EQUITY & EFFICIENCY
In Search of METRICS

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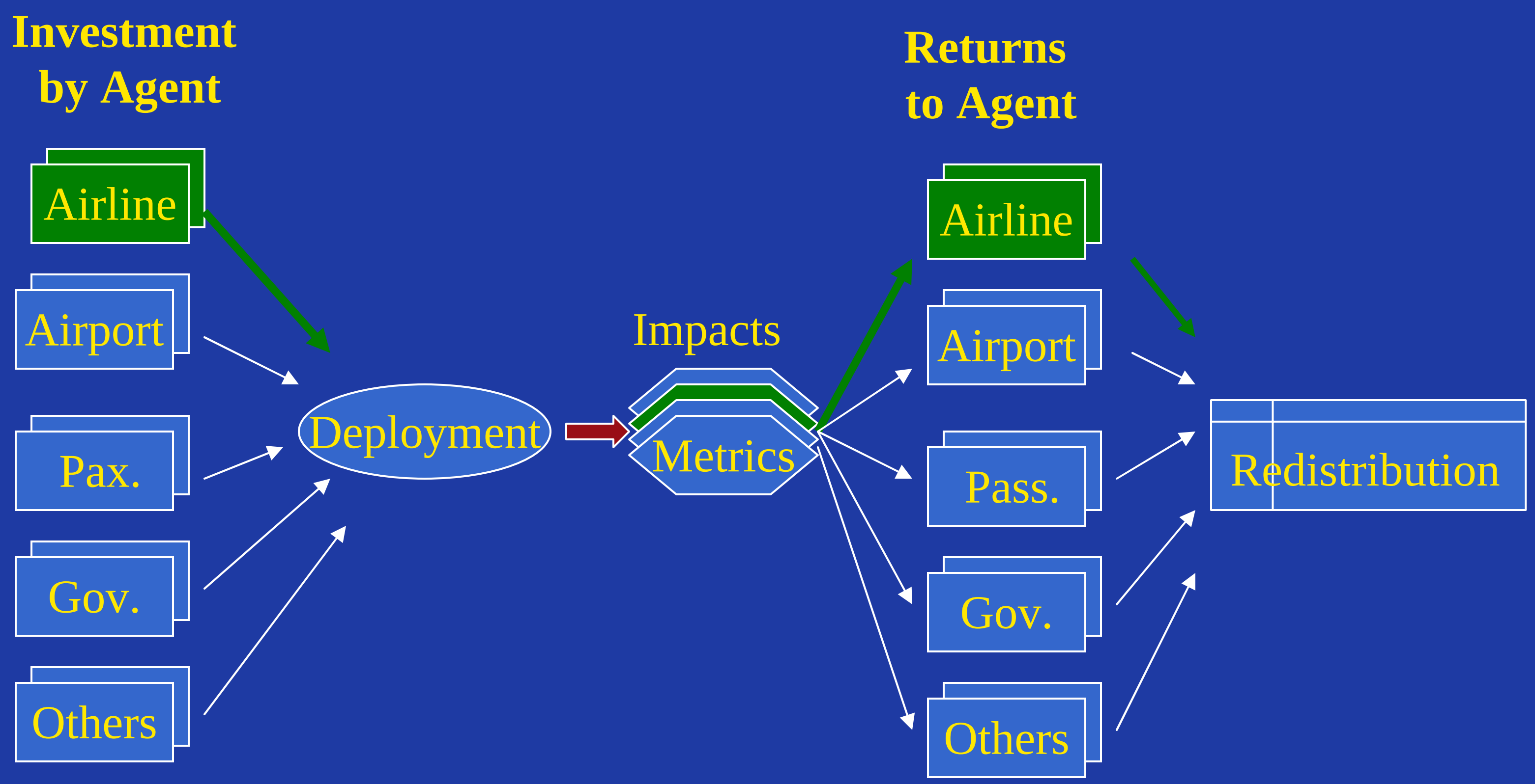
Moving Metrics

