Bayesian Networks for Estimation of Delay Propagation and Cancellation in the NAS

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CENTER FOR AIR TRANSPORTATION SYSTEMS RESEARCH

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Delay Propagation

CA
TS
R

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Motivation & Approach

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- **Delay/cancellation has steadily increased**
- **Delay at one airport has ripple effect to the whole NAS**
- **Our Bayesian Network can**
  - **Model complex, highly nonlinear, stochastic behaviors for NAS**
  - **Represent interactions between airports**
  - **Capture the complex relationship between variables in NAS, e.g.**
    - **Show how the delays are propagated to different airports under different weather conditions**
    - **Show how cancellation is impacted by other variables**

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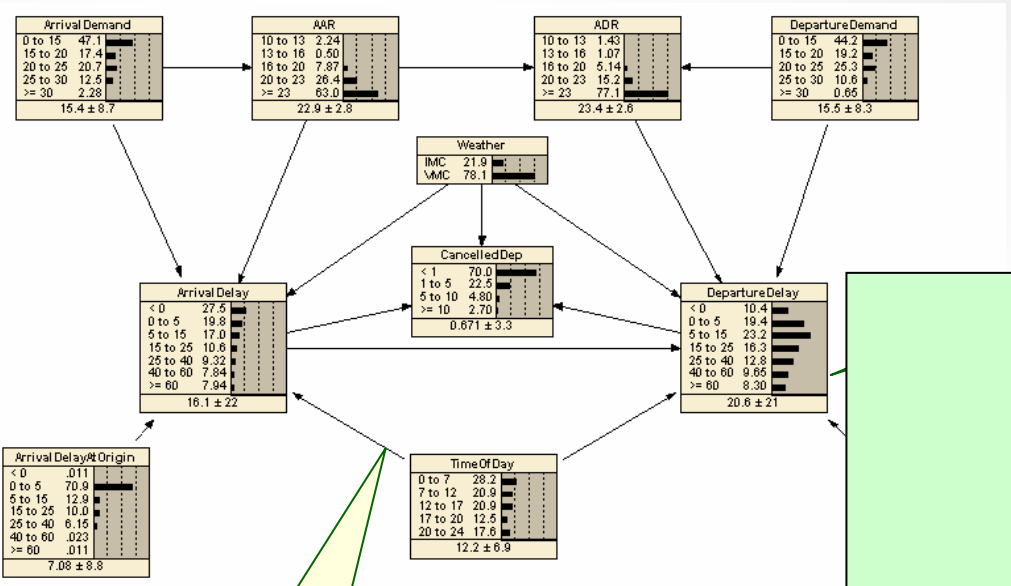
Notation & Representation

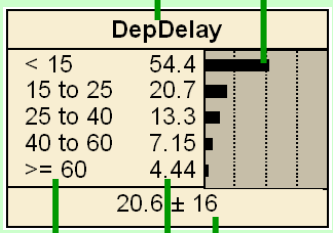


Arc: dependency

Node: a variable of interest

Node's name/ title

Probability (graphical)



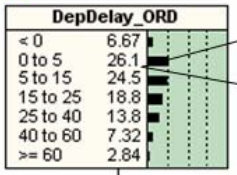
Names / ranges for possible values

Mean & std dev

Probability (numerical percentage)

Bayesian Inference

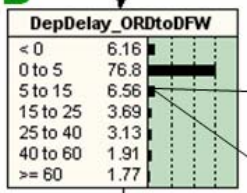
A



$P(A)$: the probability of A (prior)

$$P(a_i < A < a_j) = F(a_j) - F(a_i) = \int_{a_i}^{a_j} f(x)dx$$

B

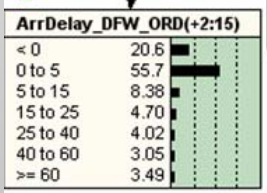


$P(B)$: the margianl probability of B

$$P(B) = P(b_i < B < b_j) = \int_{b_i}^{b_j} \int_{-\infty}^{\infty} g(y,x)dxdy$$

