



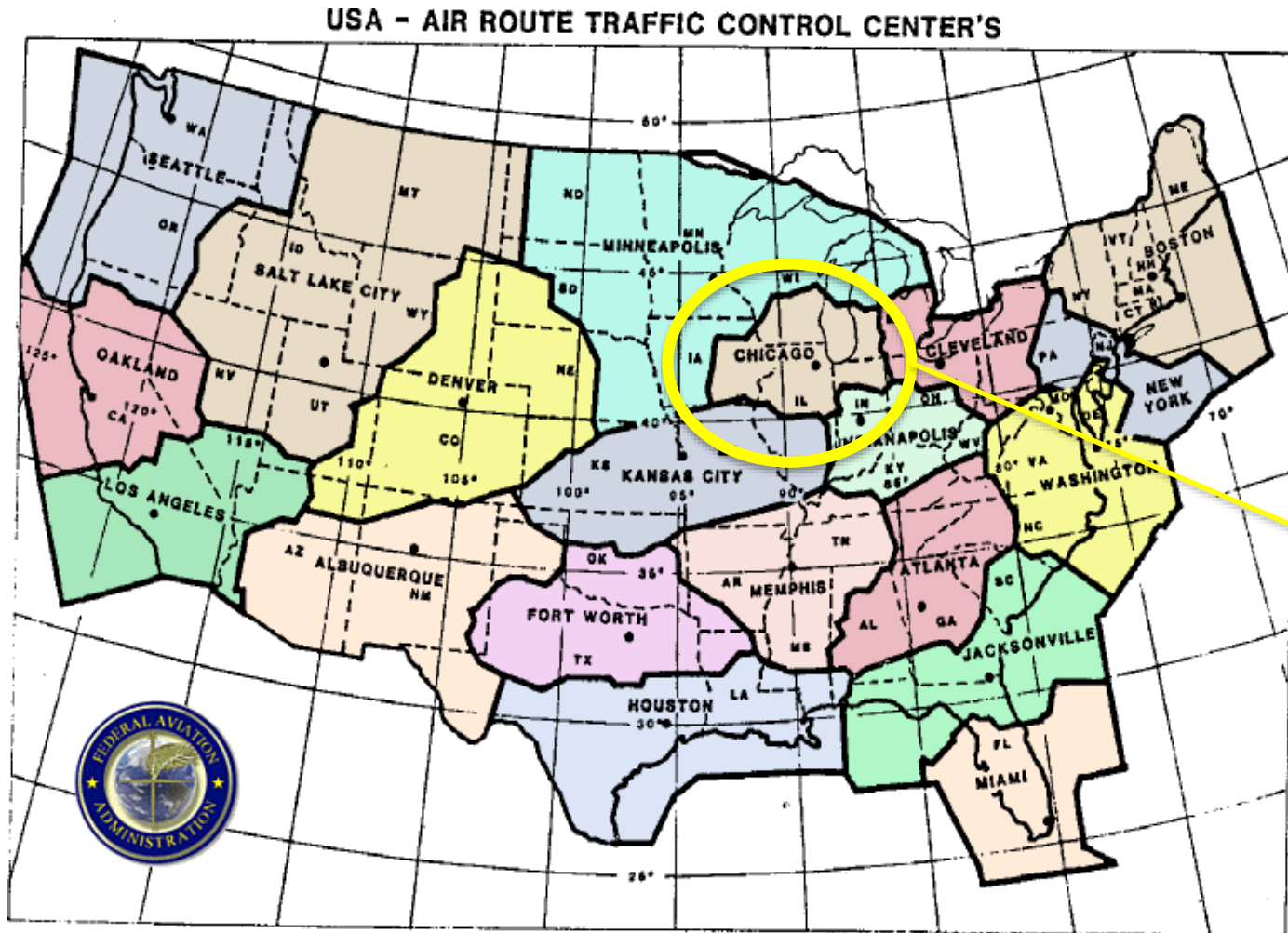
# ATC Zero: Estimating the True Cost of the Chicago Fire