NEXTOR SEMINAR

January 29, 2004

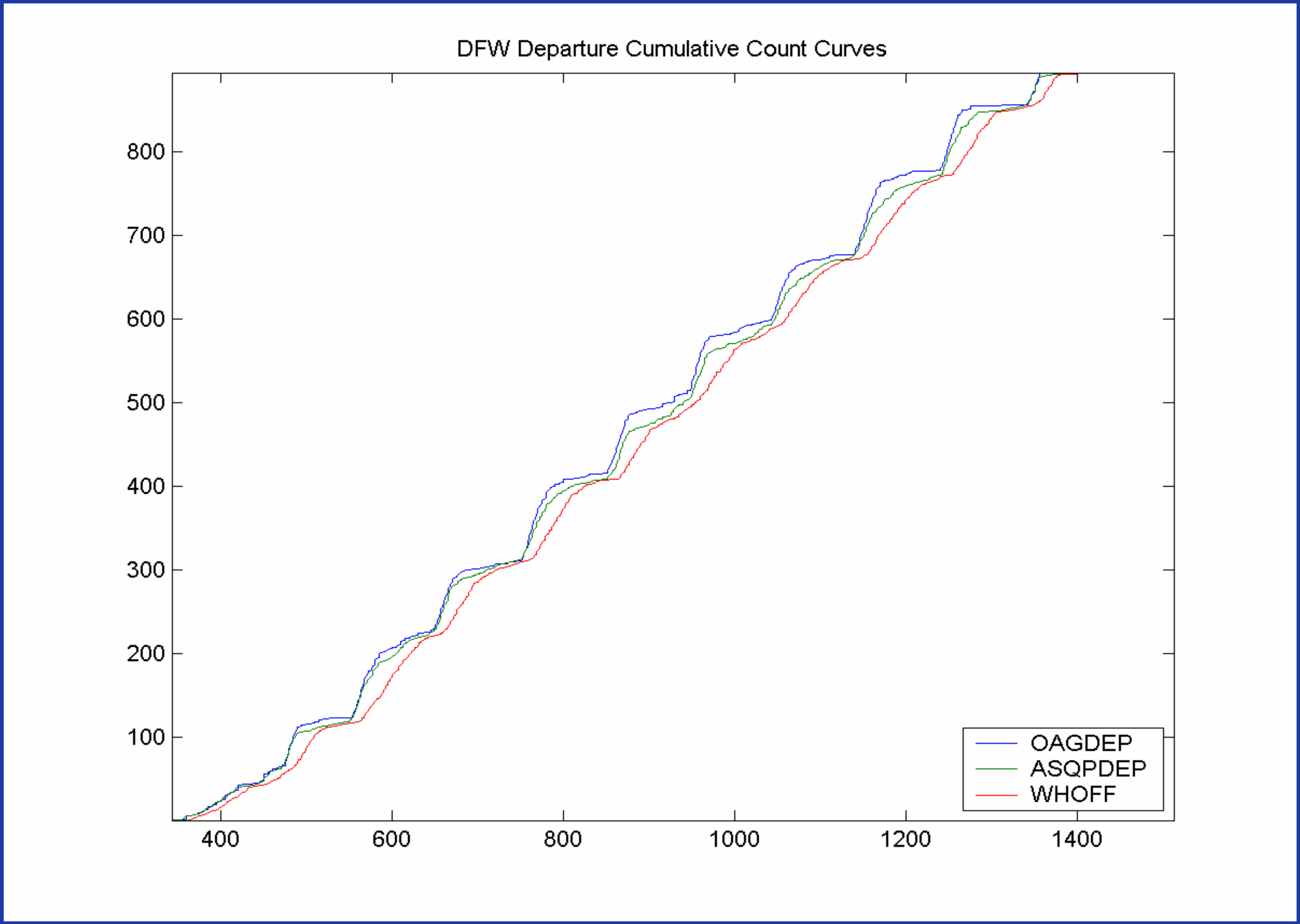
Asilomar, California

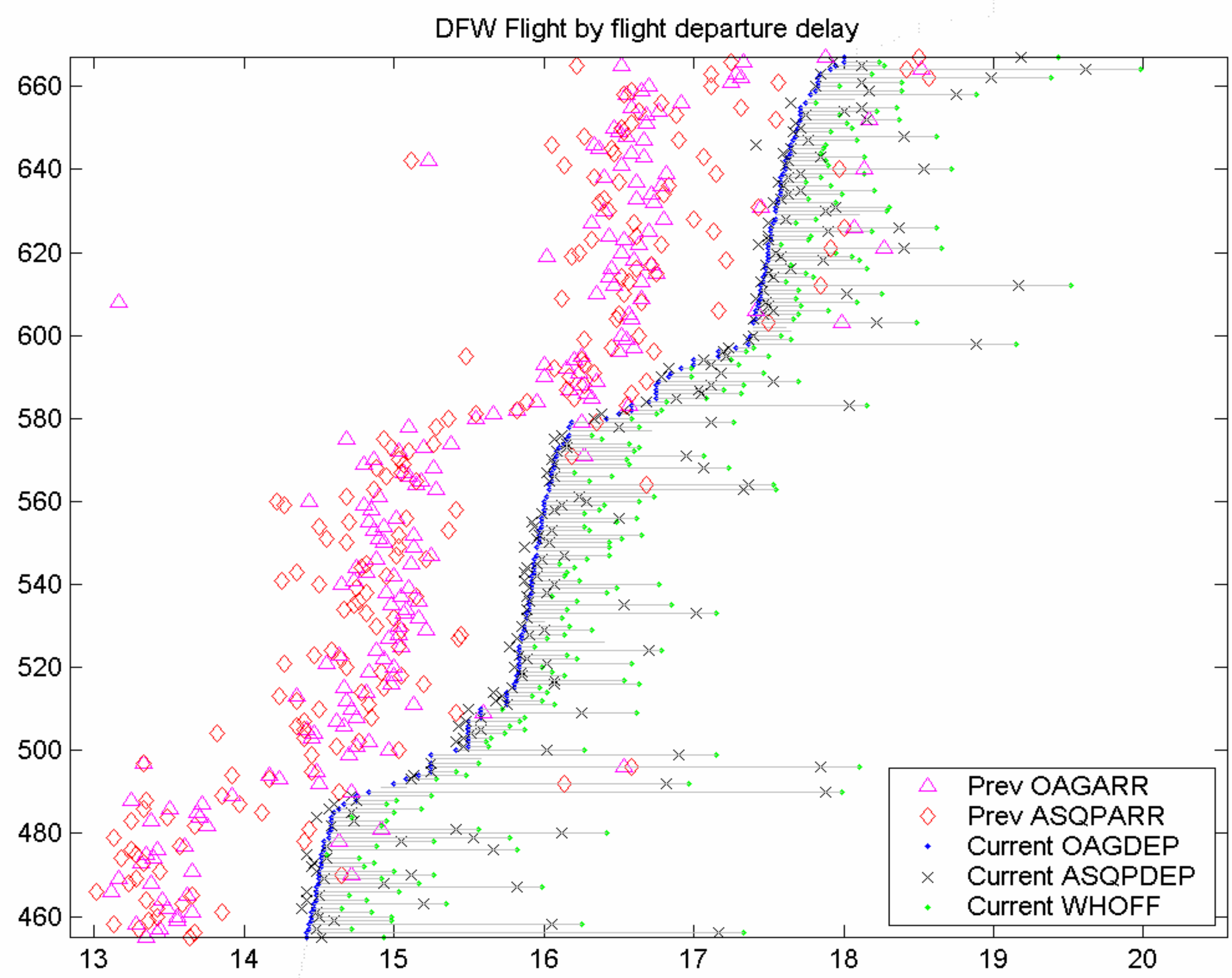
Framework for Assessing Equity



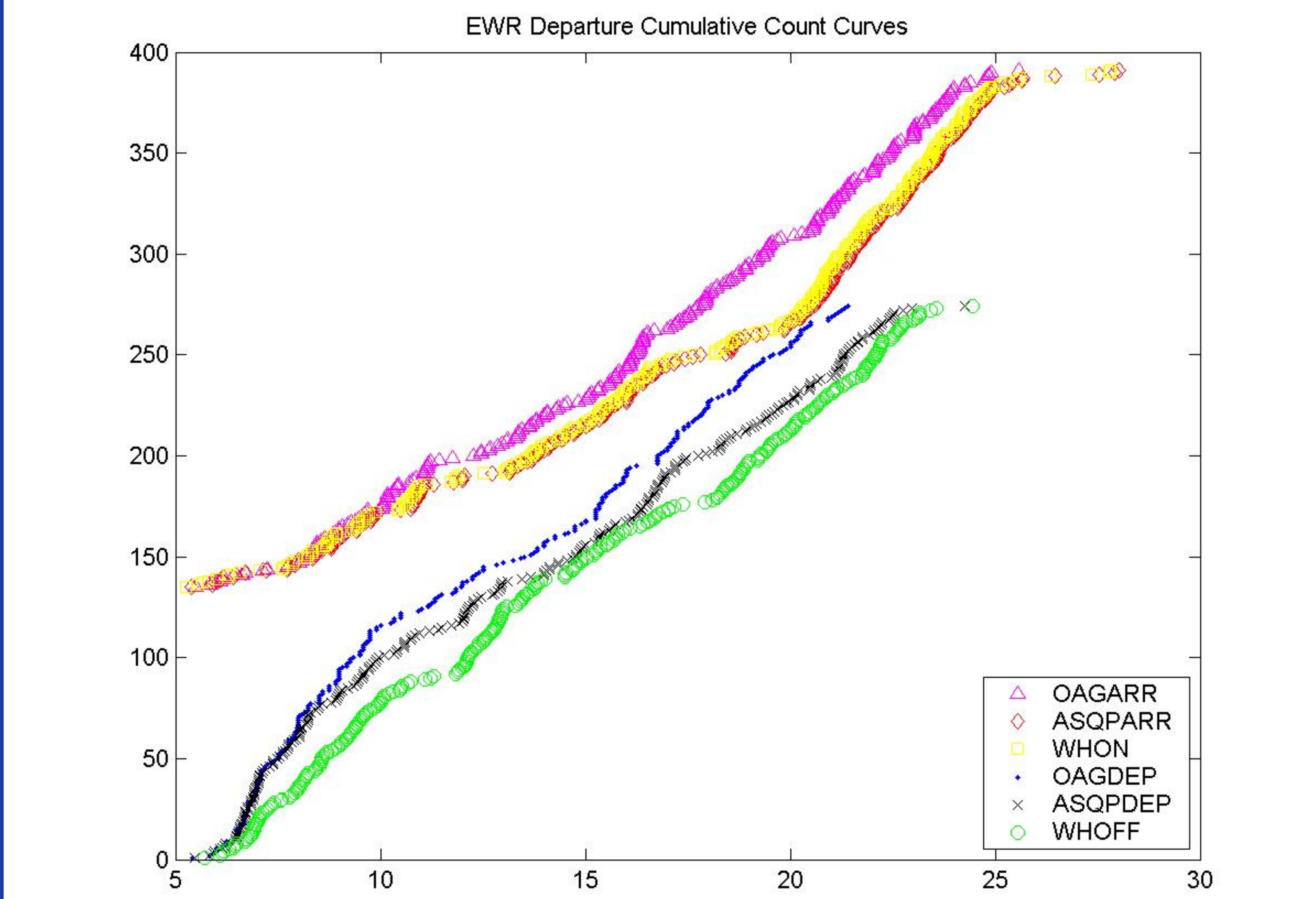
Two Equity issues

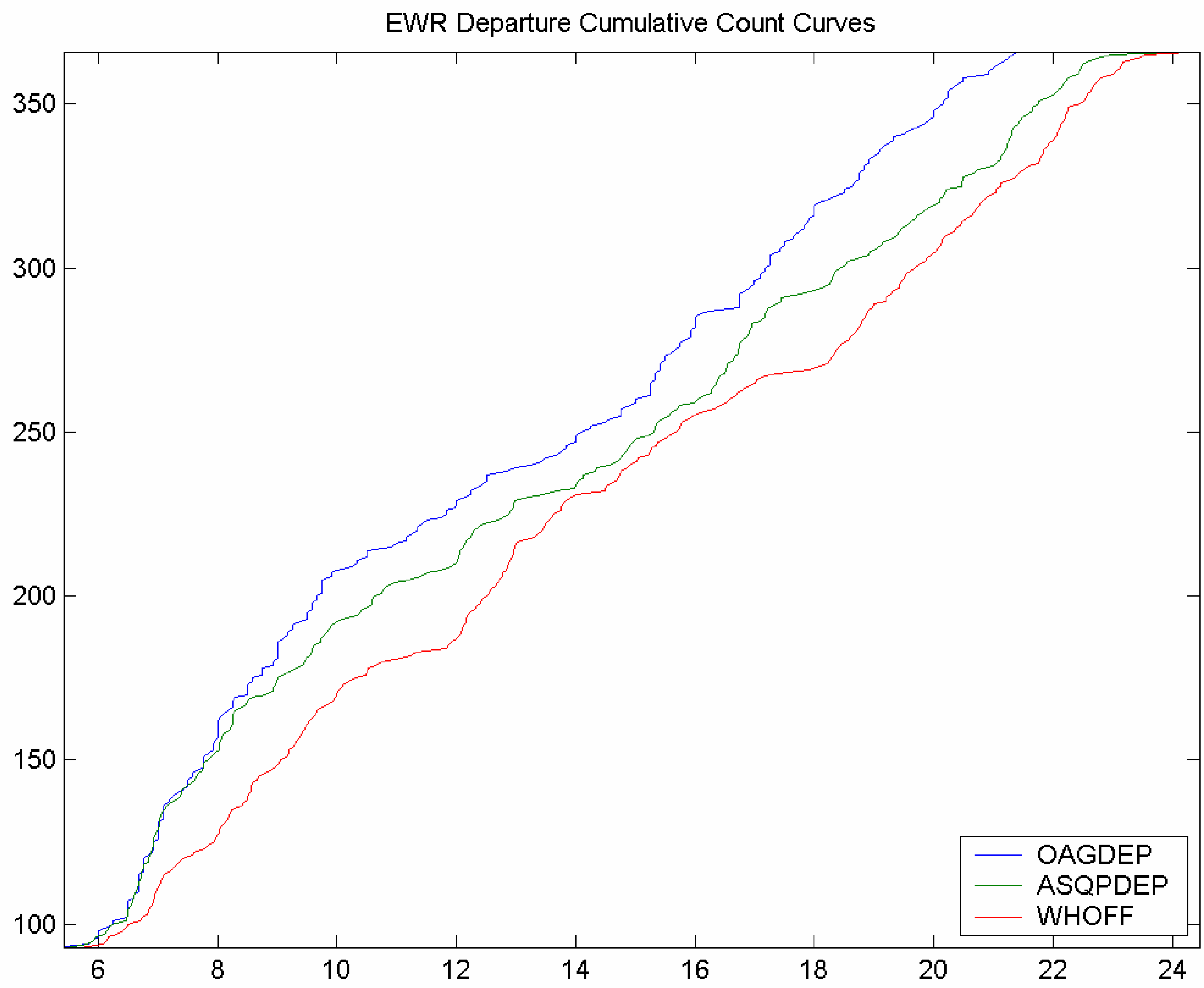
- Equity in A Queue.
  - Inherent Distribution of Delay in a Queue
