NAS Performance Models

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FAA Strategy Simulator: analyze impact on NAS of

- major policy initiatives/changes
- significant infrastructure changes
- macro-economic shifts/demand shifts
- changes in industry structure

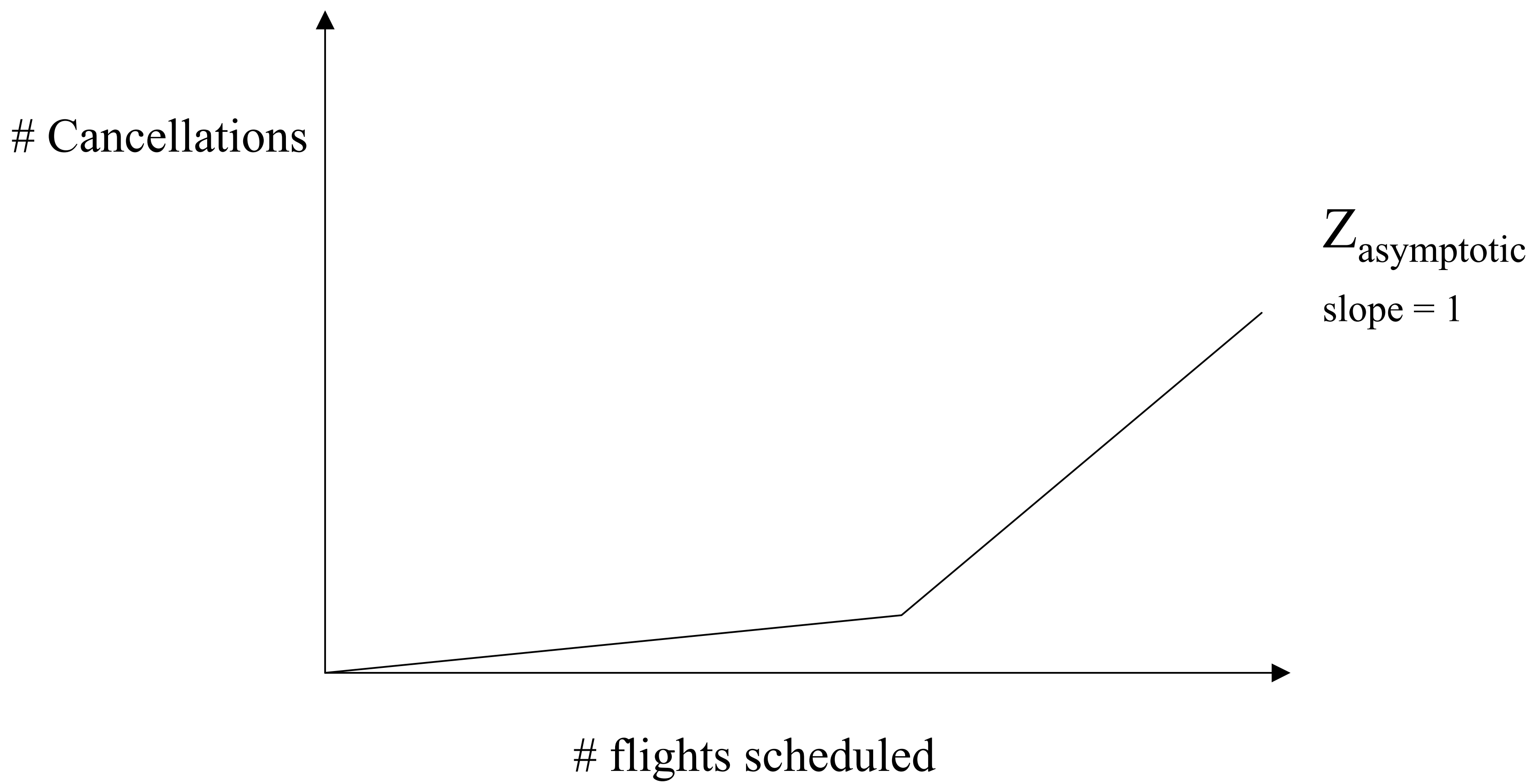
Need to model airline and other user behavior as well as basic NAS behavior

Challenge of performance modeling: predict NAS performance based on small number of key parameters

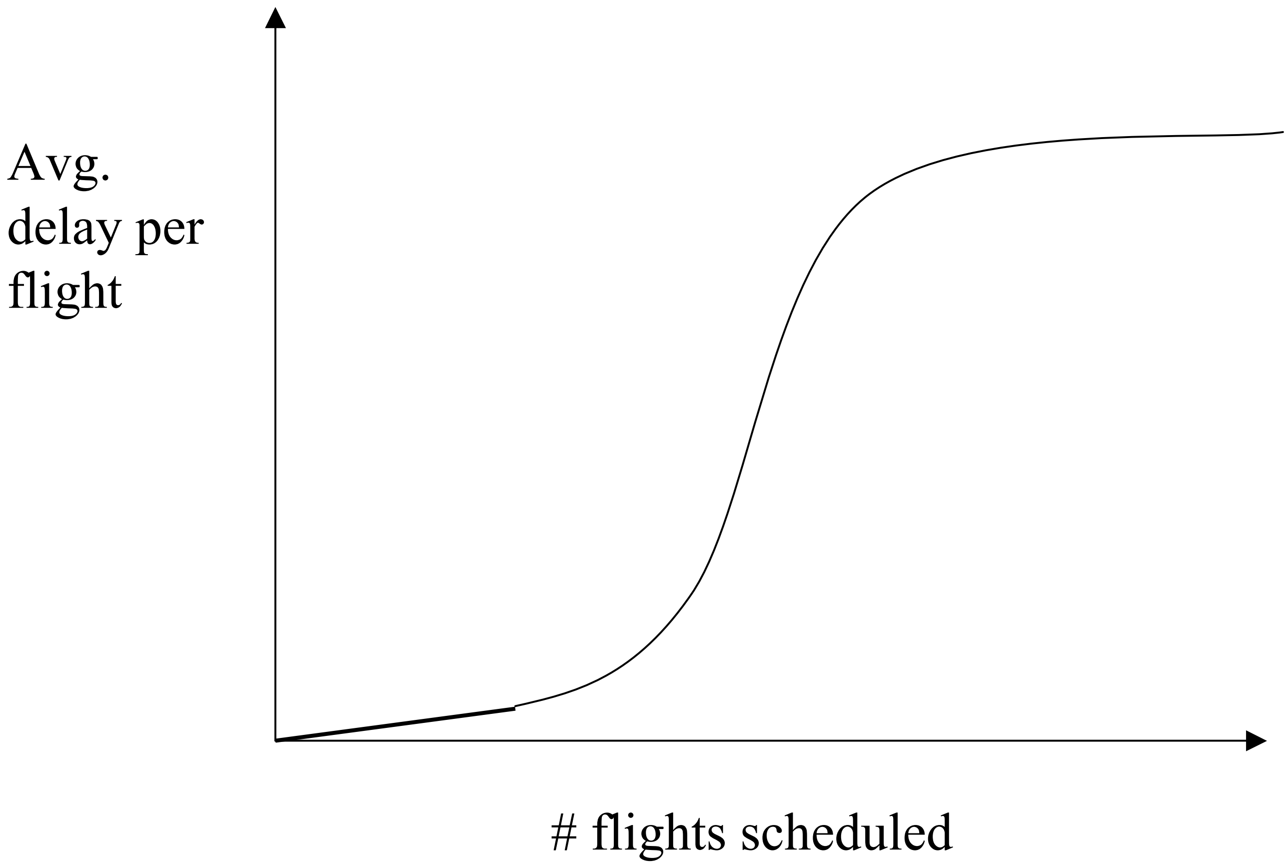
Performance Metrics

- Average Delay per Flight (more refined flight delay distribution info); % of flights on time.
- % of Flights Cancelled
- NAS-wide OAG Service level metric
- NAS-wide Actual Service level metric