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# Overview

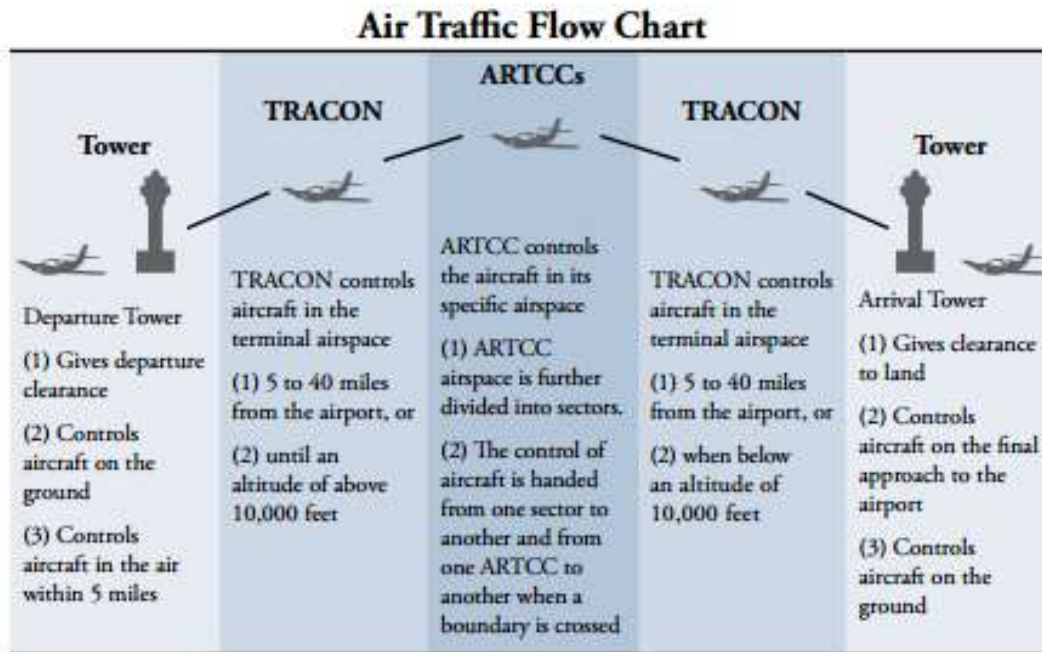
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# U.S. ARTCCs



Chicago's ARTCC is about 91,000 sq miles of airspace

# Air Traffic Management



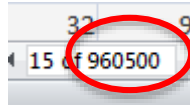
With the ARTCC down, flights had to be passed from TRACON to TRACON resulting in:

- Flying at a lower altitude (max around 20K ft)
- Flying at a slower speed

Impact:

- Flight time
  - Fuel
  - Ops (Airborne)
  - PVT
- Possible gate delays
  - Ops (Gate)
  - PVT

# Methods

- Flight Data collected for September and October of 2014 A small screenshot of a data table. The table has two rows. The first row has values 32 and 9. The second row has values 15 and 960500. A red circle is drawn around the value 960500.
- Filtered for arrivals to and departures from ORD and MDW
  - September 26-October 13 are dates of the incident
  - September 01-September 25 and October 14-October 31 are dates in the normal data set
- Data Normalized

# Normalization Example

$$1,188 \text{ flights}_{\text{norm}} * \frac{1}{44 \text{ days}_{\text{norm}}} * 17 \text{ days}_{\text{inc}} = 459 \text{ flights}_{\text{exp}}$$
$$4,299 \text{ flights}_{\text{inc}} - 459 \text{ flights}_{\text{exp}} = 3,840 \text{ flights}_{\text{canc}}$$

Used to Calculate:

- Cancellations
- Diversions
- Gate Delay Minutes

# Fuel Burn

- Filtered fuel burn data for flight levels 100-290
- Filtered for major commercial aircraft
- Used average fuel burn at various speeds