  - Equity Effects of Queue Management Efficiency
  - Intra- and Inter-Airline Impacts
  - Unit Costs to different type of users
- Differential Impacts of System Investment

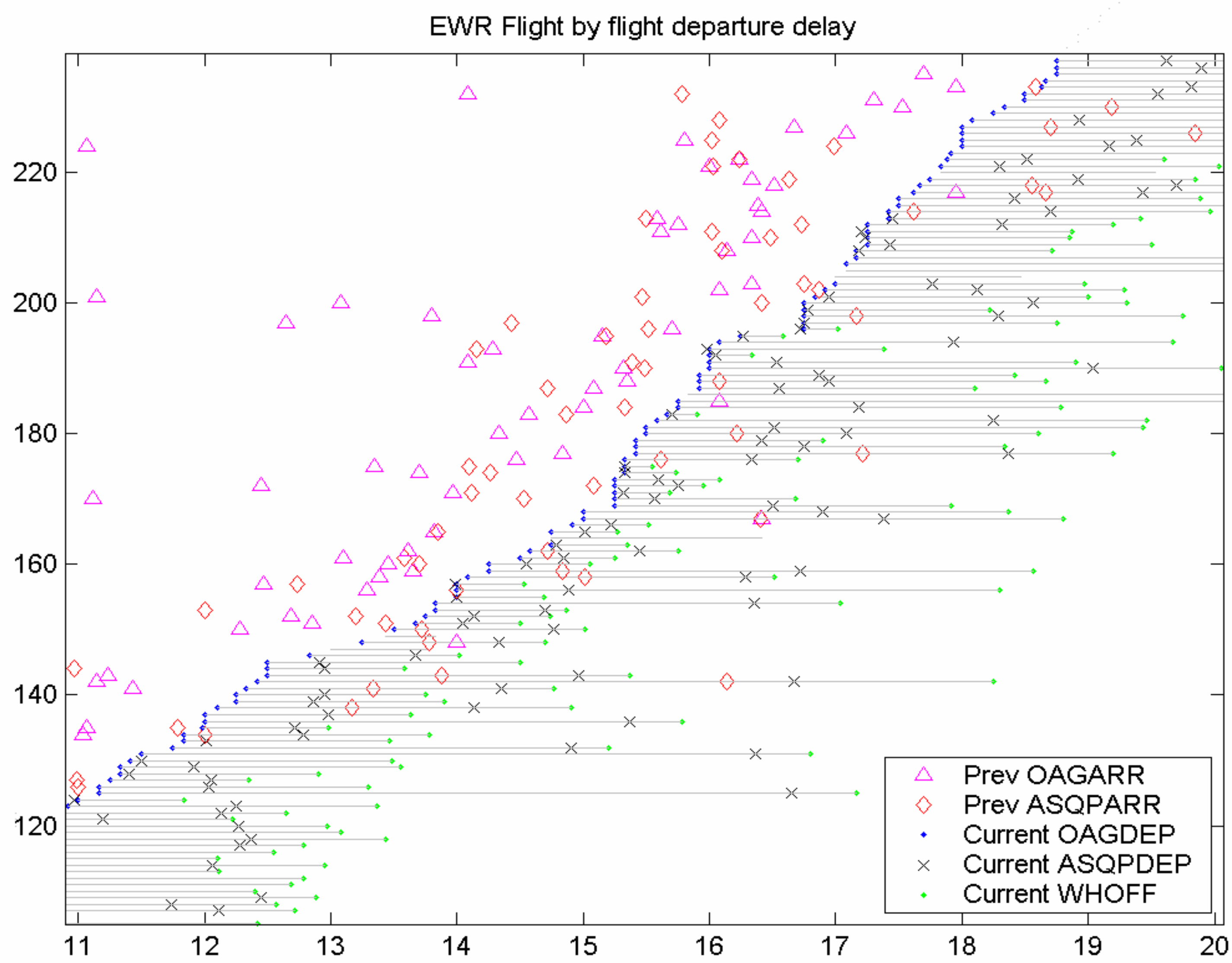

DFW Departure Cumulative Count Curves
800
700
600
500
400
300
200
100
400
600
800
1000
1200
1400
OAGDEP
ASQPDEP
WHOFF


