Assessing Flight Delays Using Weather Predictions

Benjamin Deibler, Gerardo Dutan, Lilia Guizatoullina, Nicholas Ingraselino, Justin Mintz

Advisor: Dr. Sangwon Yoon

School of Systems Science & Industrial Engineering Thomas J. Watson College of Engineering & Applied Science

The State University of New York at Binghamton

Abstract

This research aims to predict weather related flight delays and construct optimal flight schedules through the use of neural networks and simulation modeling. Delaying even one flight leads to a chain of flights being delayed which is why it is crucial for airports to handle weather conditions correctly. To ensure adverse weather conditions are handled properly, the proposed weather prediction and rescheduling (WPR) model employs a unique delay-first methodology that utilizes a long short term memory (LSTM) network to predict upcoming weather events and reschedule flights accordingly. First, weather data is passed through a delay assessment process to locate any hours with weather not suitable for flight departures. These hours are then set to be delayed. Then, using the LSTM, the WPR model predicts the upcoming 6 hours of weather including any delays. Flights are then rescheduled to bring departures back to their original schedule as fast as possible. The WPR model operates on an hourly update cycle, continuously forecasting delays for the next six hours, ensuring that users always have a six-hour outlook. With an accuracy rate of 82.7%, the WPR model effectively predicts delays and has demonstrated its capability to reschedule flights until they align with the pre-delay schedule. The WPR model is 11.28% more effective at predicting delays then traditional techniques.

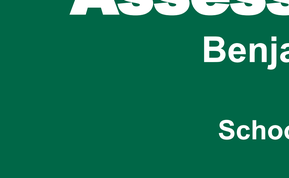
Problem Statement

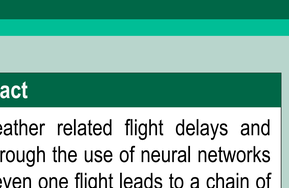
Impacts of Weather Delays

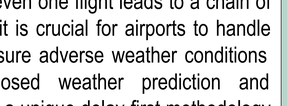
- 2017-2023: **74.26%** of delays of >15 minutes were weather related
- **7th** most total weather delays, **BUT 3rd** in time delayed to due weather
- 9/29/2023: **25%** of flights canceled due to heavy rain/flooding

Problems surrounding Delays

- Delays have lasting impacts on flight schedules
- False delays increase wasted time for both airlines and airports
- Failing to predict delays reducing the safety of passengers and staff







Background and Goal

Traditional Weather Prediction Model

Weather Data → Machine Learning → Predicted Weather → Delay Assessment → Rescheduled Flights

Goal

Increase passenger safety and flight schedule efficiency by correctly predicting weather delays ahead of schedule

- Alert Affected Personnel
- Identify Weather Delays
- Accurately Predict Weather
- Improve Take-off Efficiency

Scope & Assumptions

Scope

- Reschedule departing flights based on predicted weather
- Only consider delays due to weather
- Monitor weather at departing airport
  - Focus on weather delays affecting departing flights

Assumptions

- Observed airport: LaGuardia Airport (LGA)
  - Observation period: June - September (summertime)
- Flights can depart from LGA once per minute
- Weather conditions remain constant for each hour

Weather Prediction and Rescheduling (WPR) Model

Hourly Weather Data → Delay Assessment → LSTM → Predicted Weather and Delays → Rescheduled Flights

Traditional Model	WPR Model
1. Pre-Processing	1. Pre-Processing
2. Predict Weather	2. **Calculate Delays**
3. Calculate Delays	3. **Predict Weather**
4. Adjust Schedule	4. Adjust Schedule

Benefits & Advantages

Better Confidence in Predictions
Increased probability of correct predictions

Alert Affected Personnel
Increased minimum time from departure to announce delays

Weather Delay Type Information
Allow for better coordination of delay preparation

Weather Data & Delay Assessment Methodology

Historical Hourly Weather Data

Datetime	Temp (C)	Dew (C)	Precip (in)	Wind (mph)
2015-06-01 0:00	15	13.5	1.389	19.5
2015-06-01 1:00	14.2	12.7	0	19.1
2015-06-01 2:00	14.1	12.6	0.399	17.4
...	...	...	...	...
2024-09-30 21:00	18.2	12	0	4.2
2024-09-30 22:00	17.6	10.7	0	9.2
2024-09-30 23:00	17.5	10.8	0	7.4

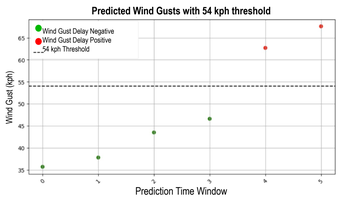
- LaGuardia (2015-2024)
- June - September (summer)
- Unit of time: hour

