



THAYER SCHOOL OF  
ENGINEERING  
AT DARTMOUTH



# Schedule Buffers and Passenger Delays

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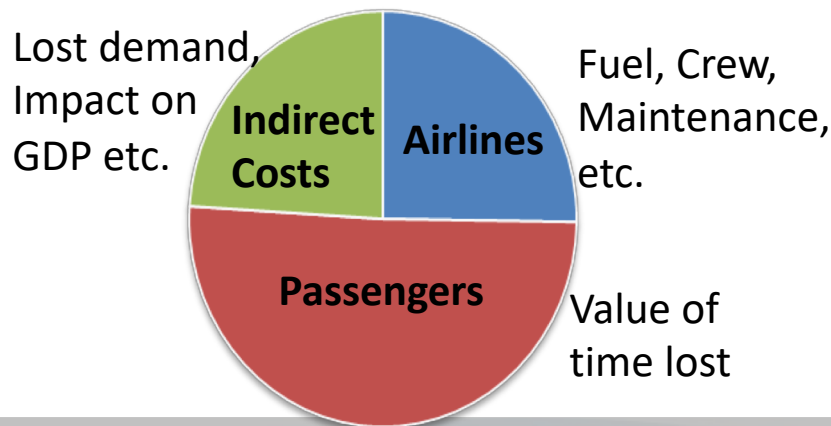
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## Starting Point: Total Delay Impact Study (2010)

- Comprehensive assessment of flight delay costs **for year 2007**
  - Conducted by: 16 researchers, 5 universities, 1 consulting firm.
  - Sponsored by: FAA through NEXTOR.
  
- Total cost for 2007 estimated to be **\$31.2 billion** [Ball et al., 2010].



Cost Component	Cost (\$ billion)
Cost to Airlines	8.3
Cost to Passengers	16.7
Cost from Lost Demand	2.2
Impact on GDP	4.0
<b>Total</b>	<b>31.2</b>

## Passenger Costs in Total Delay Impact Study

- When measured against schedule: passengers lost 240 million hours [Barnhart, Fearing and Vaze, 2014].
- Additionally, schedule buffers cost another \$6 billion to passengers (and another \$3.7 billion to airlines) [Ball et al., 2010].

Cost Components (\$ billion)	Passenger Costs	Airline Costs	Total Costs
Schedule Buffer	6.0	3.7	9.7
Delay against Schedule	9.4	4.6	14.0
Other Costs	1.3	-	1.3
<b>Total</b>	<b>16.7</b>	<b>8.3</b>	<b>25.0</b>

**That was all for 2007.**

**A lot has happened since then!!**

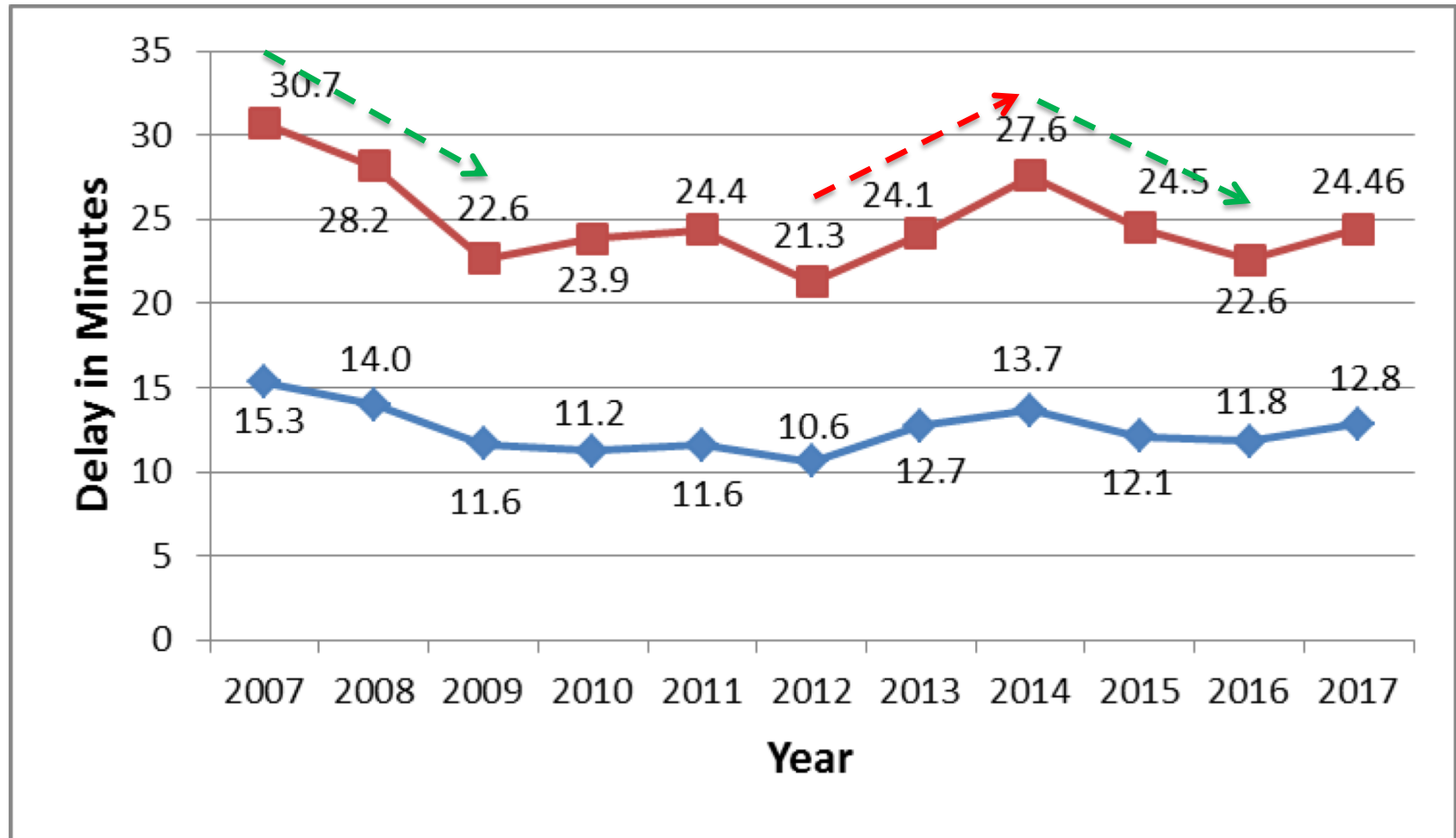
# Our Focus: Longitudinal Study of Buffers and Delays

- **General idea:** Provide annual updates on –
  - Total flight delays
  - Total passenger delays
  - Total buffers
  - Trend analyses
  - Insightful findings
  - By airline, by airport, by time-of-day, by day-of-week, by month-of-year, etc.
  
