Using Error Distributions with Model Output to Acknowledge Prediction Uncertainty: Results using Travel Demand and Transit Flow Models

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Uncertainty in Transportation Demand and Flow Models

Postulates

- There is uncertainty in predictions/forecasts: “Models are off”
- It is better to recognize than ignore the uncertainty

Practice

- Transportation demand/flow models generally produce point estimates

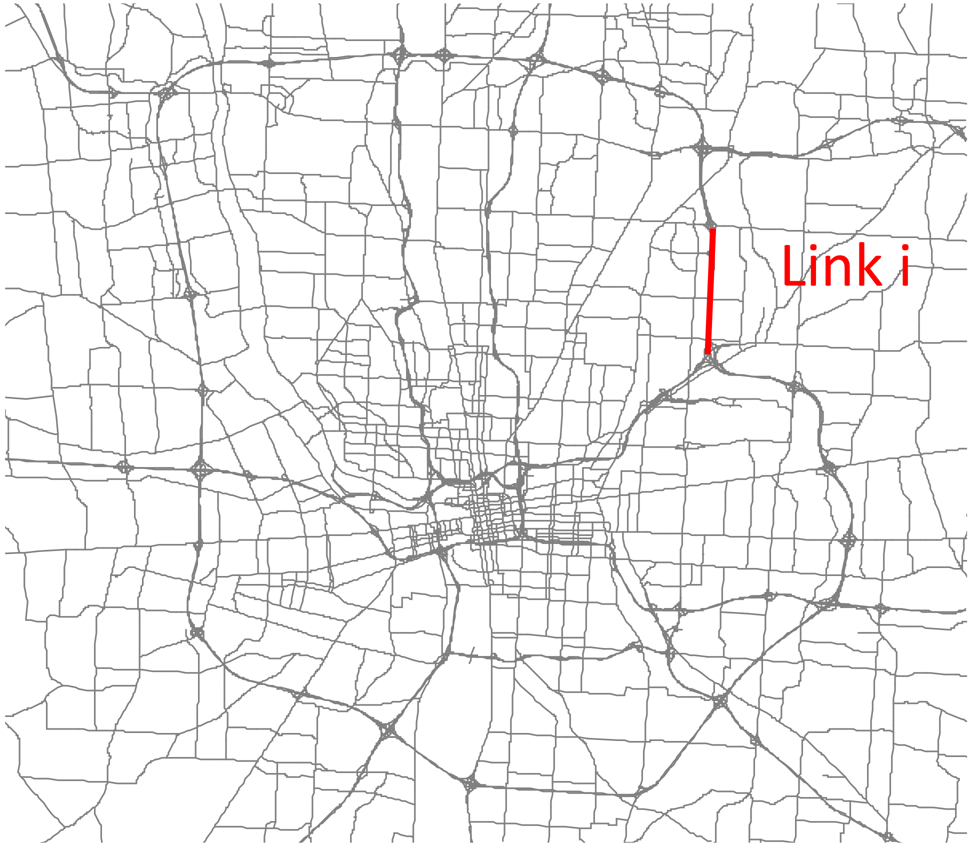
Propose and validate an approach to “add” uncertainty to model point estimates

Recognizing Differences between Models and the "Truth"

- Empirical-based studies
  - Measures of difference (e.g., RMSE) to compare models
  - *Do not provide measure for prediction uncertainty*
- Theoretical/Numerical (Monte Carlo)–based studies
  - Provide measures for prediction uncertainty based on distributions of inputs or parameters
  - *Do not account for model/assumption uncertainty*
- This approach
  - *Use differences between past model-based and observed values to determine distribution of true value, conditional on model output*

Developing Uncertainty Distributions
Difference between Model Values and Observations: Δ

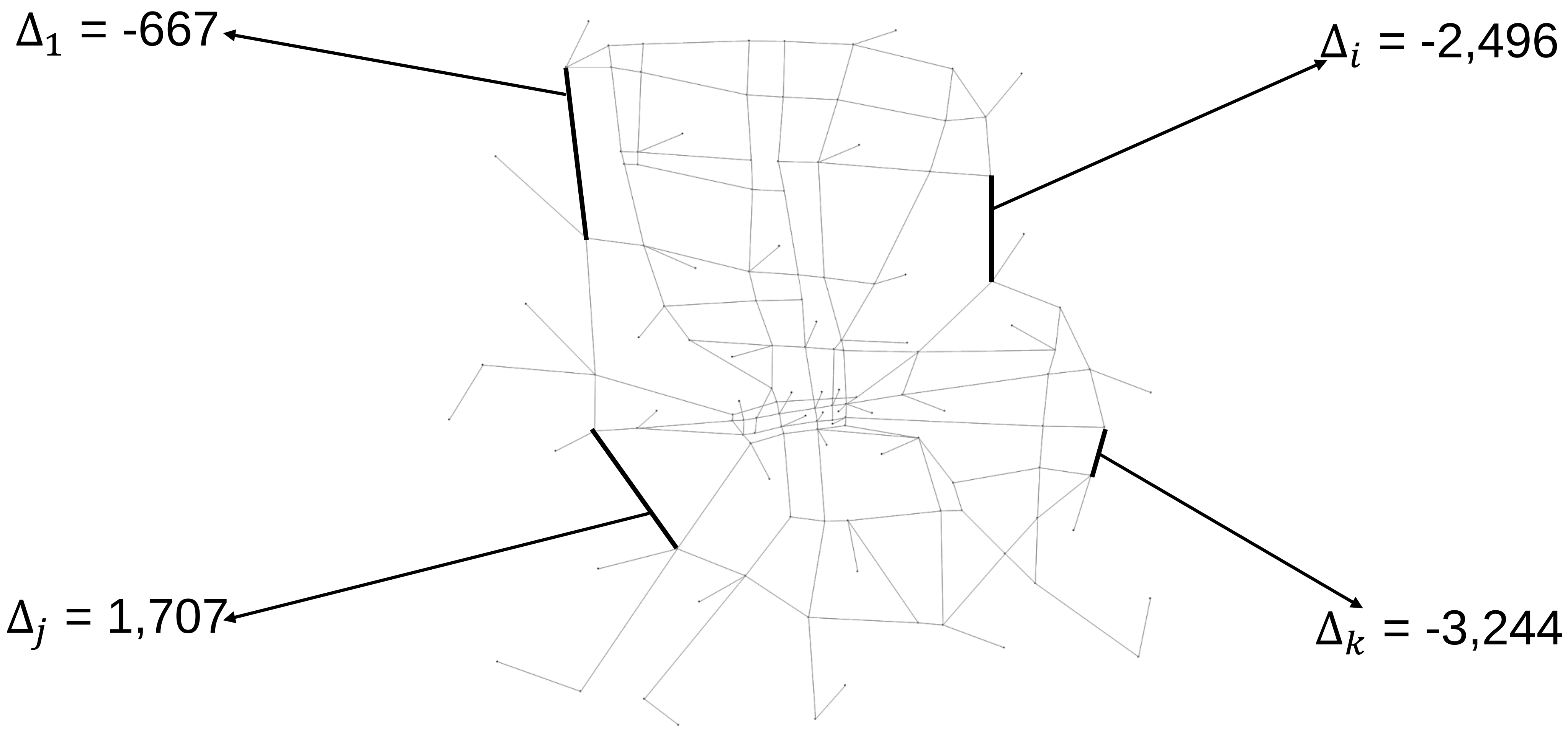
MORPC Network



	1990 Link i Volume
MORPC Model Output (M_i)	: 26,844 *
Observation (T_i)	: 29,340 *
$\Delta_i = M_i - T_i$	-2,496

** Ferdous et al. (2011) Comparison of Four Step Versus Tour-Based Models in Predicting Travel Behavior Before and After Transportation System Changes*

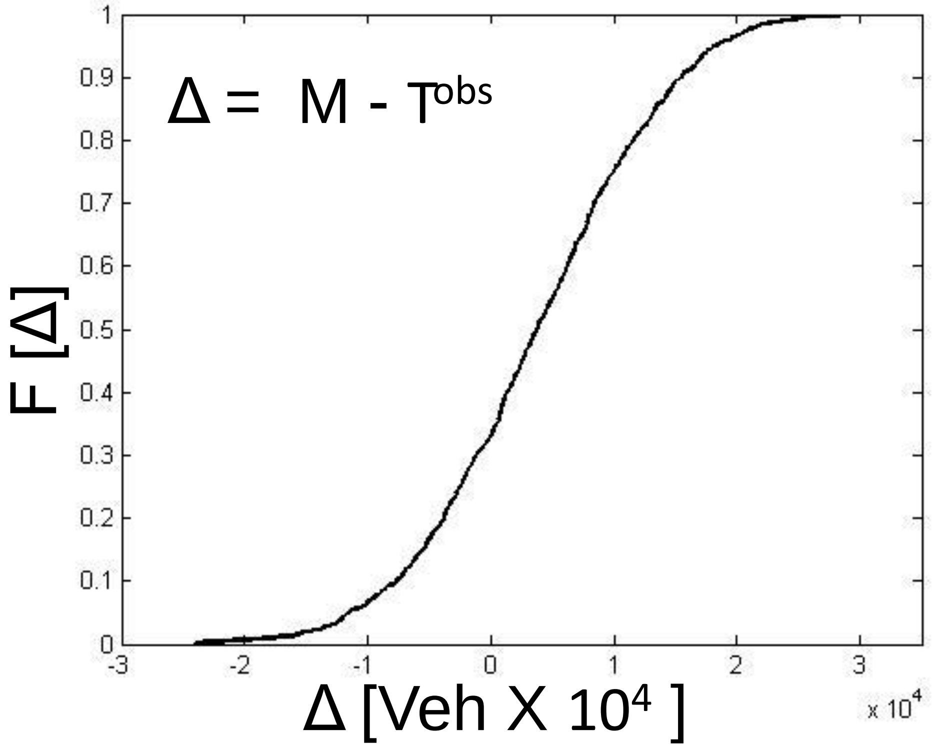
Determining Difference (Δ), Bias (b), and Error (ε) Distributions



