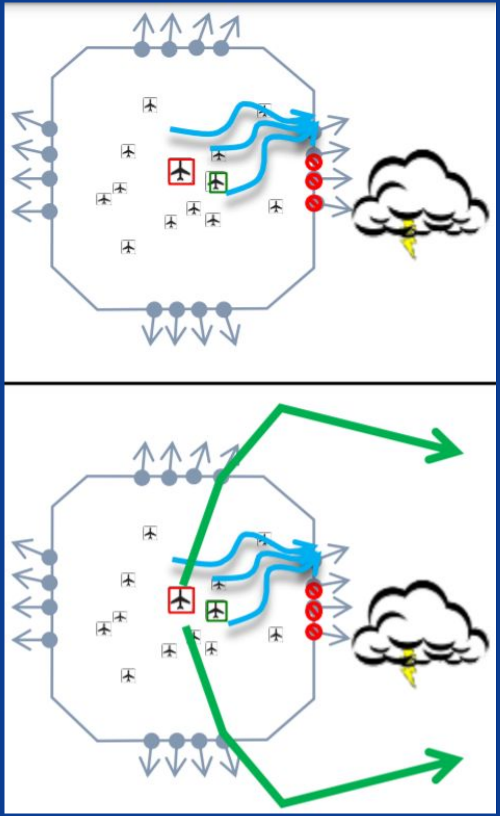
IADS

Solution

Credit: Jeremy Coupe/NASA

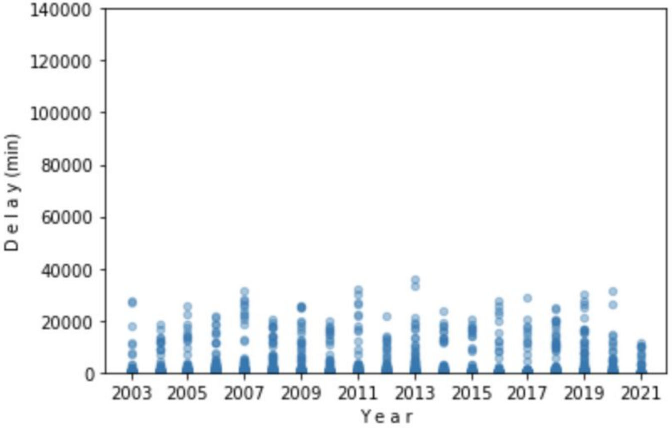
Integrated Arrival, Departure, and Surface

- Background

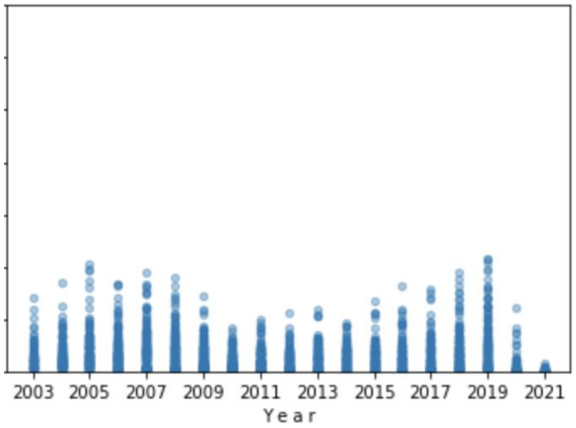


National Airspace System (NAS) Delays

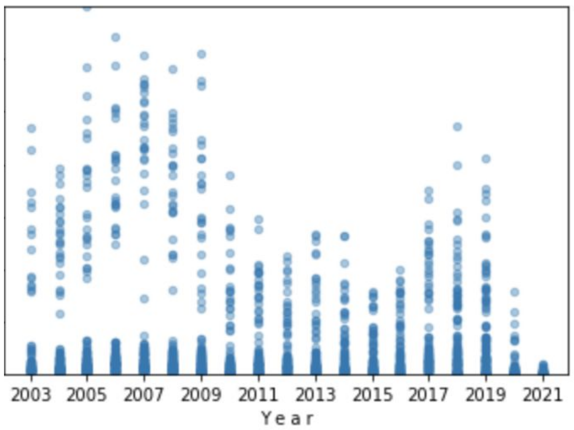
(2003-2021)



