# Simultaneous Off-Line Demand and Supply Calibration of Dynamic Traffic Assignment Systems

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# Motivation

- Dynamic traffic assignment (DTA) systems
  - Demand, supply processes and interactions
    - Several complex model components, algorithms
  - Large number of inputs and parameters
- Model parameters must reflect reality
  - Calibration aims at reducing error between system output and observed data

# Literature Review

- Individual model component calibration
  - Demand
    - OD estimation (*e.g. [ 4, 3, 1 ]* )
  - Supply
    - Sensor data fit locally (*e.g. [ 12 ]* )
    - Limited applications of network-wide estimation (*e.g. [ 9, 10 ] )*
- System-level calibration
  - Two-step process (*e.g. [ 7, 6, 11, 5 ]* )

# Methodology

$$\underset{\mathbf{x},\boldsymbol{\beta}}{Minimize} \sum_{h=1}^{H} \left[ z_1(\mathbf{M}_h, \hat{\mathbf{M}}_h) + z_2(\mathbf{x}_h, \mathbf{x}_h^a) \right] + z_3(\boldsymbol{\beta}, \boldsymbol{\beta}^a)$$

subject to:

$$\hat{\mathbf{M}}_h = f\left(\mathbf{x}_1, \ \ldots \ , \mathbf{x}_h, \boldsymbol{\beta}, G_1, \ \ldots \ , G_h\right)$$

- Advantages
  - Direct use of simulator output
  - Flexibility to include general traffic data
  - Simultaneous demand-supply estimation
  - Simultaneous OD estimation across time intervals

# Problem Dimensions

- Complex DTA function *f*
  - Highly non-linear and non-analytical (simulator)
  - Potentially noisy
    - Unreliable gradients
- Very large scale in **x**, β
  - Demand parameters (OD flows) typically dominate

# Solution

- Box Complex *[ 2 ]*
  - Span search space; locate potential optima

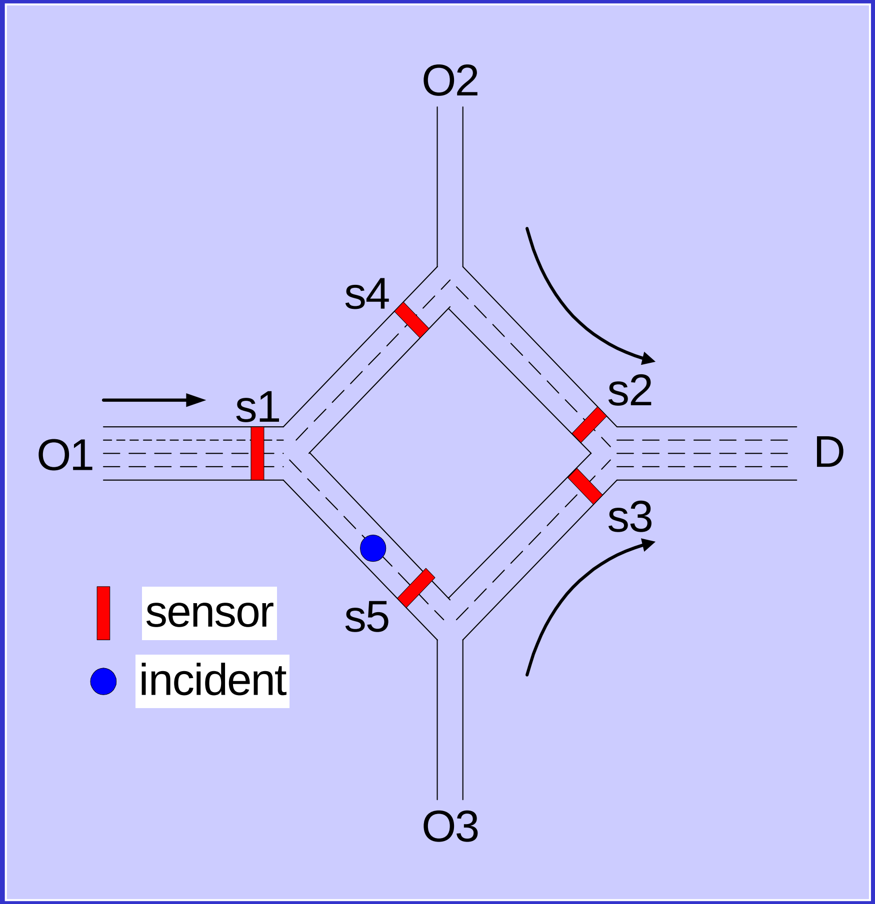
- SNOBFIT *[ 8 ]*
  - Stable Noisy Optimization by Branch and Fit
  - Refine search through local quadratic fitting