Result: 96.4 kg/min or 25.5 gallons/min

# Differences in Delay Times

Originating Airport	Avg Flight Time (min)	Impacted Flight Time (min)	Delta (min)
Albuquerque	1172	1236	64
Boston	1273	1326	53
Wash. DC (DCA)	1335	1353	18
Honolulu	1957	1907	50
Los Angeles	1229	1276	47
San Fransisco	1217	1216	-1
Seattle	1144	1153	9
Tuscon	933	952	19



# Increases to Flight/Delay Times

	Arrivals		Departures	
	Incident	Normal	Incident	Normal
Flights	17258	45935	17221	45940
Average	1312	1275	1446	1412
St. Dev	484	463	490	464
Var	234321	214544	239907	214844
P-Value	8.57		7.85	
T-99.9%	>3.29		>3.29	

- Method used for increase in average flight time (arrivals and departures) as well as increase in average arrival delay
- Multiplied average increase by number of applicable flights for total delay in minutes

Minutes Above Normal	
Total Flight Time:	1,213,887
<i>Arrivals</i>	628,373
<i>Departures</i>	585,514
Arrival Delay:	619,742

# Data Compiled for Analysis

Description	Value	Source
Arrivals (9/26-10/13)	17,263 flights	Calculated
Departures (9/26-10/13)	17,221 flights	Calculated
Cancellations	3,840 flights	Calculated
Diversions	31 flights	Calculated
Total In Flight Delay	1,213,887 minutes	Calculated
Total Gate Delay	743,933 minutes	Calculated
Total Arrival Delay	619,742 minutes	Calculated
Average Fuel Burn	96.4 kg/min	FAA
Airborn Ops Cost (no fuel)	\$314/hr	FAA IP&A
Diversion Ops Cost	\$20,703/flight	FAA IP&A
Gate Ops Cost	\$234/hr	FAA IP&A
Canceled Flight Ops Cost	\$180/flight	FAA IP&A
Fuel Cost	\$2.77/gallon	BTS
CO <sub>2</sub> Burden	180 kg/hr	CarbonIndependent.org
Social Cost of Carbon	\$39/tCO <sub>2</sub>	EPA
Personal Value of Time (PVT)	\$44.15/hr	FAA IP&A
PVT of Diverted Flight	\$14,175/flight	FAA IP&A
PVT of Canceled Flight	\$14,111/flight	FAA IP&A

# Results-PVT

- Used arrival delay to account for offsets in early departures, shorter flight paths, etc
  - Representative of total time lost between scheduled arrival and actual
  - Negative delays reflect early arrivals
- Average scheduled arrival delay
  - Normal: 4 minutes (s= 39 minutes)
  - Incident: 40 minutes (s=57 minutes)

$$10,329 \text{ hours}_{\text{delayed}} * \frac{\$44.15}{\text{hour}} = \$456,027$$

- Cancellations and diversions have PVT impacts per flight

$$\frac{\$14,175}{\text{diversion}} * 31 \text{ diversions} + \frac{\$14,111}{\text{cancellation}} * 3,840 \text{ cancellations} = \$54,625,665$$

Total cost of PVT: \$54.6M

# Results-Operating Costs

Straightforward multiplication- **\$10.6M**

Impact	Cost (USD)
Diversions	\$641,793
Cancellations	\$691,200
Gate Delays	\$2,901,339
Airborne Ops	\$6,352,675
<b>Total</b>	<b>\$10,587,007</b>

# Results-Cost of Fuel

- Total additional flight time was:
  - 1,213,887 minutes or
  - 20,231 hours
- At burn of 96.4 kg/min, an additional 30,913,077 gallons of fuel burned
- At \$2.77/gallon cost of addition fuel is:

**\$85.6M**

# Results-Environmental Cost

- The average flight releases 180 kg CO<sub>2</sub>/hr
- Social Cost of Carbon - \$39/tCO<sub>2</sub>

$$\frac{\$39}{\text{tCO}_2} * \frac{.180 \text{ tCO}_2}{\text{hr}} * 20,231 \text{ hours} = \$142,022$$

Total Environmental Cost: \$0.14M

# Results-Total Cost

Passenger Value of Time	\$55.1M
Operating Costs	\$10.6M
Fuel Cost	\$85.6M
Environmental Cost	\$0.14M
<b>Total</b>	<b>\$151.4M</b>