- This presentation includes –
  - Schedule buffers for 2007-2017
  - Passenger delays for 2007-2017

## Key Definitions

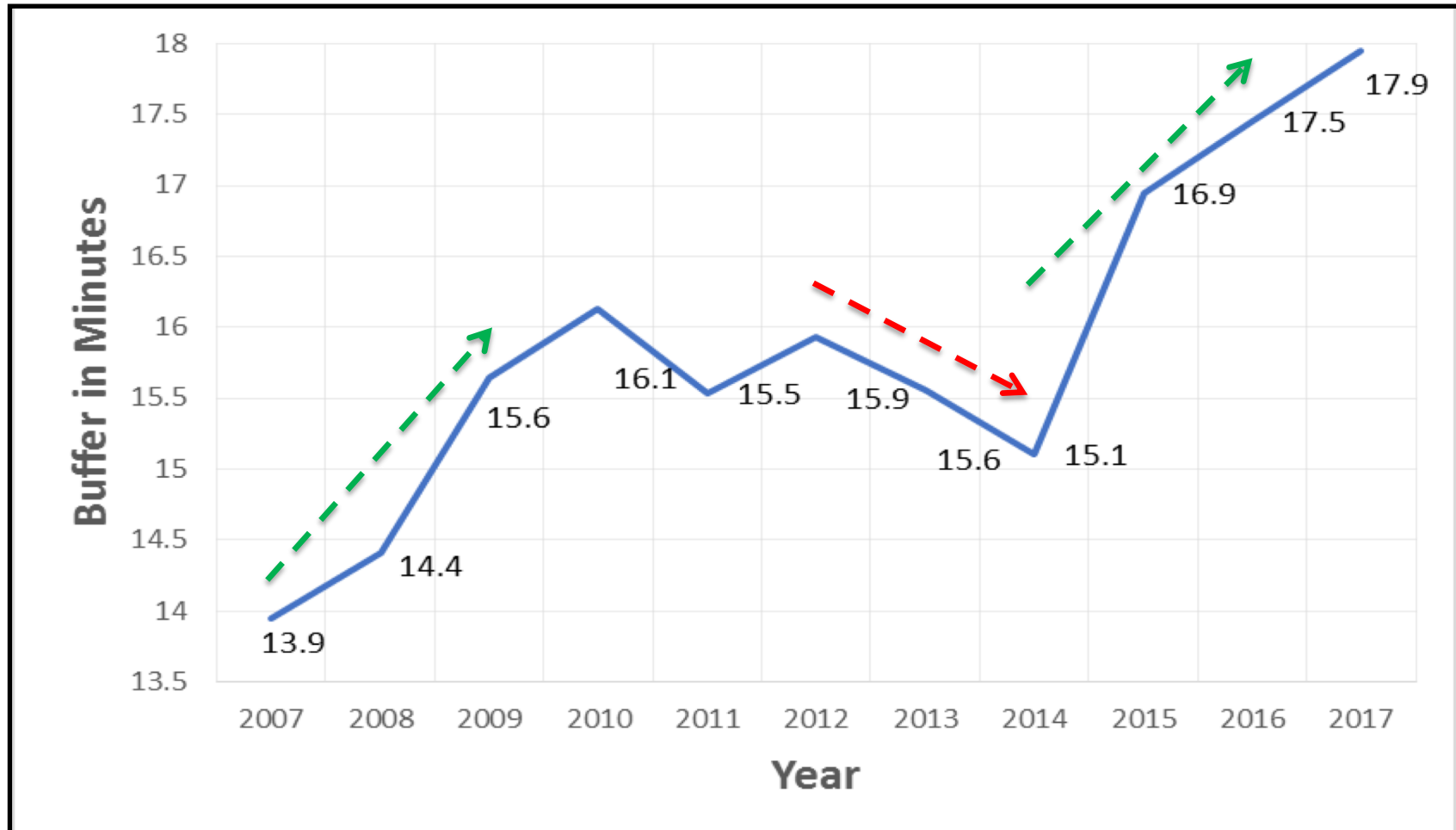
- Passenger Delay (Per Passenger)
  - = Actual Arrival Time of Each Passenger (at final destination)
    - Scheduled Arrival Time of Each Passenger (at final destination)
  - Calculated using a passenger flow disaggregation model combined with a passenger re-accommodation heuristic
- Schedule Buffer (Per Flight)
  - = Scheduled Duration of Each Flight
    - 10<sup>th</sup> Percentile of Actual Duration of Each Flight