Intuition: # Cancellations vs. # Flights Scheduled (capacity held constant)



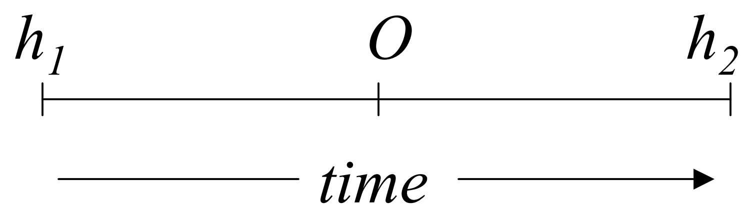
Intuition: Delay vs. # of Flights Scheduled (capacity held constant)



ρ - Measure of congestion around a scheduled operation

Assume an airport operation is either a flight departure or a flight arrival. Then for each operation, O, we compute ρ_o as follows:

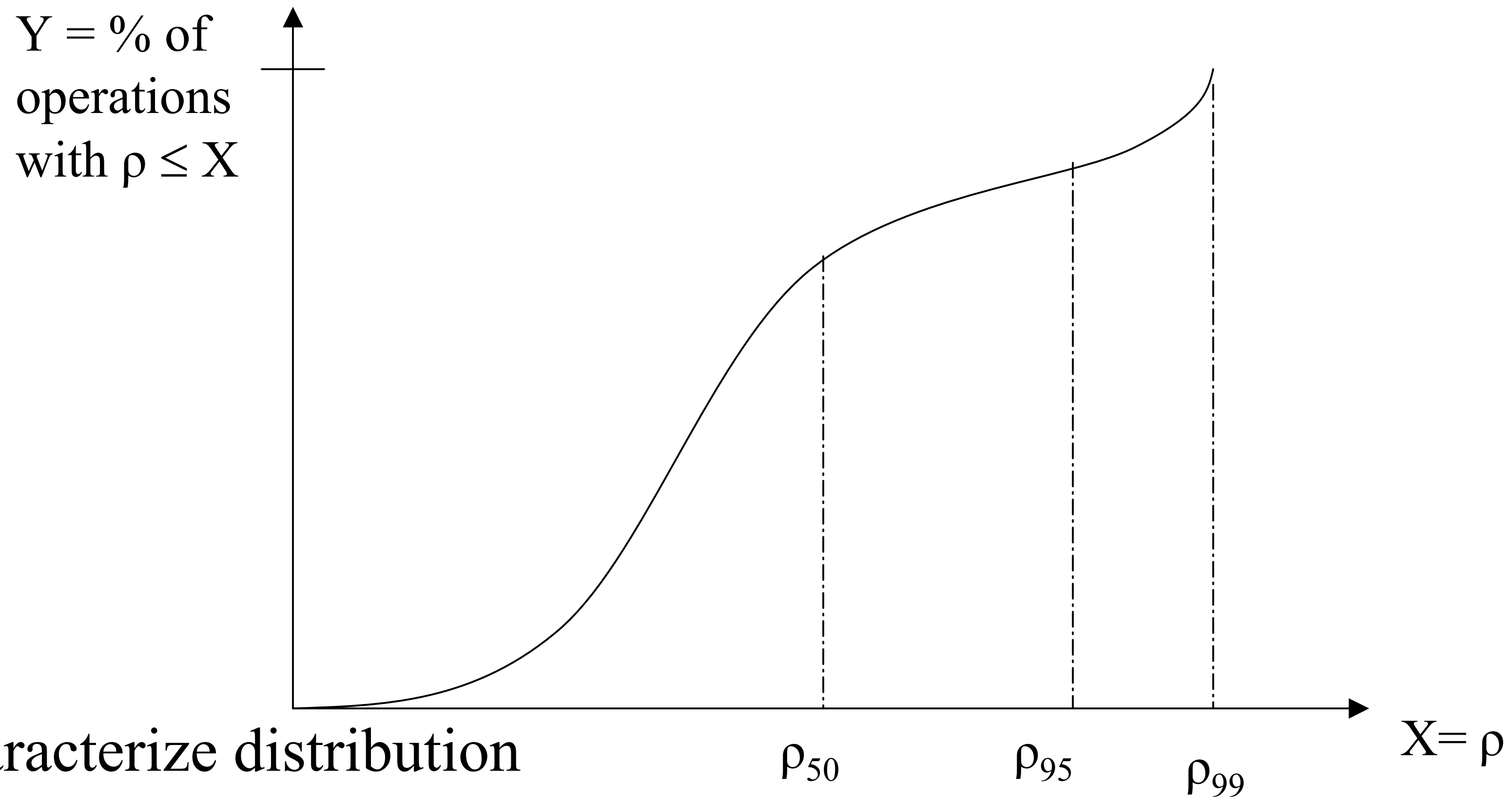
Consider the time interval, I, starting h_1 hours before O is scheduled and h_2 hours after O is scheduled



$$\rho_o = \left[\frac{\#\text{ Operations scheduled during } I \text{ at } O\text{'s airport}}{\text{Capacity(in \# operations) during } I \text{ at } O\text{'s airport}} \right]$$

ρ_o is the queueing system utilization for an interval around O ; because of the way scheduling is done and also because of GDPs and other disruptions ρ_o could sometimes be > 1

Cumulative Distribution of ρ



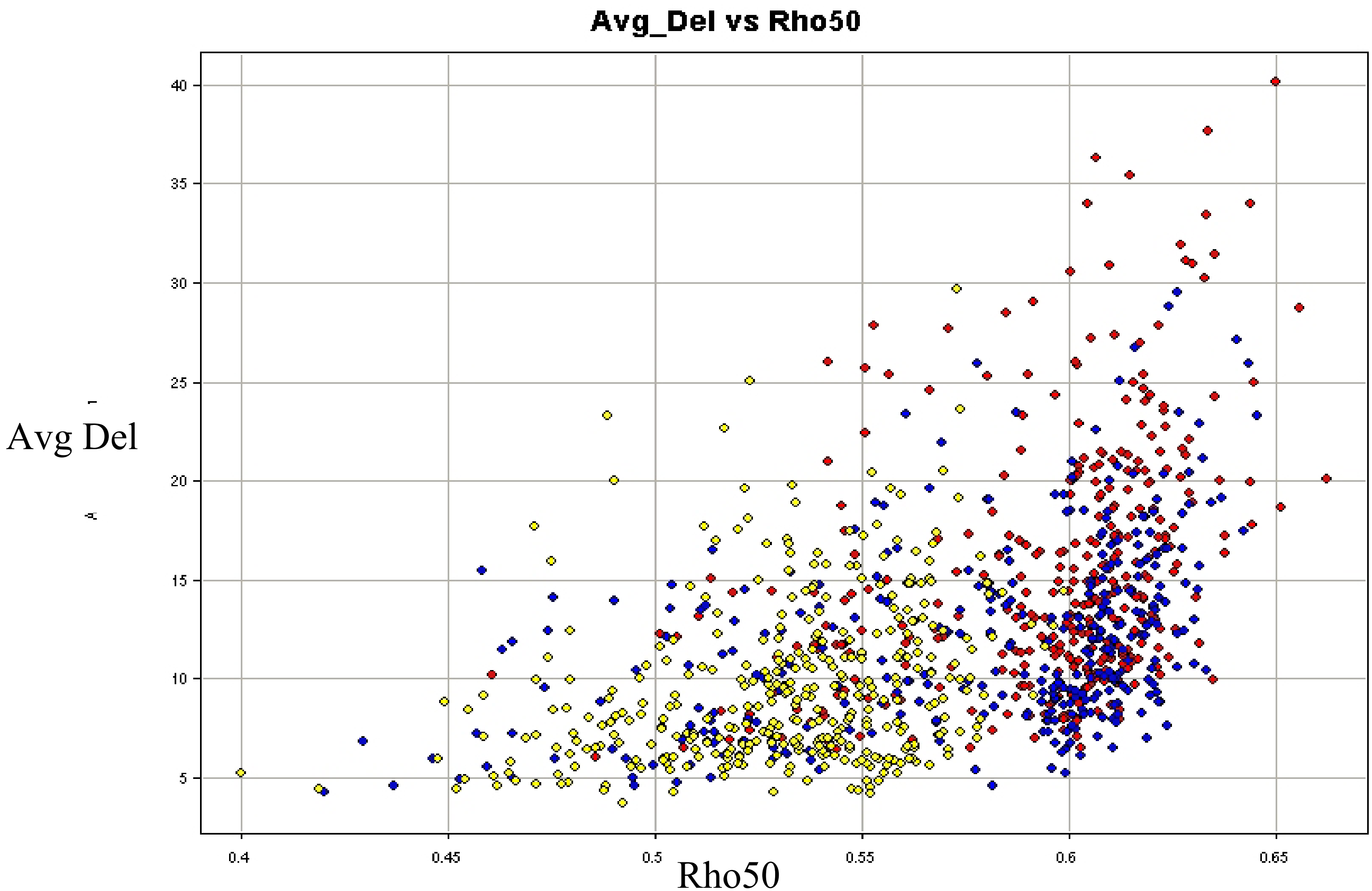
Characterize distribution by a few parameters

