Quality of Candidate Flights and Submission Prediction in Collaborative Digital Departure Reroute

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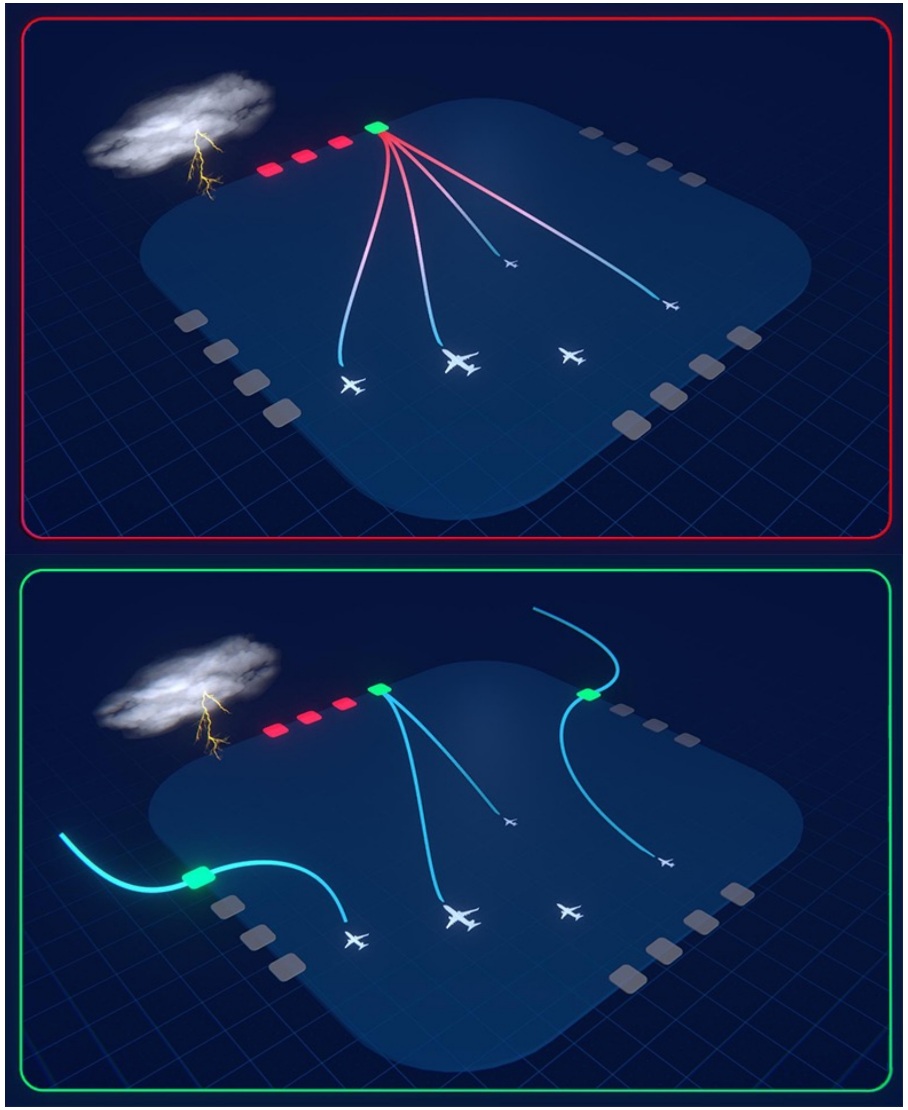
Background



- NASA's Digital Information Platform (DIP)
- Field evaluations at Dallas/Fort Worth International Airport (KDFW)
- D10 Terminal Radar Approach CONtrol (TRACON) composed of 16 departure fixes along the terminal boundary
- **Problem:**
  Departure fixes impacted by severe weather and aircraft separation requirements causing delay
- **Solution:**
  Reroute flights using an alternative route on a different departure fix to avoid restrictions and reduce delay
- DIP enables reroute capability through the Collaborative Digital Departure Reroute (CDDR) Service

Collaborative Digital Departure Reroute

Purpose

- Service provides reroute decision support to flight operators and air traffic control
- Flight operators evaluate reroute options to reduce delay, fuel burn, and CO_2 emissions

Service Details

- Input: ***Trajectory Option Set (TOS)*** = a set of alternative routes
- Predicts delay on filed route and each TOS alternative route
- Computes delay savings on each TOS alternative route relative to filed route
- Computes system level savings from rerouting a single flight
- Proposes ***candidate flights*** = TOS routes with predicted delay savings > predefined threshold

TOS routes → CDDR Service → Candidate flights → Flight operators evaluate options → Request reroute (“Submitted”) → Air traffic control