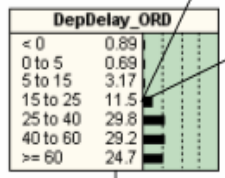
$$P(B) = \sum_i P(B \mid A_i)P(A_i)$$

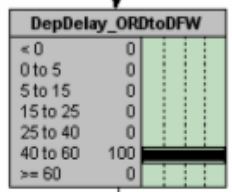
C

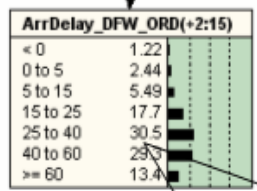


$P(A \mid B_j)$: the posterior probability of A given B_j

$$P(A \mid B_j) = \frac{P(B_j \mid A)P(A)}{P(B_j)} \quad \text{[Bayes Rule]}$$

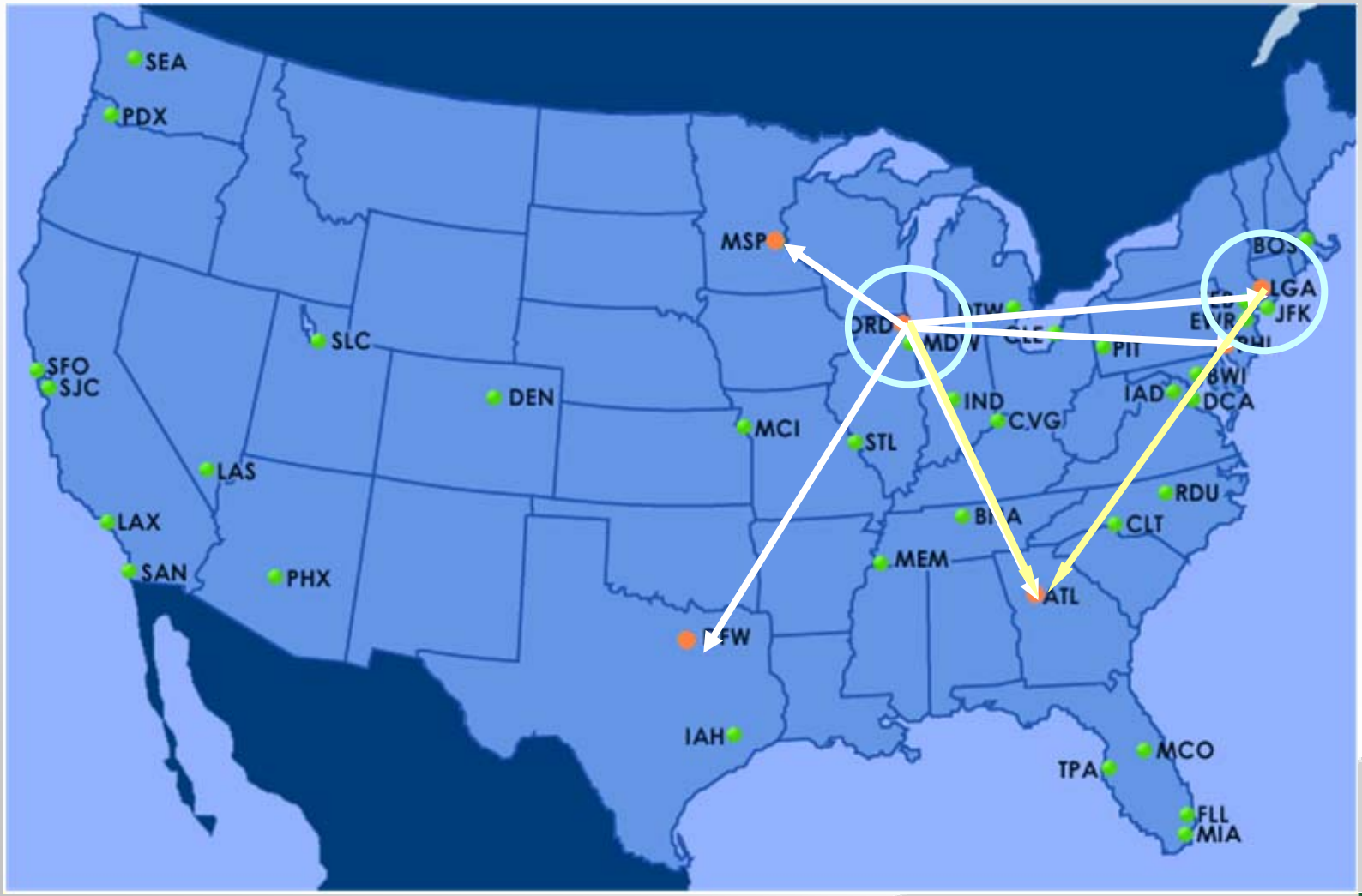






$P(C \mid B_i)$: the conditional probablility of C given B_i (likelihood)

Delay Propagation



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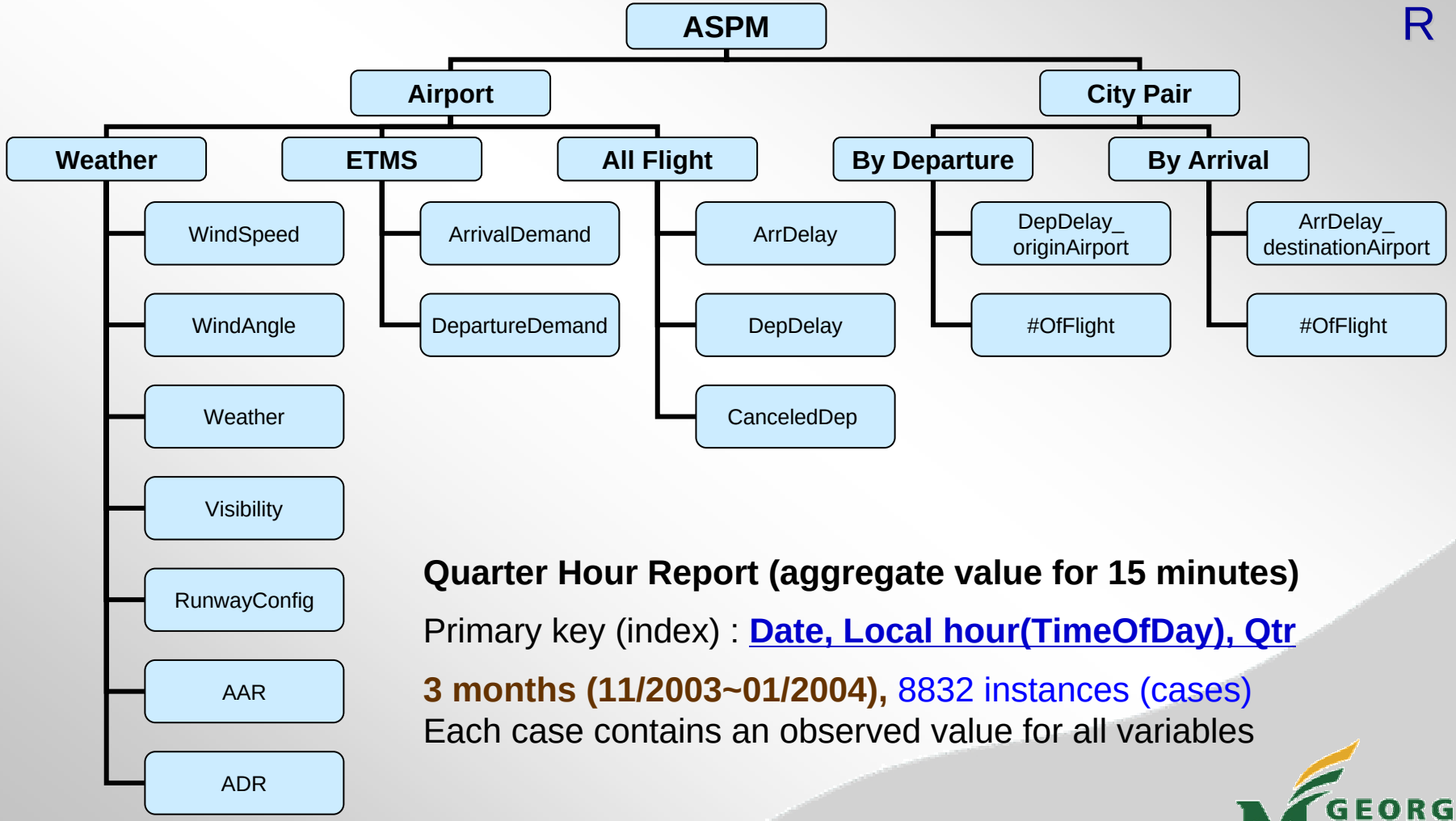
Data for Constructing Model