Charlotte



LaGuardia

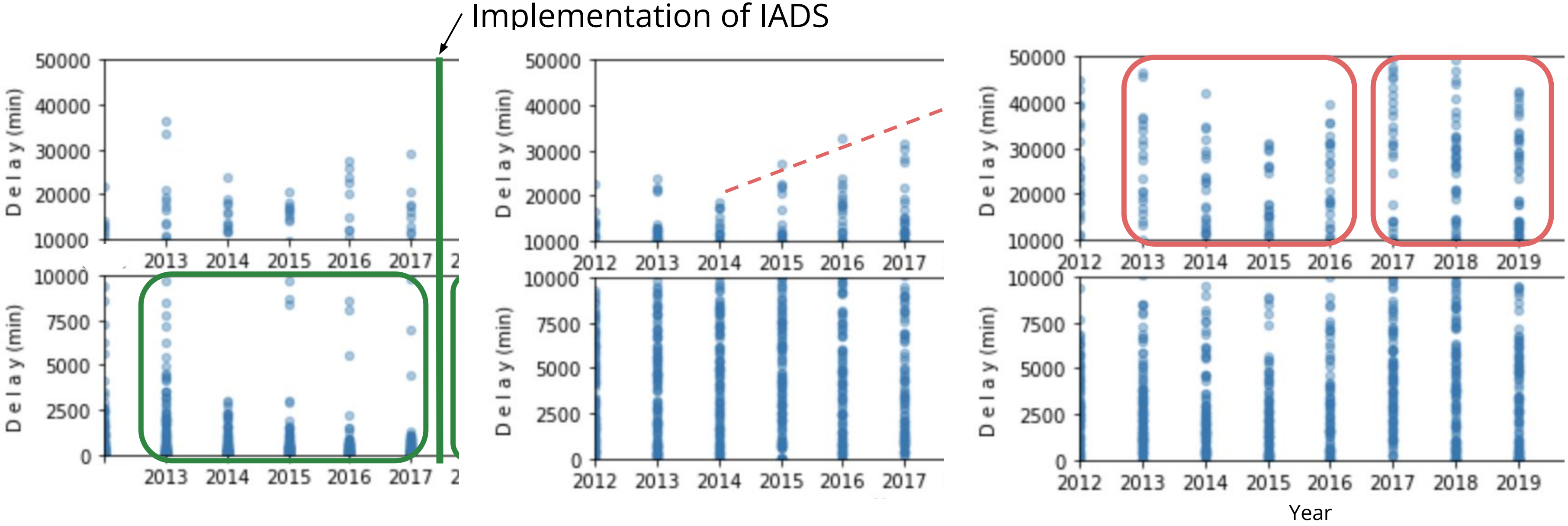


Newark

The delays in Charlotte are concentrated towards the low ends vs LaGuardia and Newark