- Distribution of ρ (or any of ρ_{50} , ρ_{50} , ρ_{50}) could be calculated for a single airport on a single day, the NAS on a single day, the NAS over a week, etc.
- For a given day, ρ is determined by the OAG schedule and the airport capacity profile *for that day*. Airport capacity on a given day depends on VMC/IMC status (VMC = visual meteorological conditions, IMC = instrument meteorological conditions), runway configuration, etc. ➔ ***ρ has potential to capture impact of weather and VMC/IMC capacity differences.***
- ***Modeling challenge:***

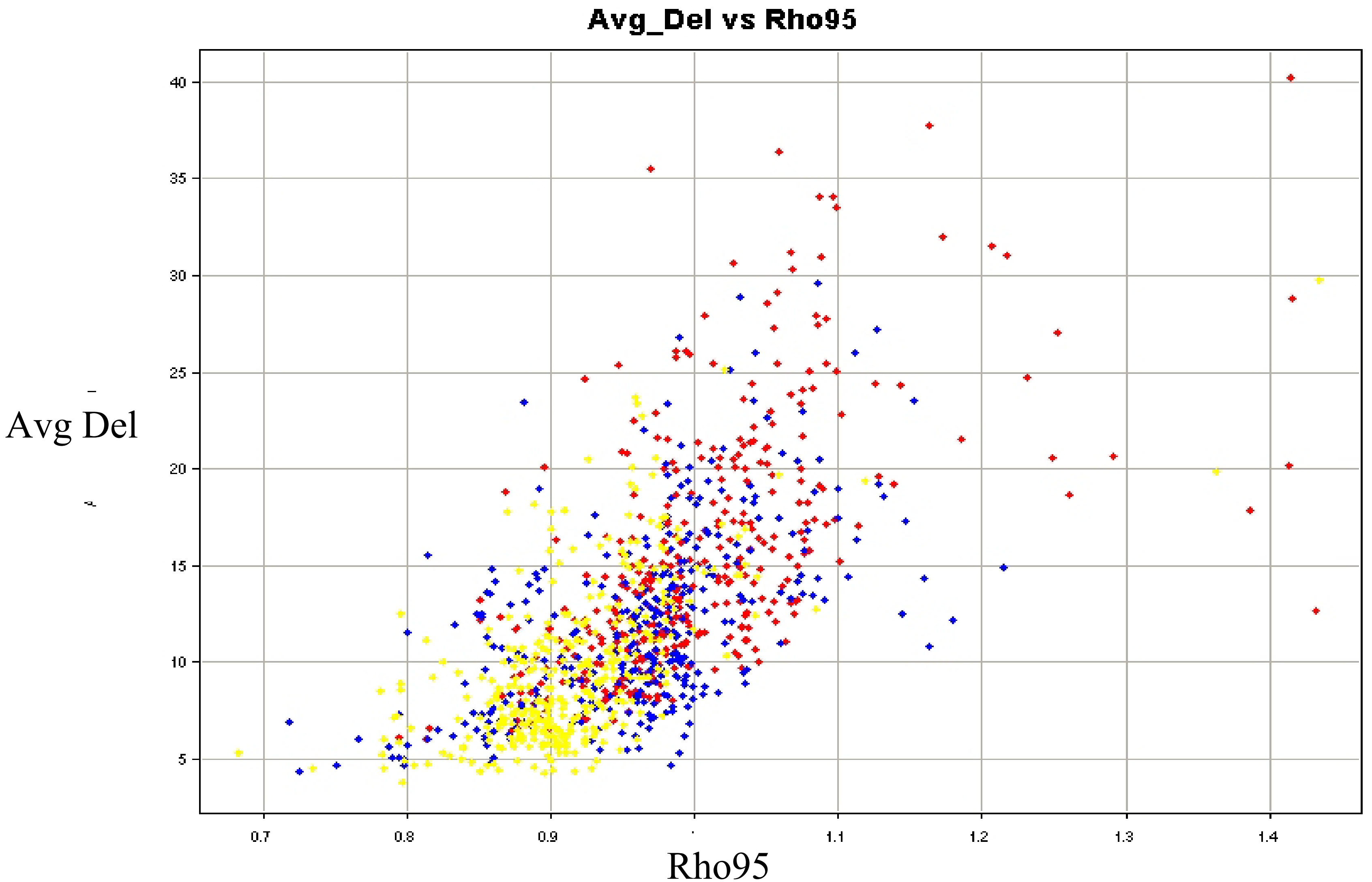
  Capacity + demand ➔ ρ ➔ average flight delay, flight cancellation probability.