## Average Passenger Delay Per Passenger



Avg. passenger delay **decreased by 20%** from 2007 to 2017

## Average Schedule Buffer Per Flight



Avg. schedule buffer **increased by 29%** from 2007 to 2017

## Approximate Total Costs (in \$ Billion)

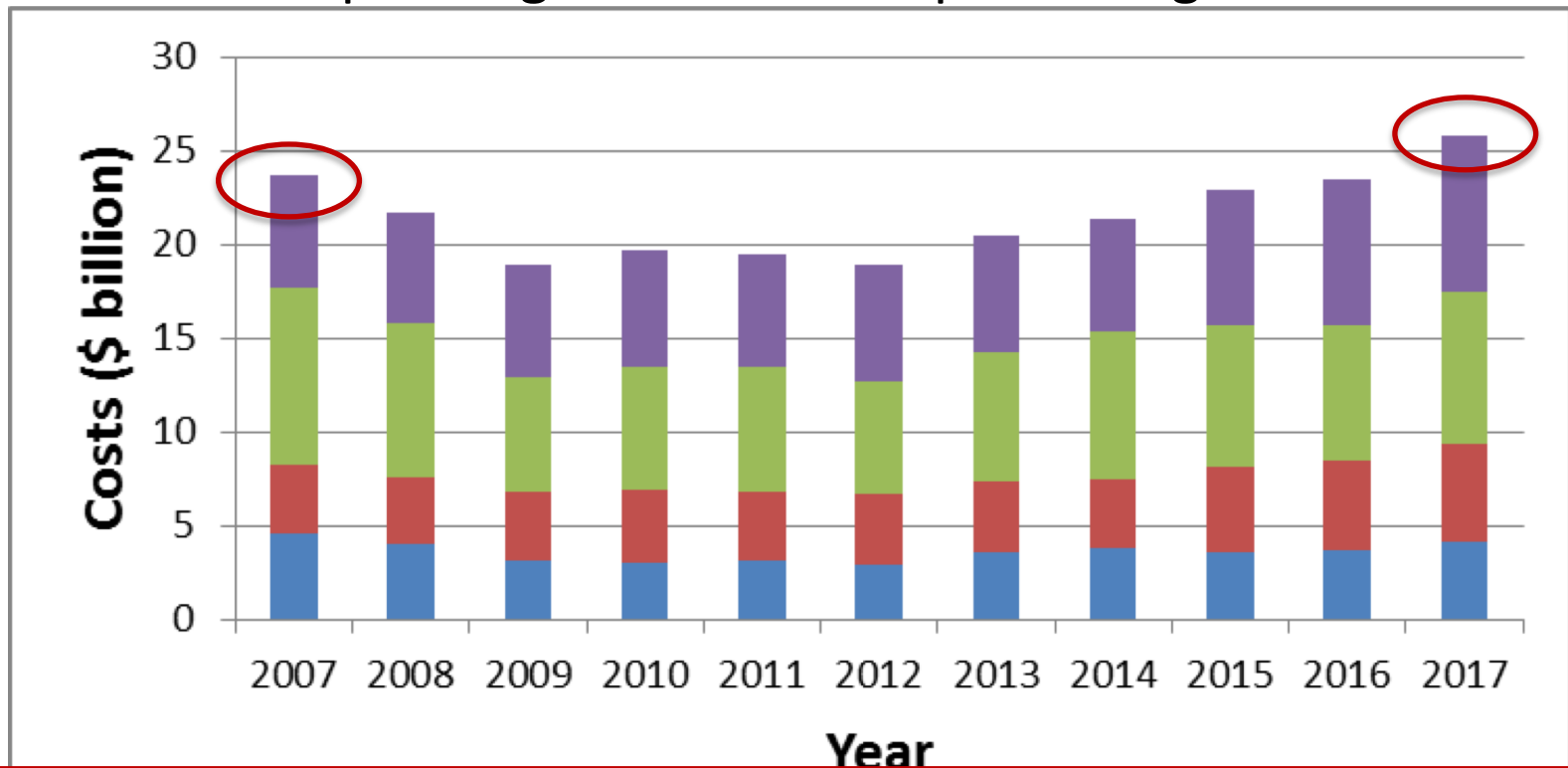
- A highly approximate analysis: We scaled all averages by the annual total passengers on AOTP-reported flights.

Year	Airline Costs		Passenger Costs		Total Costs
	Delay	Buffer	Delay	Buffer	
2007	4.60	3.70	9.40	6.00	<b>23.70</b>
2008	3.99	3.63	8.20	5.89	<b>21.70</b>
2009	3.10	3.68	6.16	5.97	<b>18.92</b>
2010	3.03	3.84	6.57	6.23	<b>19.67</b>
2011	3.11	3.69	6.69	5.98	<b>19.48</b>
2012	2.90	3.84	5.93	6.23	<b>18.90</b>
2013	3.55	3.83	6.86	6.21	<b>20.45</b>
2014	3.80	3.71	7.84	6.02	<b>21.37</b>
2015	3.63	4.50	7.52	7.29	<b>22.94</b>
2016	3.69	4.80	7.19	7.78	<b>23.46</b>
2017	4.18	5.16	8.13	8.37	<b>25.84</b>



## Approximate Total Costs (in \$ Billion)

- A highly approximate analysis: We scaled all averages by the annual total passengers on AOTP-reported flights.

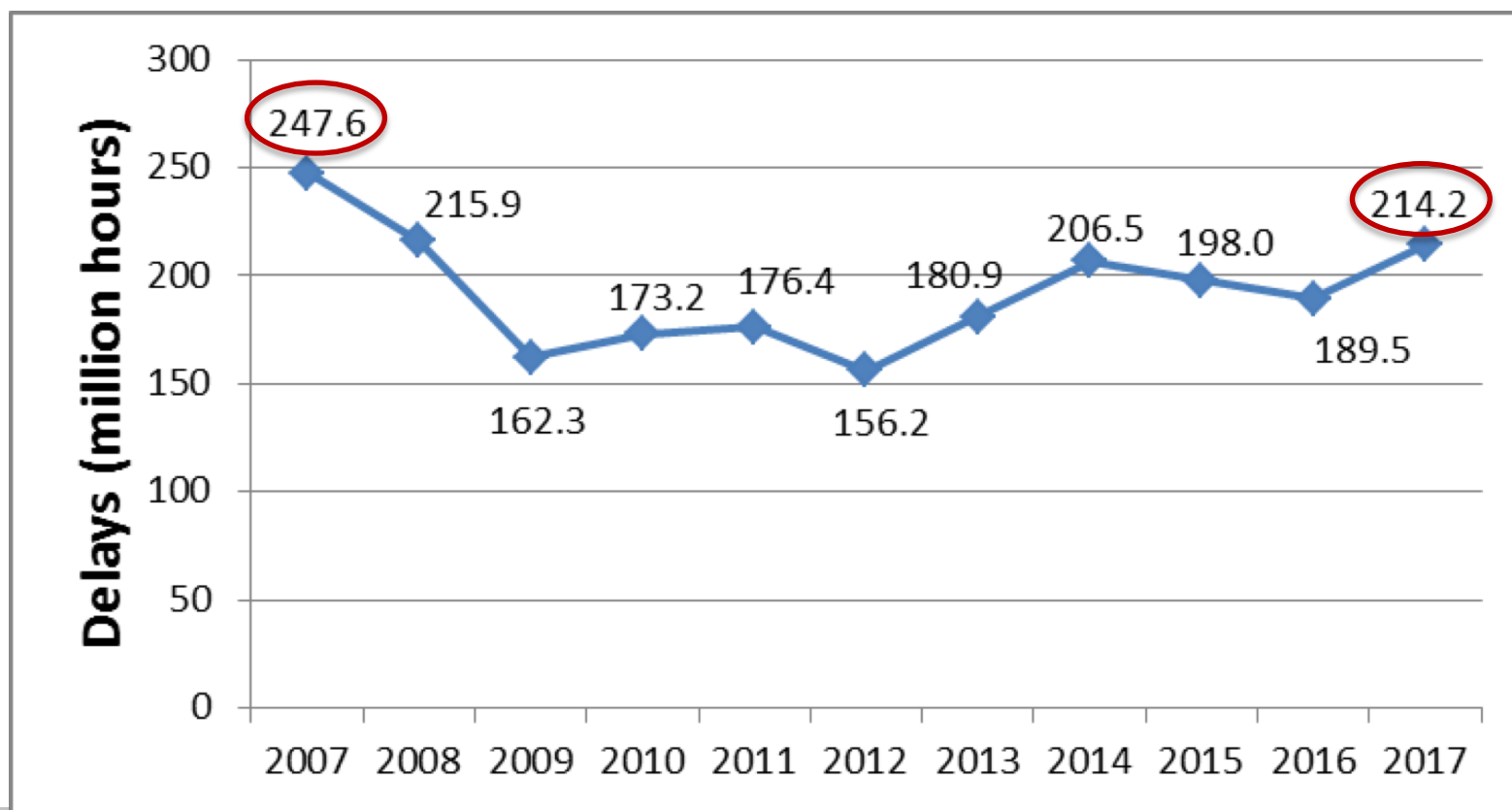


According to this approximate analysis, the total delay+buffer cost in **2017 is 9% higher than in 2007**