Data Source: FAA

High vs Low Interval Delays



Charlotte

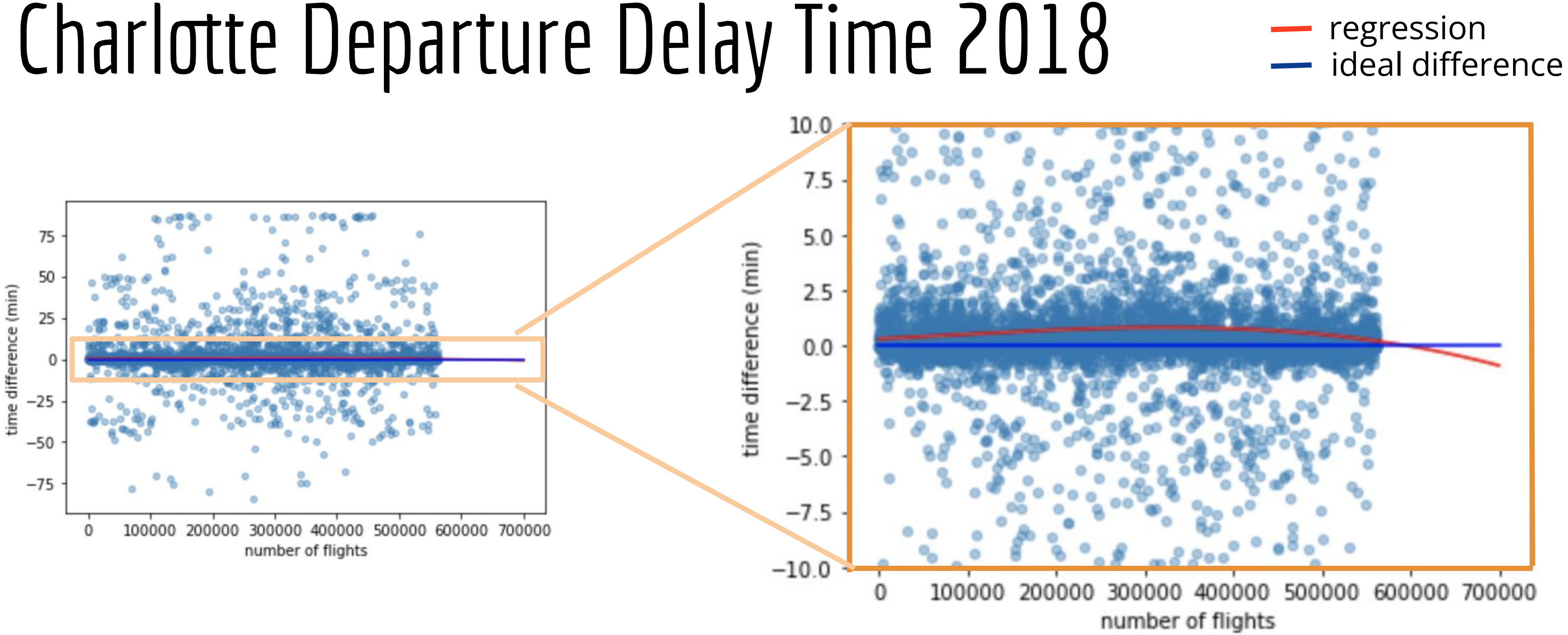
LaGuardia

Newark

Delays reduced after IADS

Data Source: FAA

Charlotte Departure Delay Time 2018

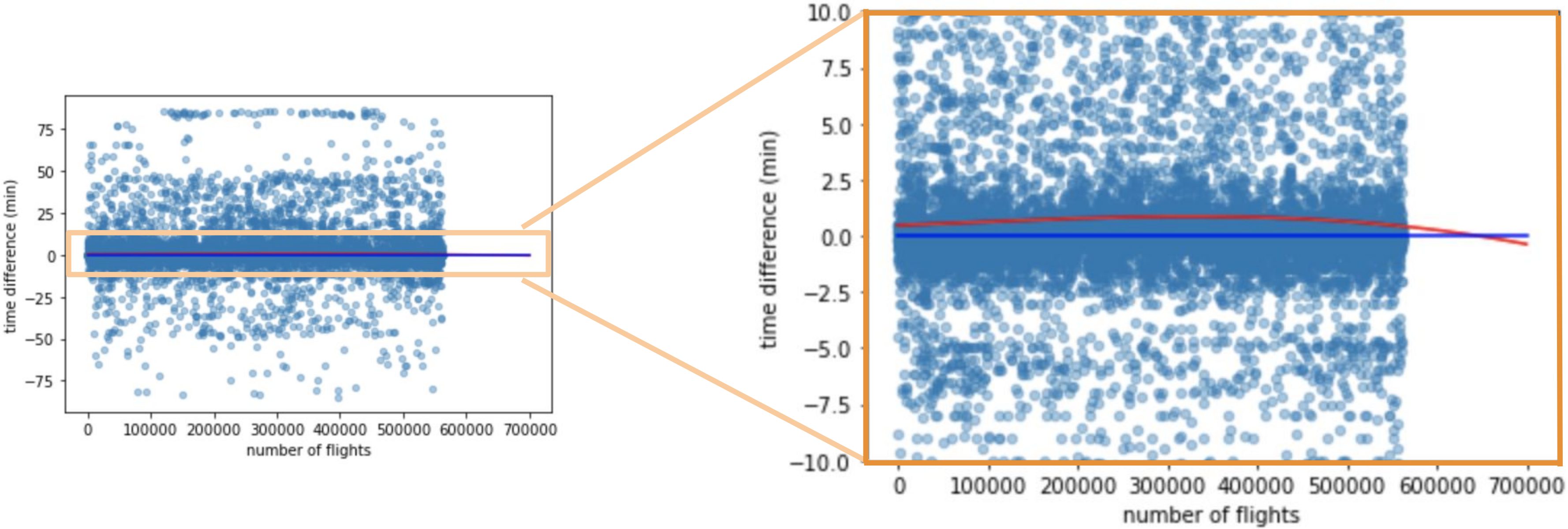


As the number of flights increases, the actual time becomes less than the scheduled time (less delay)