1041 Segments in *Ferdous et al.*

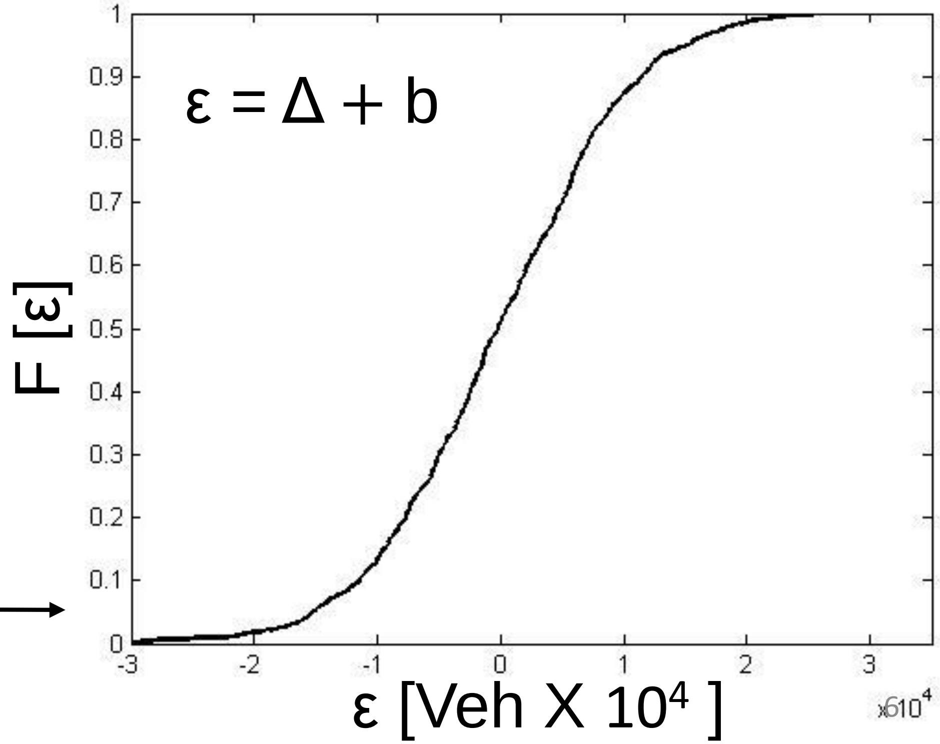
Determining Difference (Δ), Bias (b), and Error (ε) Distributions

Differences Between Models and Observations

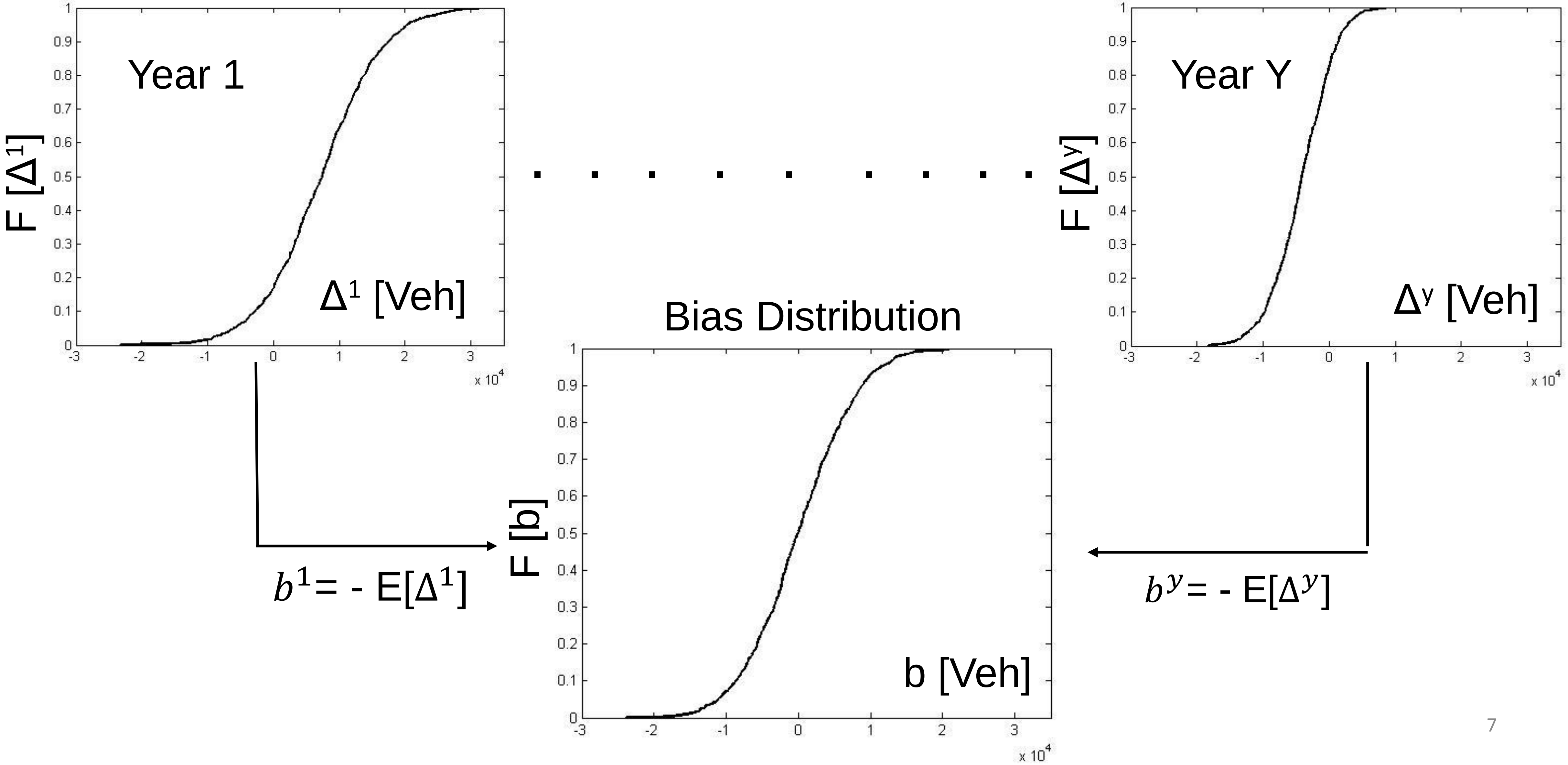


Bias: b = - E[Δ] = -1,155

Unbiased Error



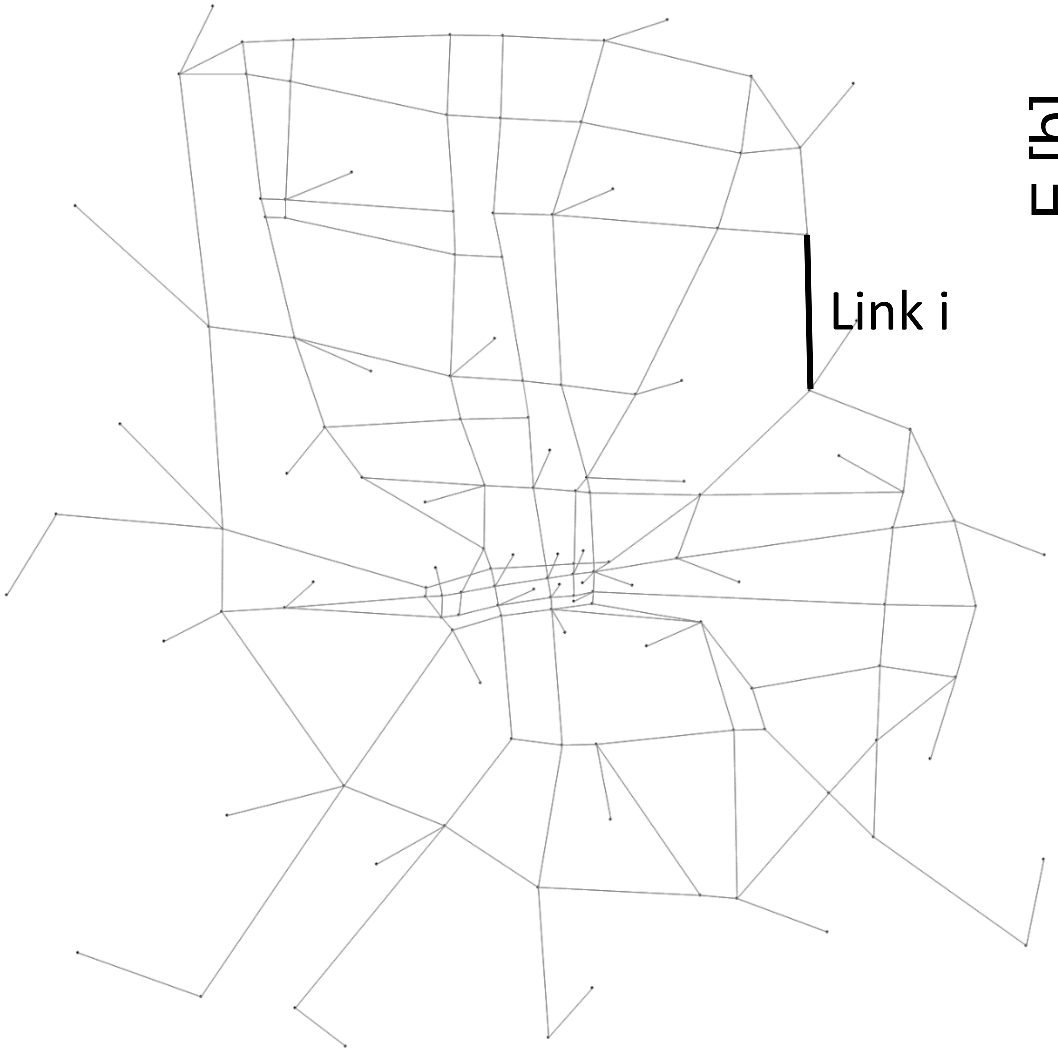
Determining Bias Distribution



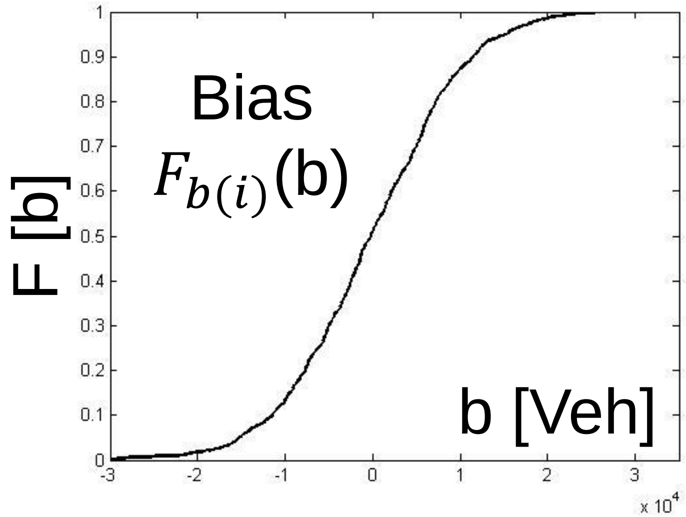
Prediction/Forecast on Link i: $F_i(T_i|M_i)$