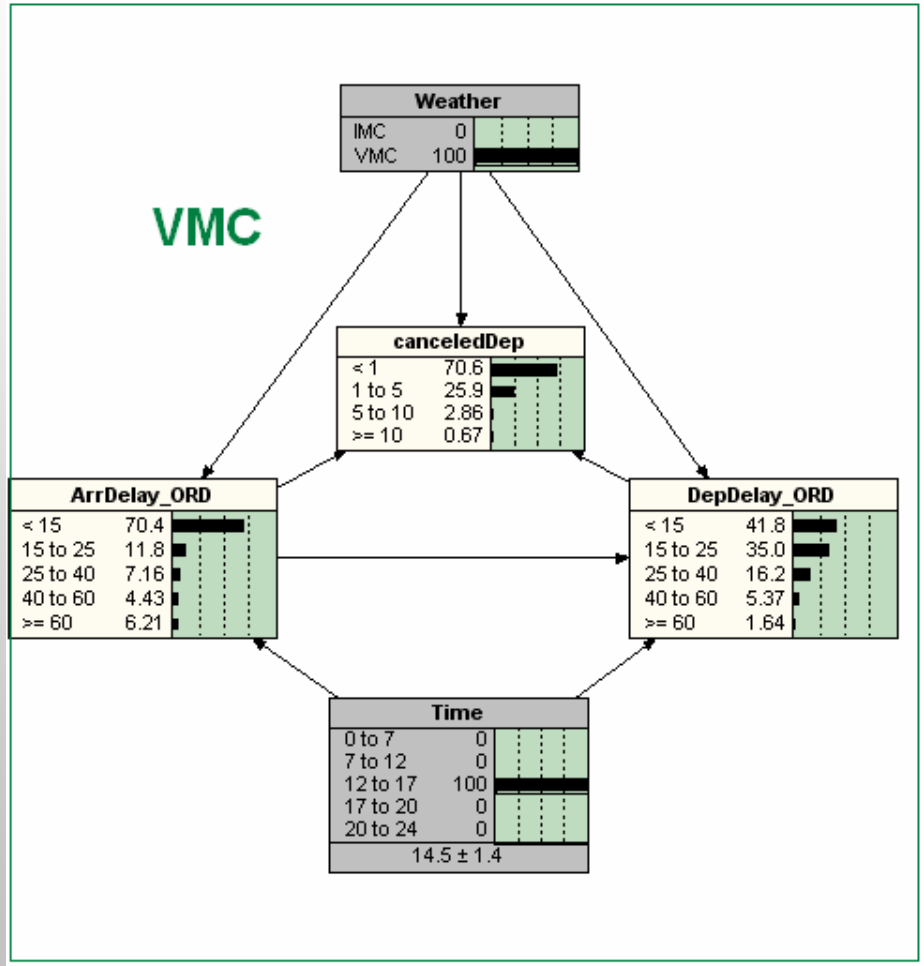


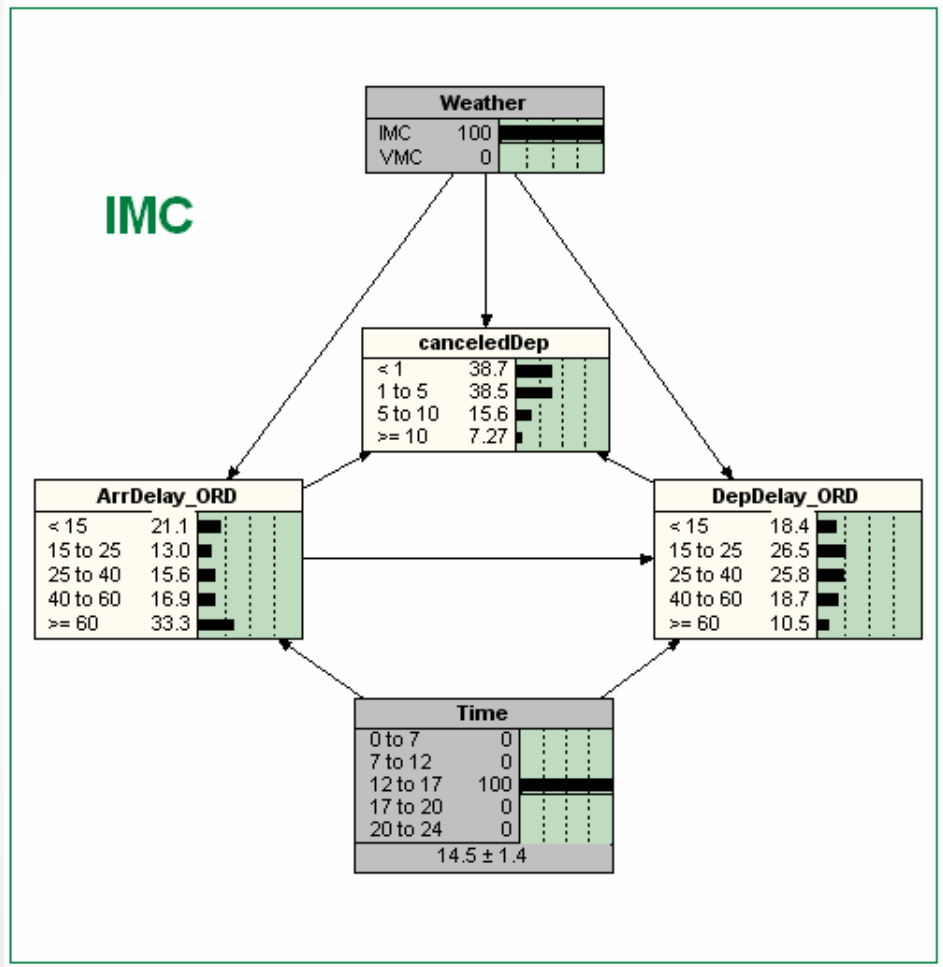
Quarter Hour Report (aggregate value for 15 minutes)

Primary key (index) : **Date, Local hour(TimeOfDay), Qtr**

3 months (11/2003~01/2004), 8832 instances (cases)
Each case contains an observed value for all variables