Data Analysis

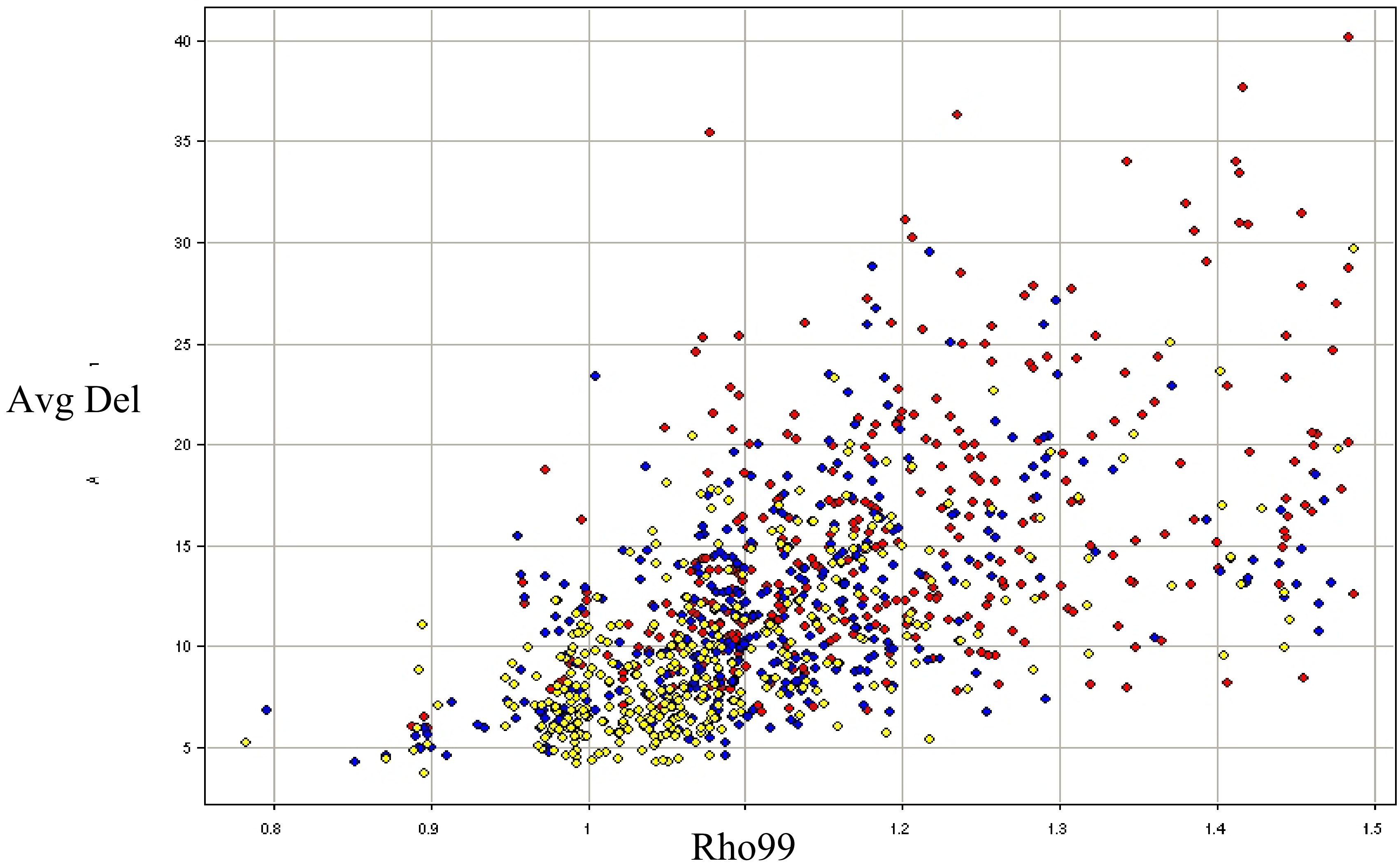
- For each day under consideration:
  - Set up 24 1-hour buckets at each airport
  - Determine number of scheduled operations (from OAG)
  - Determine capacity (max number of ops) – depends on IMC/VMC, runway config, etc
  - Calculate ρ for each bucket – assign this ρ value to each operation in bucket
- Create buckets based on ρ-values; create ρ distribution by combining data from all days and all airports under consideration.