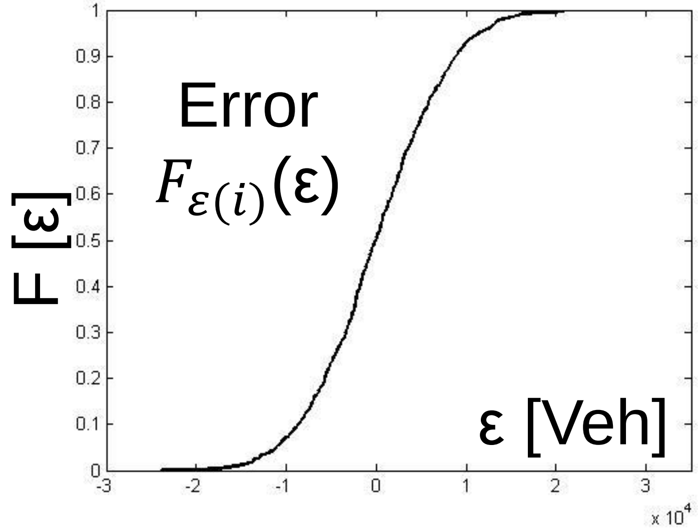
Model for 2005

M_i = 58,071



F_b and F_ε from 1990 and 2000





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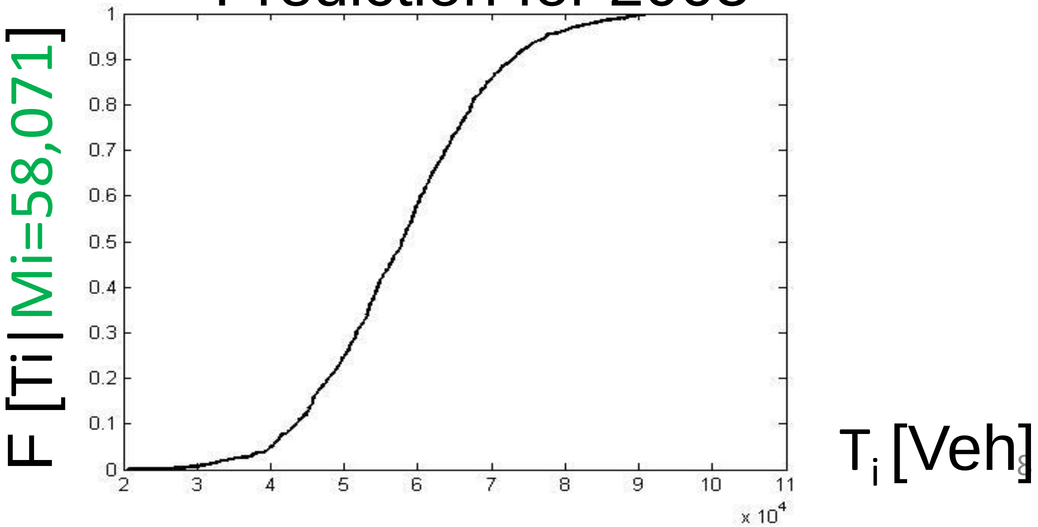
Prediction for 2005



Validation Study

- Use subset of model/observation data to estimate bias and error distribution
- Use estimated bias and error distributions with remaining model output to produce uncertainty in model predictions/forecasts
- Use observations for remaining data (“known outcomes of prediction/forecast”) with modeled uncertainty to determine empirical distributions of probabilities of observations
- Compare empirical distributions to theoretical distributions

Prediction/Forecast on Link i: $F_i(T_i|M_i)$

Model for 2005

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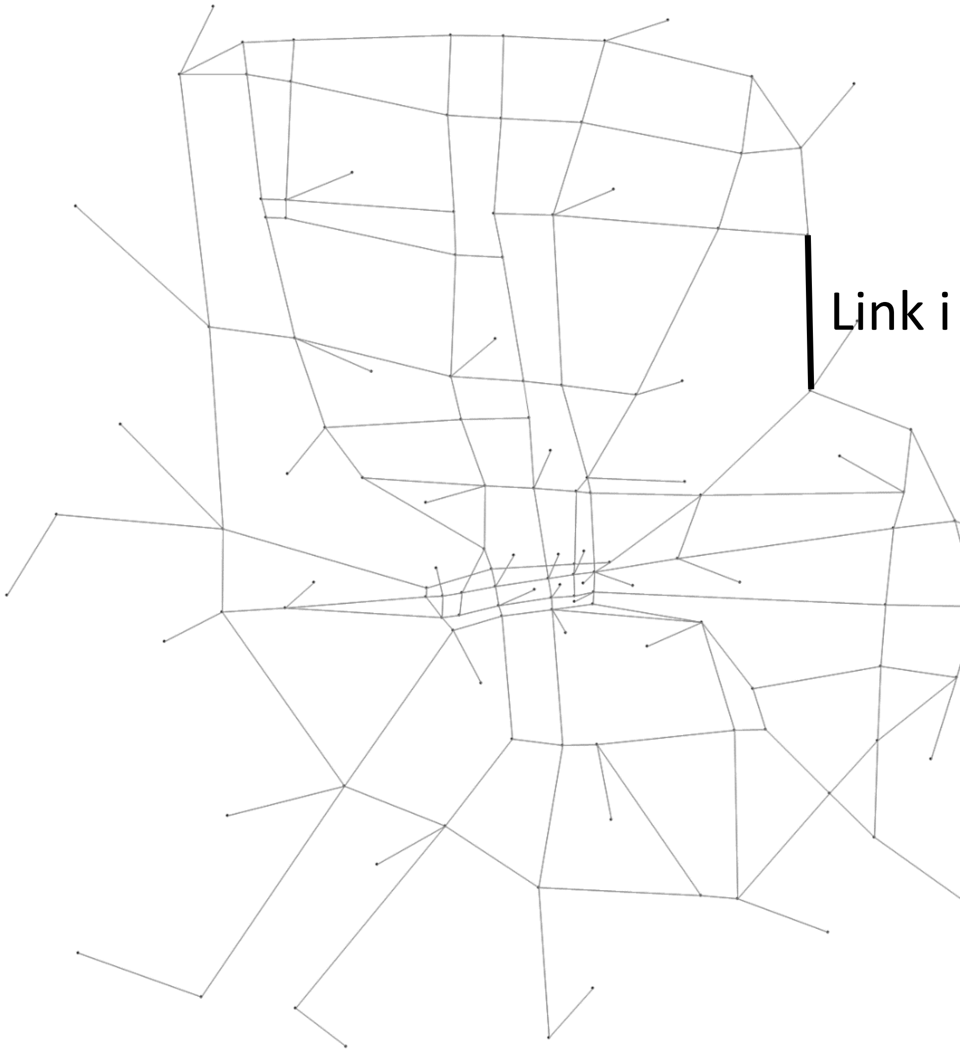
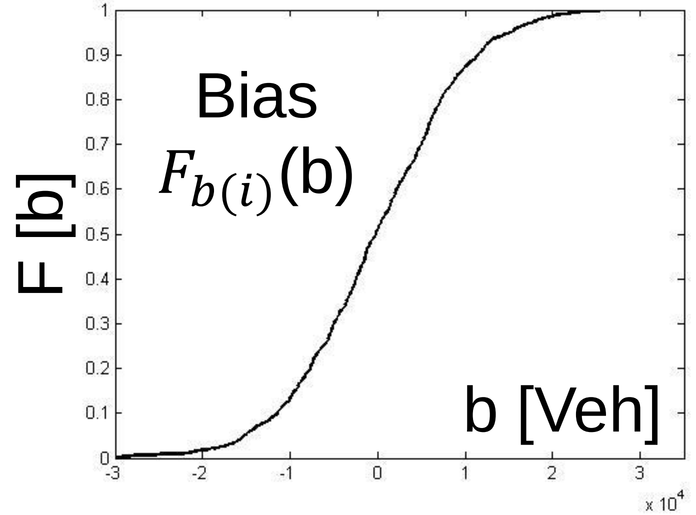
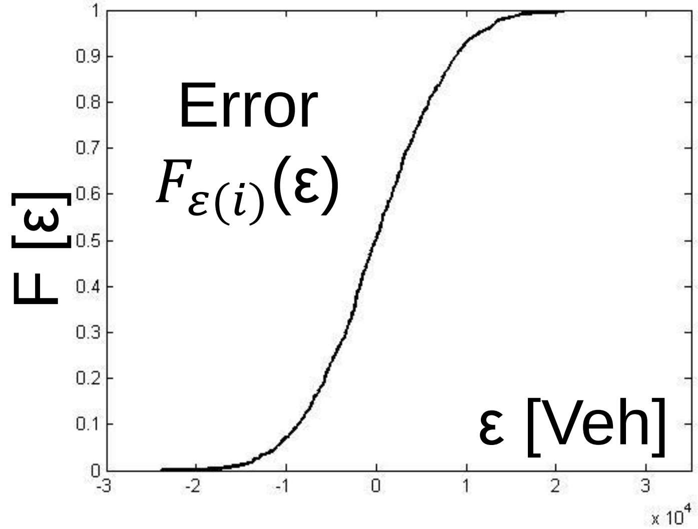