ORD: Delay & Cancellation





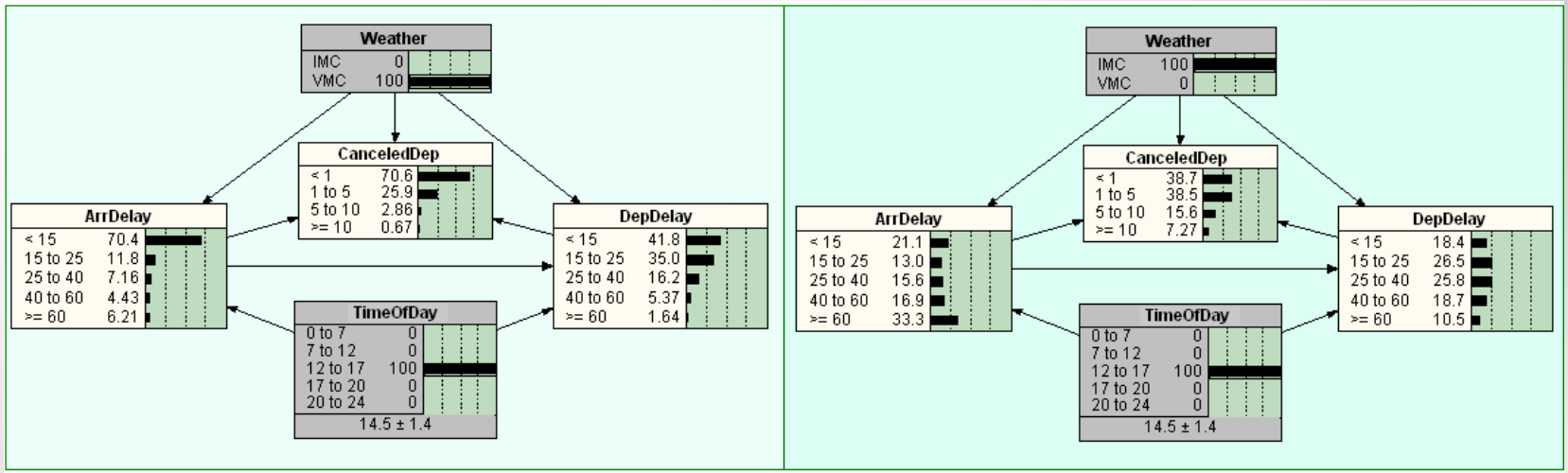
Example: Comparing Airports

CA
TS
R

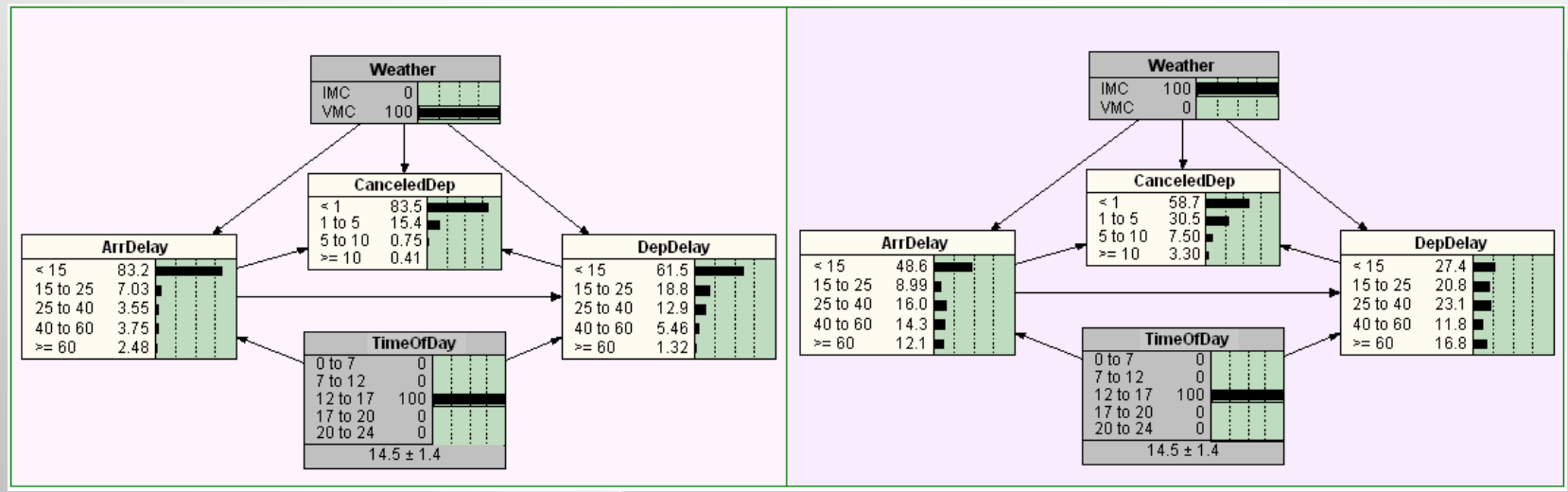
VMC

IMC

ORD



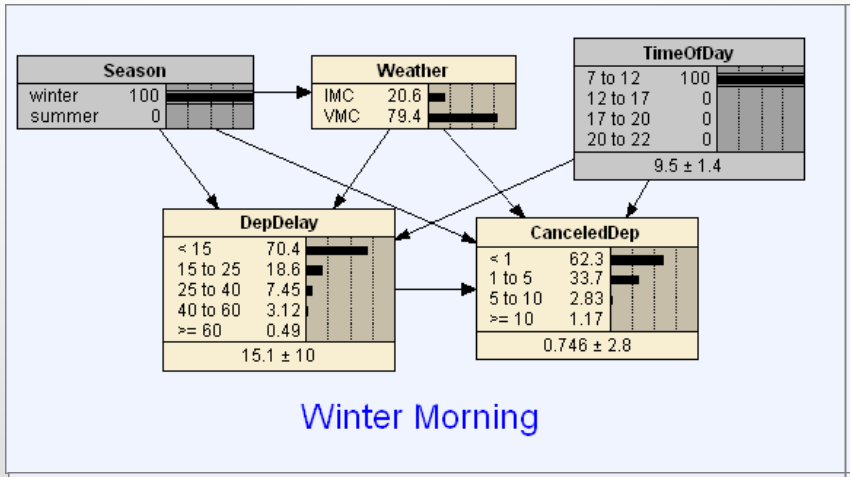
LGA



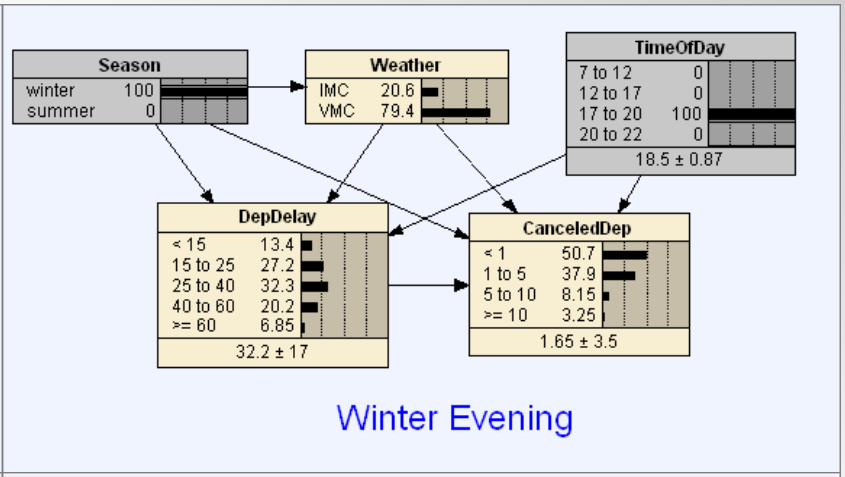
Flight Cancellation (ORD)