DFW Flight by flight departure delay
660
640
620
600
580
560
540
520
500
480
460
13
14
15
16
17
18
19
20
Prev OAGARR
Prev ASQPARR
Current OAGDEP
Current ASQPDEP
Current WHOFF

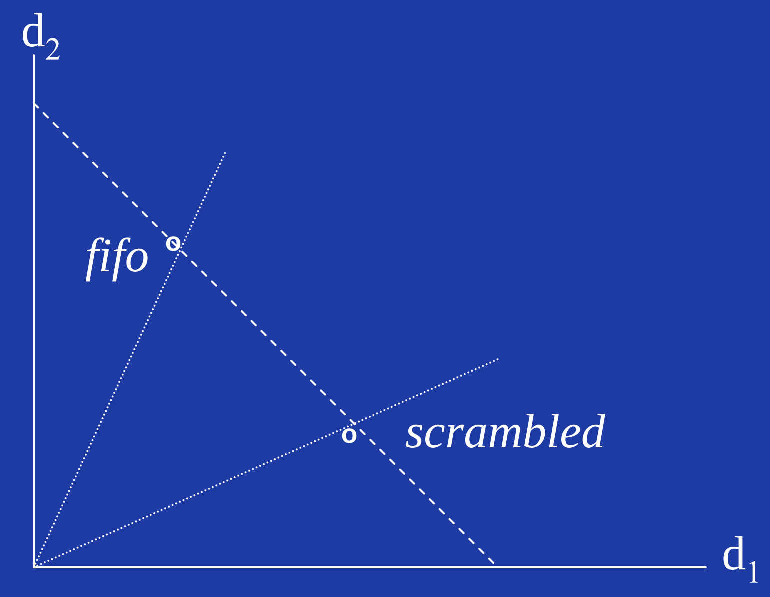
Bad Day at EWR May 24, 1999



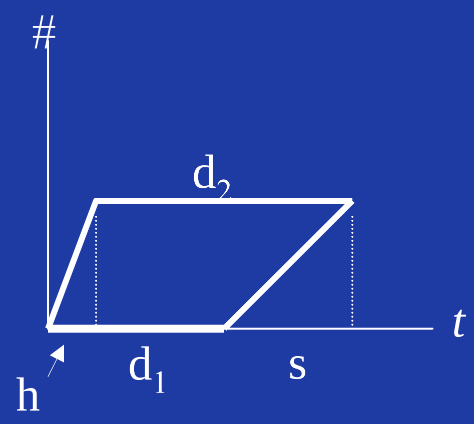

EWR Departure Cumulative Count Curves
350
300
250
200
150
100
6
8
10
12
14
16
18
20
22
24
OAGDEP
ASQPDEP
WHOFF


EWR Flight by flight departure delay
Prev OAGARR
Prev ASQPARR
Current OAGDEP
Current ASQPDEP
Current WHOFF
120
140
160
180
200
220
11
12
13
14
15
16
17
18
19
20

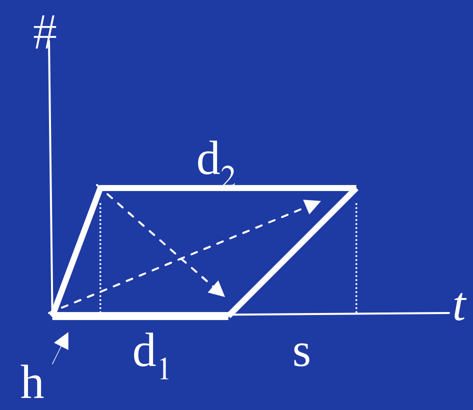
Equity in Queues



Measuring Queue Disruption

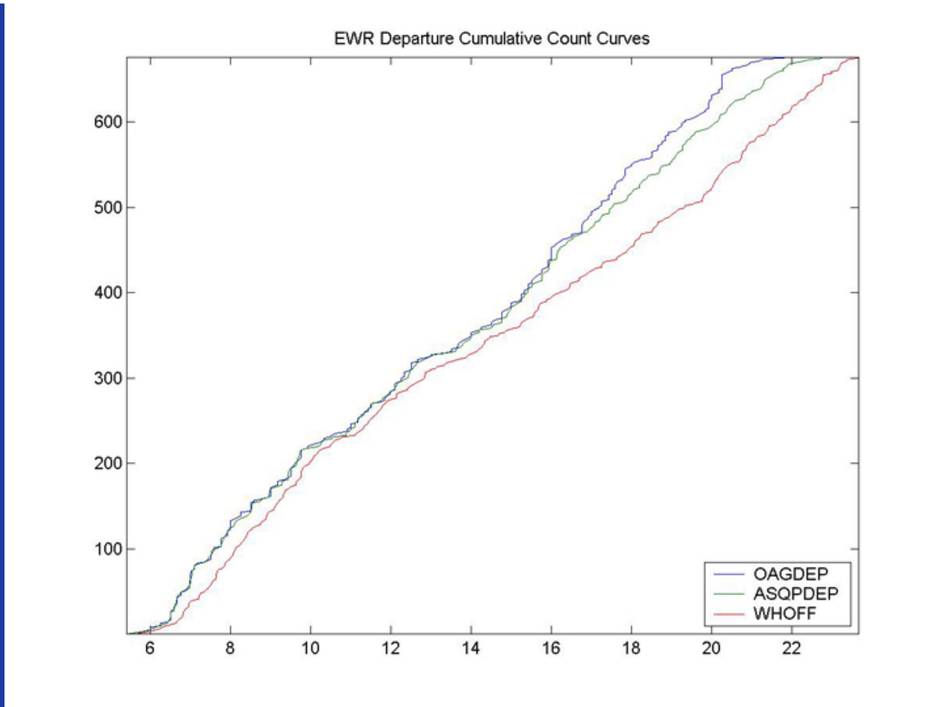


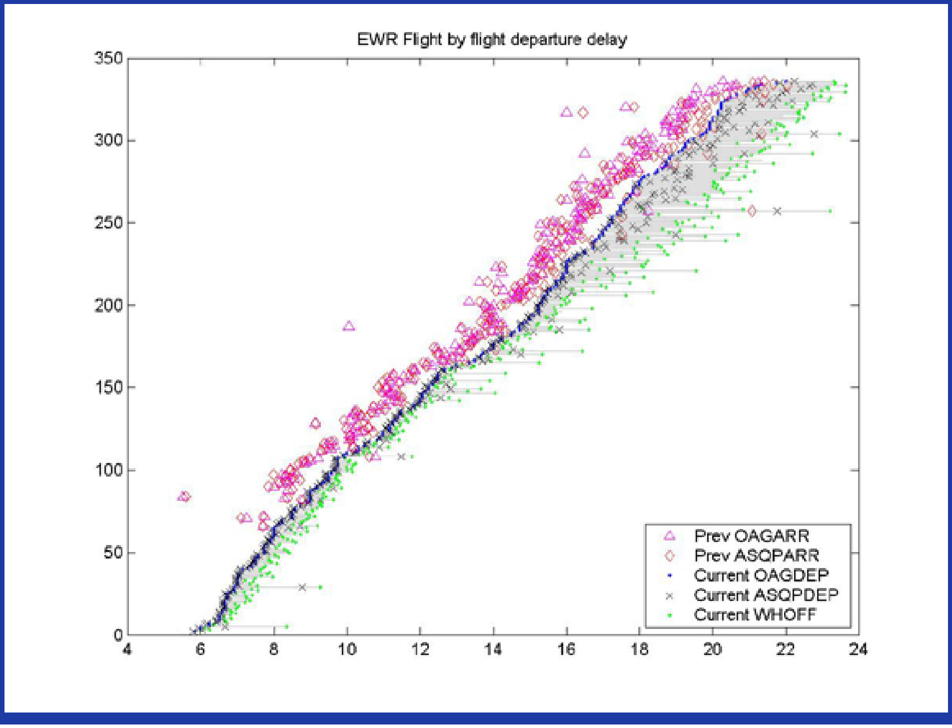
fifo



Scrambled

h	s	d_1	d_2	d_{avg}	c.v.	d_1	d_2	*c.v.*	*R*
1	2	3	4	3.5	3.5	*5*	*2*	*4.1*	**1.17**
1	3	3	5	4	8.5	*6*	*2*	*10*	**1.18**
1	0.5	3	2.5	2.75	5.5	*3.5*	*2*	*5.9*	**1.07**