CDDR Service helps flight operators with reroute decision process

Objectives

Quality of Candidate Score

Gain insight into which candidate flights are higher quality

Key Points

- Would enable user to focus on best candidate flights for reroute
- Would aid decision-making process
- Identify high quality candidate flights that were not submitted to improve submissions

Binary Classification Model

Predict if the flight operator will submit a candidate flight for reroute
(Discussed in paper)

Data

- Data from operational CDDR system at KDFW between 4/28/2022 and 3/27/2023
- 927 candidate flights: 820 not submitted, 107 submitted
- Six data elements identified as features:

Data Element	Description
Candidate duration	Duration alternative route was considered a candidate flight (in minutes)
OFF delay savings*	Estimated delay savings at the runway (in minutes)
IN delay savings*	Estimated delay savings at the arrival gate (in minutes)
System level delay savings for the airline*	Estimated system level delay savings for subsequent flights from the same carrier (in minutes)
Controller-Pilot Data Link Communication (CPDLC)	Whether the aircraft has equipment to communicate reroutes digitally (boolean)
Probability of delay savings*	Probability that the alternative route has OFF delay savings > predefined threshold

* Indicates sampled at:

1) Flight's pushback time from the gate (not submitted candidate flights)

2) Last time the flight operator submitted the reroute (submitted candidate flights)

Data (Continued)

Data Engineering

- Converted boolean data elements to integers
- Changed delay savings signs so positive indicates savings
- Removed candidate flights with null values

