



Disclaimer

This presentation has not been reviewed by SHRP 2 and reflects solely the opinion of the presenter. It does not necessarily reflect the opinion of the National Academies, its units, or any group or individual helping oversee the work of SHRP 2 contractors

McCormick



Northwestern Engineering

Northwestern University Transportation Center

Incorporating Reliability Performance
Measures in Evaluation Tools:
Physics, Psychology and Economists

International Conference on Travel Time Reliability

Vancouver, BC

October 15-16, 2009

Reliability and Project Evaluation

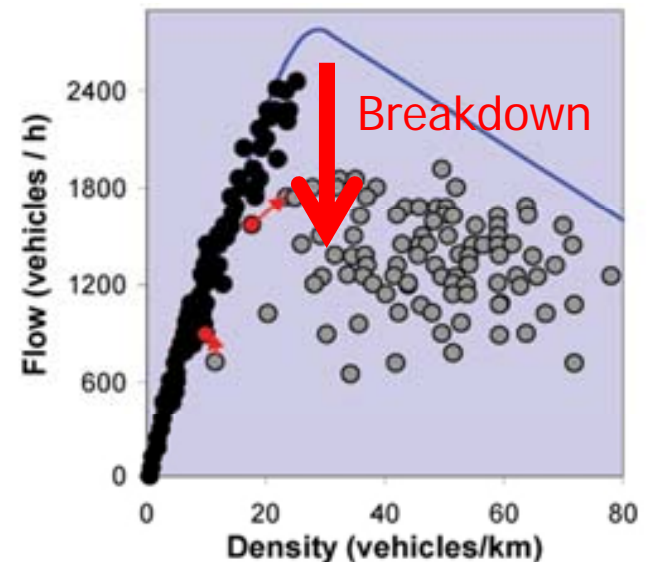
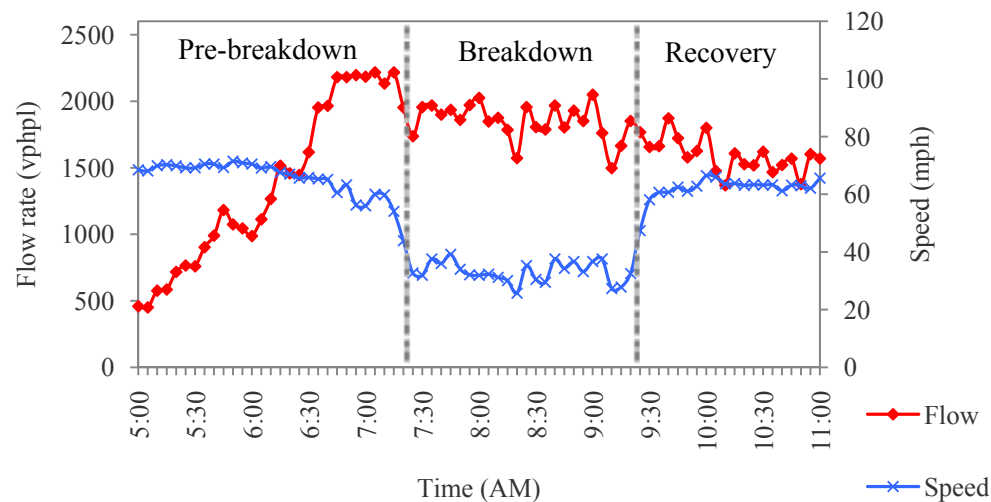
- People care about reliability
- Reliability affected by both Design, Operation, and Management
- Reliability affected by user behavior: in response to management, over the long run
- Challenges for project evaluation: reference for comparison

Reliability and System Management

- Traffic physics: human behavior causes unreliability– inherent randomness, collective effects