# Deep Dive I: Passenger Delays Against Schedule

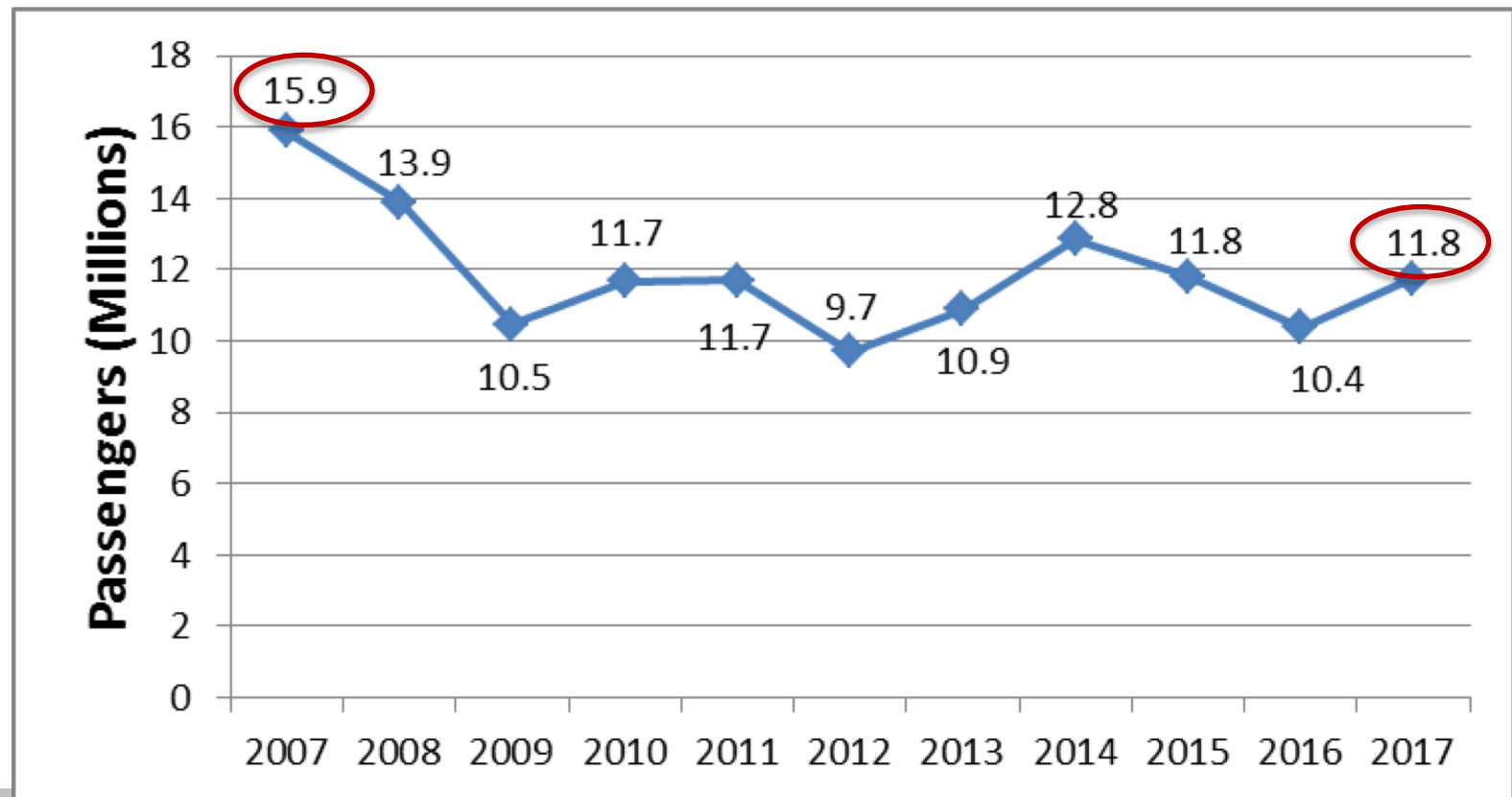
## Total Passenger Delays (in Million Hours)