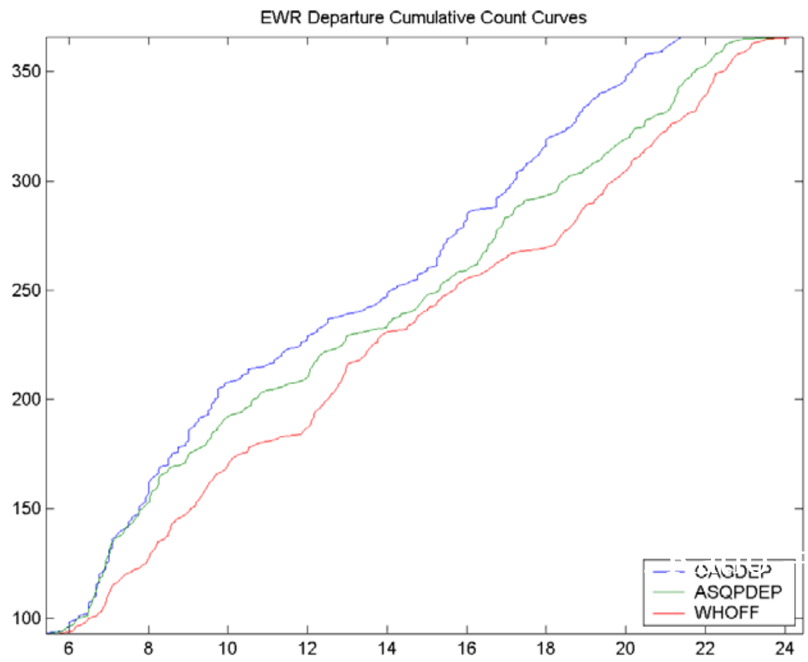


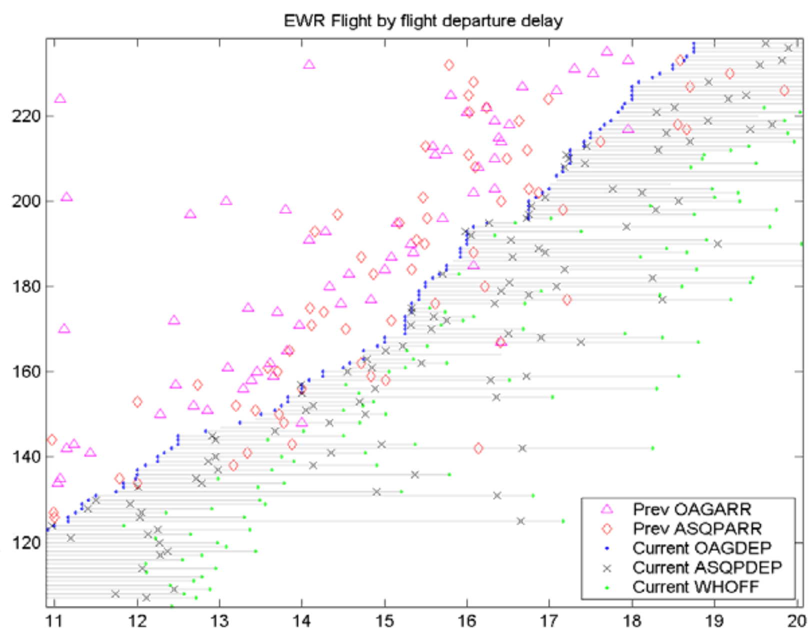
Good Day at EWR

d_{avg} = 57.9
σ = 49.6
c.v. = 42.5

d_{avg} = 57.9
σ = 56.8
c.v. = 55.7

C.V. Ratio = 1.31



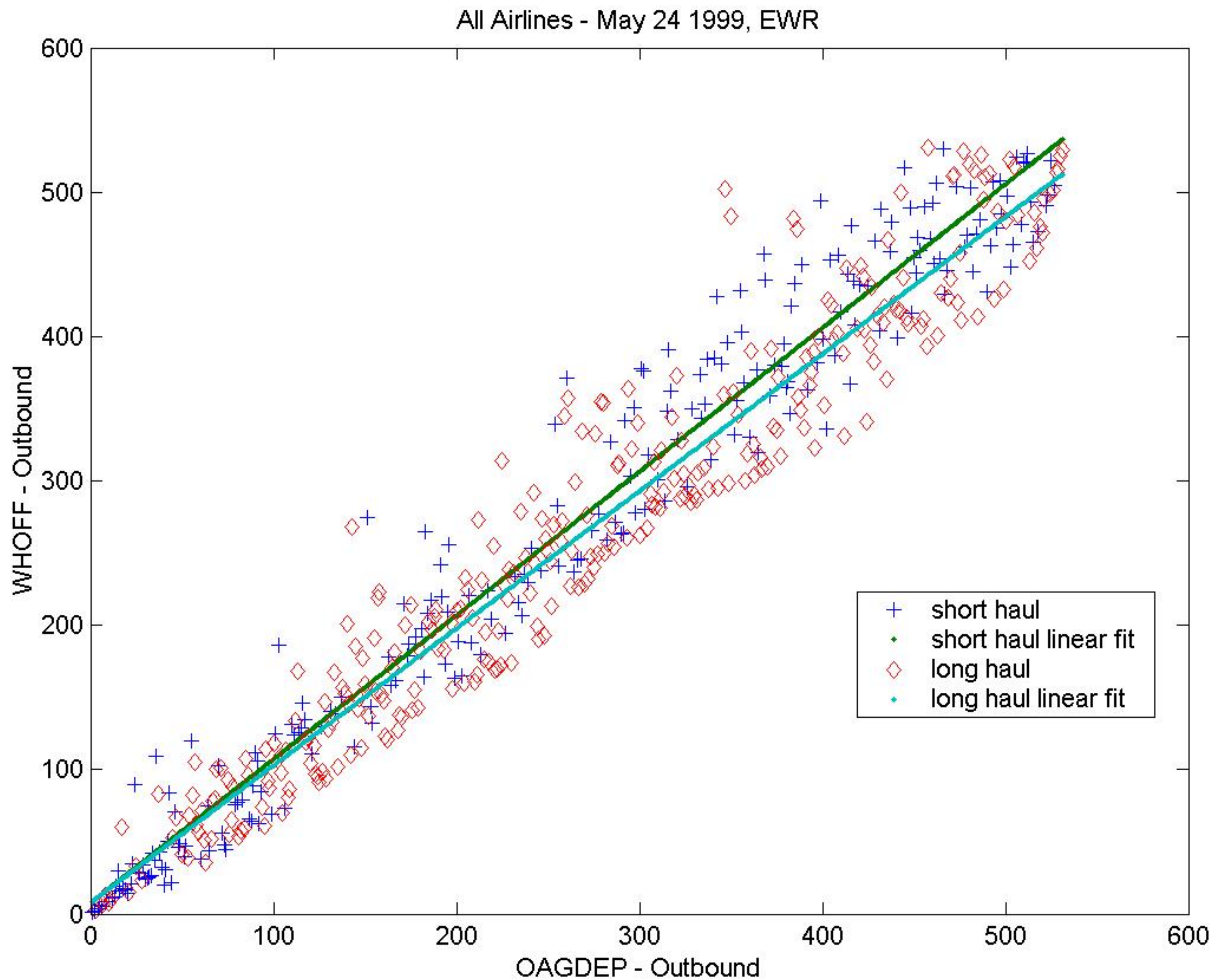


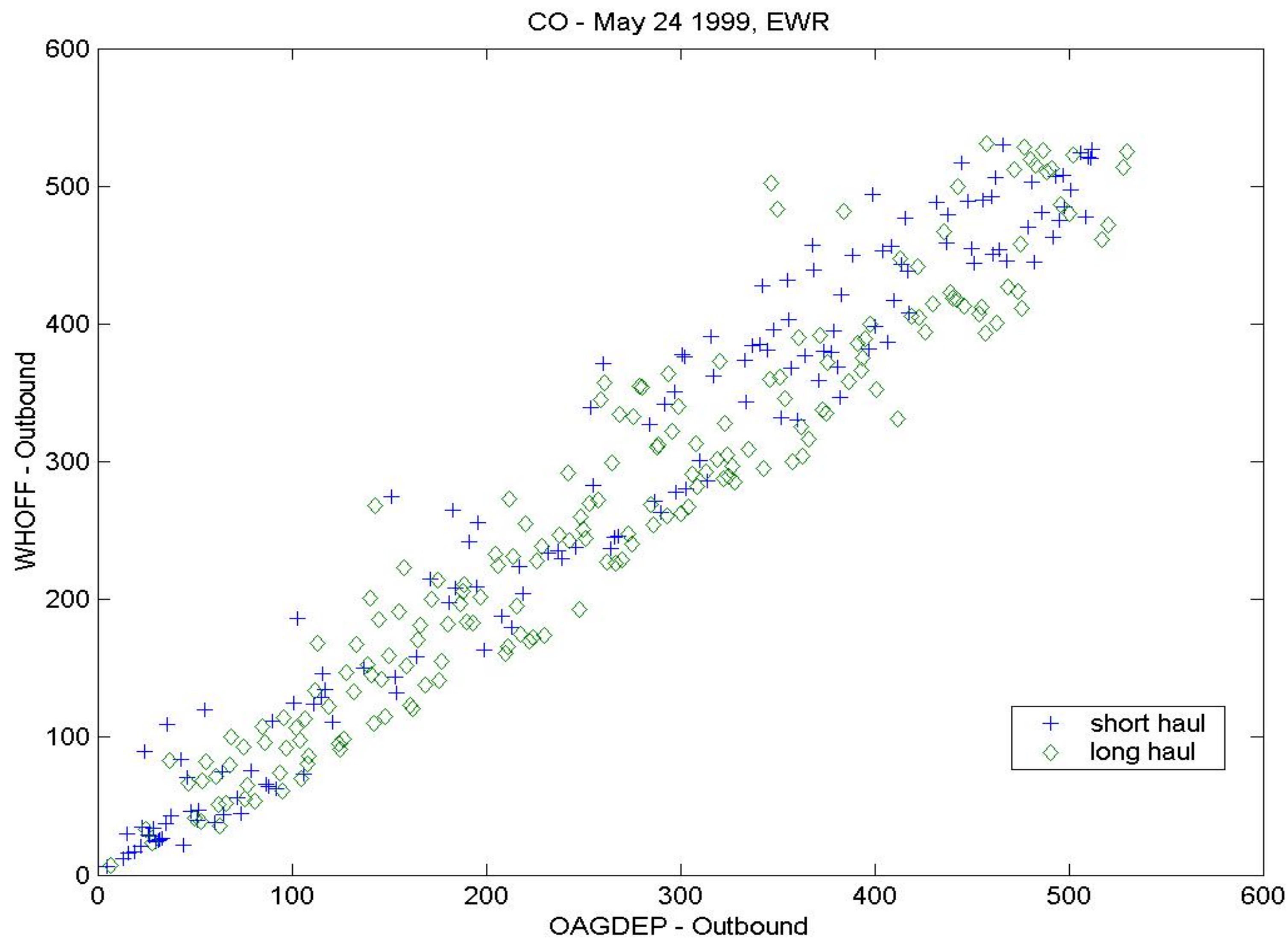
Bad Day at EWR