(All Predictors)
Temp, Dew, Humidity, Precip, Precip Prob, Wind Speed, Wind Gusts, Wind Direction, Air Pressure, Cloud Cover, Visibility

Calculating Delays

Delay Condition	Threshold
Wind Gust	≥ 54 kph
Visibility*	< 0.55 km
Temperature*	> 50 °C
Thunderstorm	TRUE

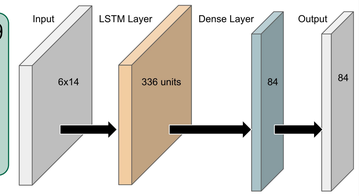
T-Storm Condition	Threshold
Dew Point	> 12.778 °C
Humidity	> 80%
Precipitation	> 8.128 mm/hr
Wind Gust	> 32 kph
Air Pressure	< 1010 mb
Cloud Cover	> 50%

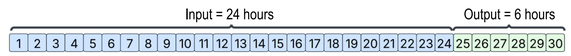


*Data used does not contain delays due to visibility or temperature

Weather Prediction LSTM & Analysis

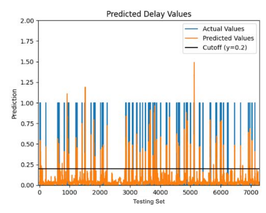
- Training Set: 2015-2019
- Test Set: 2020-2024
- 24 hour Lookup
- 6 hour Prediction
- Upweight Delay



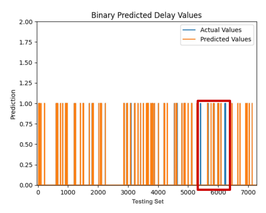


Predicted Delay Analysis

Weak Delay Signal Strength



Strong Delay Signal Strength



Flight Data & Rescheduling Process

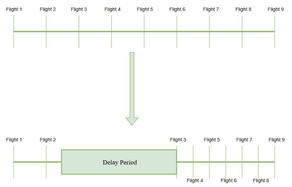
Departing Flight Log Data

Carrier Code	Date	Tail Number	Scheduled Departure Time
NK	8/9/2024	N603NK	5:45
AA	8/9/2024	N818NN	6:00
AA	8/9/2024	N925AN	6:00
...	...	...	...
OO	8/9/2024	N256SY	21:59
YX	8/9/2024	N124HQ	22:00
F9	8/9/2024	N390FR	22:50

- LaGuardia (test dates)
- Sorted by departure time
- Unit of time: minute

Rescheduling process

- Predictions are considered
- Predicted delays ground all flights
- One flight departure per minute
- Process repeats until flights reach original departure times



Testing Process / Risk Mitigation

Rescheduling Process

Testing Days

- 3 days with thunderstorms
- 3 days with clear weather
- 1 day with strong winds

Temperature and visibility were not tested because of how uncommon these events are

Timestamp Tested for Each Day	Test Hours Included in the Timestamp
0:00	6
6:00	6
12:00	6
18:00	6
Total	24

Risks & Error

		Reality	
		Weather Delay	No Weather Delay
Prediction	Weather Delay	Correct	Type II Error
	No Weather Delay	Type I Error	Correct

Type I Error
- Failing to Predict Adverse Weather
- Dangerous take-off conditions

Type II Error
- Falsely Predicting Adverse Weather
- Reduces flight Efficiency

Results & Key Findings

WPR Model

		Reality	
		Delay	No Delay
Prediction	Delay	38	13
	No Delay	16	101

Accuracy Rate: **82.7%**

Error Margin: **17.3%**

Traditional Weather Prediction Model

		Reality	
		Delay	No Delay
Prediction	Delay	40	14
	No Delay	19	96

Accuracy Rate: **80.5%**

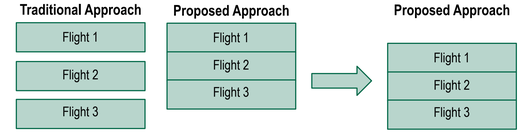
Error Margin: **19.5%**

Key Findings

- WPR Model is more accurate
- WPR Model reduces Type I Error
- WPR Model reduces Type II Error

Future Work

Flight Buffer Optimization



Potential Impacts

- Improve departure efficiency by finding the optimal time between take-offs
- Rescheduling process prevents propagation

Other Future Work

- Improve its temporal granularity — **Hours → Minutes**
- Add seasonal variability — **Summer → Winter**
- Incorporation of additional airports — **Departing → Landing**

Meet the Team