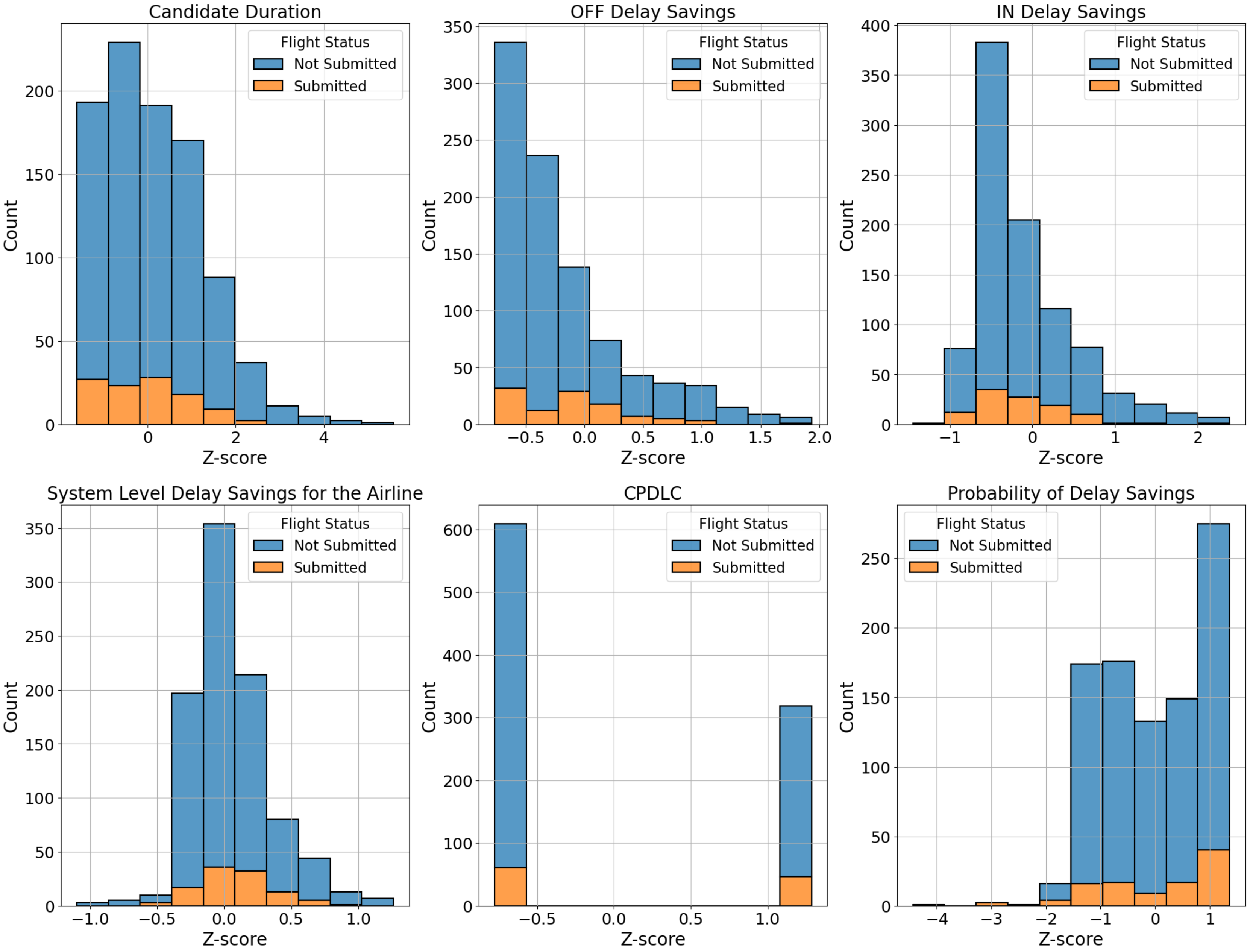
Z-score Normalization

- Mean and standard deviation for each feature
- Used data from 4/28/2022 - 9/16/2022

Removed Outliers

- Identified for normalized features in the full data set
- Outside median ± 3.5 x Interquartile Range

Data (Continued)



Key Points

- Focus on bins with higher ratio of submitted to not submitted candidate flights
- Some candidate flights with high delay savings were not submitted (data challenge)

Quality of Candidate Score

Objective: Gain insight into the quality of candidate flights to determine if they are a good option for submission

Method: Assign a score to each candidate flight using a summation of weighted normalized features

$$\text{Quality Score} = \sum_{n=1}^{6} w_n f_n$$

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No “true” score

- Submitted status used to indicate high quality
- Bin flights based on scores
- Compute submitted fraction for each bin

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Weight Options

- Baseline: all weights to 1, poor results
- Weight permutations from -1 to 1 in 0.2 increments (1,771,561 options)

Quality of Candidate Score (Continued)

Weight Permutation Steps

1. Scores computed and normalized between 0 and 1
2. Each flight assigned a bin based on its score (10 bins total)
3. Computed submitted fraction and mean normalized score for each bin
4. Check at least six bins are defined
5. Best fit line: x-axis = mean normalized score, y-axis = submitted fraction
6. Calculated residuals, R^2, and slope of best fit line to evaluate weight permutation performance

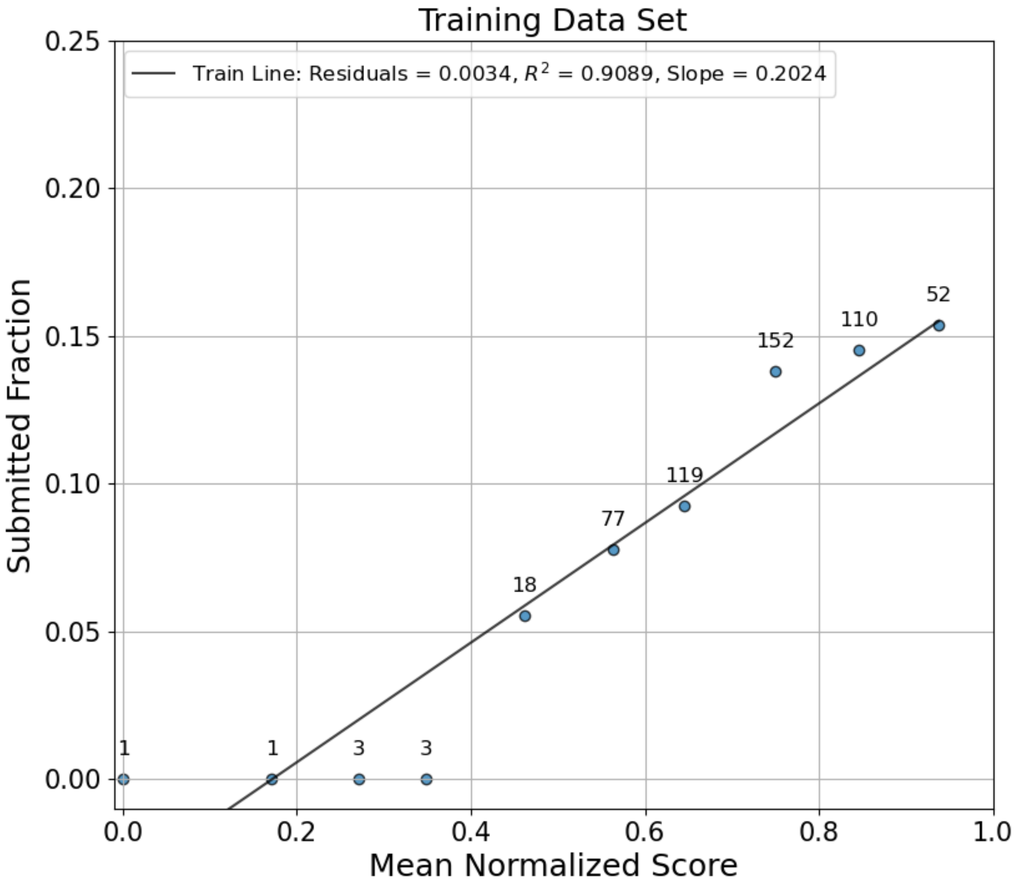
Quality of Candidate Score (Continued)