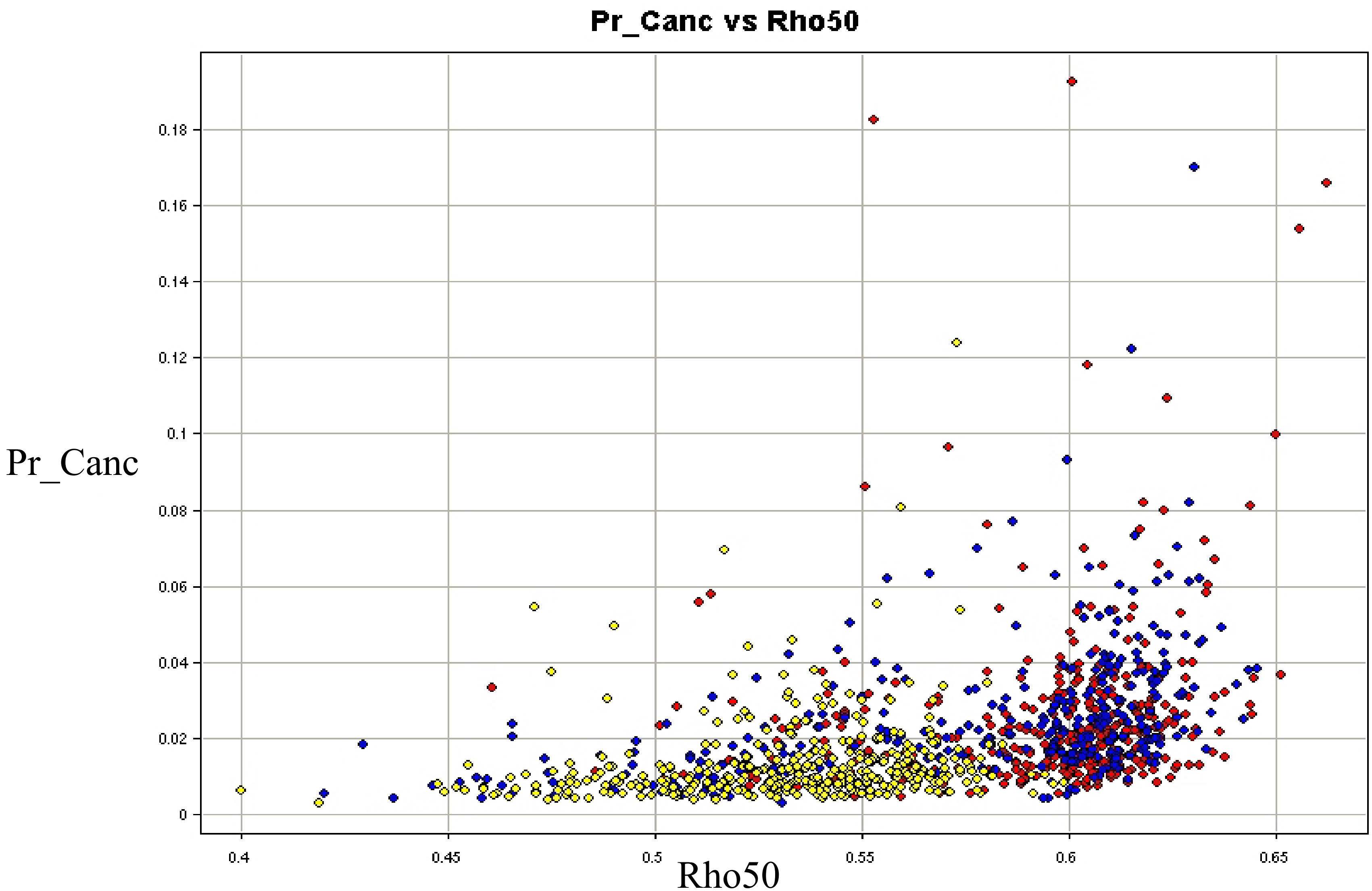


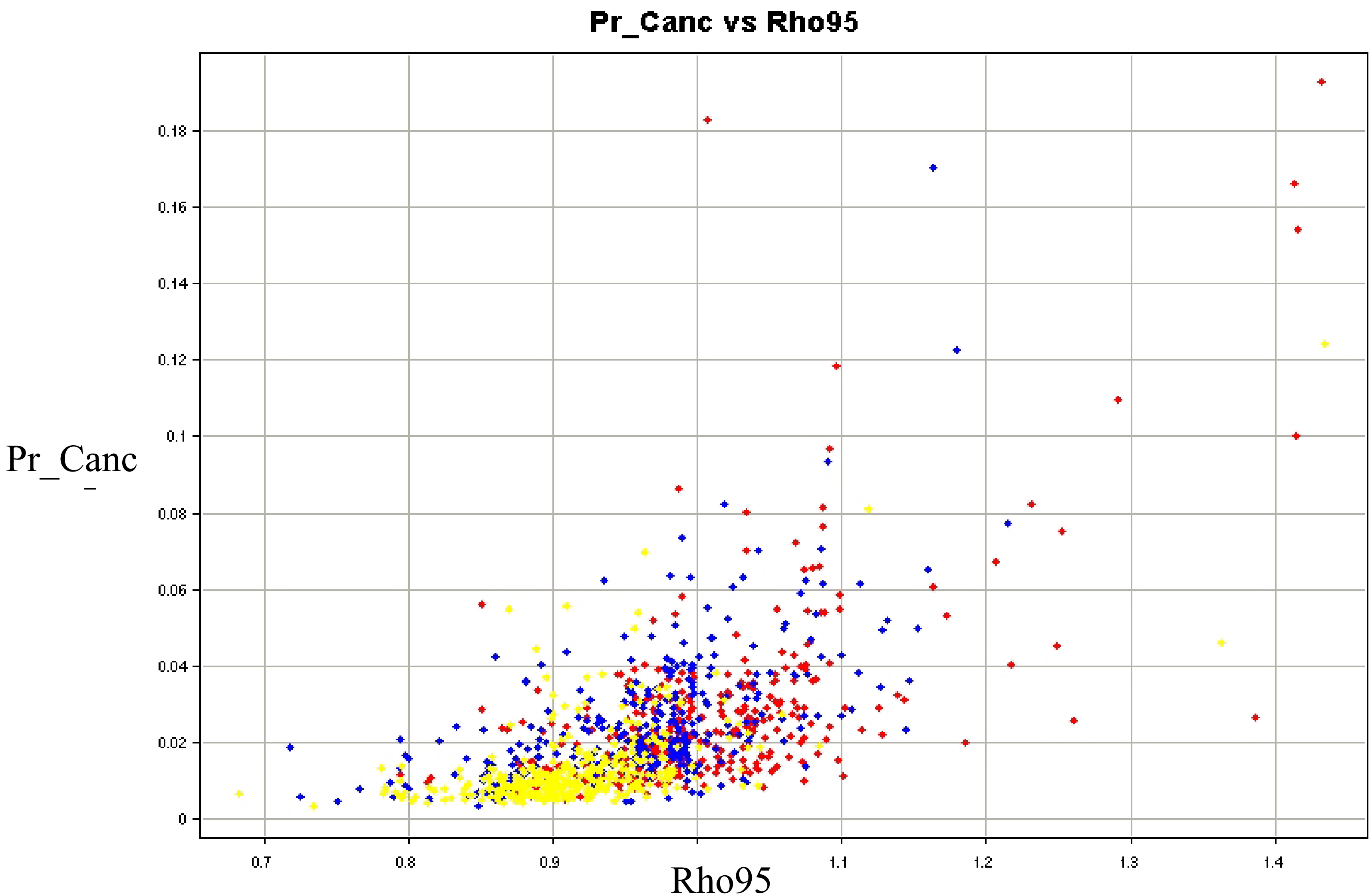
Avg_Del vs Rho50
Avg Del
Rho50
40
35
30
25
20
15
10
5
0.4
0.45
0.5
0.55
0.6
0.65


Avg_Del vs Rho95
40
35
30
25
20
15
10
5
0.7
0.8
0.9
1.1
1.2
1.3
1.4
Avg Del
Rho95

