Analysis of convective weather impact on pre-departure routing of flights from Fort Worth Center to New York Center

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*University of California Irvine*

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*Georgia Institute of Technology*
Convective weather event
Dominant routing
Convective weather event

Impact on dominant routes
Convective weather event

Use of alternate routes
Motivation

Understand use of alternate routes
**Motivation**

*Understand use of alternate routes*

- Set flow rates through regions of airspace
Motivation

**Understand use of alternate routes**

- Set flow rates through regions of airspace
- Estimate airline decisions
Motivation

*Understand use of alternate routes*

- Set flow rates through regions of airspace
- Estimate airline decisions

**Objective**

Model the reduction in use of clear weather routes from Fort Worth Center to New York Center in the presence of convective weather.
• Identify clear weather routes
Approach

- Identify clear weather routes
  - Find flight tracks on historical clear-weather days
• Identify clear weather routes
  • Find flight tracks on historical clear-weather days
  • Group spatially similar tracks

Given
• Weather impact values per hour
• Departures per hour

Find
• Relationship between weather impact and departures
Approach

- Identify clear weather routes
  - Find flight tracks on historical clear-weather days
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- Calculate values quantifying weather impact

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*Given*
  • Weather impact values per hour
  • Departures per hour

*Find*
  Relationship between weather impact and departures
Clear-weather flight tracks

Flight tracks from 78 clear weather days in 2014
## Dominant city pairs

<table>
<thead>
<tr>
<th>Origin Airport</th>
<th>Destination Airport</th>
<th>Number of Flights</th>
</tr>
</thead>
<tbody>
<tr>
<td>DFW</td>
<td>LGA</td>
<td>1,225</td>
</tr>
<tr>
<td>DFW</td>
<td>EWR</td>
<td>601</td>
</tr>
<tr>
<td>DFW</td>
<td>JFK</td>
<td>153</td>
</tr>
<tr>
<td>DAL</td>
<td>TEB</td>
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<td>OKC</td>
<td>EWR</td>
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<td>TEB</td>
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<tr>
<td>PWA</td>
<td>TEB</td>
<td>12</td>
</tr>
</tbody>
</table>

↑

↓
Flight tracks from 78 clear weather days in 2014
Dominant city pair flight tracks

Flight tracks from 78 clear weather days in 2014

- All tracks: 2,400
- Dominant tracks: 2,152
Cut departure and arrival portions of tracks
Cut departure and arrival portions of tracks

- Departure and arrival track segments
- Enroute tracks
Enroute portion of tracks

Flight tracks from 78 clear weather days in 2014
Remove outliers

- Outlier tracks: 123
- Other top origin-destination tracks: 2,029
Other top origin-destination tracks: 2,029
Initial clear-weather flight track clusters

- Cluster A: 529
- Cluster B: 1,343
- Cluster C: 157
Clear-weather flight track clusters

- Cluster 1: 81
- Cluster 2: 448
- Cluster 3: 1,343
- Cluster 4: 157
Identify clear weather routes
- Find flight tracks on historical clear-weather days
- Group spatially similar tracks

Calculate values quantifying weather impact
- Identify tracks following clear weather routes
- Model route use as function of weather impact

**Given**
- Weather impact values per hour
- Departures per hour

**Find**
Relationship between weather impact and departures
Convective weather impact

15 minute forecast
Convective weather impact

30 minute forecast
Convective weather impact

45 minute forecast
Convective weather impact

75 minute forecast
Convective weather impact

90 minute forecast

[Map showing convective weather patterns across the United States]
Convective weather impact

105 minute forecast
Convective weather impact

120 minute forecast
Create lane

Points spaced by 15 minutes
Create lane

**Mean points**
Create lane

Southern boundary
Create lane

15 minutes segments
Convective weather polygon dwell time

15 minute flight time
Convective weather polygon dwell time
<table>
<thead>
<tr>
<th>Flow line</th>
<th>Dwell [min]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.60</td>
</tr>
<tr>
<td>2</td>
<td>1.71</td>
</tr>
<tr>
<td>3</td>
<td>0.00</td>
</tr>
<tr>
<td>4</td>
<td>1.56</td>
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<tr>
<td>5</td>
<td>5.05</td>
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<td>6</td>
<td>5.02</td>
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Average dwell time: 2.76 [min]
Convective weather polygon dwell time