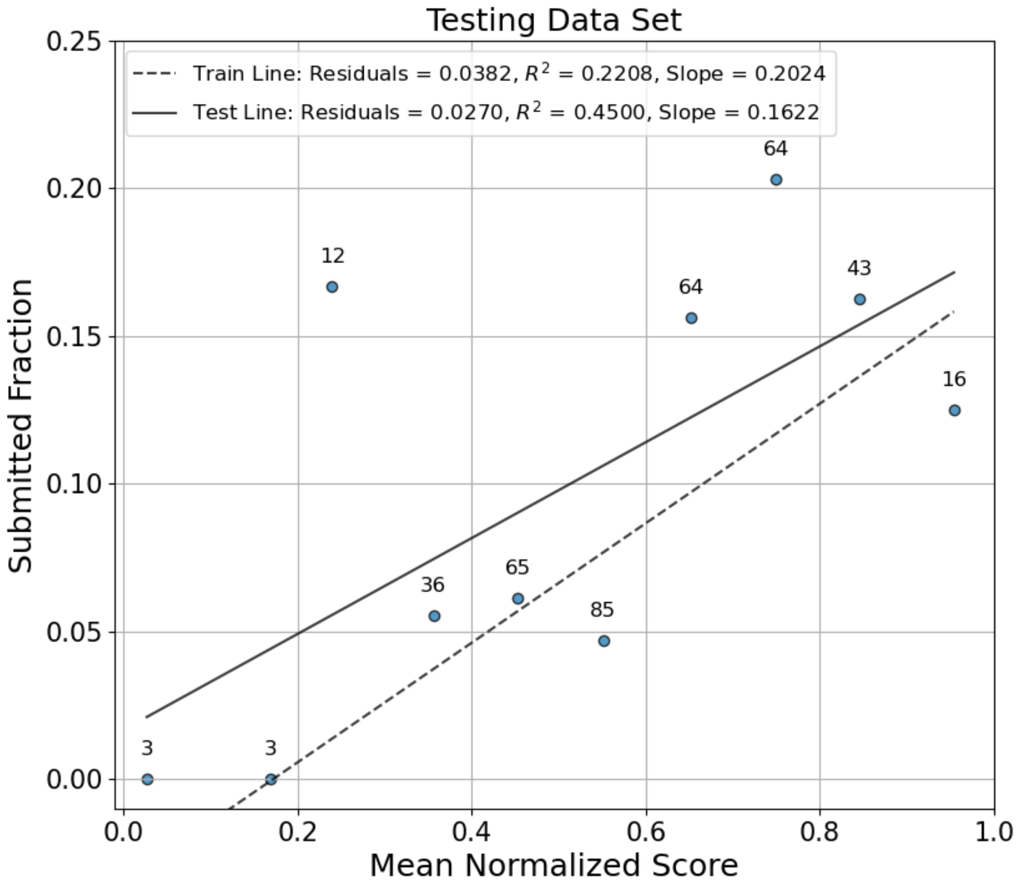
Group	Date Range	Percentage of Data	Routes Not Submitted	Routes Submitted
Training	4/28/22 – 9/16/22	57.8%	473	63
Testing	9/17/22 – 3/27/23	42.2%	347	44

- For each set of weights, steps performed on:
  1. Full training dataset
  2. Stratified 3-fold cross validation on training dataset
- Resulted in best fit lines for the full training dataset, training folds, and validation folds
- Computed average residuals and average R^2 only if the sign of the slopes for all best fit lines matched
- Reported weights producing minimum average residuals and maximum average R^2
- Applied best weights to testing data

Quality of Candidate Score (Continued)

Feature	Weight
Candidate duration	0
OFF delay savings	1
IN delay savings	-1
System level delay savings for the airline	0
CPDLC	0.2
Probability of delay savings	0.4





- Higher quality score means higher submitted fraction
- Challenge: High quality candidate flights not submitted because of hidden constraints and human factors

Conclusion

Quality of Candidate Score

- Developed initial scoring method to identify higher quality candidate flights
- Would enable user to focus on the best candidate flights for reroute
- Would aid in decision-making process
- Identify high quality candidate flights that were not submitted to improve submissions

Future Work

- Evaluate other weight possibilities
- Investigate other scoring methods
- Test other data elements as features
- Goal: Provide scoring method in real-time operations