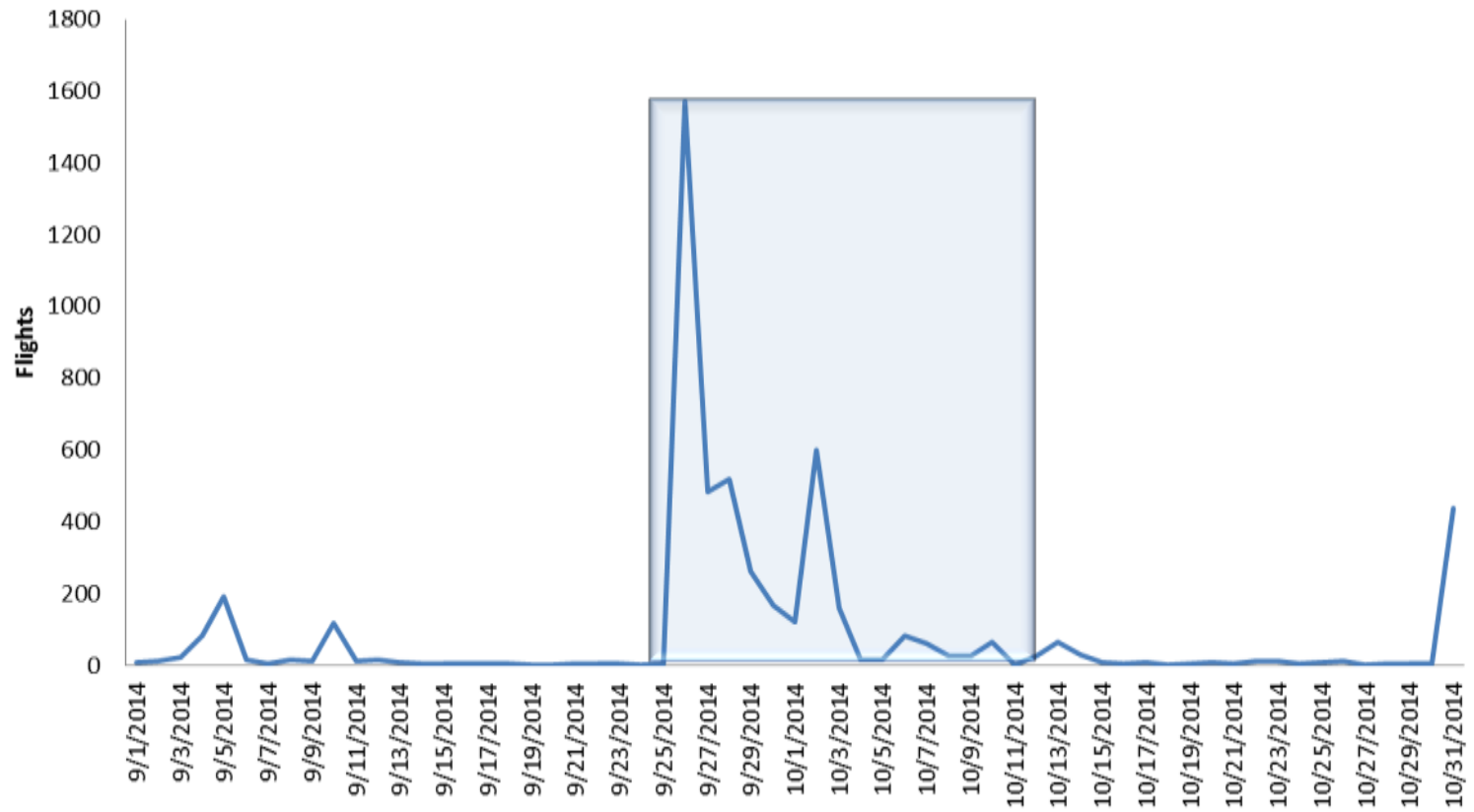
# Discussion

- Scope is limited to a conservative estimate
  - U.S. Travel Association estimate (10/2): \$123M
- If you use consider potential upsides: \$164.3M
  - 4,584 cancellations vs 3,840
  - Avg 5 min added to flight time, ZAU handles ~5% of air traffic
- Other costs incurred: damages, overtime/travel, equipment/installation