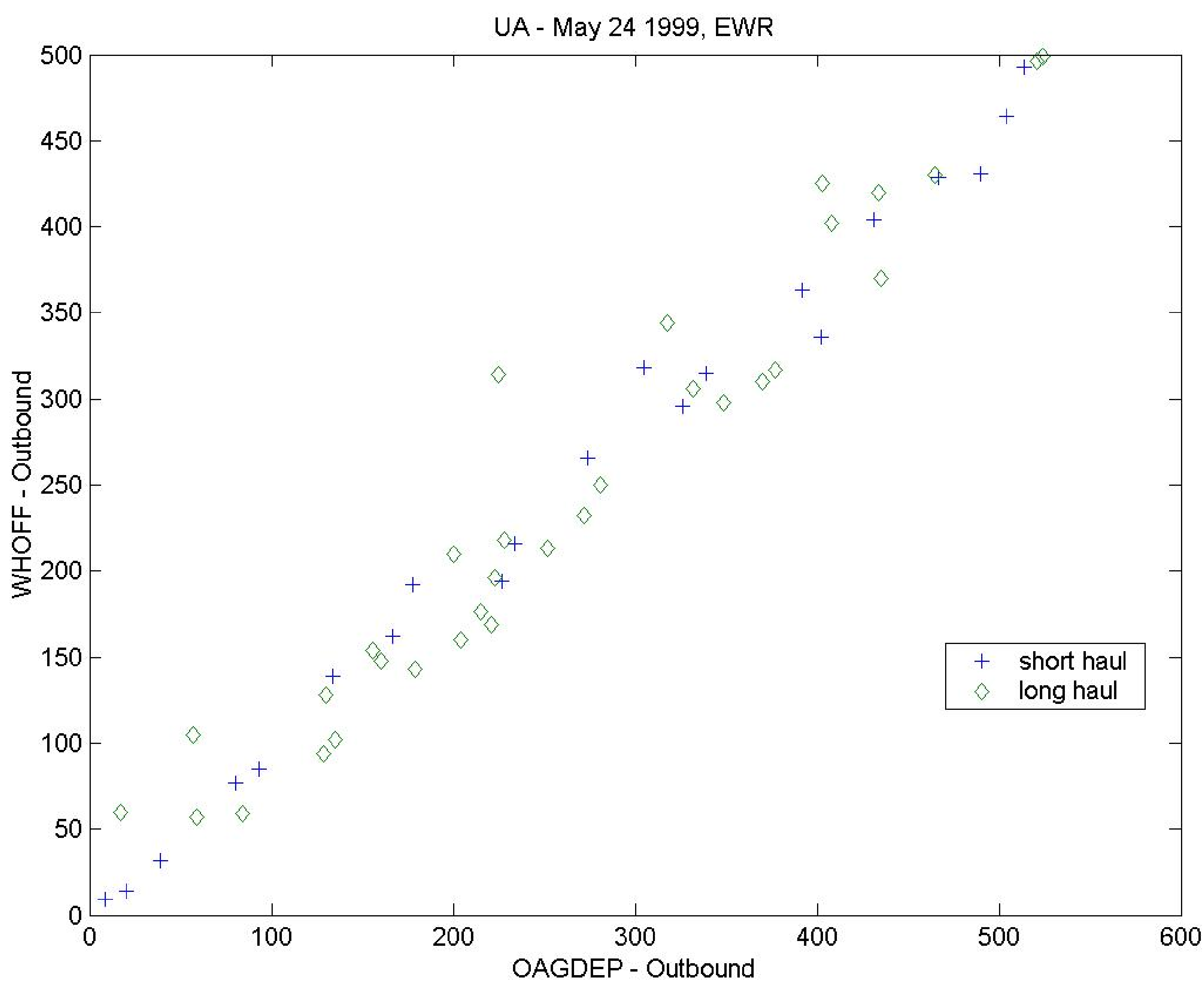
d_{avg} = 105.1
σ = 46.6
c.v. = 20.6

d_{avg} = 105.1
σ = 73.6
c.v. = 51.6

C.V. Ratio = 2.50


All Airlines - May 24 1999, EWR
WHOFF - Outbound
OAGDEP - Outbound
0
100
200
300
400
500
600
short haul
short haul linear fit
long haul
long haul linear fit