F_b and F_ε from 1990 and 2000





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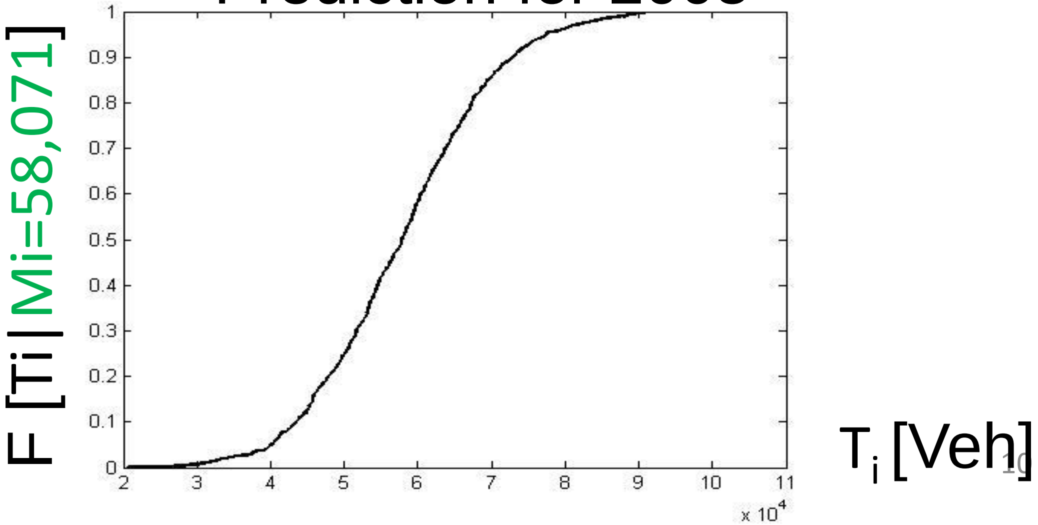
Prediction for 2005

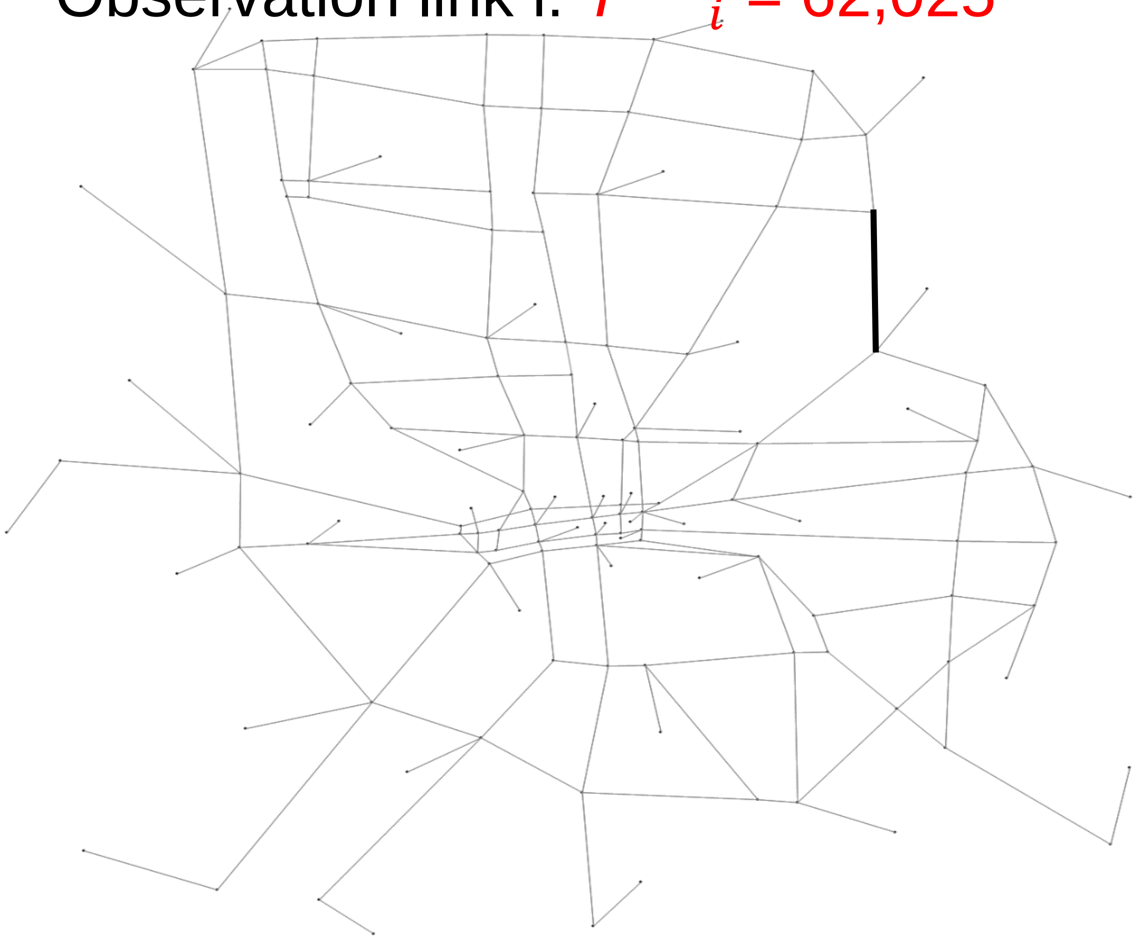


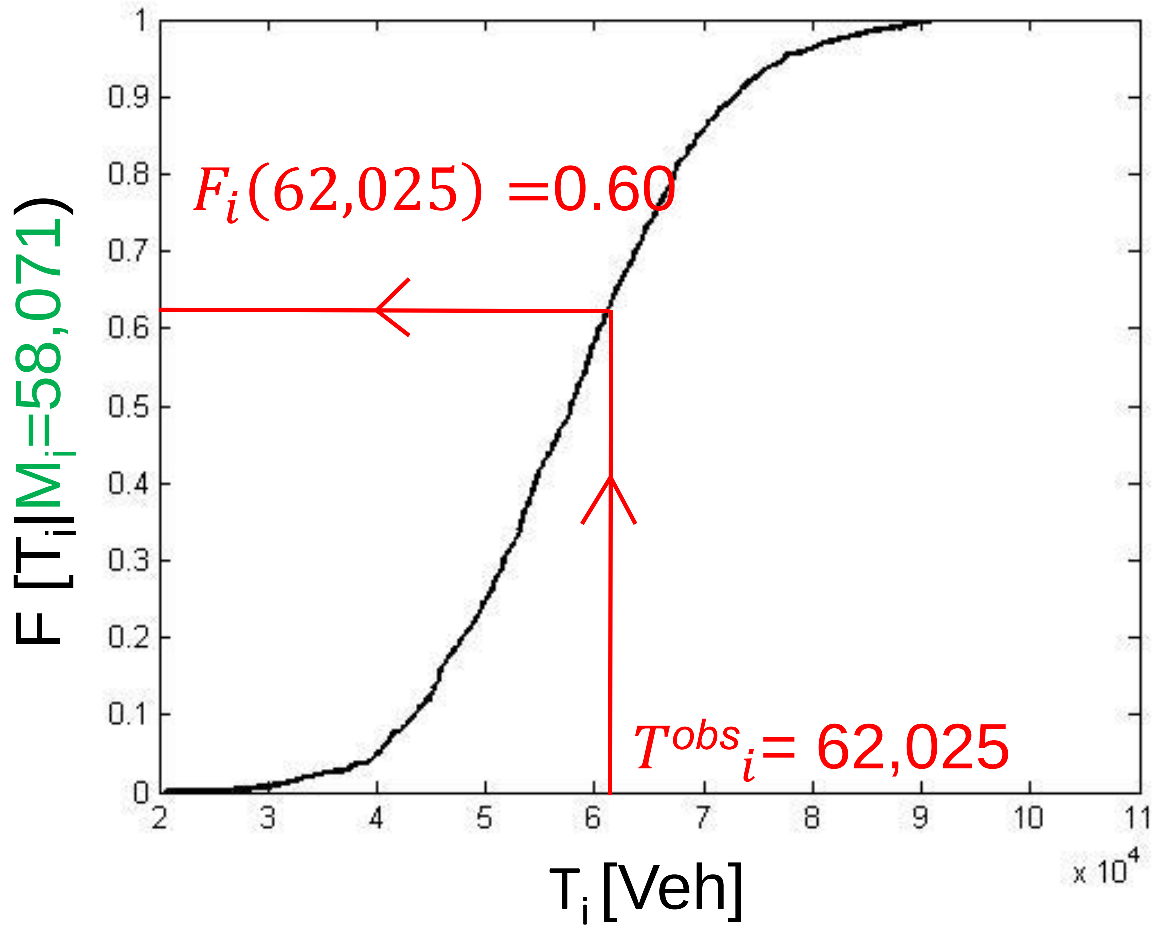
Validation Logic: Probabilistic Forecast of Observation T^{obs} on Link i