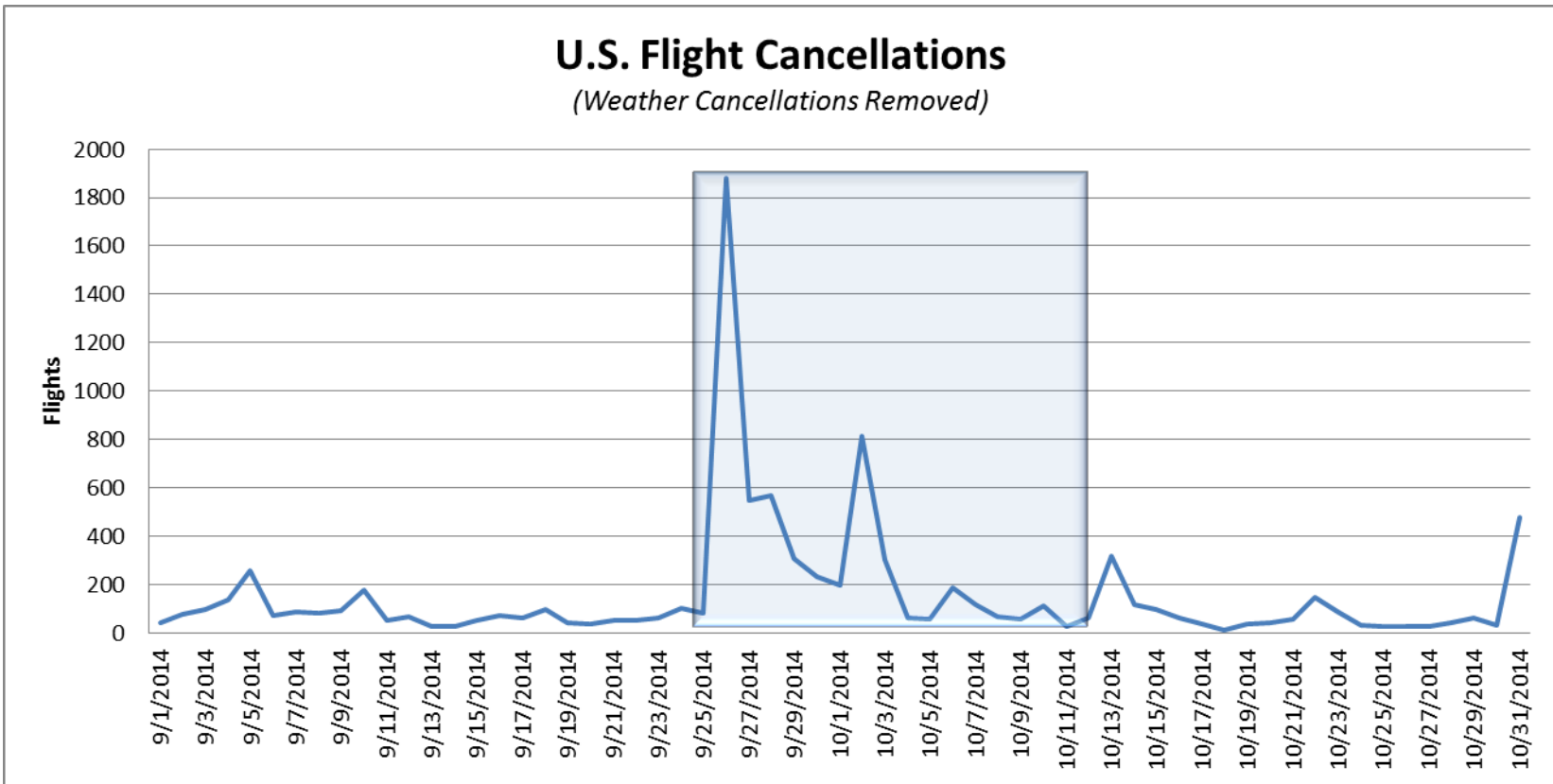
## Daily Cancelled Flights at ORD and MDW