Total passenger delays **decreased by 13%** from 2007 to 2017

## Number of Disrupted Passengers (in Millions)

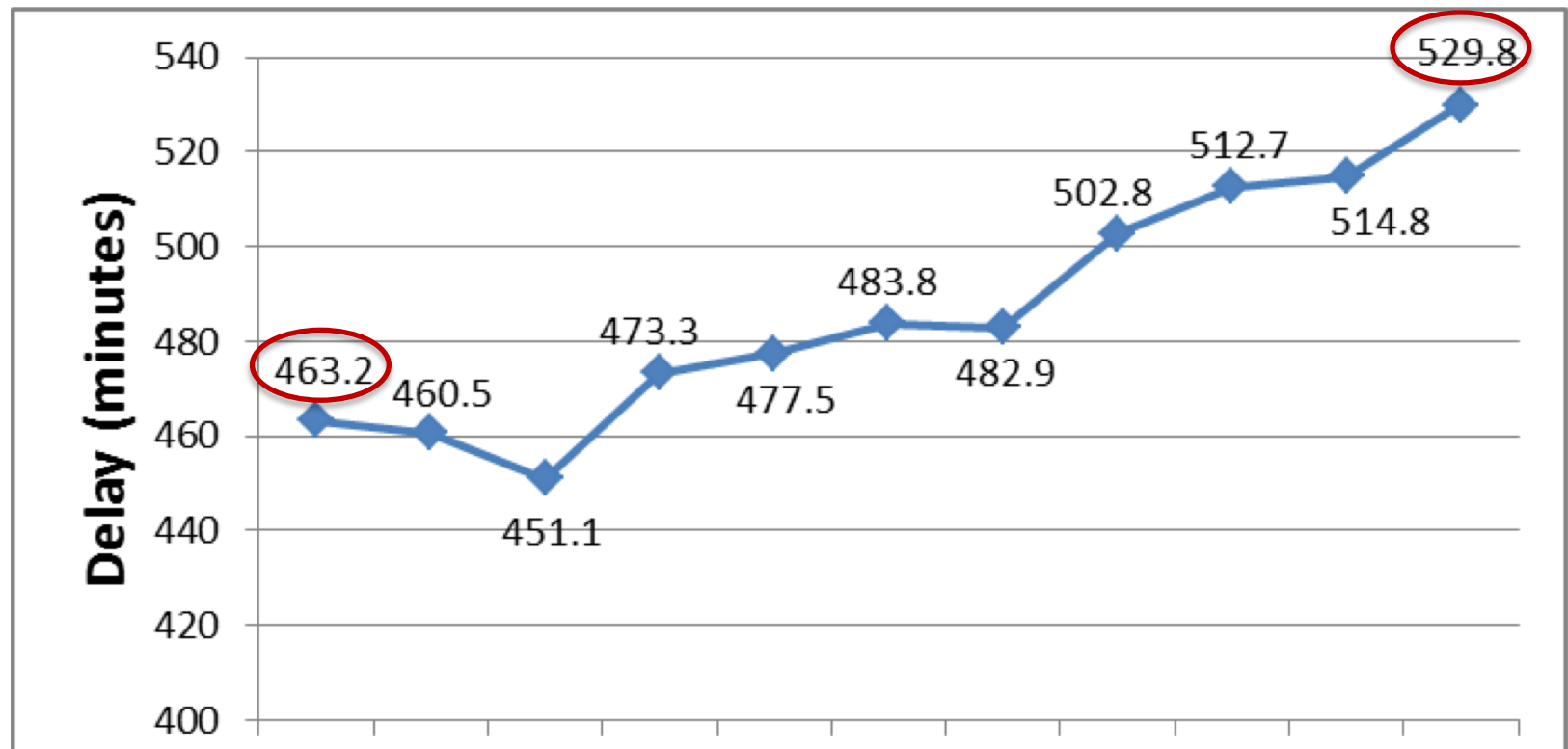
- Disrupted passengers = those on cancelled flights + those who miss a connection



Disrupted passengers **decreased by 26%** from 2007 to 2017

## Avg. Delay to Disrupted Passengers (in Minutes)

- Depends on the ease of rebooking: affected by seat availability



Delay to disrupted passengers **increased by 67 minutes per passenger** from 2007 to 2017