In 2005

Model link i: M_i = 58,071

Observation link i: $T^{obs}{}_i$ = 62,025

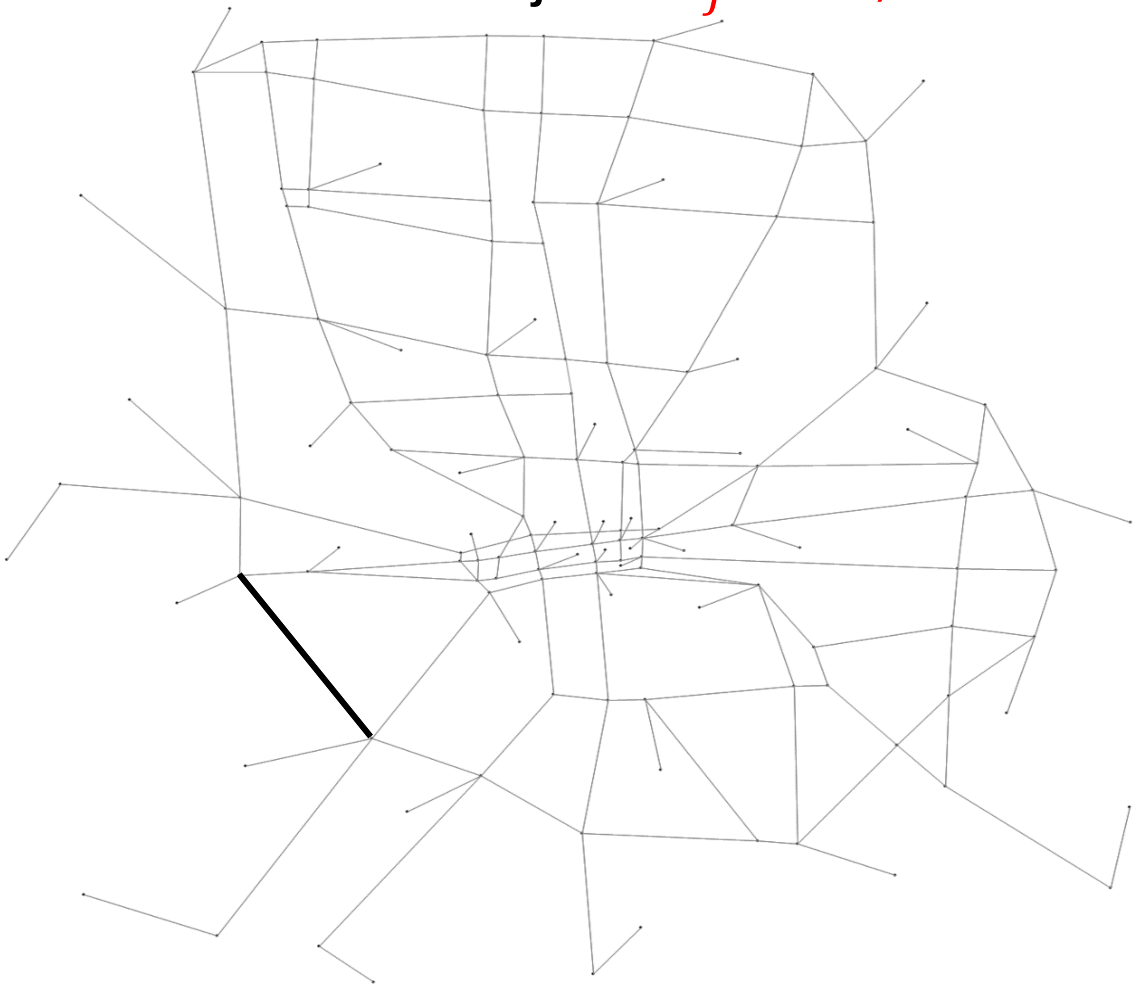


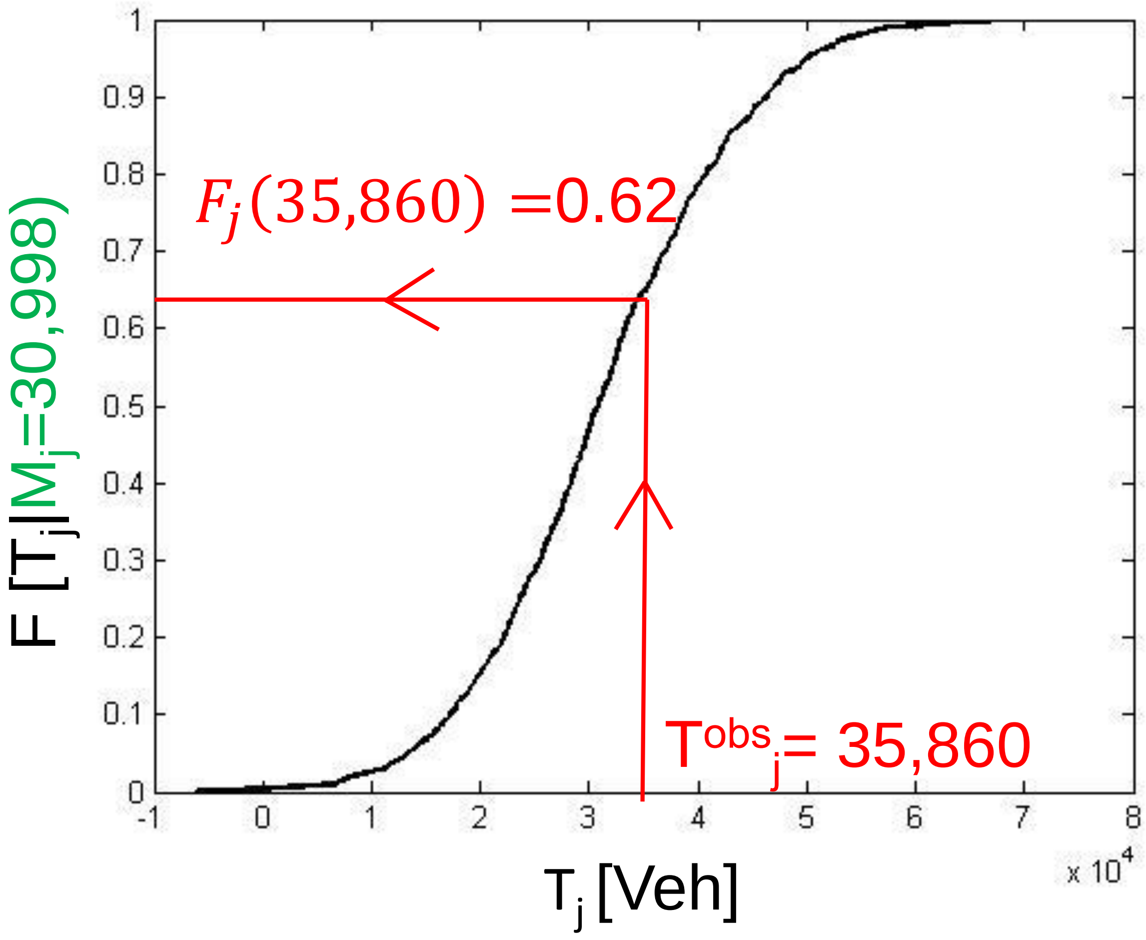


In 2005

Model link j: M_j = 30,998

Observation link j: $T^{obs}{}_j$ = 35,860

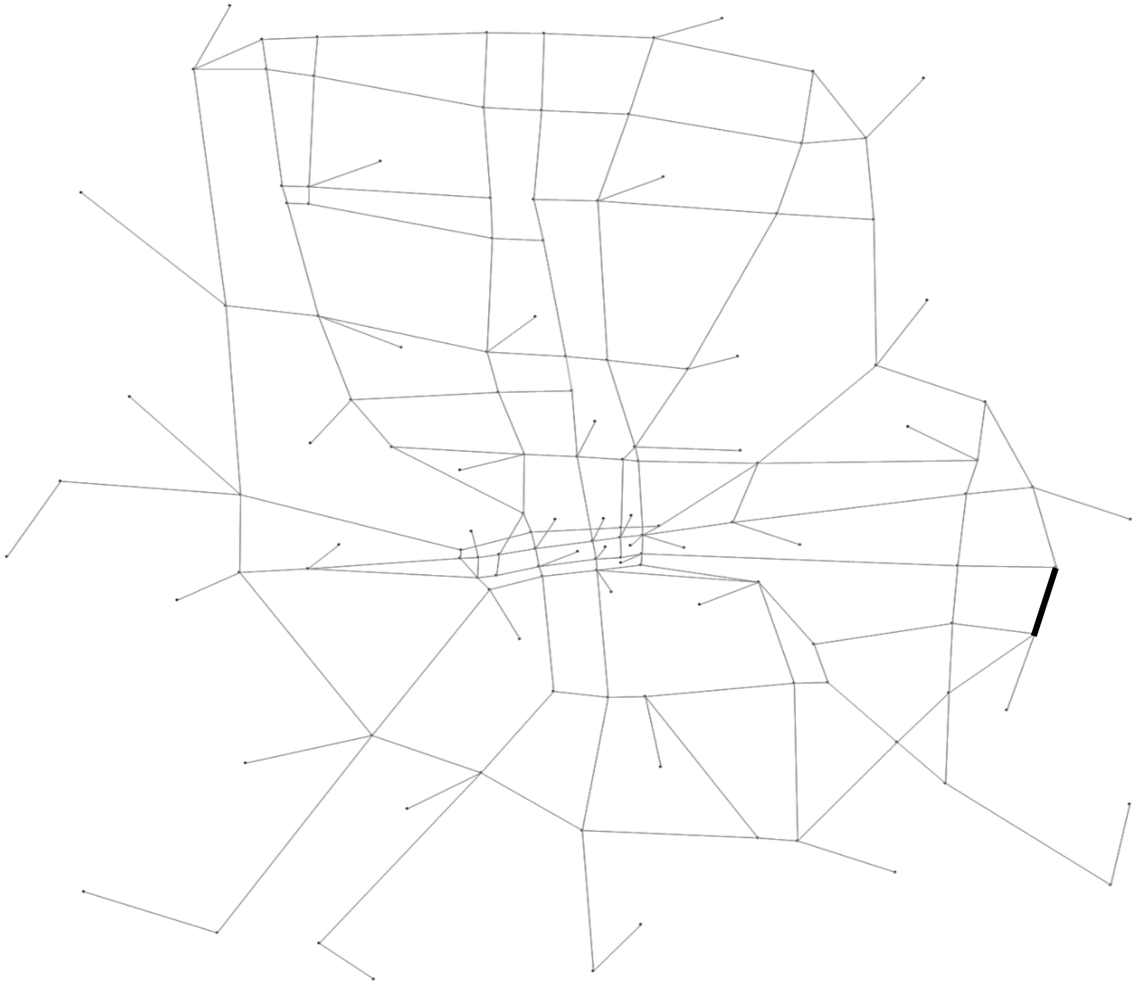


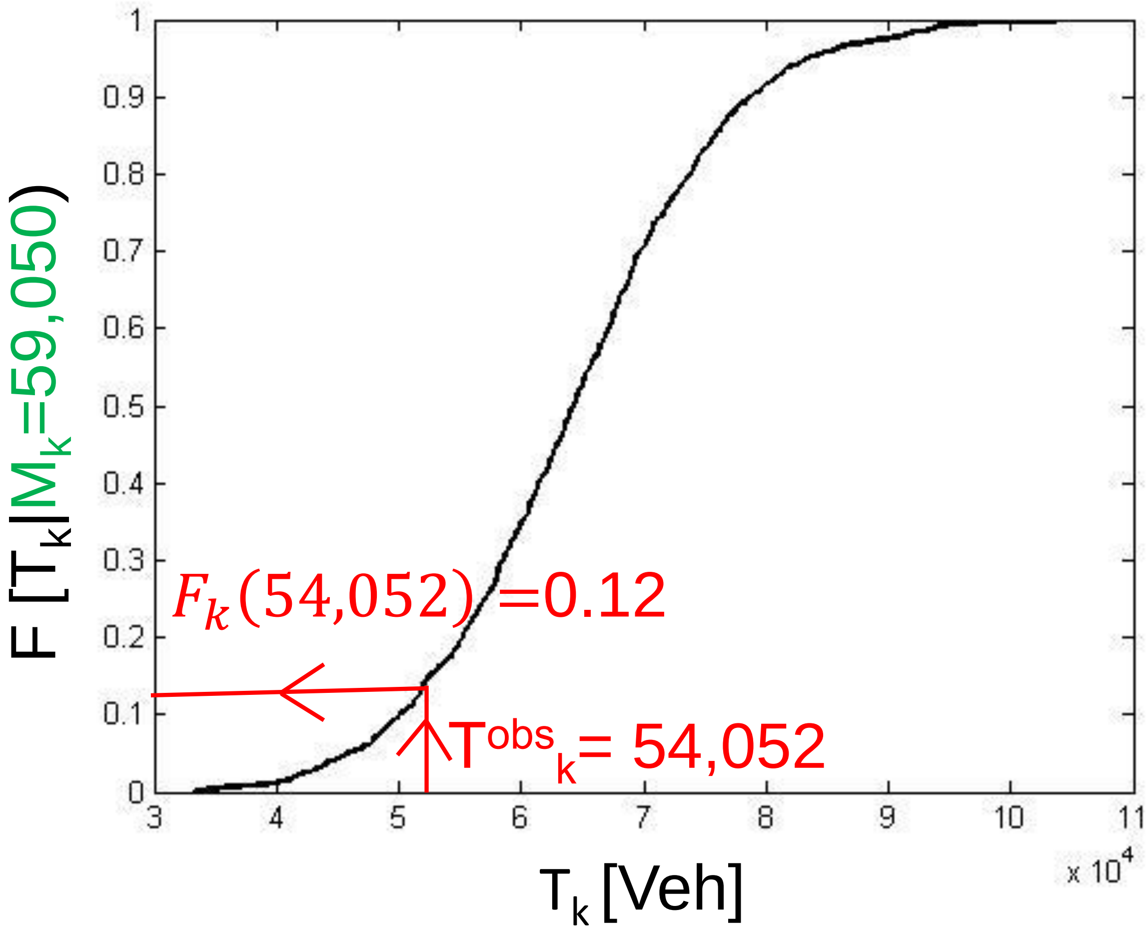


In 2005

Model link k: M_k = 59,050

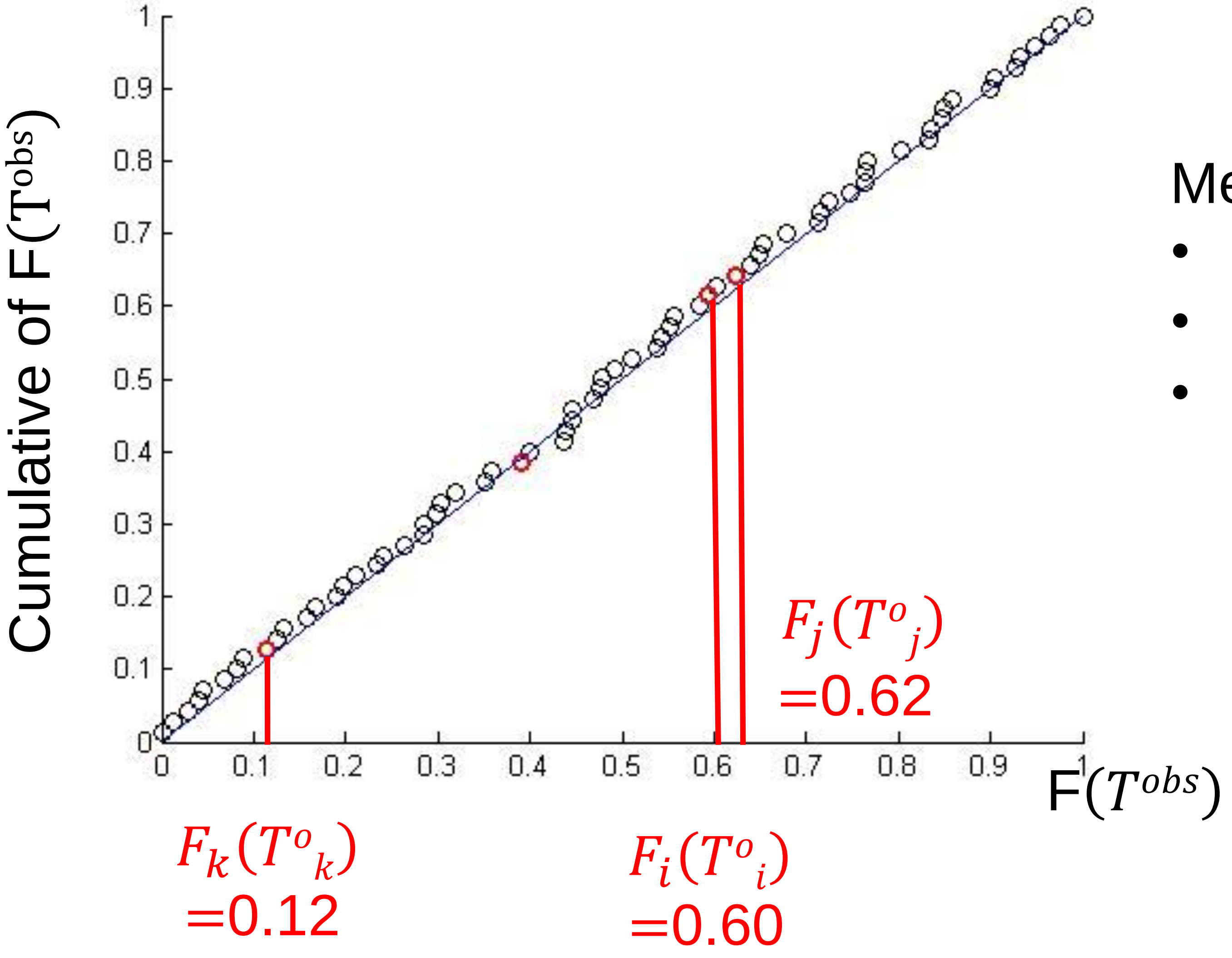
Observation link k: $T^{obs}{}_k$ = 54,025





Monte Carlo Logic:

Well-calibrated uncertainty should produce points around 45^o line



Metrics of discrepancy w/ 45^o line

- AAD: |Avg. Dif. (45^0, pts.)|
- MD: |Max. Dif. (45^0, pts.)|
- Area (45^0, pts.)

Larger metric values imply poorer empirical distributions

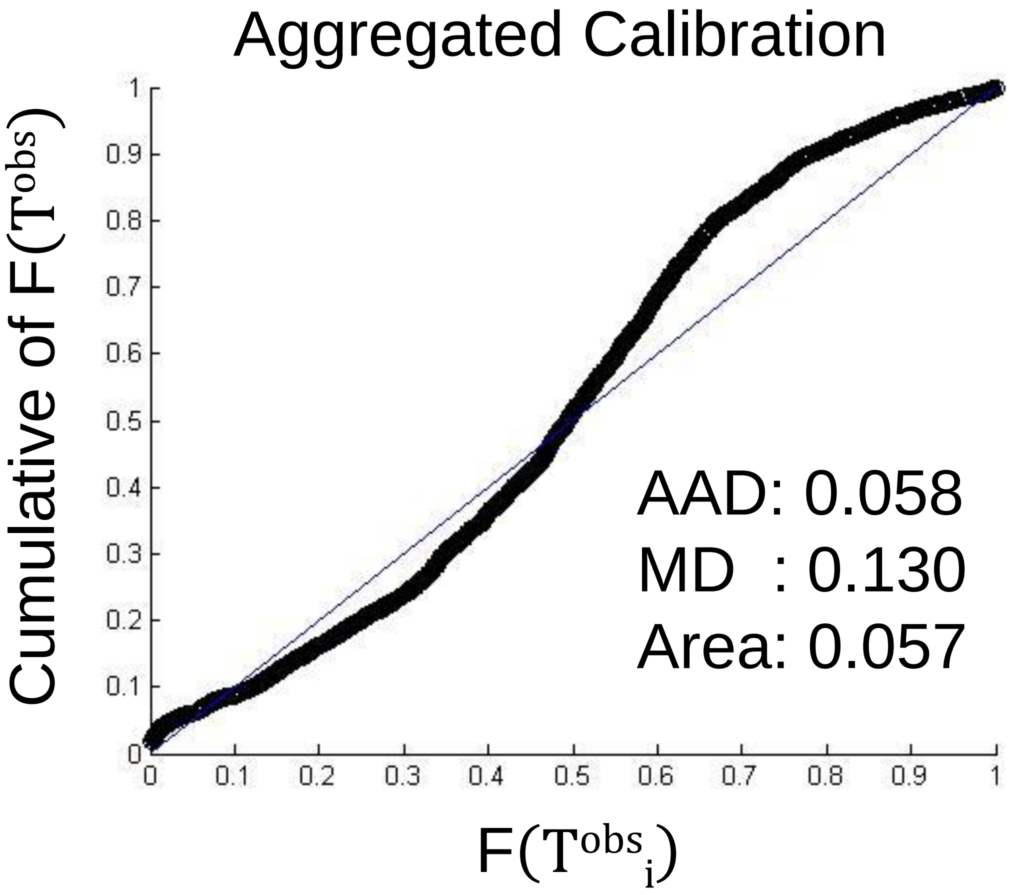
Empirical Applications

- Link volumes from traffic assignment
  - Mid-Ohio Regional Planning Commission model outputs and observations
  - Values from *Ferdous et al. (2011)*: Tour-based model