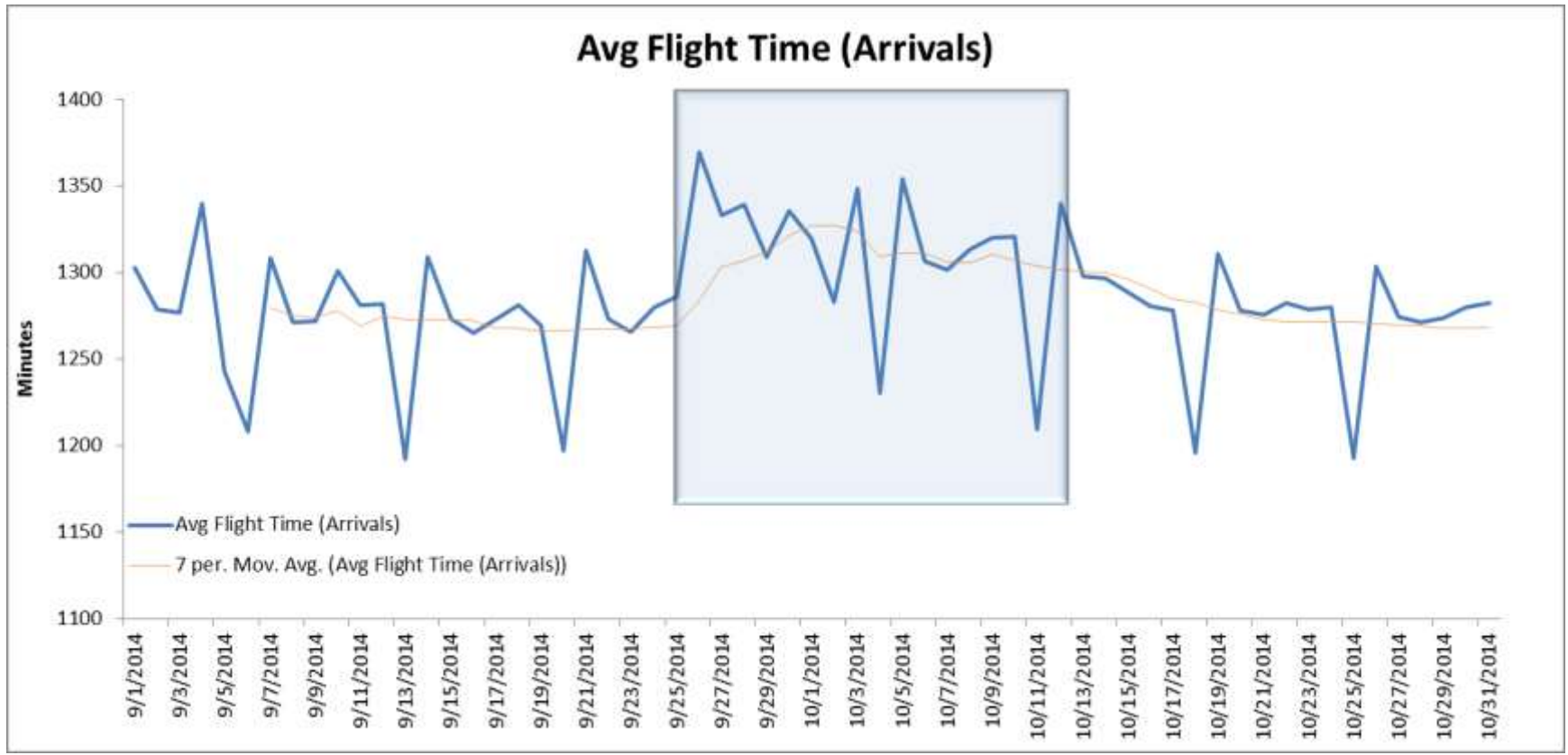
(Weather Delays Removed)