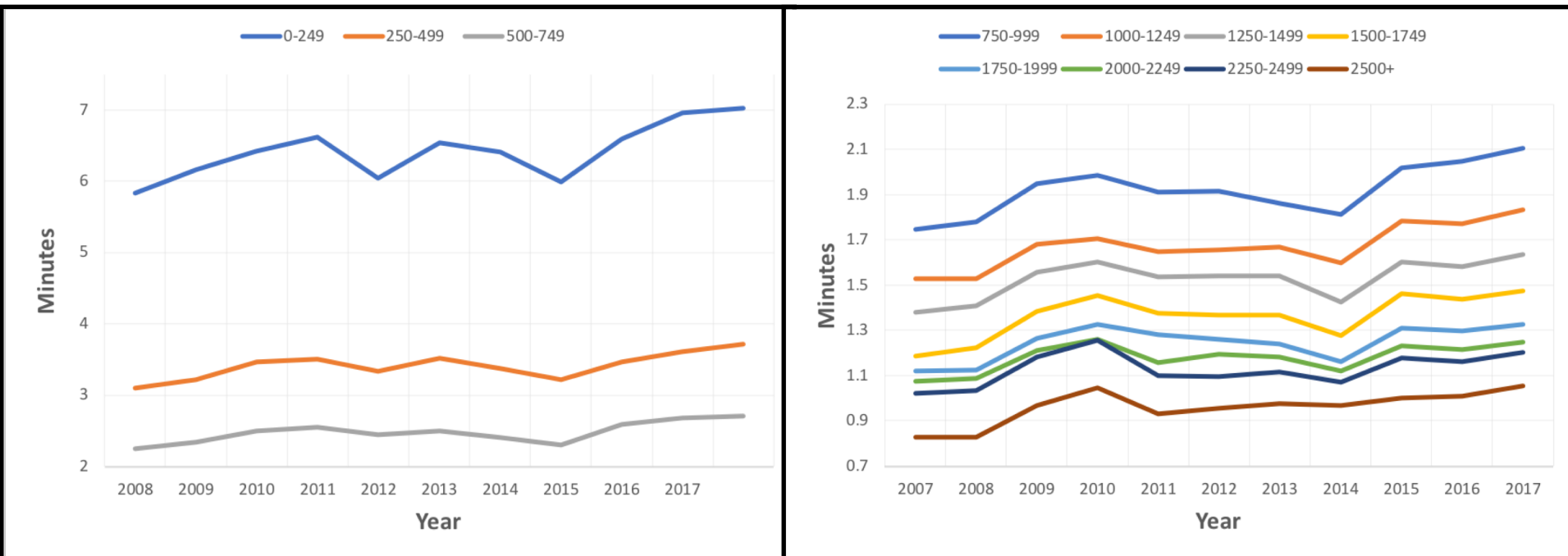


# Deep Dive II: Schedule Buffers



## Avg. Buffer per 100 Miles: By Distance Group

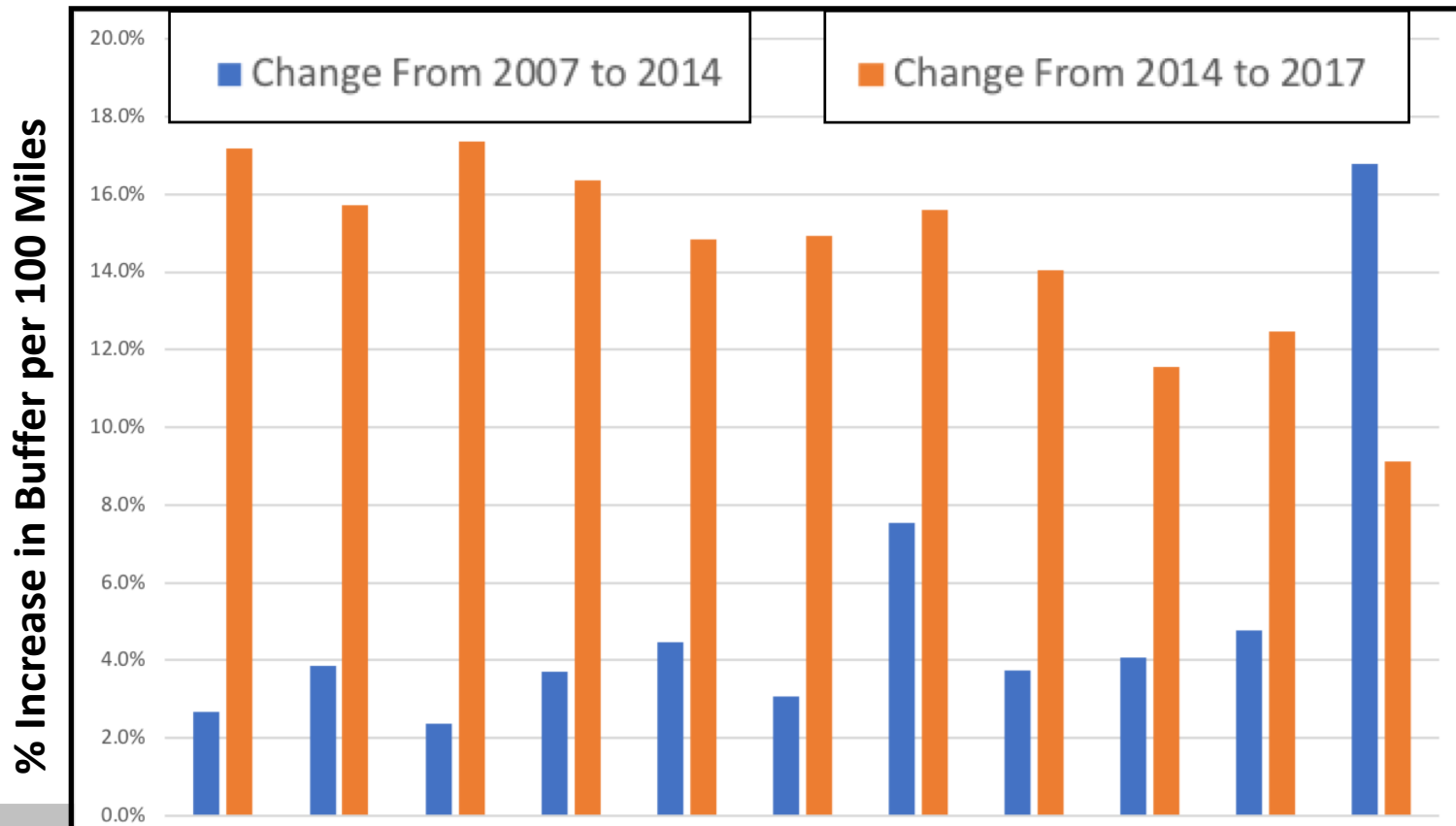
- Buffers per 100 mile increased for all 11 distance categories (0-249 miles, 250-499 miles, ... , 2500+ miles).



Buffer increases are **not driven by stage length** changes

## Avg. Buffer per 100 Miles: By Distance Group

- Average increase from 2007 to 2014 was 5.2%.
- Additional average increase from 2014 to 2017 was 14.5%.