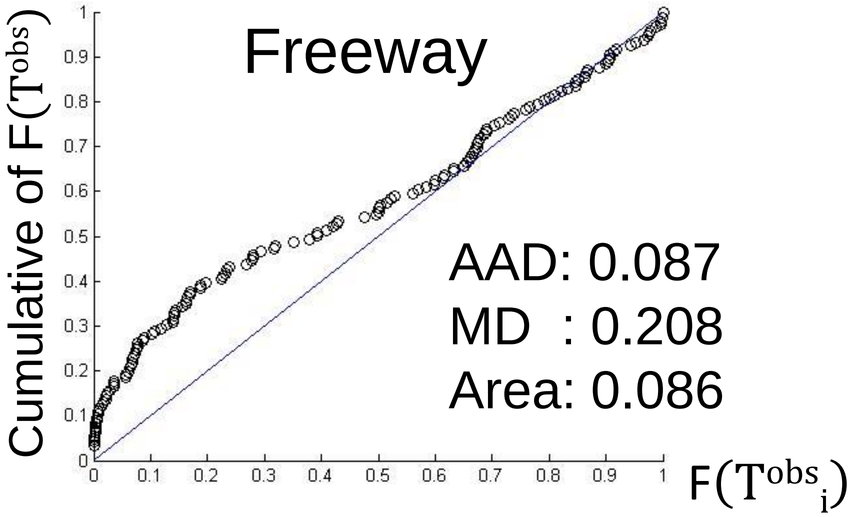
- Bus passenger OD (B2A) flows from estimations based on boarding and alighting data
  - The Ohio State University Campus Transit Lab OD flow observations
    (http://transitlab.osu.edu/campus-transit-lab)
  - Boarding and alighting data from observations used with Iterative Proportional Fitting (IPF) method to produce model estimates

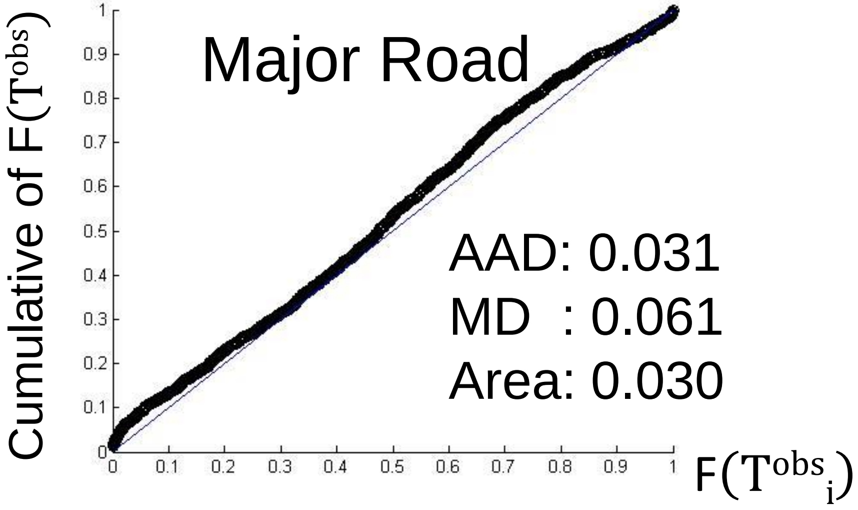
Traffic Assignment Validation
Using Ferdous et al. MORPC Data

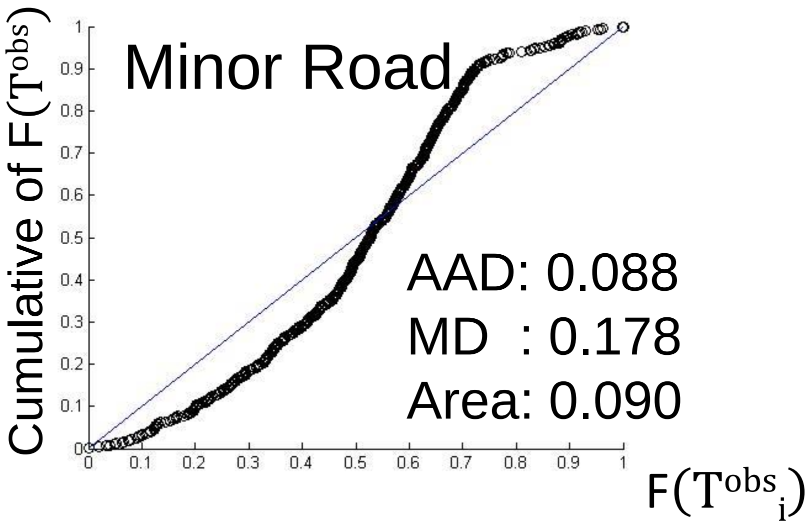
- Model/Observation years: 1990, 2000, 2005
- Calibrate using two years to predict third year: All (3) combinations
- Calibrate one bias and one error distribution using all segments: “Aggregated Calibration”
- Pool results