- Population-based global search
  - Gradient-free approach

# Case Study

- Objectives
  - Demonstrate and evaluate calibration approach
    - Simultaneous temporal demand estimation
    - Simultaneous demand-supply estimation
    - Impact of speed data
  - Validate solution algorithm
    - Examine performance: sensitivity analysis

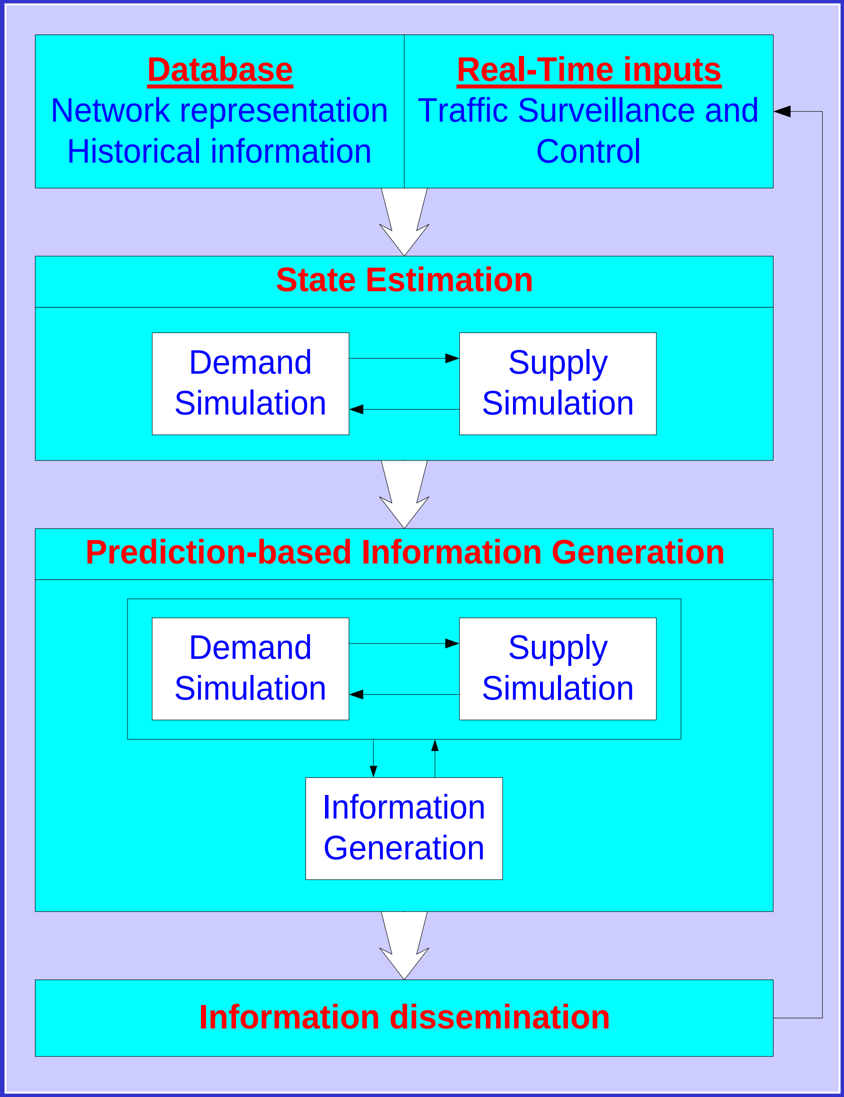
# Network




- “Actual conditions”:MITSIM
  - Flexible scenarios
  - 50 minutes (10 intervals)
  - Sensor data: counts, speeds
- Calibration
  - DynaMIT
  - Demand variables: OD flows, route choice
  - Supply parameters: capacities, speed-density function parameters

# DynaMIT Overview

- Demand simulation
  - Dynamic OD flow estimation and prediction
  - Route choice and response to information
- Supply simulation
  - Queuing
  - Traffic dynamics
- Interactions