Data Source: NASA

Charlotte Arrival Delay Time 2018

regression
ideal difference



As the number of flights increases, the actual time becomes less than the scheduled time (less delay)

Data Source: NASA

Github link

Efficiency

Impacts

- Conservation of fuel, time, and money
  - $5 to $10 million saved per minute
  - 90% correlation with satisfaction
  - Reduction of CO_2 emissions per km
- Aviation Noise
  - Reduced effect on surrounding environment and community
  - Less health risks/disturbances
  - Unaltered wildlife behavior

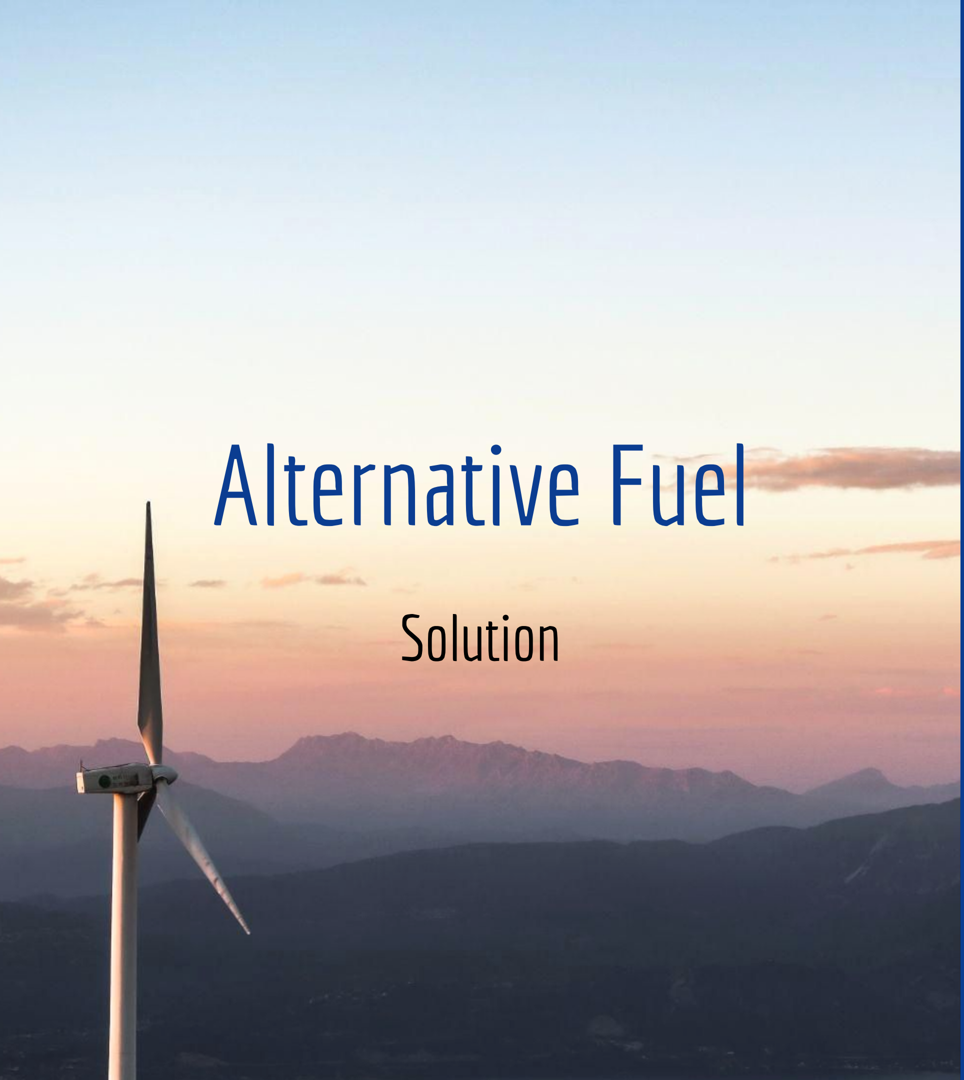
Fuel

Jet Fuel

Problem

Conventional fuel problems

- Harmful emissions
  - Carcinogenic - health effects
  - Carbon emissions - climate change
- Limited by fossil fuels