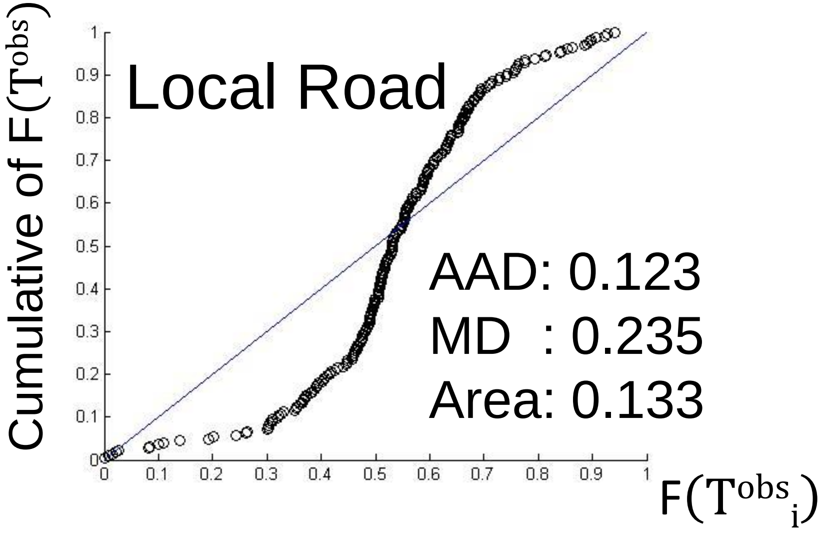


Traffic Assignment Validation
Aggregated Calibration for Segmented Predictions



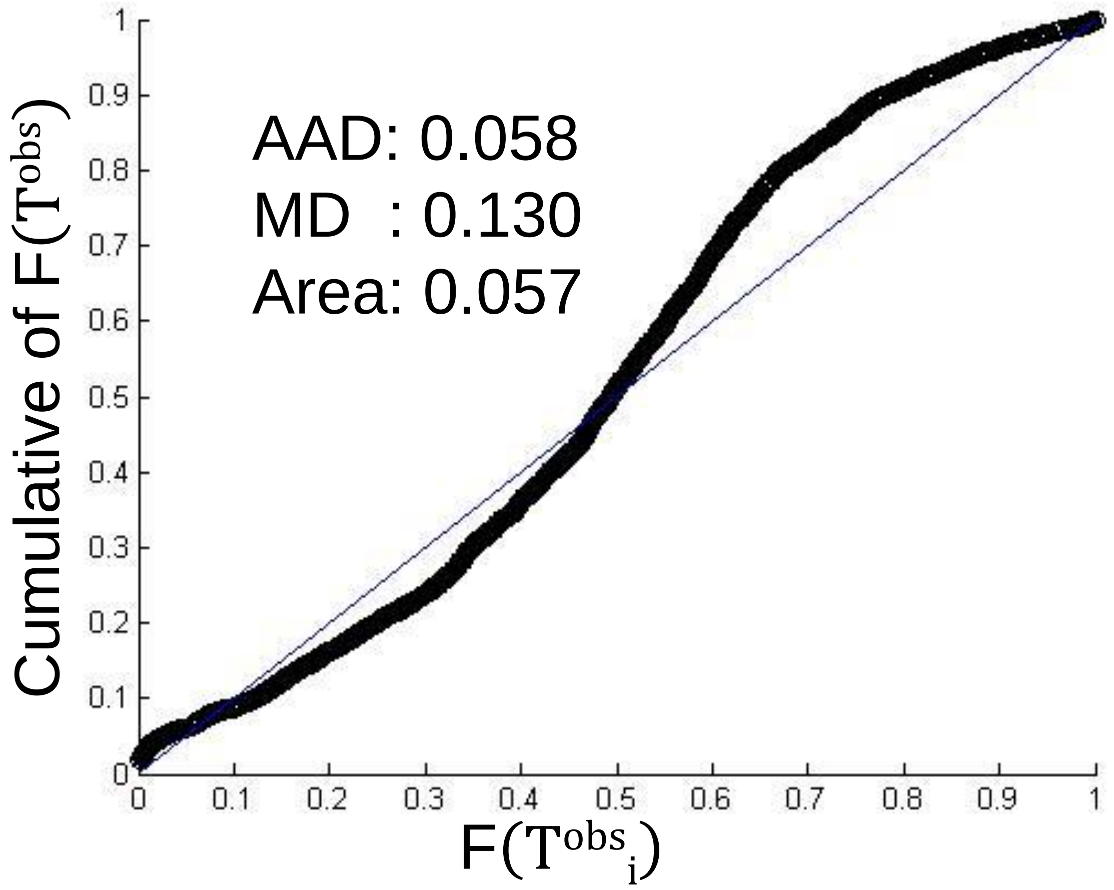




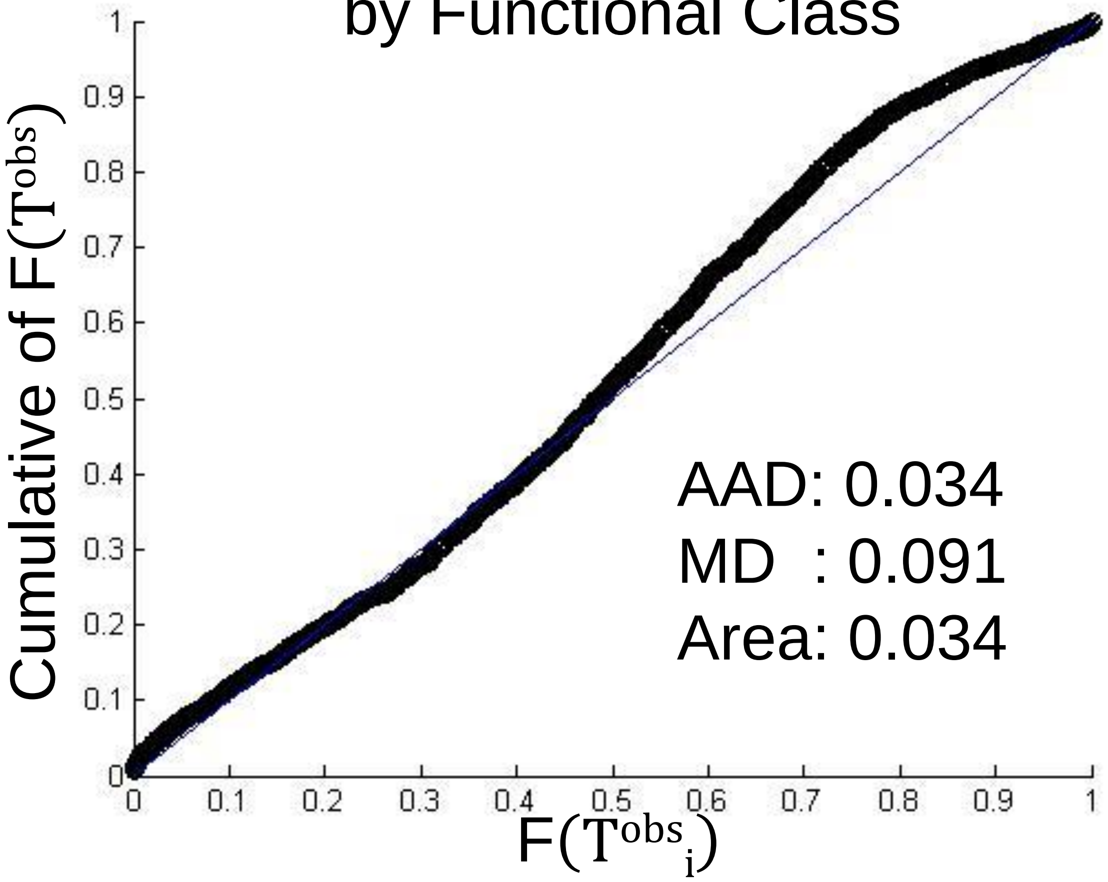


Traffic Assignment Validation
Aggregated vs. Segmented (Bias and Error) Calibration

Aggregated Calibration



Segmented Calibrations by Functional Class



Calibrating Bias and Error Distributions for Each Functional Class Improves Results

Empirical Applications

- Link volumes from traffic assignment
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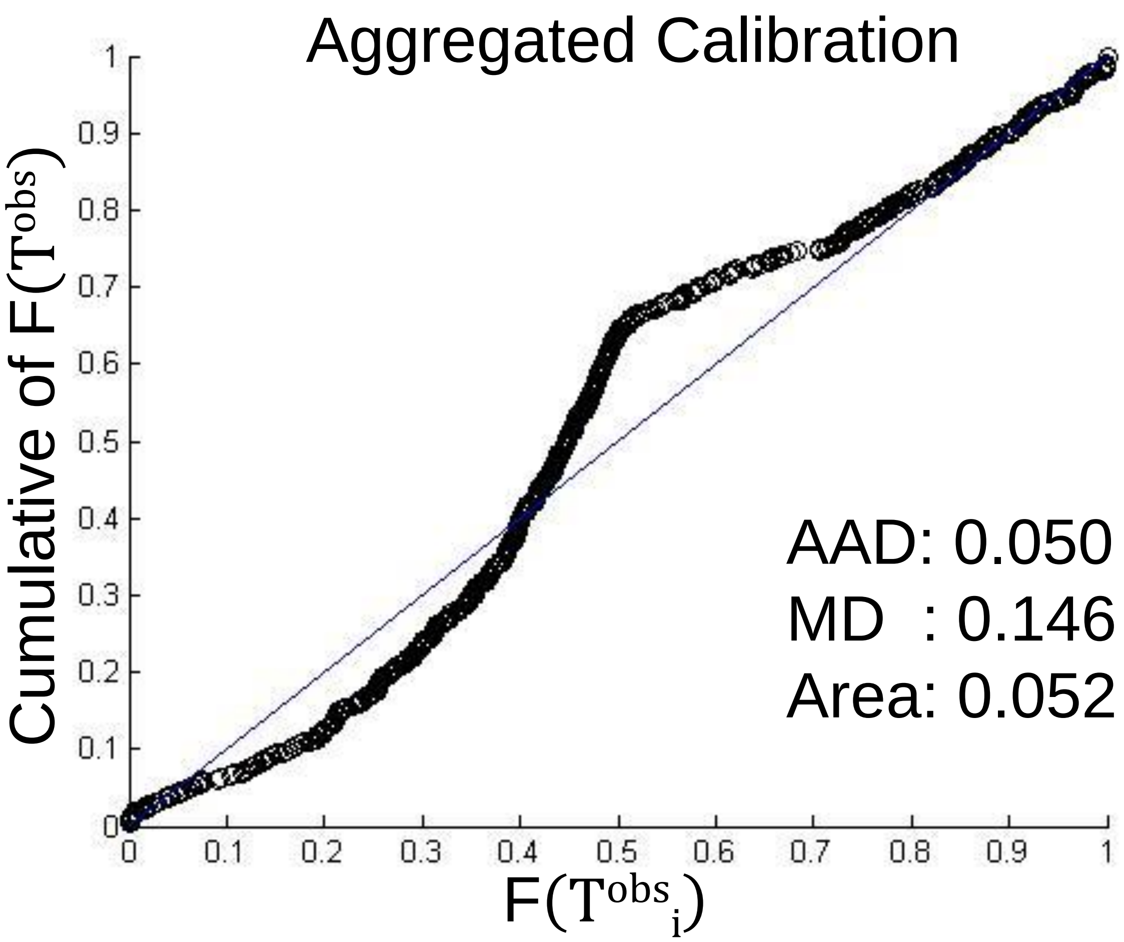
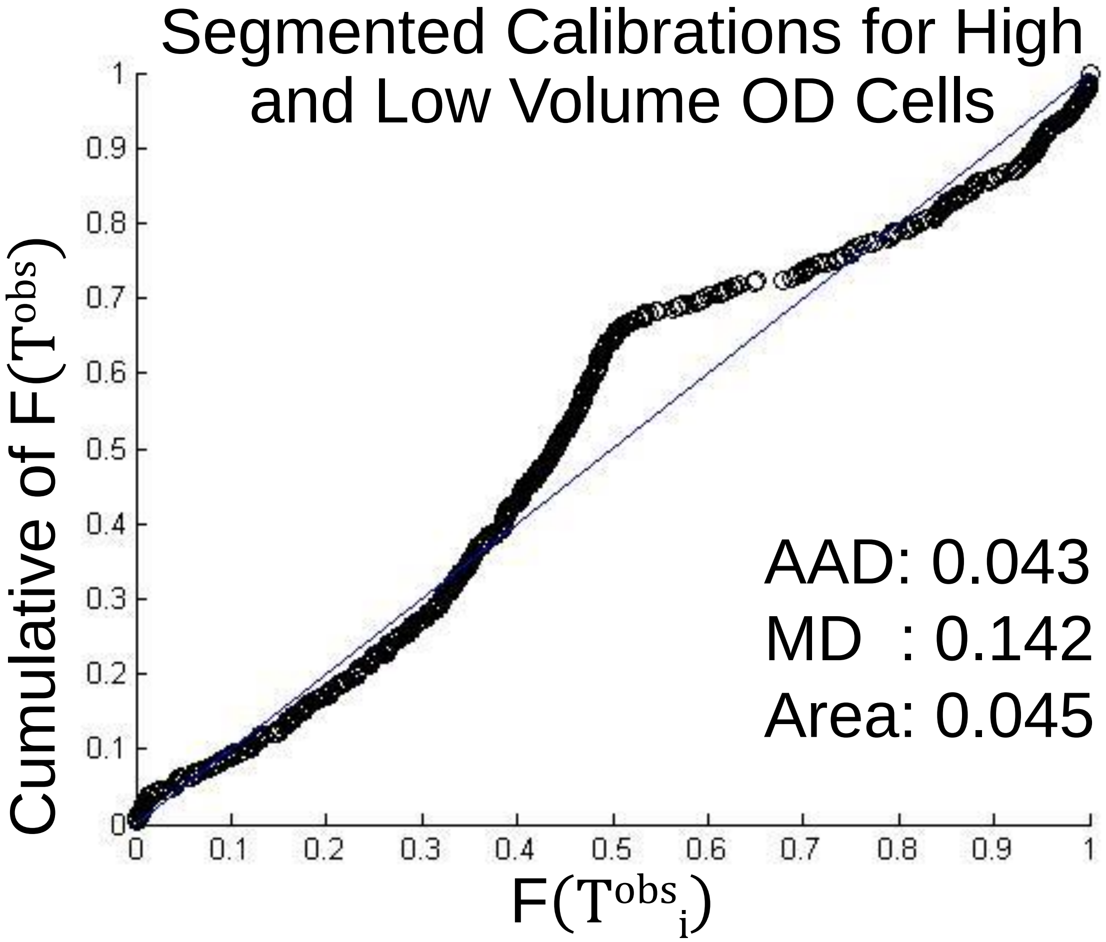
- Bus passenger OD (B2A) flows from estimations based on boarding and alighting data
  - The Ohio State University Campus Transit Lab OD flow observations (http://transitlab.osu.edu/campus-transit-lab)
  - Boarding and alighting observations for six academic terms
  - Model output using Iterative Proportional Fitting (IPF) method

Bus OD Flow
Aggregated vs. Segmented (Bias and Error) Calibration





Calibrating Bias and Error Distributions for High/Low Volume Cells Improves Results

Conclusions

- Preliminary validation studies indicate the approach is capturing uncertainty appropriately
- Additional studies needed to refine approach and produce more robust validation studies ("spin-off" research investigations also envisioned)
- *Request for agency model validation data*

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