# Estimators and MOE

- Reference estimator
  - Known demand, local supply parameter fitting
- Network-wide estimators

| Estimated Parameters | Calibration Data | |
|---|---|---|
| | Counts | Counts+Speeds |
| Supply (known Demand) | $S_c$ | $S_{cs}$ |
| Supply and Demand | $SD_c$ | $SD_{cs}$ |

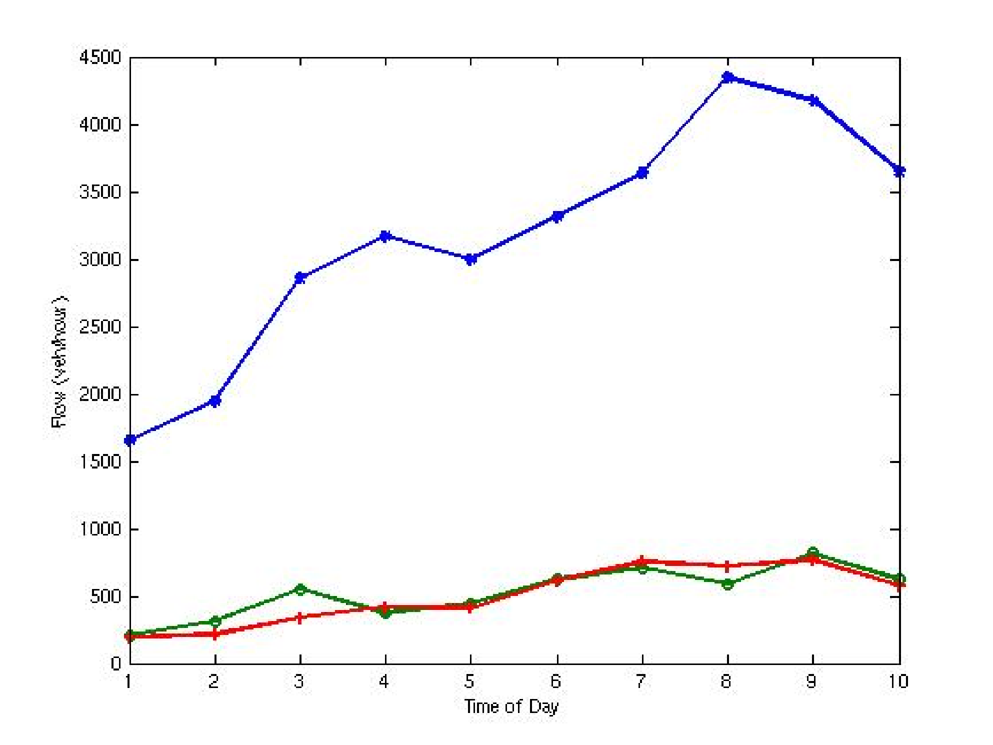
$$RMSE = \sqrt{\frac{1}{S}\sum_{i=1}^{S}\left(y_i - \hat{y}_i\right)^2}$$

$y_i, \hat{y}_i$ : observed and fitted sensor data

$S$ : total number of data points

# Base Case

- Representative demand, supply situations
  - Route choice
  - Weaving and merging behavior
  - Incident
  - OD flow profiles:



# Base Case Results

| Scenario | Sensor Data Used for Calibration | | | |
|---|---|---|---|---|
| | Counts | | Counts + Speeds | |
| | $RMSE^c$ | $RMSE^s$ | $RMSE^c$ | $RMSE^s$ |
| **S** | 15.89 (7.6) | 2.86 (25.7) | 16.86 (1.9) | 2.29 (40.5) |
| **SD** | 15.87 (7.7) | 3.02 (21.6) | 16.69 (2.9) | 2.24 (41.8) |