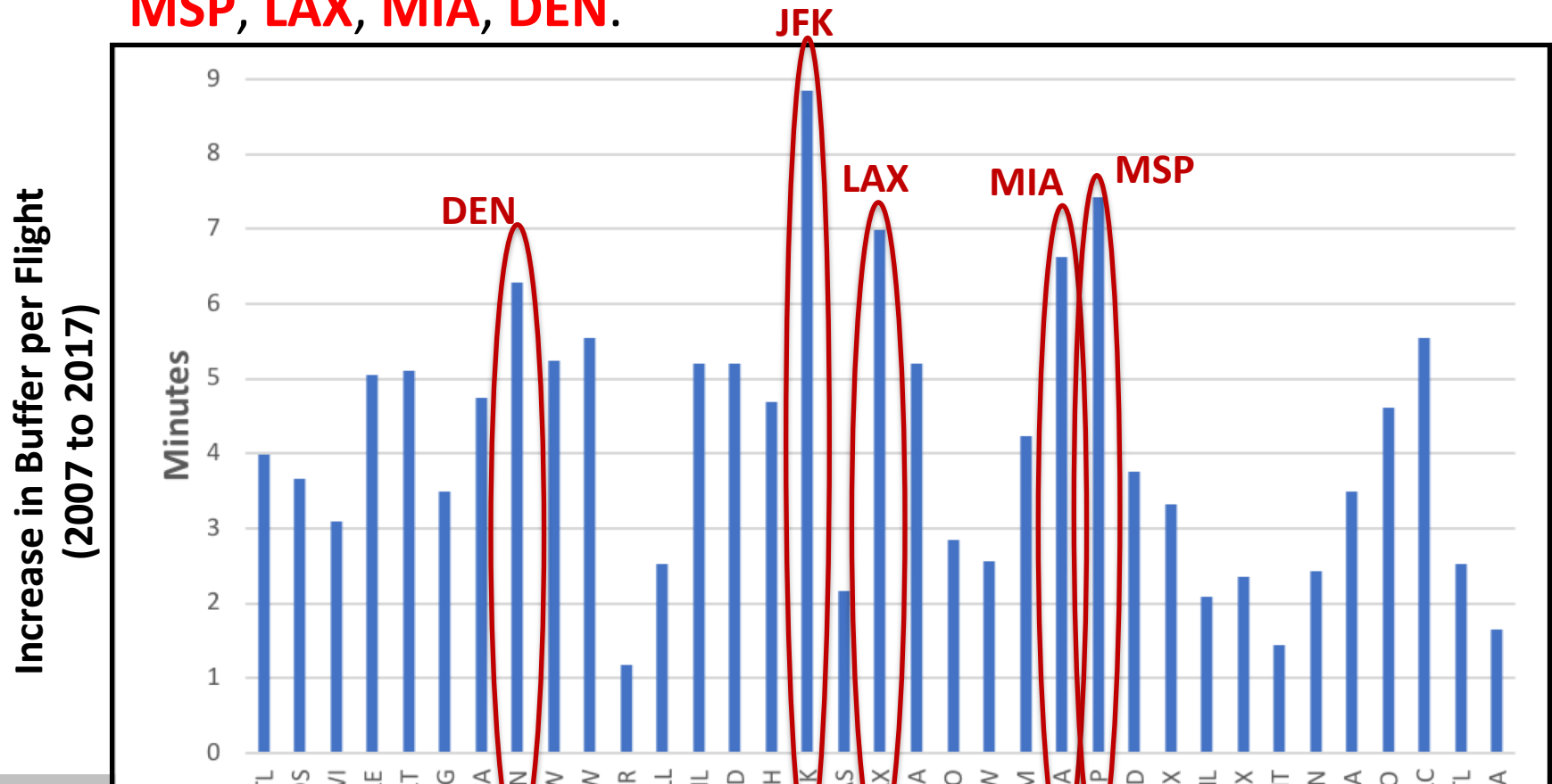


Most buffer increases happened **after 2014**



## Increase in Buffer per Flight: OEP35 Airports

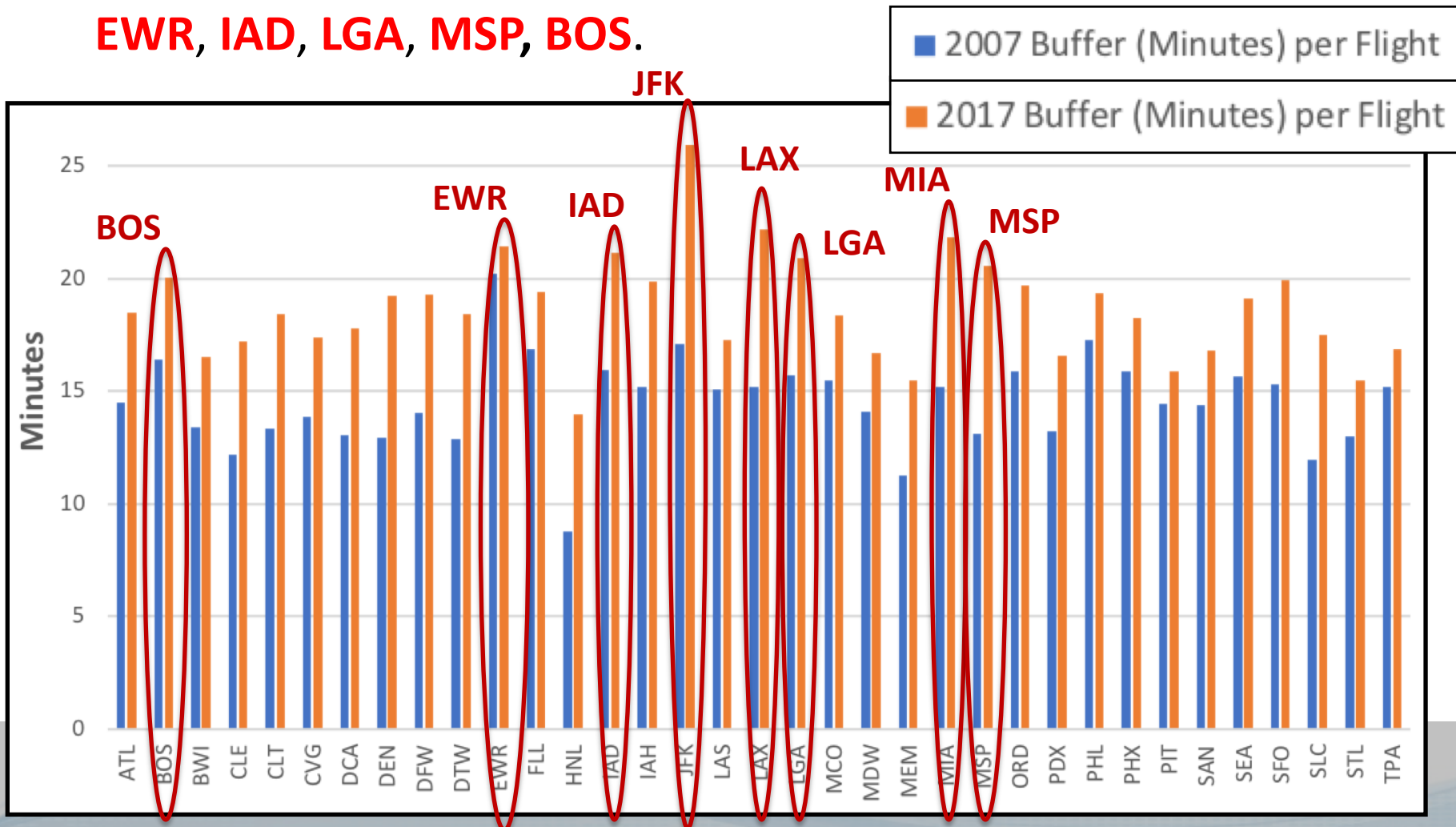
- Largest per-flight increase (>6 min) from 2007 to 2017: **JFK**, **MSP**, **LAX**, **MIA**, **DEN**.