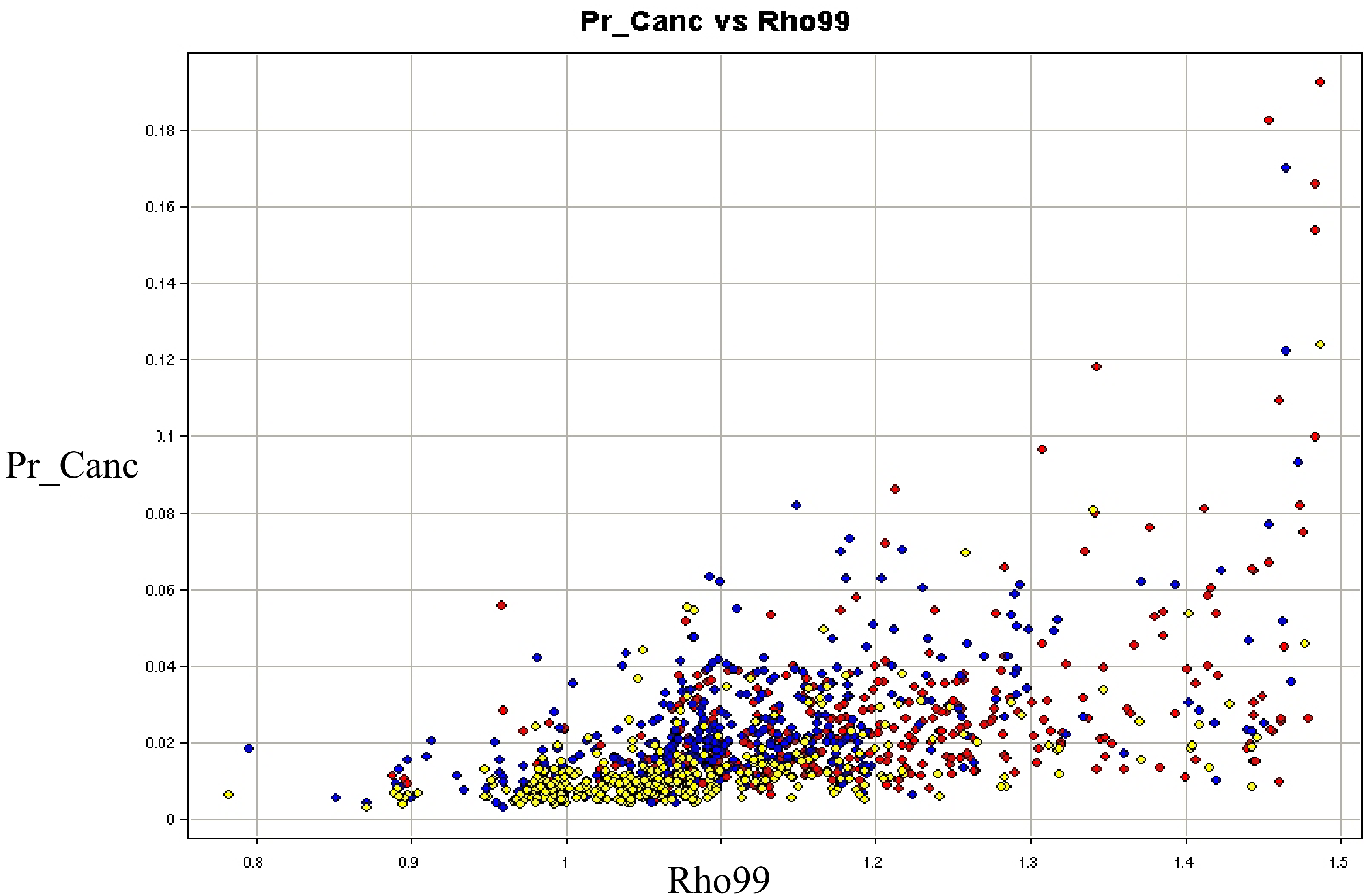
Avg_Del vs Rho99

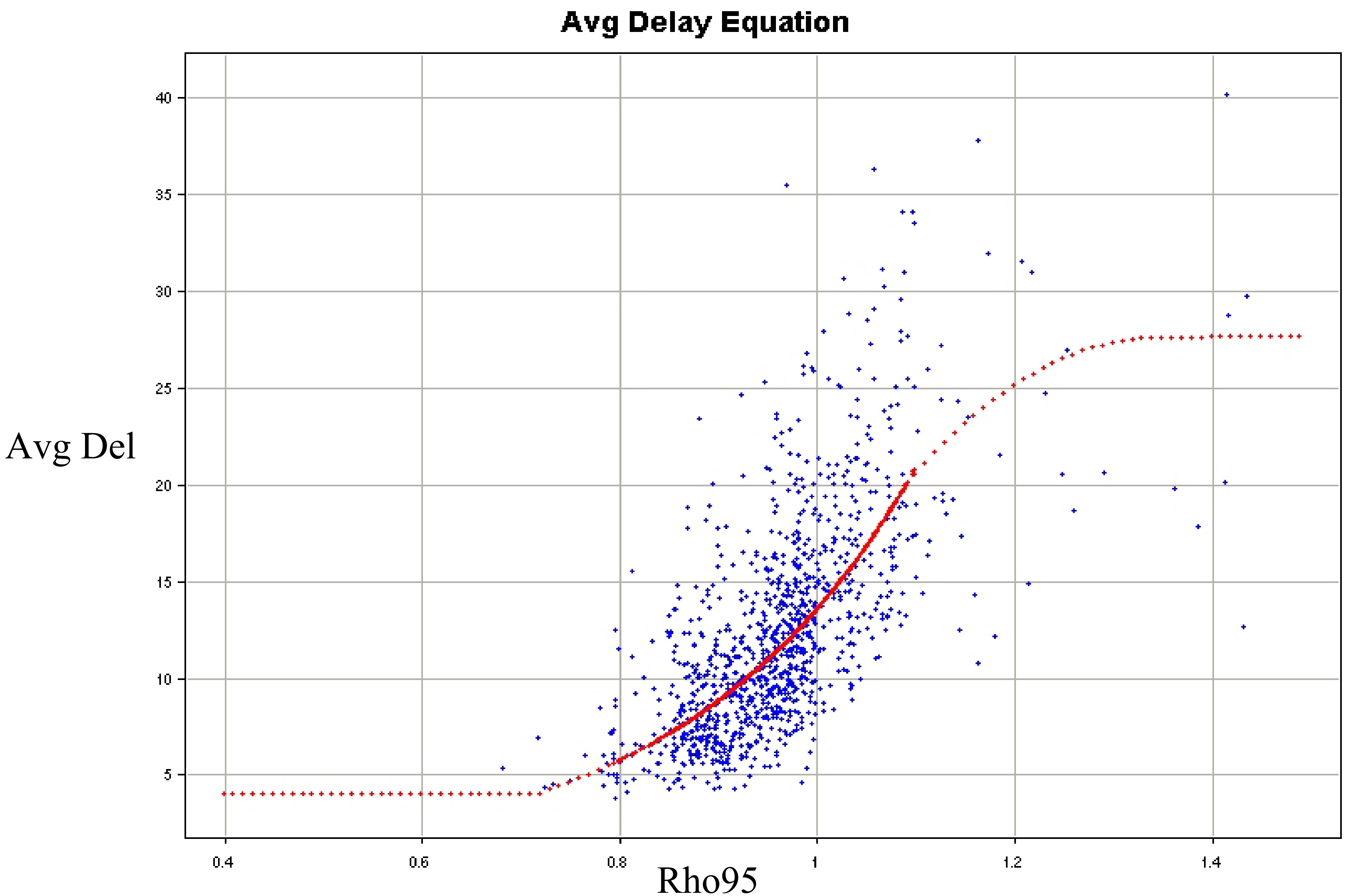



Pr_Canc vs Rho50
Pr_Canc
Rho50
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0.4
0.45
0.5
0.55
0.6
0.65

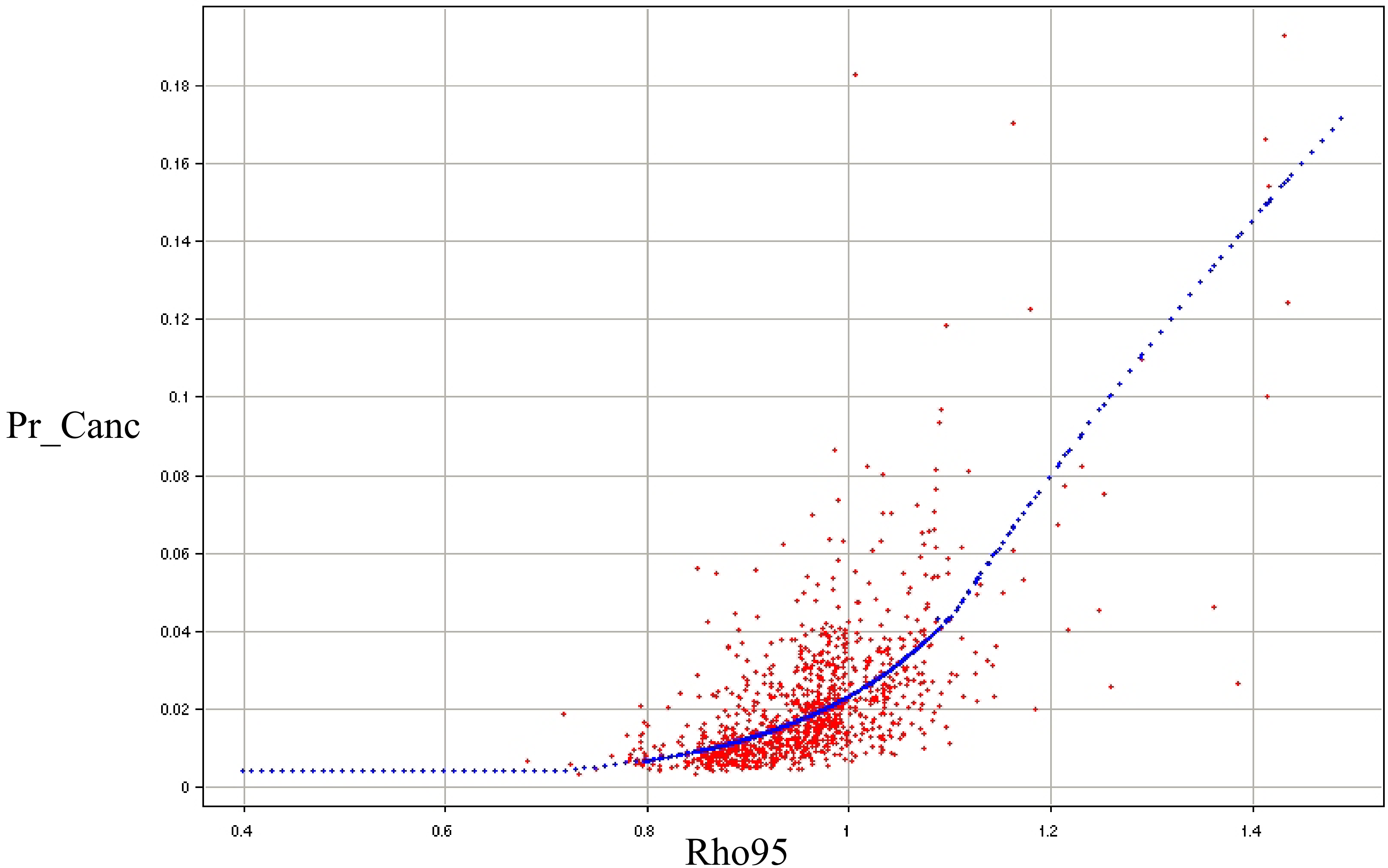


Pr_Canc vs Rho95
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0.7
0.8
0.9
1.1
1.2
1.3
1.4
Pr_Canc
Rho95


Pr_Canc vs Rho99
Pr_Canc
0.18
0.16
0.14
0.12
0.08
0.06
0.04
0.02
0
0.8
0.9
1
1.2
1.3
1.4
1.5
Rho99