CA
TS
R

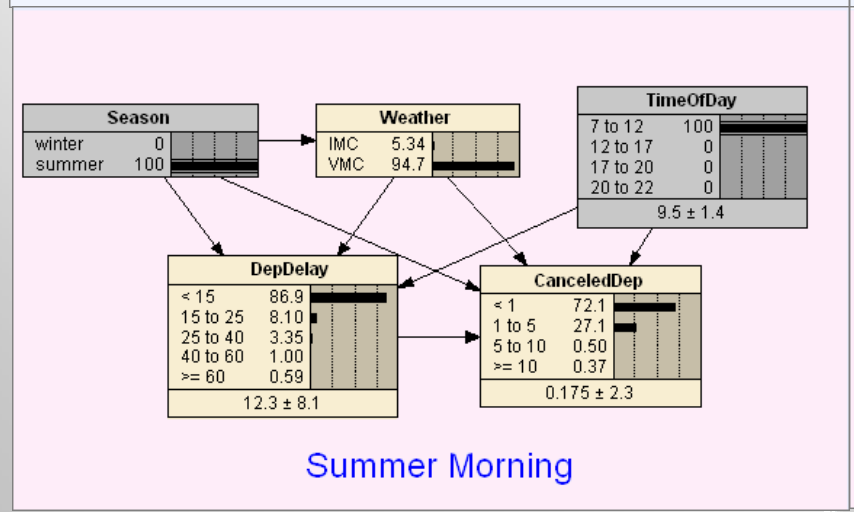
Winter vs. Summer; Morning vs. Evening



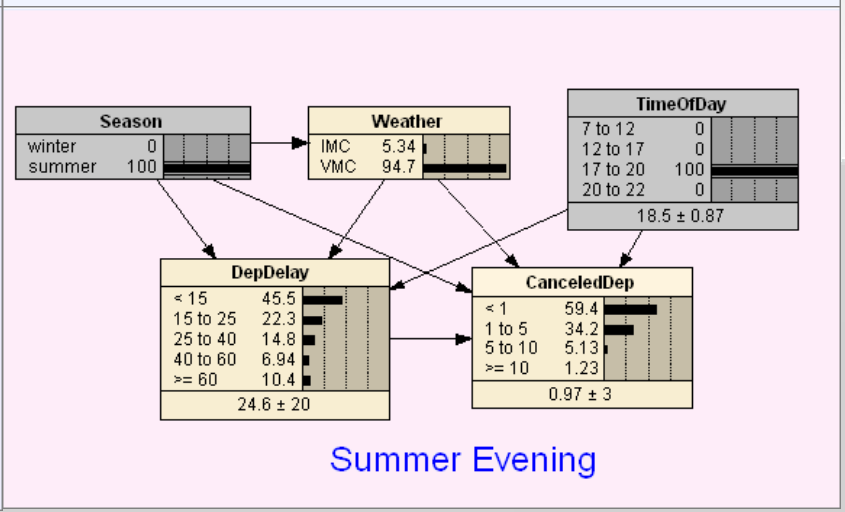
Winter Morning



Winter Evening

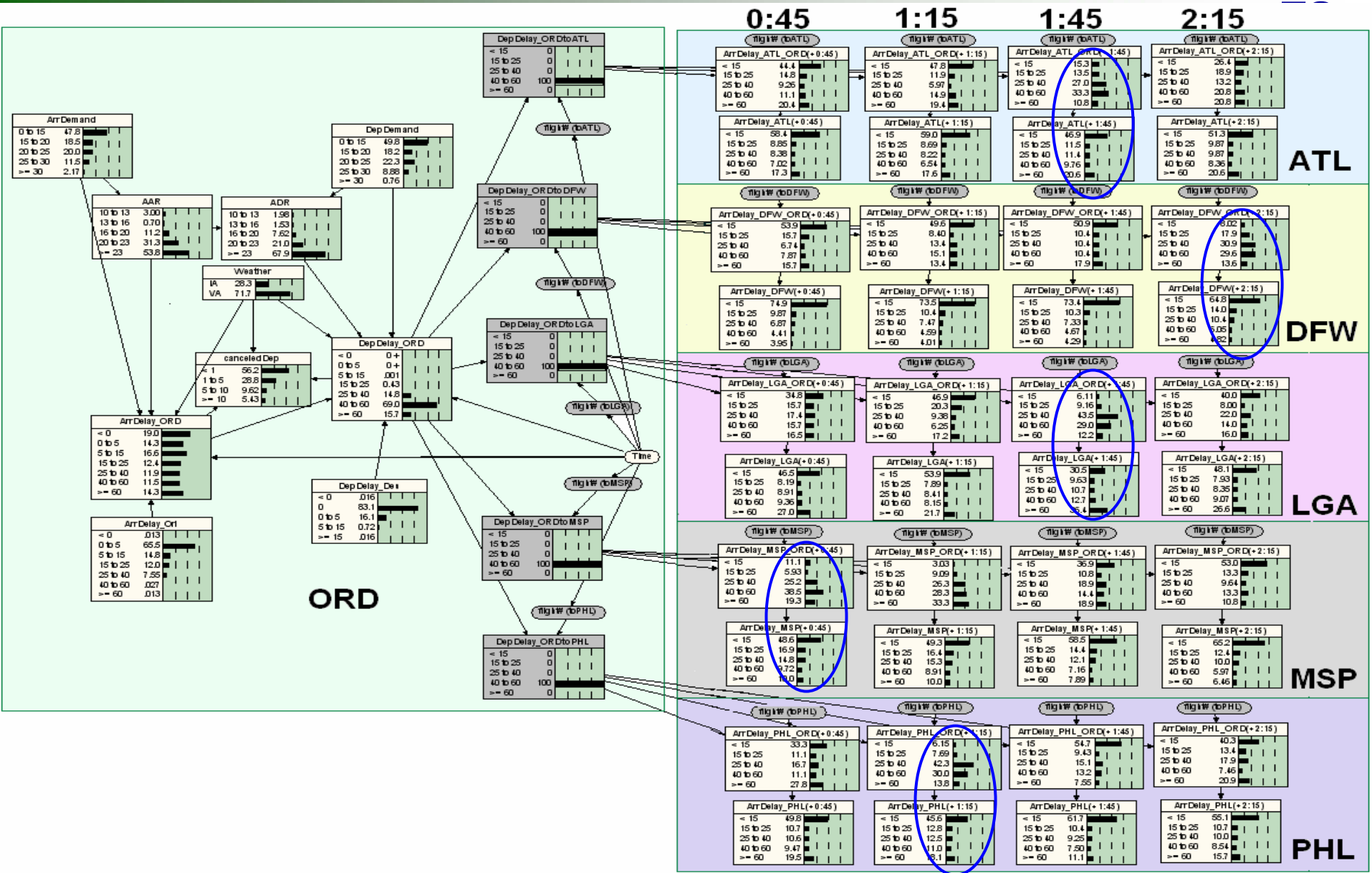


Summer Morning



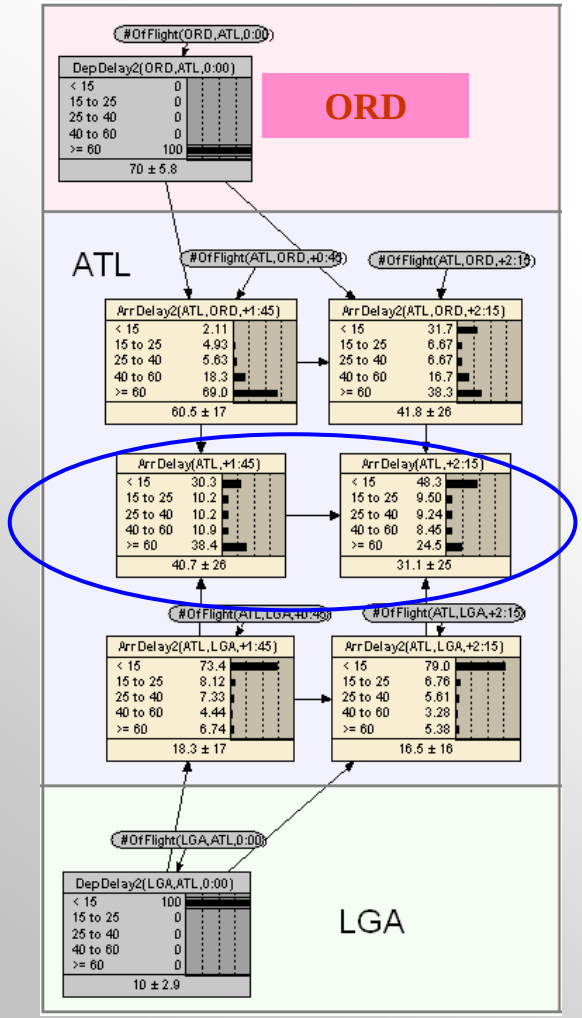
Summer Evening

Delay Propagation from ORD

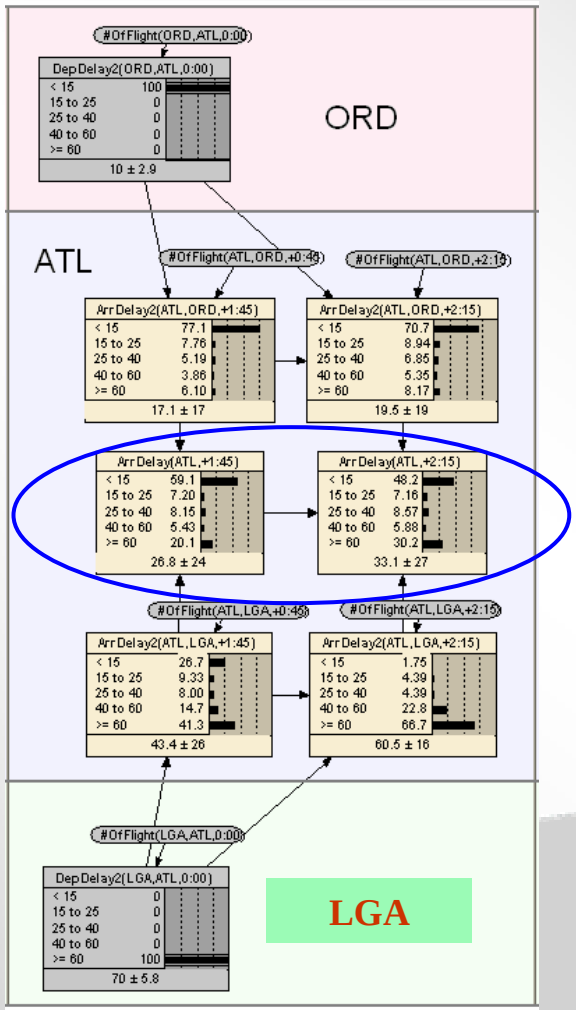


Delay Propagation Into ATL

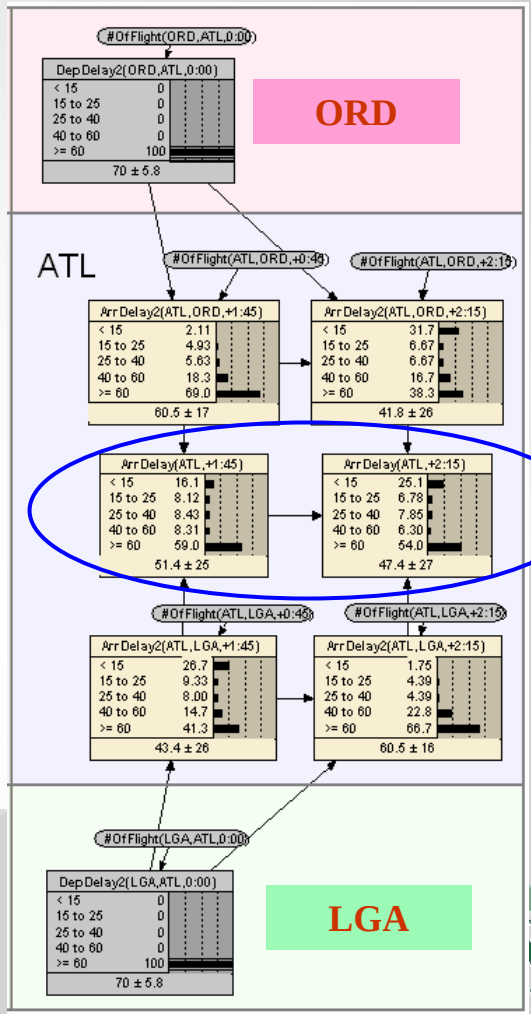