Reference: $RMSE^c$ = 17.19, $RMSE^s$ = 3.85

S : Network-wide supply calibration

SD : Joint supply-demand calibration

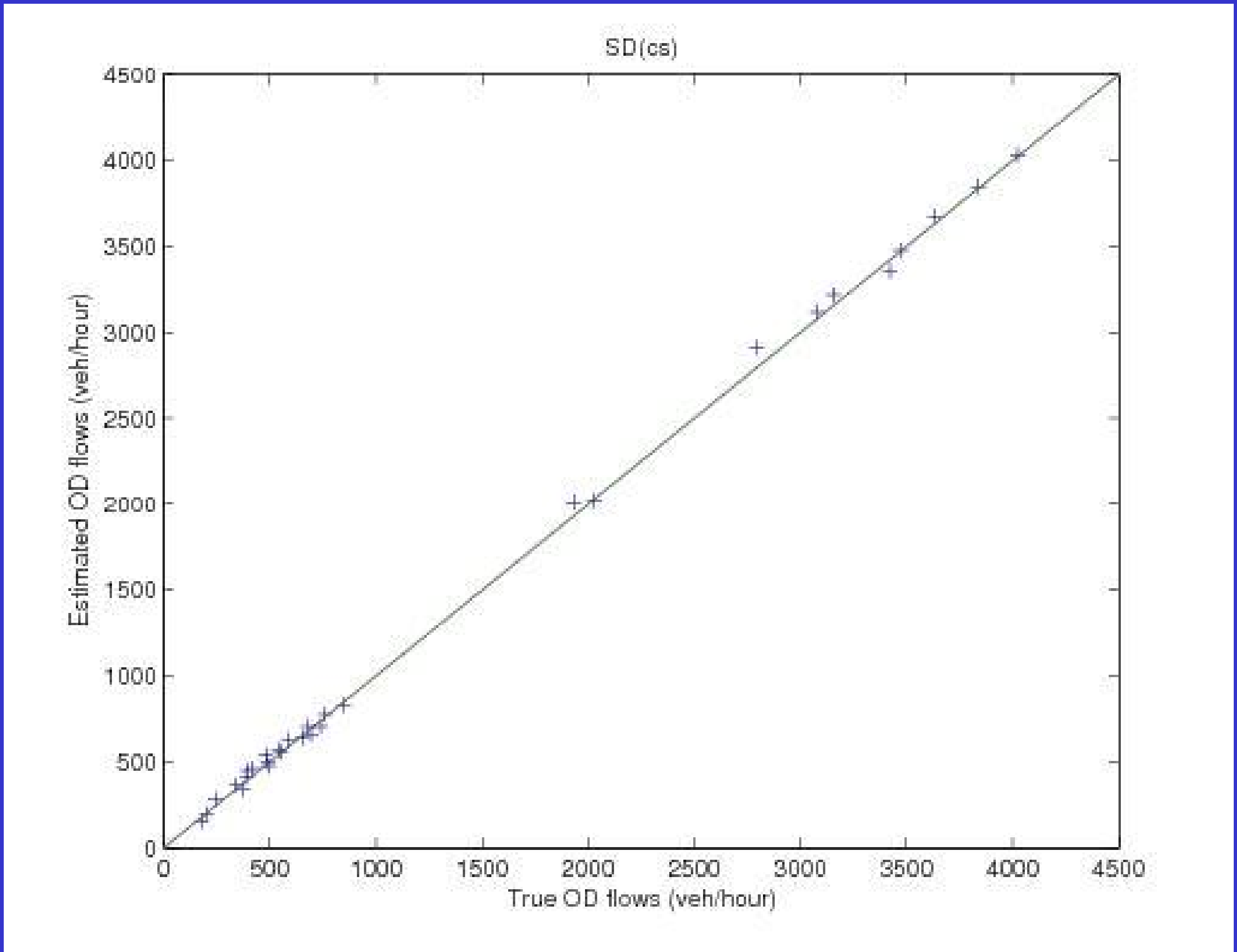
( ) : Percent improvement over Reference