Avg. buffer per flight **increased at each OEP35 airport**

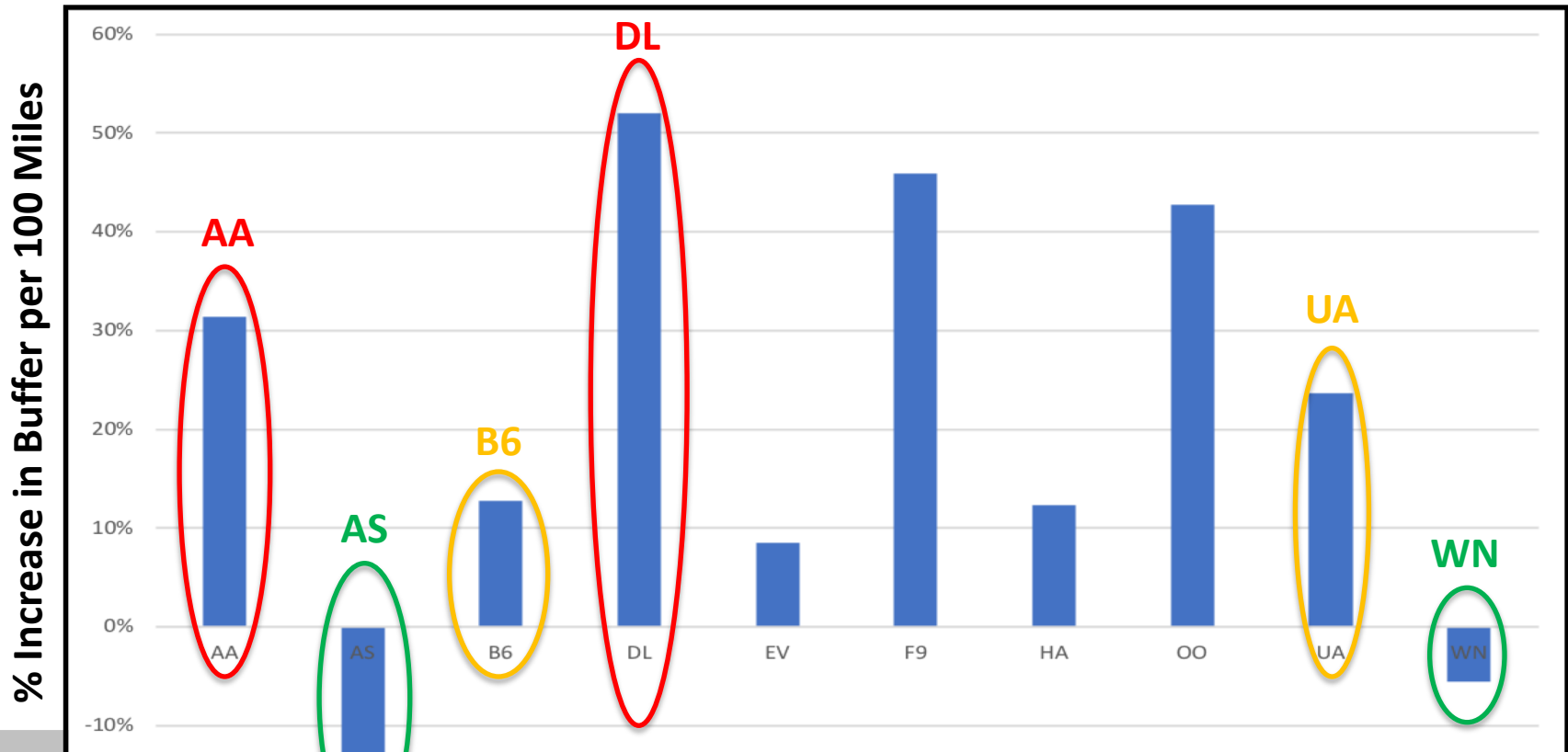
## Buffer per Flight (in 2017): OEP35 Airports

- Largest per flight buffers (>20 min) in 2017: **JFK**, **LAX**, **MIA**, **EWR**, **IAD**, **LGA**, **MSP**, **BOS**.



## % Increase in Buffer per 100 Miles: By Airline

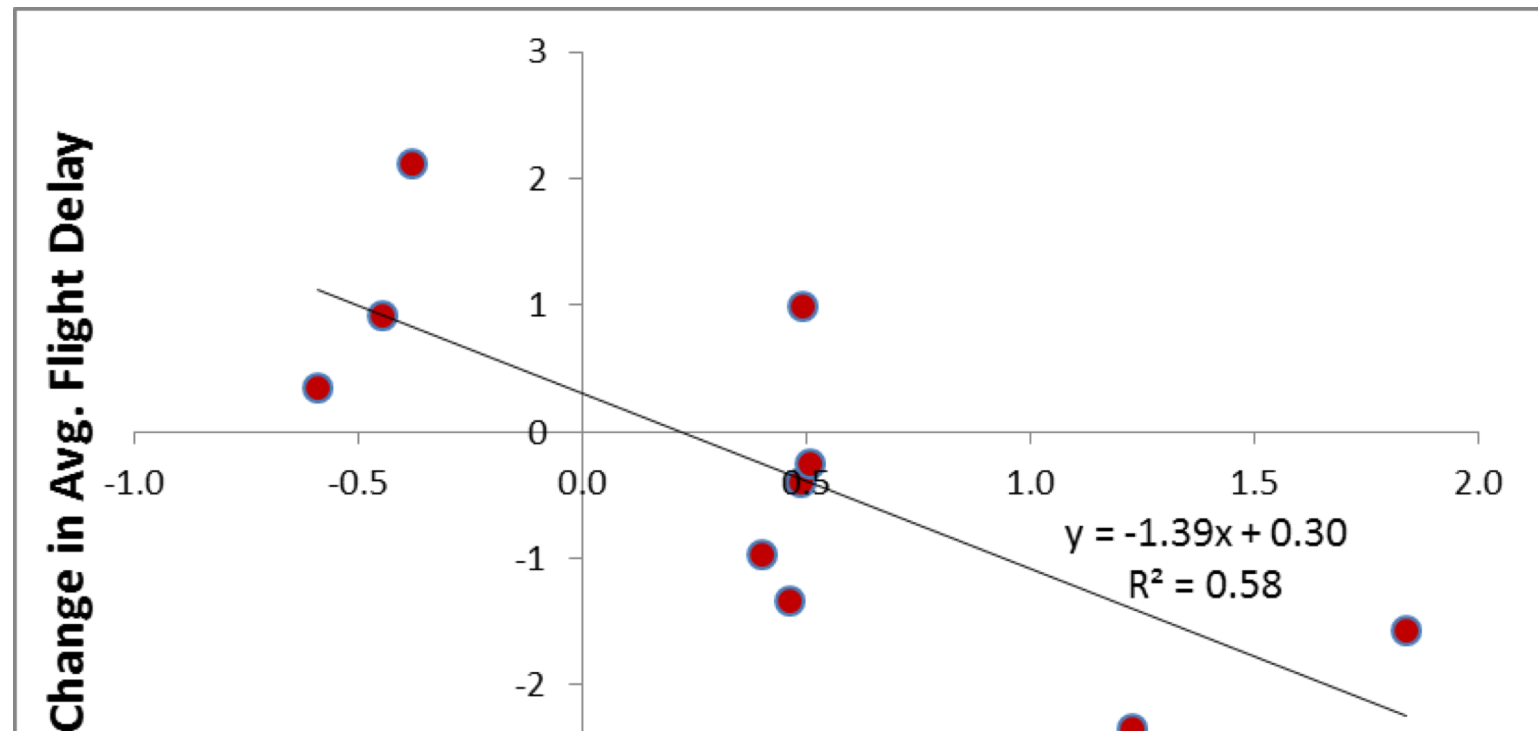
- Large increase for **DL**, **AA**; Small increase for **UA**, **B6**.
- Decrease for **AS**, **WN**.



**Airlines differed significantly** in terms of changes in buffers

## Change in Delay/Flight Vs. Change in Buffer/Flight

- An excellent predictor of year-to-year change in average flight delay is the year-to-year change in average schedule buffer.



Buffer increase of 1 minute associated with a flight delay decrease of **1.4 minutes**



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