Scenario 1 - ORD Delay



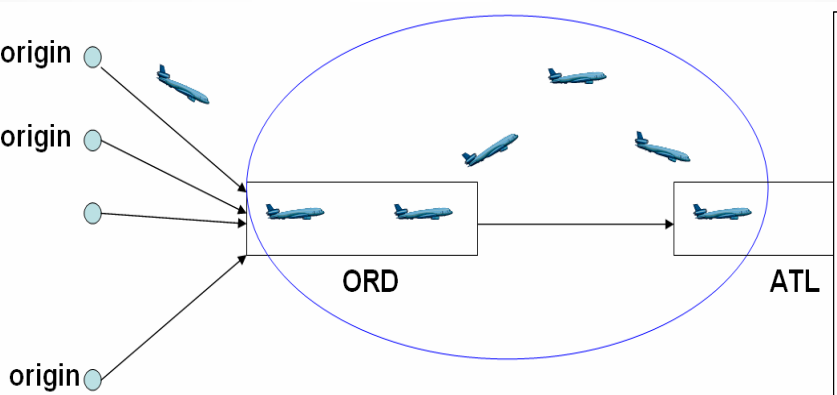
Scenario 2 - LGA Delay

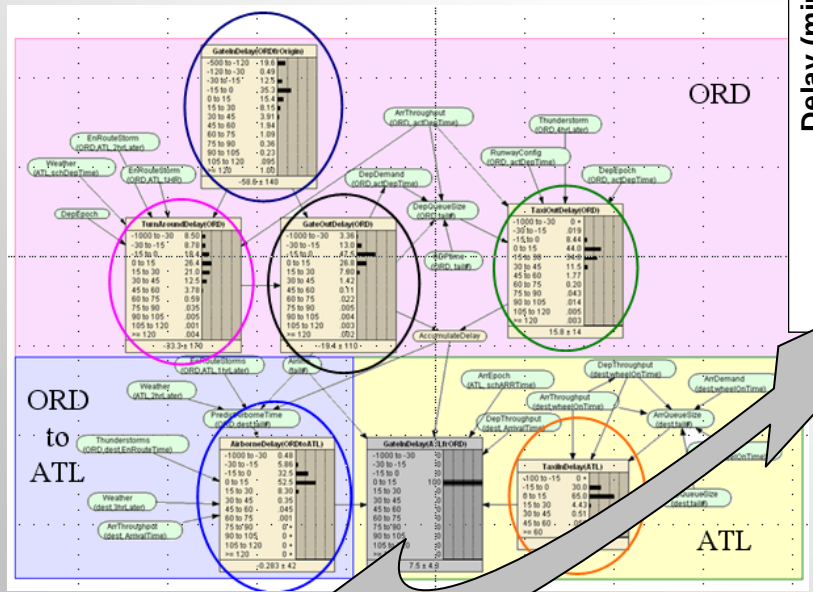


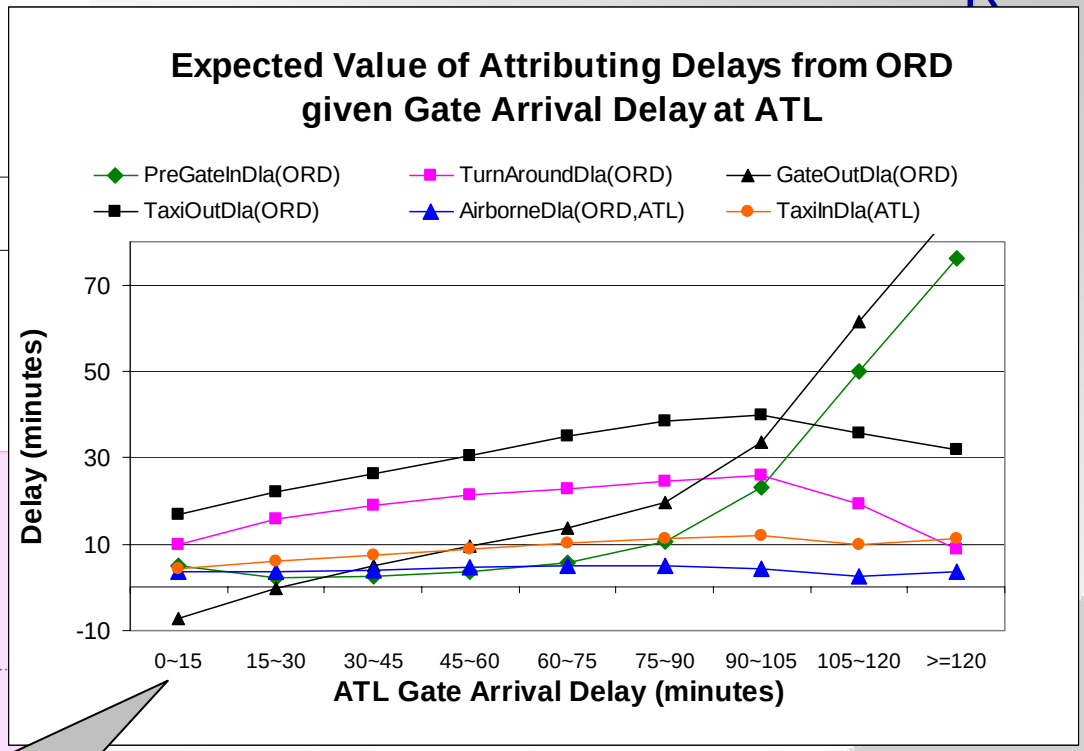
Scenario 3 - Both Delay



Decomposing Delay

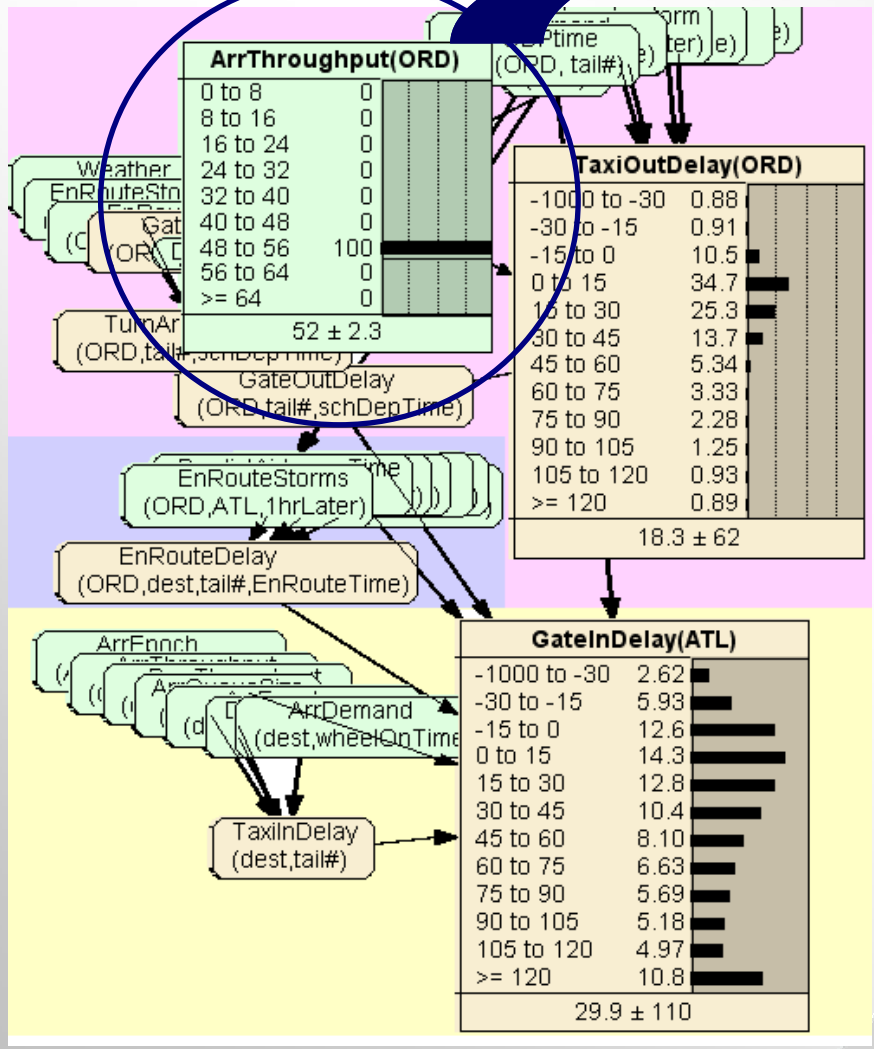


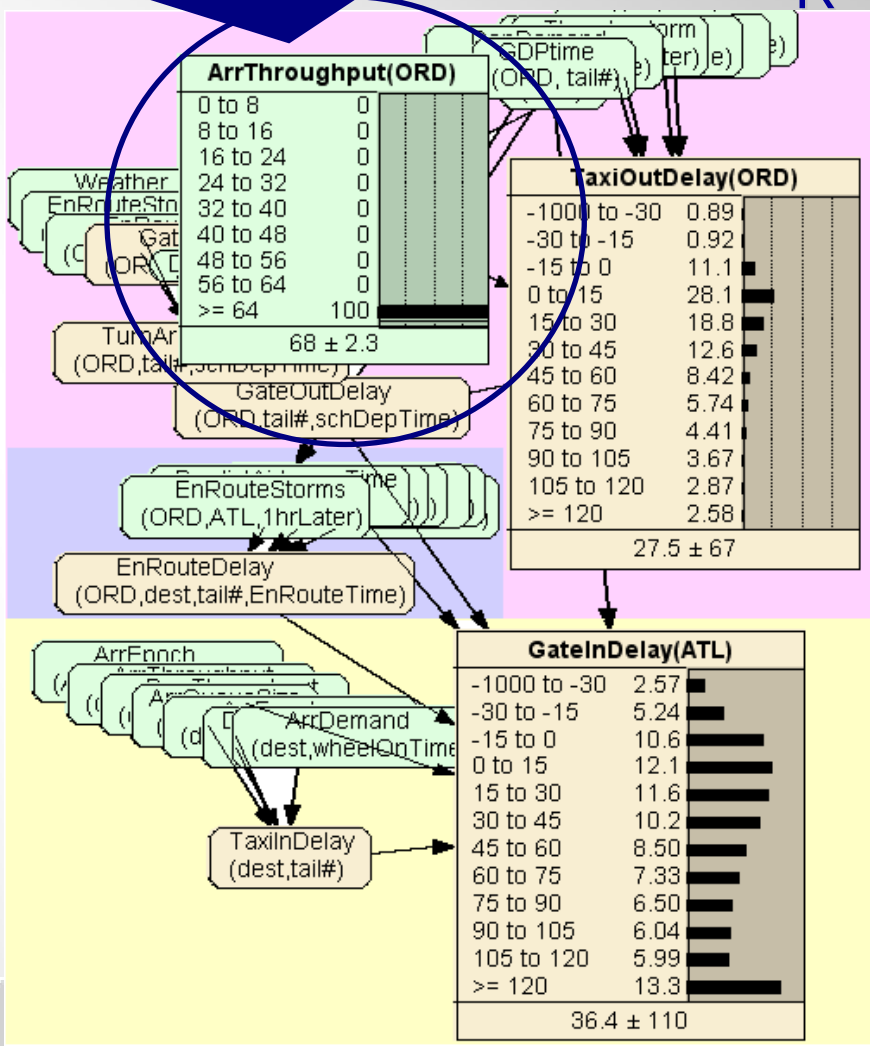




Given evidence for GateInDelay(ATL,ORD)

What If Scenarios





Conclusions