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15 minute flight time
### Convective weather polygon dwell time

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**Diagram:**
- Convective weather polygon
- 15 minute flight time

**Table:**
- Flow line 1 dwell time: 0.60 minutes
- Flow line 2 dwell time: 1.71 minutes
Convective weather polygon dwell time

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**ave.** 2.76

![Diagram of convective weather polygon dwell time with flow lines and dwell times.](image)
Example convective weather

Now-cast
Example convective weather

30 minute forecast
Example convective weather

45 minute forecast
Example convective weather

60 minute forecast
Example convective weather

75 minute forecast
Example convective weather

90 minute forecast
Example convective weather

105 minute forecast
Approach

✓ Identify clear weather routes
  ✓ Find flight tracks on historical clear-weather days
  ✓ Group spatially similar tracks
✓ Calculate values quantifying weather impact
→ Identify tracks following clear weather routes
  • Model route use as function of weather impact

**Given**
  • Weather impact values per hour
  • Departures per hour

**Find**
  Relationship between weather impact and departures
Convective weather season

- April through September 2014 and 2015
Convective weather season

- April through September 2014 and 2015
- Departing between 7 AM and 10 PM, EDT
Convective weather season

- April through September 2014 and 2015
- Departing between 7 AM and 10 PM, EDT
- Total of
  - 12 months with 15 hours per day = 5,490 hours
  - 8,334 flights between dominant city pairs

Impact on Fort Worth Center to New York Center
- 1,774 hours with convective weather
- 3,854 departing flights using dominant routes
- Average 2.2 departures per hour
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→ Model route use as function of weather impact

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**Find**

Relationship between weather impact and departures
Route use during convective weather events

![Graph showing flow rate vs. mean dwell time](image_url)
Route use during convective weather events

![Graph showing the relationship between mean dwell time (in minutes) and flow rate (aircraft/hour). The 95th percentile is indicated by red dots.](image)

- X-axis: Mean dwell time [min]
- Y-axis: Flow rate [aircraft/hour]
- 95th percentile is marked with red dots.
Route use during convective weather events

![Chart showing flow rate (aircraft/hour) vs. mean dwell time (min). The chart includes a red line indicating an exponential fit and markers for the 95th percentile.]
Route cluster use models

Cluster 1
Cluster 2
Cluster 3
Cluster 4

Mean dwell time [min]

Flow rate [aircraft/hour]

Mean dwell time [min]

Flow rate [aircraft/hour]

Cluster 3

Cluster 1
Cluster 2
Cluster 3
Cluster 4

Flow rate [aircraft/hour]

Mean dwell time [min]

Cluster 3
Route cluster use models

Cluster 1
Cluster 2
Cluster 3
Cluster 4

Mean dwell time [min]

Flow rate [aircraft/hour]

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Mean dwell time [min]
Application example

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Mean dwell time [min]

Flow rate [aircraft/hour]

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Mean dwell time [min]
Flow rate [aircraft/hour]

Cluster 1
Max rate

Mean dwell time [min]
Flow rate [aircraft/hour]
Application example
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Application example

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Cluster 3
Cluster 4

Mean dwell time [min]

Flow rate [aircraft/hour]

Cluster 3
Max rate
Actual rate

Mean dwell time [min]

Flow rate [aircraft/hour]
Application example

Cluster 1
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Cluster 3
Cluster 4

Mean dwell time [min]

Flow rate [aircraft/hour]

Cluster 4
Max rate
Actual rate

Mean dwell time [min]
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Summary

- Identify clear weather routes
  - Find flight tracks on historical clear-weather days
  - Group spatially similar tracks
- Calculate values quantifying weather impact
- Identify tracks following clear weather routes

Given
- Weather impact values per hour
- Departures per hour

Find
Relationship between weather impact and departures:
Exponential curve fit
✓ Identify clear weather routes
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✓ Calculate values quantifying weather impact
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**Given**
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**Find**
- Relationship between weather impact and departures
  - Exponential curve fit
Future work

- Cluster tracks that do not conform to a clear weather route cluster
Future work

- Cluster tracks that do not conform to a clear weather route cluster
- Expand clear weather route clustering to other origin and destination Centers
Future work

- Cluster tracks that do not conform to a clear weather route cluster
- Expand clear weather route clustering to other origin and destination Centers
- Create network from route clusters for traffic flow modeling
Questions?