CO - May 24 1999, EWR
WHOFF - Outbound
OAGDEP - Outbound
0
100
200
300
400
500
600
short haul
long haul



UA - May 24 1999, EWR
WHOFF - Outbound
OAGDEP - Outbound
short haul
long haul
0
50
100
150
200
250
300
350
400
450
500
0
100
200
300
400
500
600

The Costs Of Delay

- Account for different types of delays (where, when)
- Consider distributional effects
  - Technologies may shift to whom delay occurs
  - Different user types value delay differently
- Nonlinear effect of duration of delay (e.g. issue of buffer)

Case Study Using ITWS

- Queuing Analysis of departures
- Uses MIT/LL Estimates of Capacity Gain
- Simulates Queue Evolution
  - Delay by Aircraft Type
  - Delay by Flight Type
  - Delay by Airline

- Summary by Airline:

Delay Segmentation

Table 1: Calculations for Delay to Operators

	On ground – engines off	On Ground - engines on	Airborne Delay
Less than buffer*	None	Idling aircraft costs	Airborne aircraft costs
More than buffer**	Crew costs	Idling aircraft costs + Crew costs	Airborne aircraft costs + Crew costs

* If the airborne time is less than the planned OAG flight schedule (minus buffer, taxi in/out times), then saved delay is multiplied by the crew costs to counterbalance the cost of the delay taken on the ground.

** If the delay is more than the connection time, an administrative cost is added per connecting passenger

Unit Costs of Delay

- Assumptions
  - A buffer of 10 minutes for flights longer than 50 minutes gate-to-gate
  - A slack time of 20 minutes in turn-around times
  - A slack time of 45 minutes for connections
  - 45 minutes maximum engines-on ground delay