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- **Constructed stochastic model to represent relationship for variables in NAS**
- **Applied model to analyze cause & effect**
  - **Impact of weather on delay & cancellation**
  - **Effects of season and time of day**
  - **Propagation of delay from airport to airport**
  - **Major contributing factors to each phase of delay**
- **Model is complementary with simulation models**

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Acknowledgements

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- The following individuals from NASA Ames provided valuable comments, suggestions and support:

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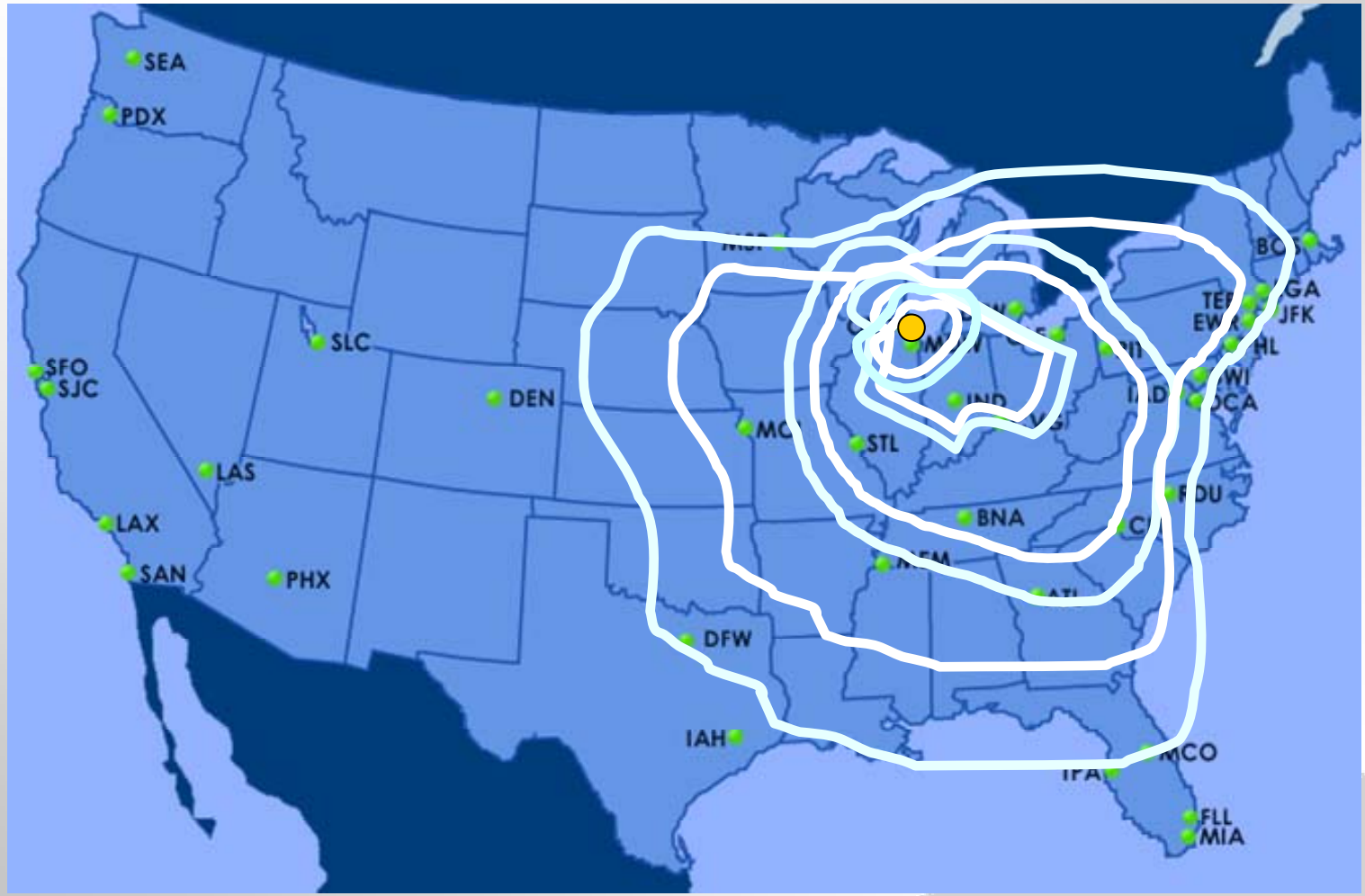
Thank You



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