Avg Delay Equation
40
35
30
25
20
15
10
5
0.4
0.6
0.8
1
1.2
1.4
Avg Del
Rho95

Probability Cancellation Equation



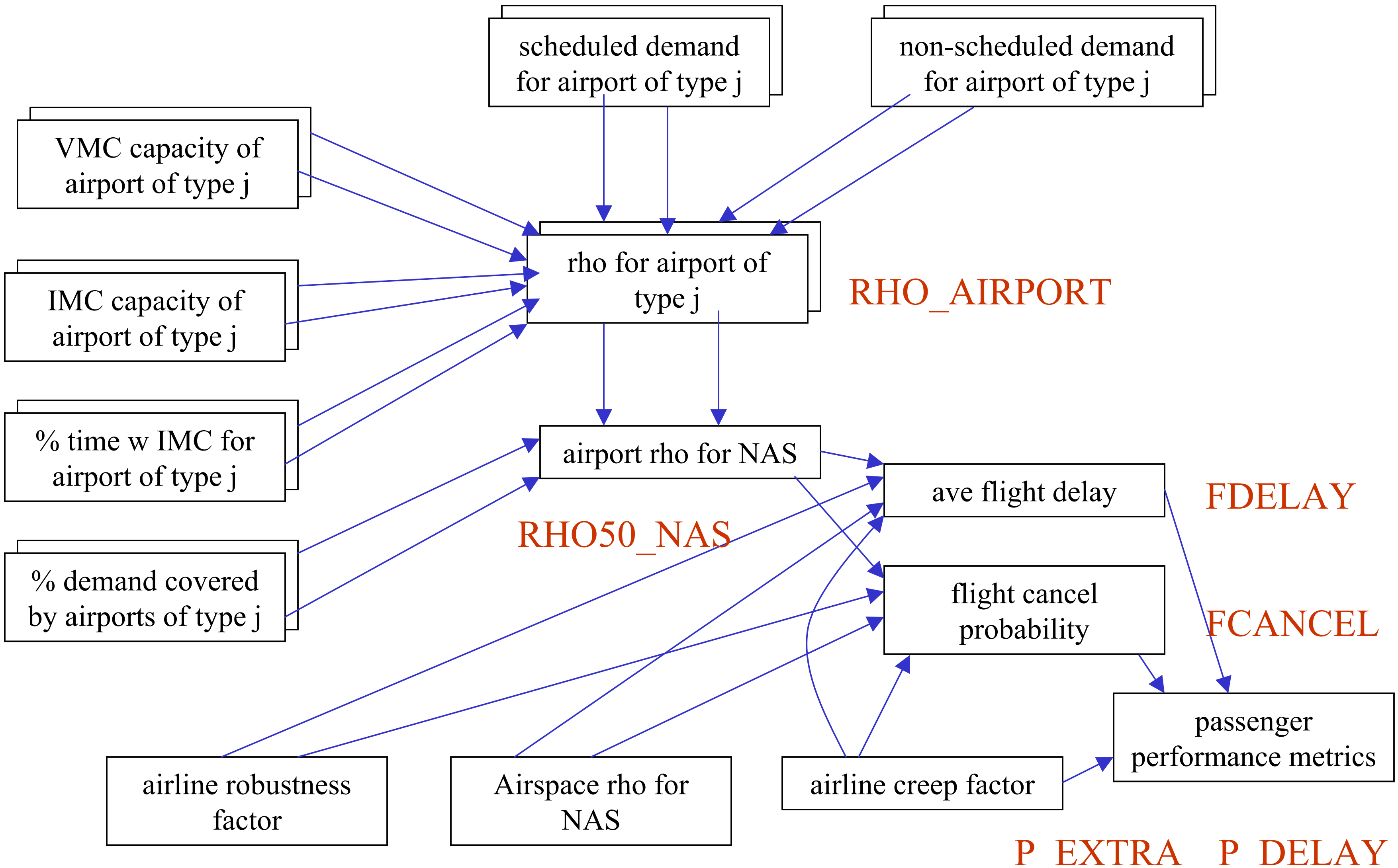
- *Average_Delay*
  - Avg_Del = 4.0048 0.4 < = Rho95 < 0.72
  - Avg_Del =0.178*EXP(4.3247*Rho95) 0.72 < = Rho95 < 1.09
  - Avg_Del = -115.41*(Rho95^2)+310.87*Rho95-181.8
    1.09 < Rho95 < = 1.35
  - Avg_Del = 27.25 + LN(Rho95) 1.36 < = Rho95 < 1.49

  R – Square = 63.2%

- *Probability Cancellation*
  - Pr_Cancel = 0.0040 0.4<= Rho95 < 0.72
  - Pr_Cancel = 0.00004*EXP(6.3406*Rho95) 0.72 <=Rho95<1.0
  - Pr_Cancel = 0.425*LN(Rho95) + 0.0015 1.0 <= Rho95 < 1.49

  R – Square = 84.6%

NAS Performance



Results of multiple regression for Ln(AvgDel_Flight_Min)

	Avg Delay (min)		Delay Cancellation (90)		Delay Cancellation (120)		Delay Cancellation (150)	
	Coeff	**p-value**	**Coeff**	**p-value**	**Coeff**	**p-value**	**Coeff**	**p-value**
Constant	-1.1018	0.0000	-1.1356	0.0000	-1.1772	0.0000	-1.2118	0.0000
Rho50	1.4293	0.0000	1.3588	0.0000	1.3569	0.0000	1.3615	0.0000
Rho95	1.7996	0.0000	1.9610	0.0000	2.0463	0.0000	2.1173	0.0000
Rho99	0.8615	0.0000	0.8823	0.0000	0.8857	0.0000	0.8900	0.0000
R-Square		46.29%		50.09%		51.38%		52.21%

Results of multiple regression for Ln(Pr_Canc)

	Coefficient	**p-value**
Constant	-9.6486	0.0000
Rho50	2.3942	0.0000
Rho95	3.0201	0.0000
Rho99	1.1391	0.0000
R-Square	45.38%	

Ln(AvgDel_Flight_Min)

= - 0.741 + 1.36 Rho50 + 1.68 Rho95 + 0.835 Rho99
- 0.207 Month_Fall - 0.128 Month_Spring
- 0.0682 Pre 9/11_N- 0.127 Day_Mon
- 0.183 Day_Tue - 0.146 Day_Wed

Predictor	Coeff	P-value
Constant	-0.7409	0
Rho50	1.3622	0
Rho95	1.6774	0
Rho99	0.8346	0
Month_Fall	-0.2071	0
Month_Spring	-0.1283	0
Pre 9/11	-0.0682	0.012
Day_Mon	-0.1271	0
Day_Tue	-0.1827	0
Day_Wed	-0.1457	0

R-Sq = 54.3%

Ln(Pr_Canc)

= - 6.95 - 1.98 Rho50 + 3.07 Rho95 + 1.13 Rho99
- 0.163 Month_Fall- 0.229 Month_Spring
- 0.513 Pre 9/11_N + 0.118 Day_Mon
+ 0.217 Day_Tue + 0.172 Day_Wed

Predictor	Coeff	p-value
Constant	-6.9512	0
Rho50	-1.981	0.001
Rho95	3.0686	0
Rho99	1.1257	0
Month_Fall	-0.1626	0
Month_Spring	-0.2291	0
Pre 9/11	-0.513	0
Day_Mon	0.1182	0.006
Day_Tue	0.2171	0
Day_Wed	0.1725	0

R-Sq = 54.9%

Based on Fridays from 2000, 2001, 2002

Results of multiple regression for Ln(AvgDel_Flight_Min)

	Avg Delay (min)	
	Coeff	**p-value**
Constant	-1.3918	0.0000
Rho50	1.9297	0.0270
Rho95	1.9451	0.0045
Rho99	0.8749	0.0116
Month_Fall	-0.1893	0.0016
Month_Spring	-0.0920	0.1100
R-Square		62.97%