$RMSE^c$ : root mean square error, counts

$RMSE^s$ : root mean square error, speeds

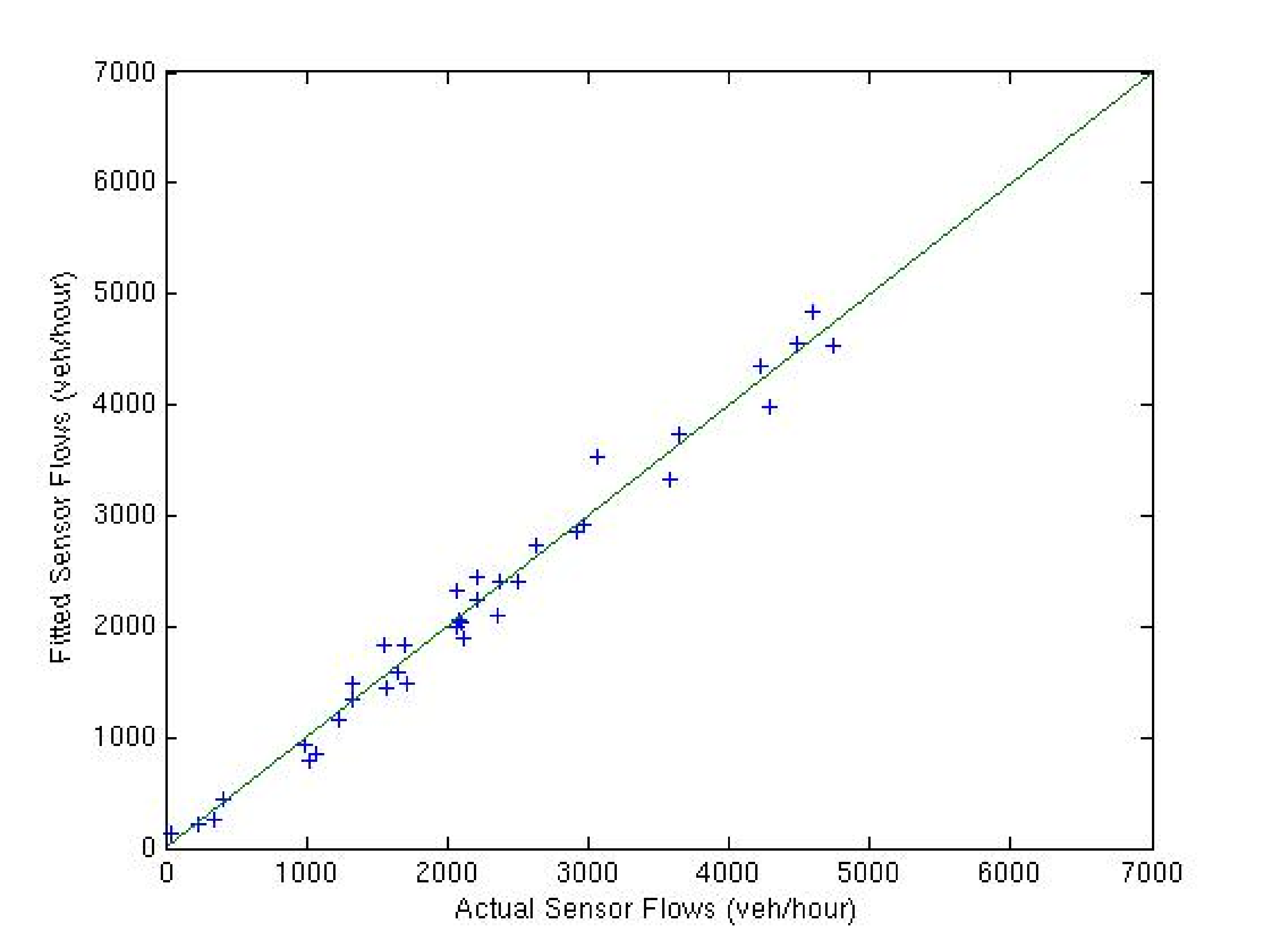
# Base Case Results

## Estimated vs. “True” OD Flows



# Base Case Results

## Simulated vs. Actual Sensor Flows



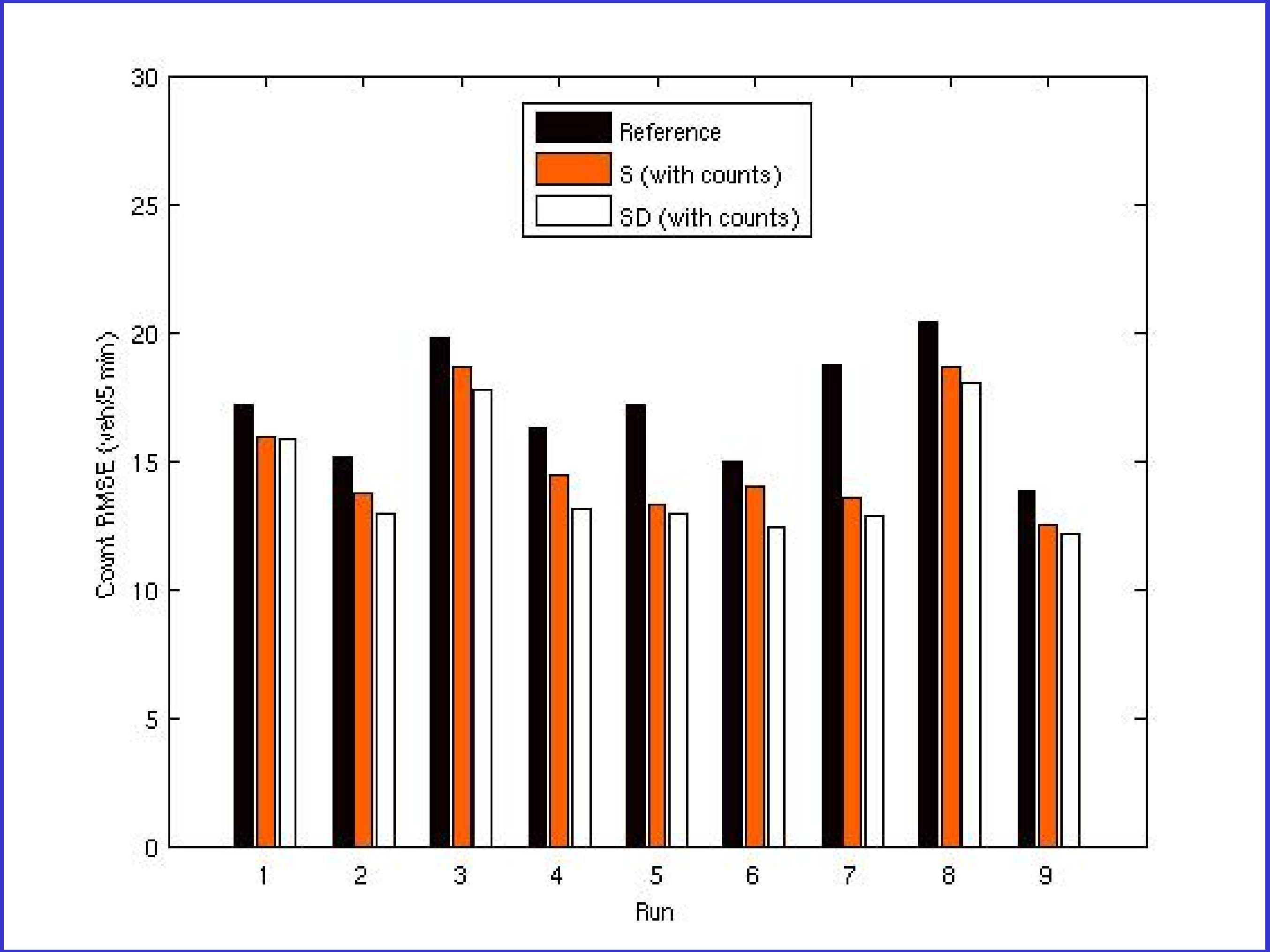
# Sensitivity Analysis

| Factor | Levels | | |
|---|---|---|---|
| | **-1** | **0** | **1** |
| **Route choice** | -0.01 (Time-insensitive) | -0.03 | -0.15 (Deterministic) |
| **OD spatial** | Lower main flow Higher side flow | Balanced | Higher main flow Lower side flow |
| **OD temporal** | Historical (No variance) | Historical + Low-variance error | Historical + High-variance error |
| **Desired speed** | Slower | Typical | Faster |

| Run | Factors | | | |
|---|---|---|---|---|
| | Route Choice | OD: Spatial | OD: Temporal | Desired Speed |
| 1 (Base) | 0 | 0 | 0 | 0 |
| 2 | -1 | 0 | 0 | 0 |
| 3 | 1 | 0 | 0 | 0 |
| 4 | 0 | -1 | 0 | 0 |
| 5 | 0 | 1 | 0 | 0 |
| 6 | 0 | 0 | -1 | 0 |
| 7 | 0 | 0 | 1 | 0 |
| 8 | 0 | 0 | 0 | -1 |
| 9 | 0 | 0 | 0 | 1 |