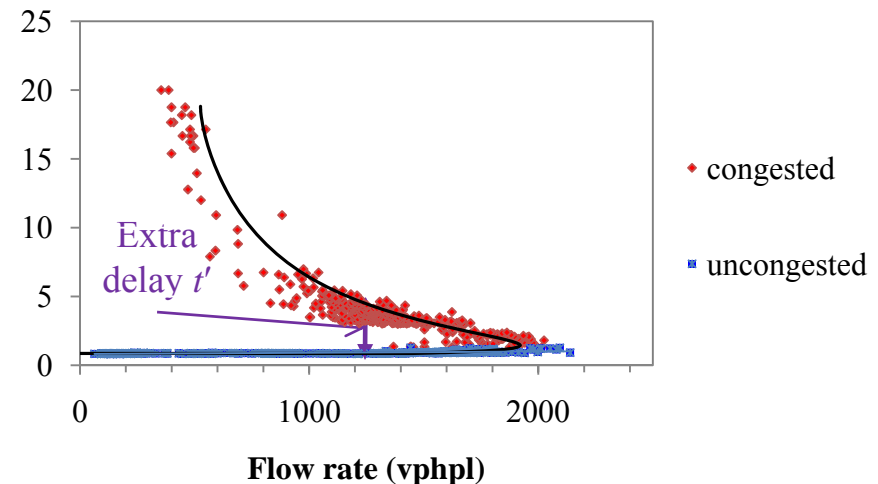
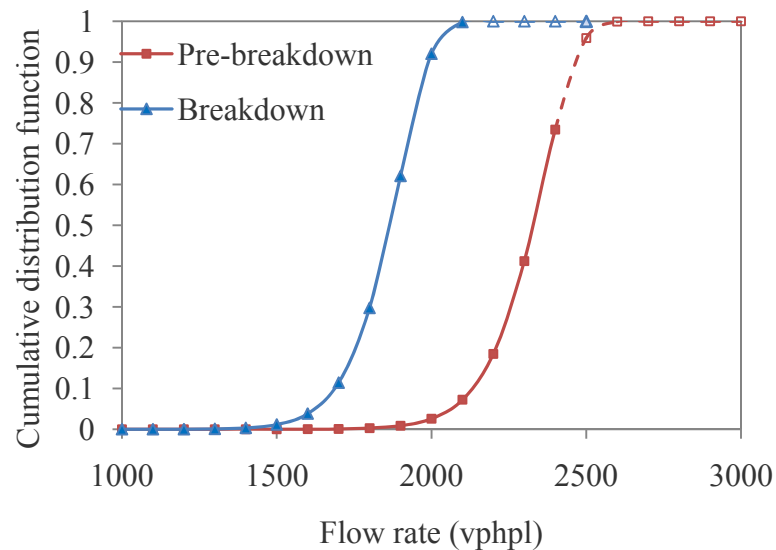
Flow Breakdown

- Flow breakdown is a collective phenomenon resulting from many individual decisions
- While some of its aspects are predictable and systematic, flow breakdown remains an inherently stochastic phenomenon
- Empirical studies have documented that breakdown might occur with some probability at various flow rates.



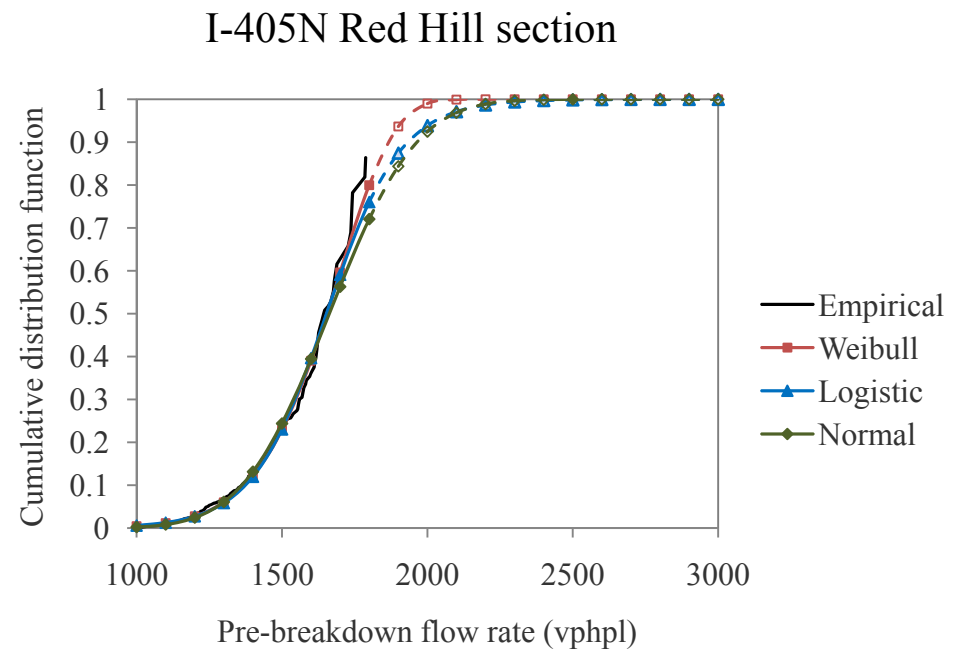
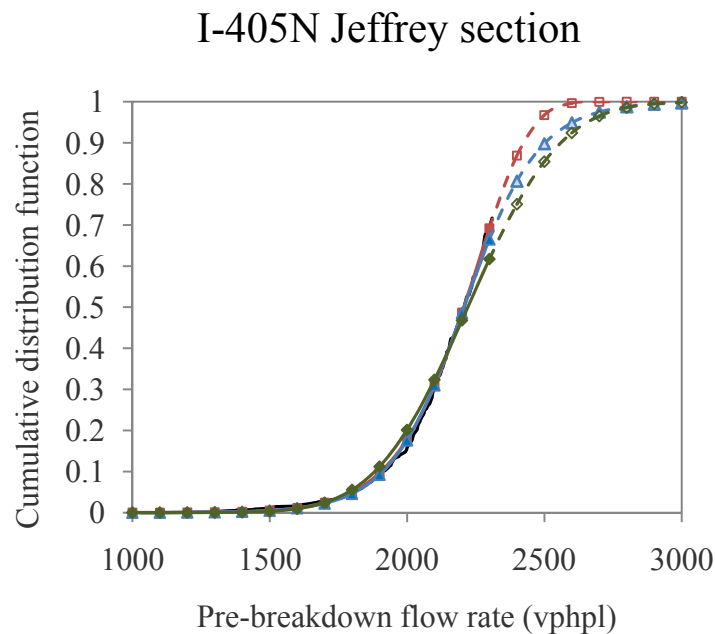
Flow Breakdown and Travel Time Reliability