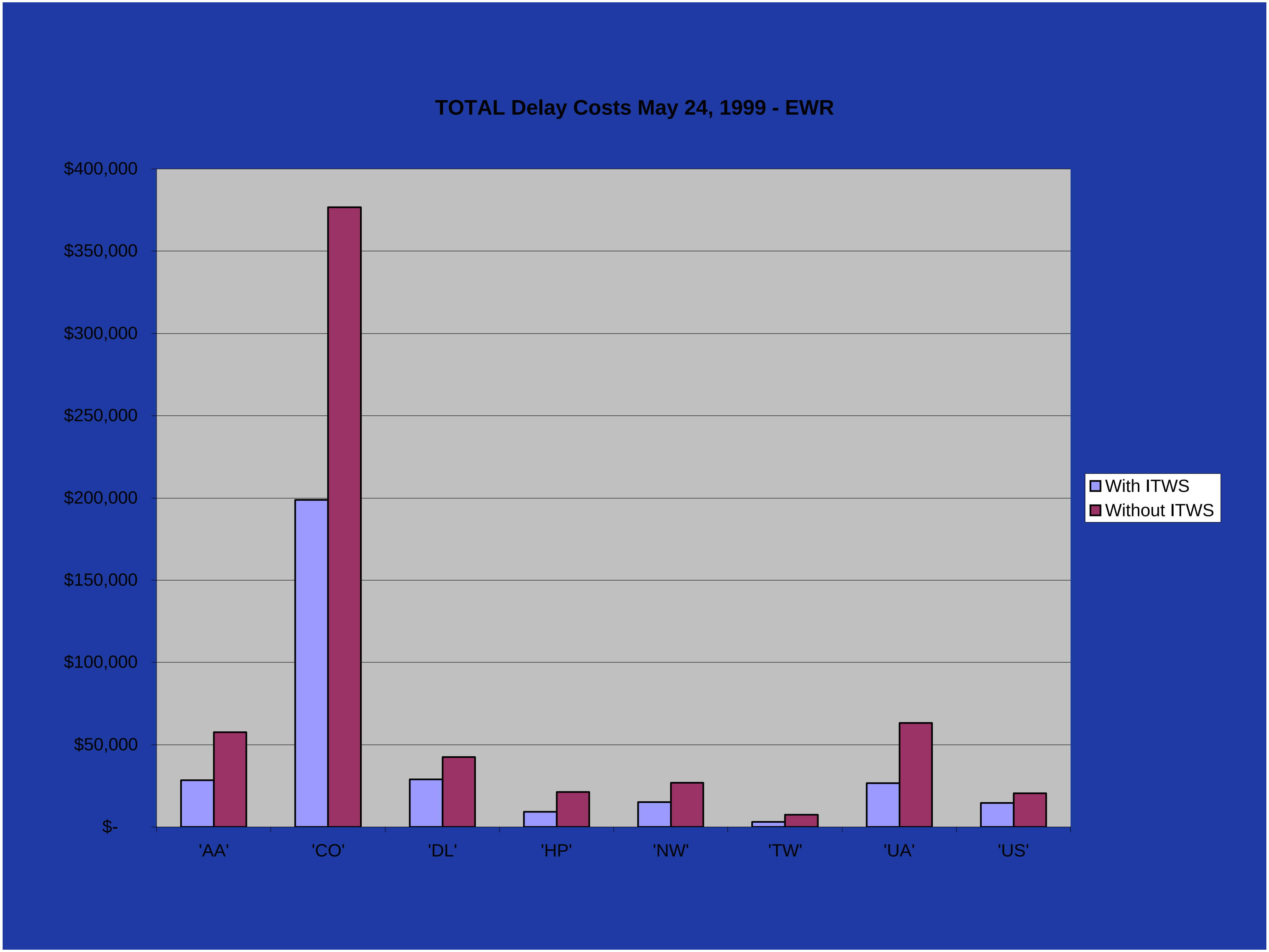
Unit Costs of Delay

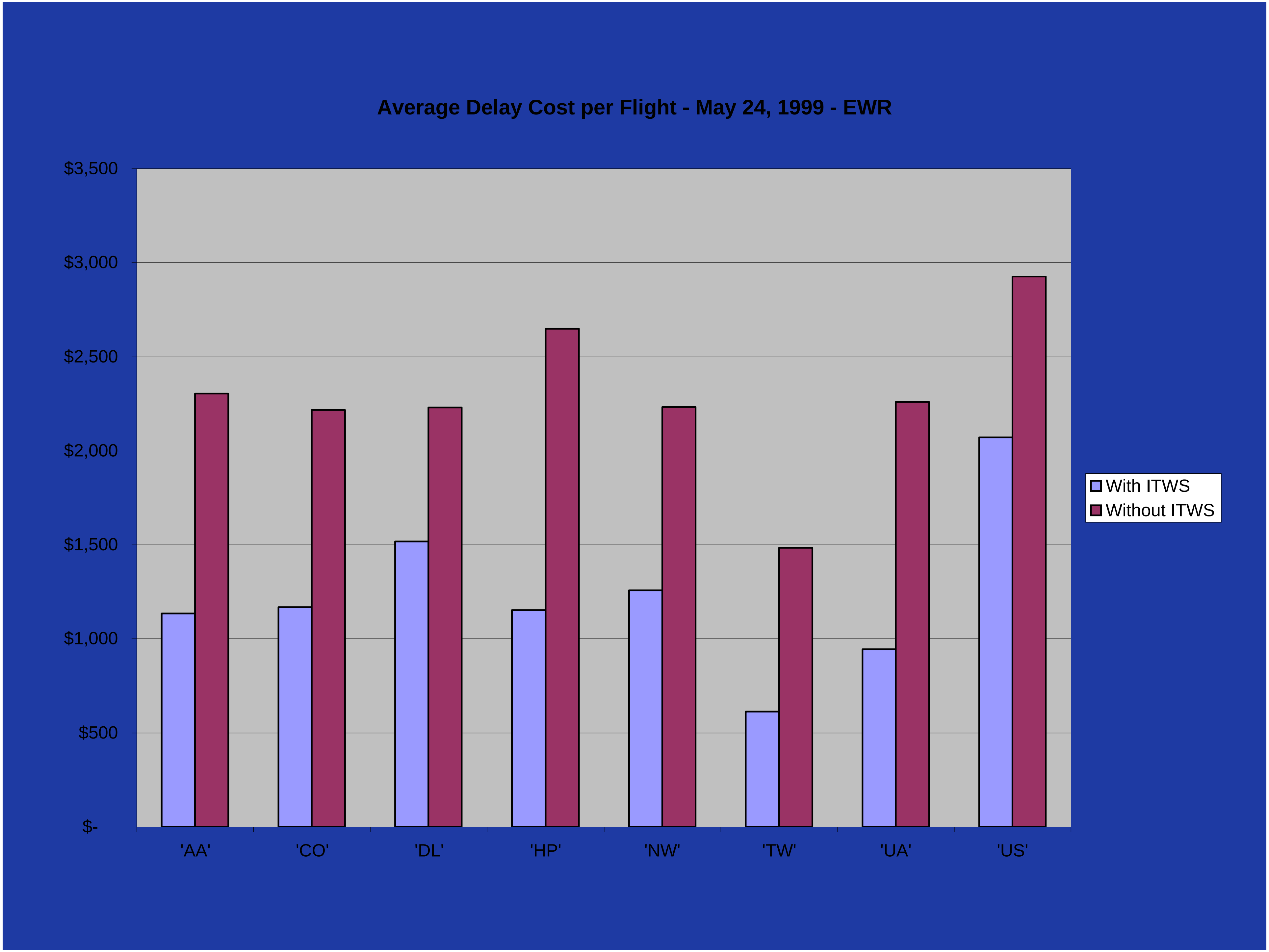
Table 2: Value for Delay to Operators (dollars per minute)

	On ground – engines off	On Ground - engines on	Airborne Delay
Less than buffer	$0	$5.36	$31.58
More than buffer	$22.38*	$27.74	$53.96

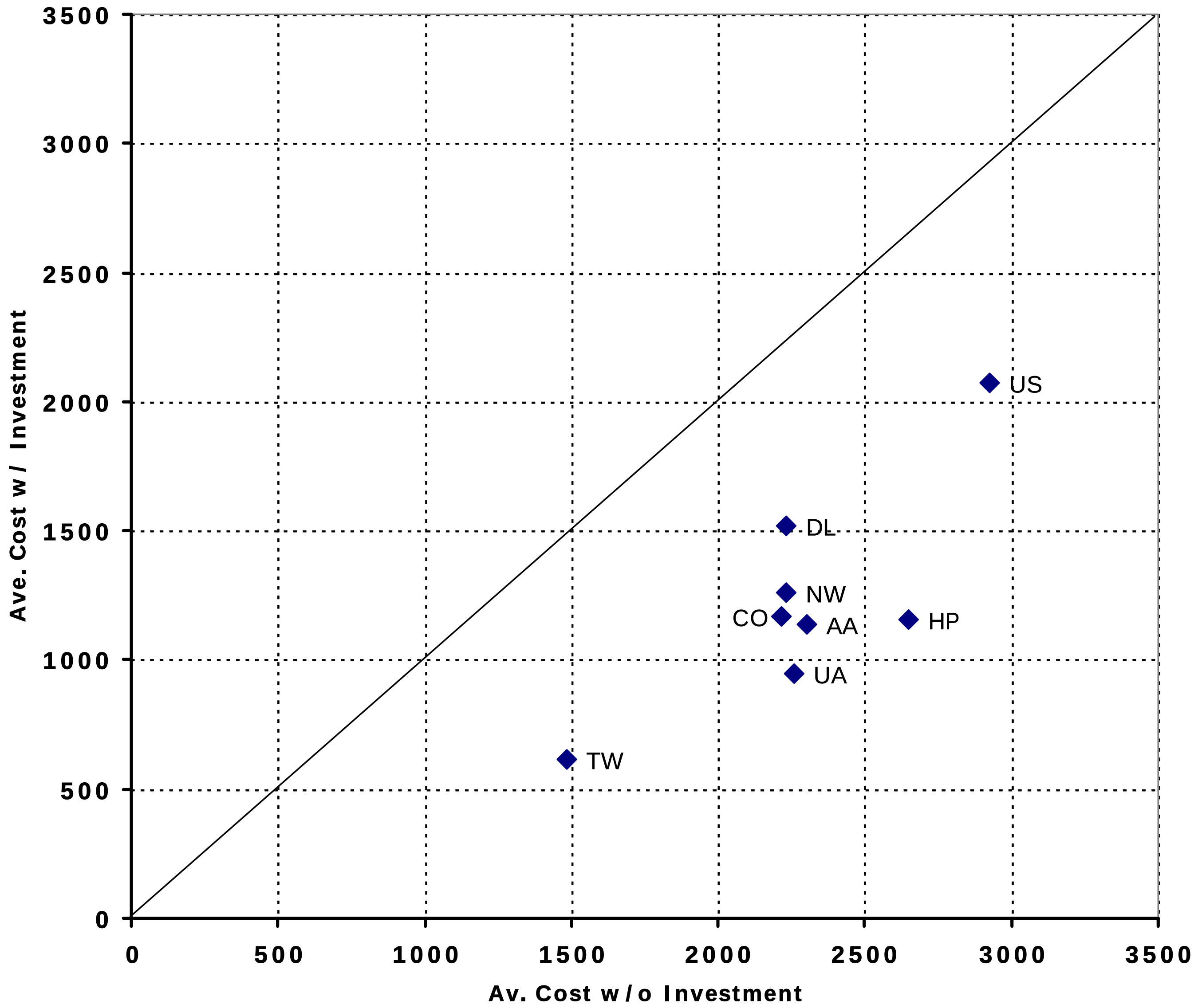
*Also used for Taxi delay greater than 45 minutes and the crew time savings when the aircraft flies faster than expected.

Based on data from the Air Transport Association Website, "System Capacity: Part II – Cost of ATC System Delays" http://www.air-transport.org/public/industry/display1.asp?nid=5773, July 24, 2003.


TOTAL Delay Costs May 24, 1999 - EWR
$400,000
$350,000
$300,000
$250,000
$200,000
$150,000
$100,000
$50,000
$-
'AA'
'CO'
'DL'
'HP'
'NW'
'TW'
'UA'
'US'
With ITWS
Without ITWS


Average Delay Cost per Flight - May 24, 1999 - EWR
$3,500
$3,000
$2,500
$2,000
$1,500
$1,000
$500
$-
'AA'
'CO'
'DL'
'HP'
'NW'
'TW'
'UA'
'US'
With ITWS
Without ITWS

Delays Costs by Airline



Differentiating The Costs Of Delay

- Need to capture how the different stakeholders might value delay, e.g.:
  - Under "degraded operations", hubbing airlines with little or no slack or buffer times may be more adversely affected because of delay propagation
  - Under "normal operations, airlines with limited buffers will have very little time wasted on the ground
  - Technological improvements may benefits users differently