Alternative Fuel

Solution

- Hydroprocessed Esters and Fatty Acids (HEFA)
  - Efficient production reduces costs
  - Outperforms jet fuel
  - Limited by oil availability
- Fischer–Tropsch (FT)
  - Fossil fuel
  - Contains aromatics, sulfur-free
  - Expensive technology
- Alcohol-to-Jet (ATJ)
  - Contains aromatics
  - Carbon recycling
  - Established ethanol production

Goal Programming

Solution

- Optimization model decides between alternative fuel options
- Priorities
  - Economic Sustainability
  - Operational Efficiency
  - Natural Resource Conservation
- Constraints
  - Financial issues
  - Limited resources

Goal Programming Model

- Chebyshev
- Lexicographic
- Archimedean

$$\sum_{i=1}^{m} w_1 [d_1^+ + d_2^- + d_3^+] + w_2 [d_4^+ + d_5^-] + w_3 [d_6^- + d_7^- + d_8^-]$$

Constraints

Financial Issues: $\sum_{j=1}^{n} F_j \leq T_F$

Limited Resources: $\sum_{j=1}^{n} R_j \leq T_R$

and $X_j, Y_j, Z_j, d_i^-, d_i^+ \geq 0$

General objective equation

$$\sum_{j=1}^{n} A_{ij} Z_j = b_j - d_j^{\pm} + d_j^{\pm}$$

Objective-Specific Models

Economic Sustainability goals:

$$\sum_{j=1}^{n} A_{fnij\ (flight\text{-}numbers)} X_{fnj} = b_1^{ES} - d_1^- + d_1^+$$

$$\sum_{j=1}^{n} A_{cij\ (cost)} X_{cj} = b_2^{ES} - d_2^- + d_2^+$$

$$\sum_{j=1}^{n} A_{ufij\ (use\text{-}of\text{-}fuel)} X_{ufj} = b_3^{ES} - d_3^- + d_3^+$$

Operational Efficiency Goals:

$$\sum_{j=1}^{n} A_{atij\ (air\text{-}traffic\text{-}planning)} Y_{atj} = b_4^{OE} - d_4^- + d_4^+$$

$$\sum_{j=1}^{n} A_{taij\ (turnaround\text{-}of\text{-}aircrafts)} Y_{taj} = b_5^{OE} - d_5^- + d_5^+$$

Natural Resource Conservation Goals:

$$\sum_{j=1}^{n} A_{drij\ (depletion\text{-}of\text{-}natural\text{-}resources)} Z_{drj} = b_6^{NRC} - d_6^- + d_6^+$$

$$\sum_{j=1}^{n} A_{wij\ (total\text{-}waste)} Z_{wj} = b_7^{NRC} - d_7^- + d_7^+$$

$$\sum_{j=1}^{n} A_{laij\ (total\text{-}landing\text{-}area)} Z_{laj} = b_8^{NRC} - d_8^- + d_8^+$$

Green Energy

Impacts

- Reduced costs/emissions
  - 1 gallon *conventional* fuel = 23 pounds of CO_2
  - 1 gallon *renewable* fuel = 9.6 pounds of CO_2
    - 13.4 pound decrease
    - 150 gallons of renewable fuel = - 1 ton CO_2
  - Emission abatement from indirect effects, $400 per ton of CO_2

Summary

Problems

- Scheduling
  - Why delays happen
  - Impacts of delays
- Jet Fuel
  - Environmental issues of conventional fuel

Solutions

- IADS
  - Solves NAS delays at airports
  - Implementing into busy domestic & international airports to target arrival delays
- Alternative Fuel
  - Hydroprocessed Esters and Fatty Acids
  - Fischer–Tropsch
  - Alcohol-to-Jet
- Goal programming

Future Research

- IADS
  - Implementing into other domestic international airports
  - Shorter implementation times
    - Tracking data in airports
    - Data analysis/ understanding trends
- Biofuel
  - Variety of biofuels
  - Data collection/analysis
    - Goal programming

What We Gained

- Research experience
  - Reading through papers
  - Documenting important information
- Presentation and paper writing skills
  - Perfecting flow
- Machine Learning
  - Practice with IADS data
  - Matplotlibs
  - Applying data analysis in real world situations

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Questions?

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Efficiency: https://unsplash.com/photos/rf6ywHVkrlY

Fuel: https://unsplash.com/photos/gGAXHKCKoUY

Jet Fuel: https://unsplash.com/photos/DqF_3g6lZak

Alternative Fuel: https://unsplash.com/photos/-s1w1SguZTI

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