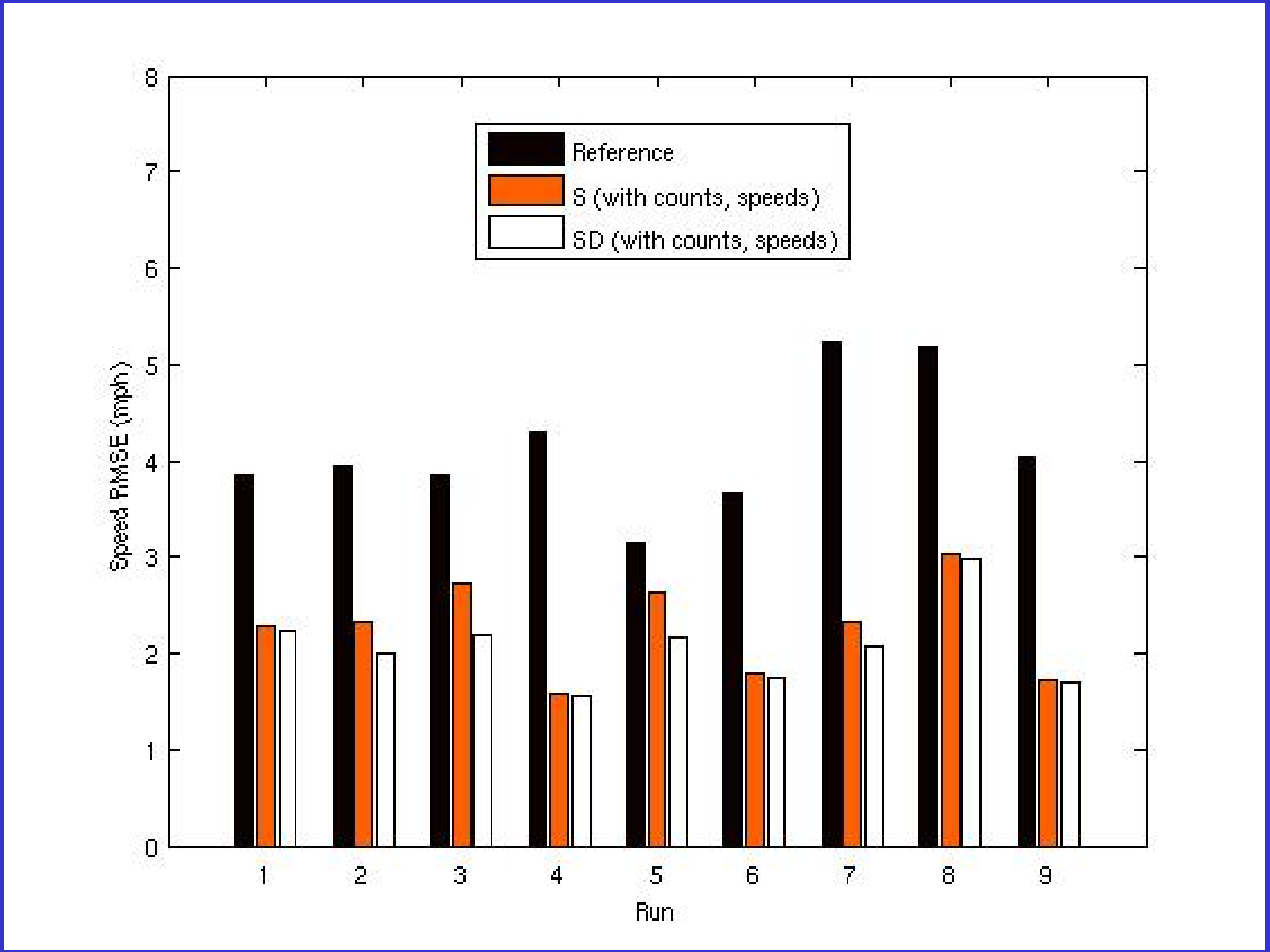
# Sensitivity Analysis Results

## Fit to Sensor Counts



# Sensitivity Analysis Results

## Fit to Sensor Speeds



# Conclusion

- Network-wide supply calibration
- Speed data significant
- Simultaneous demand-supply estimation feasible, efficient
- Approach robust under various demand, supply conditions
- Current research: Application to real networks

# References

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