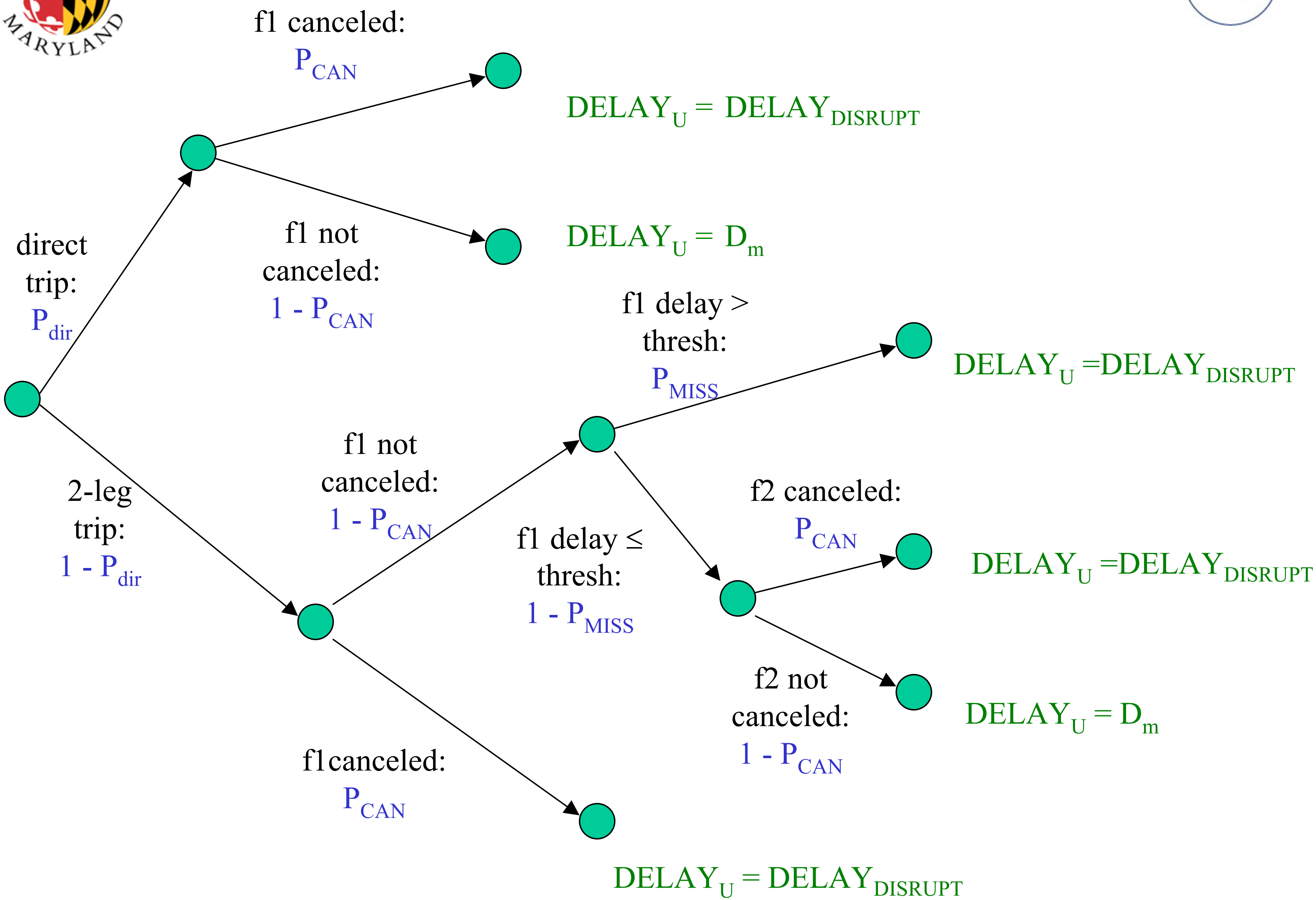
Results of multiple regression for Ln(Pr_Canc)

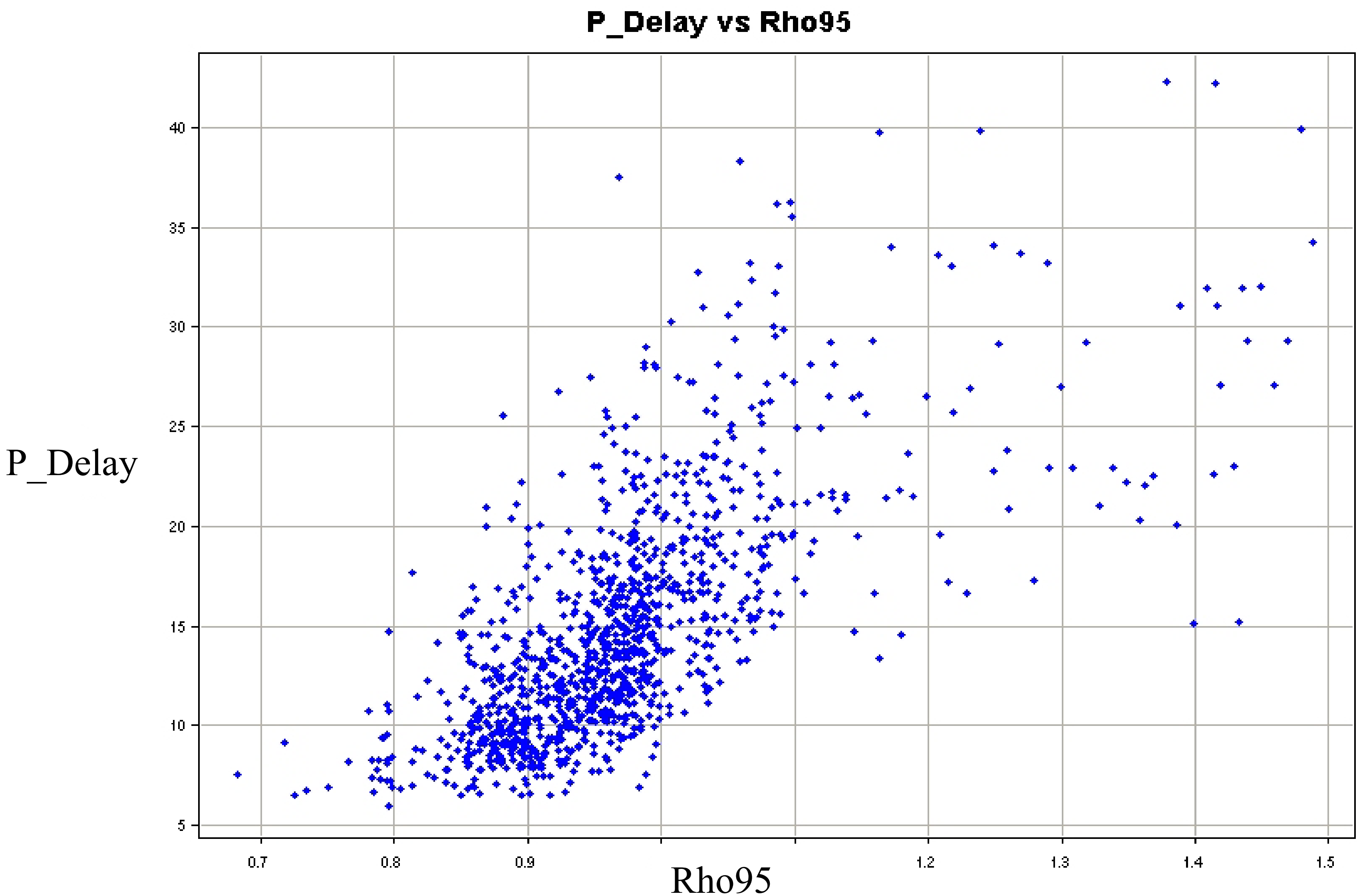
	Pr_ Cancellation	
	Coeff	**p-value**
Constant	-8.0055	0.0000
Rho95	2.9864	0.0021
Rho99	1.0671	0.0610
Pre9/11_N	-0.3436	0.0005
Month_Fall	-0.2207	0.0284
Month_Spring	-0.2474	0.0104
		56.25%

Conclusions of Analysis

- Basic concepts are sound
- Rho95 is best single predictor
- Some variation remains to be characterized
- Airline behavior changes based on:
  - Load factor on that day, e.g. very high loads ➔ fewer cancellations
  - Day-of-week

Passenger Delay Metric

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P_Delay
Rho95

Model Features

Track changes in NAS performance as a function of:

- Changes in airport infrastructure
- Changes in demand
- Changes in weather or ability of technology to adapt to weather, e.g. (VMC cap)/(IMC cap)
- Technology improvements that imply capacity enhancements

On-Going Work

- Add independent variables, etc to achieve “best” model
- Create “best” model compatible with Vensim (focus this summer)
- Specific issues to address:
  - Control variable that drives cancellation and delay models
  - Daily → yearly model
  - Airspace effects
  - Refined passenger model
  - GA effect
  - Airport-specific effects (delay → airports; airports → delay)
  - Delay distribution information