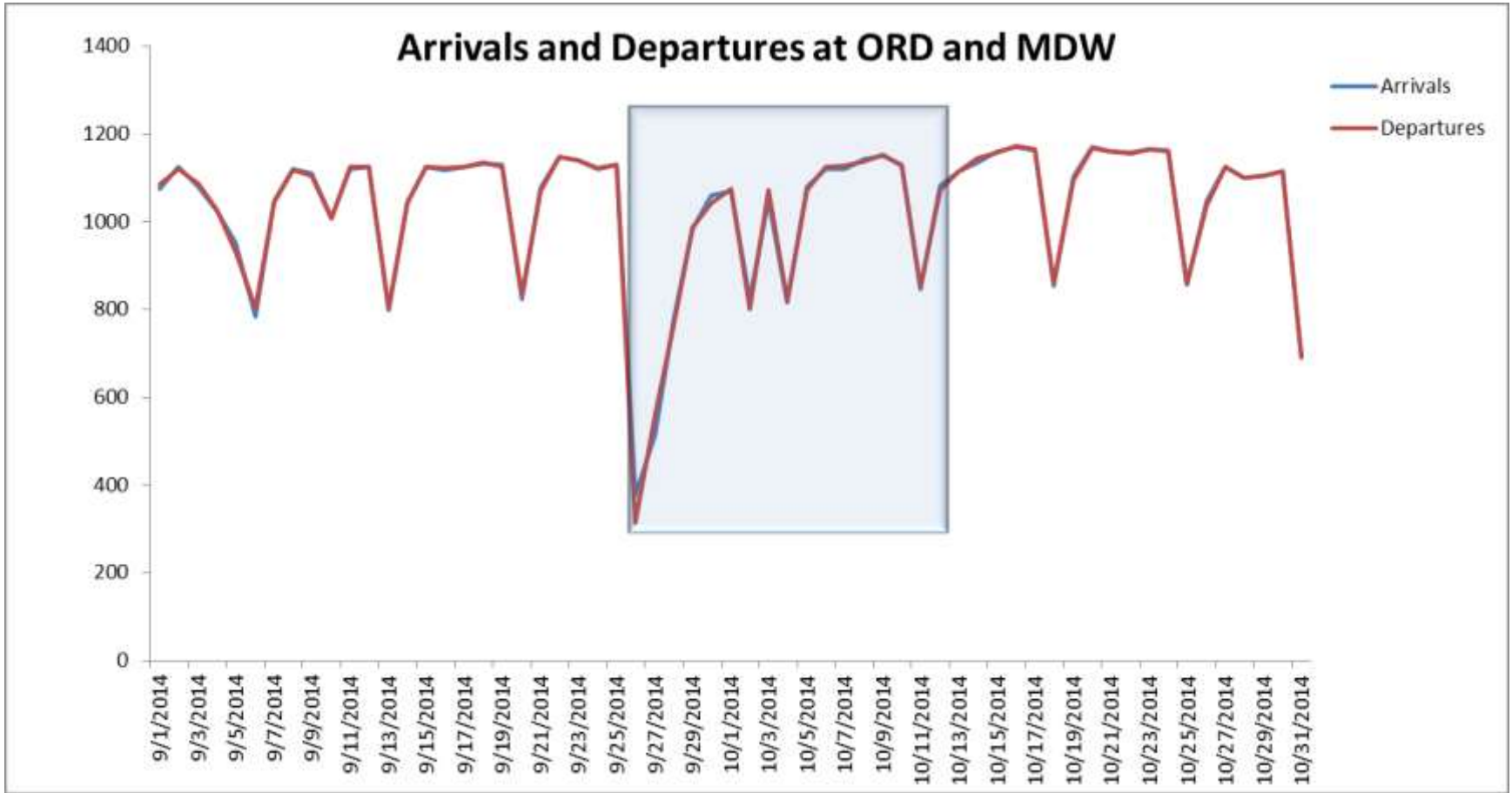


# U.S. Flight Cancellations

(Weather Cancellations Removed)







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