- Pre-breakdown and breakdown flow rates are viewed as random variables
- The difference between two distributions indicates “capacity drop” during flow breakdown (Banks, 1991; Cassidy and Bertini, 1999).
- During flow breakdown extra delay is encountered



Probabilistic Description of Flow Breakdown

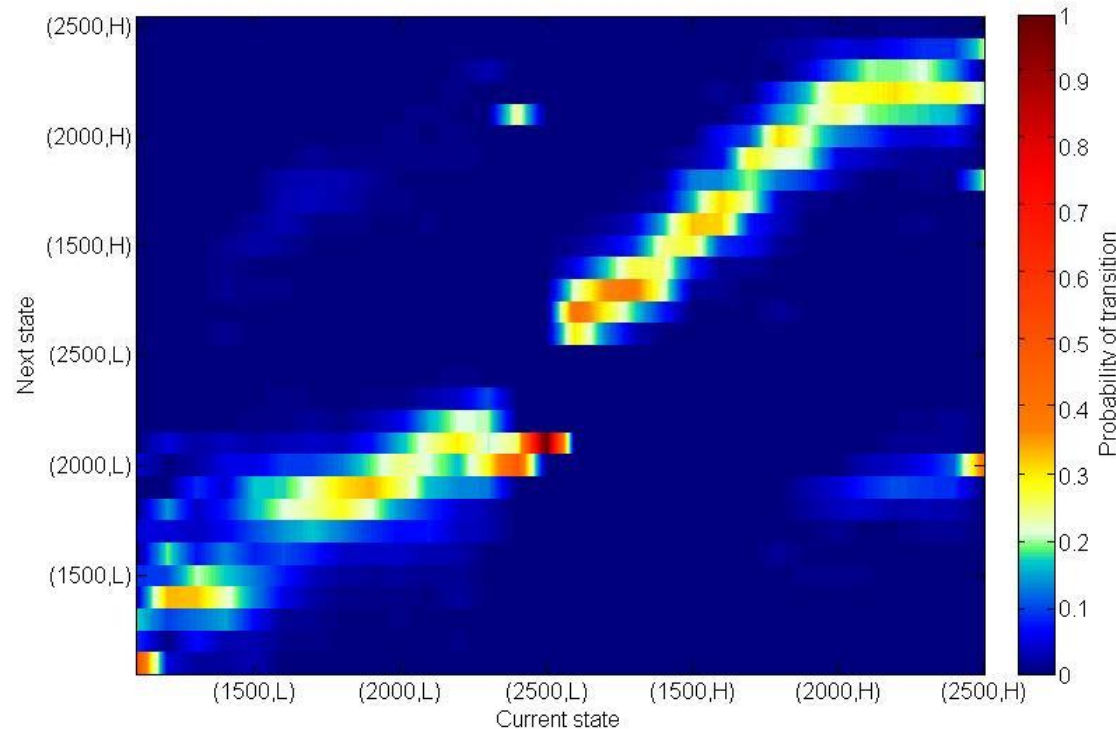
- Pre-breakdown flow rate is viewed as a random variable
- MLE of the pre-breakdown flow rate distribution function based on censored observations
- Kaplan-Meier estimate provides the empirical distribution



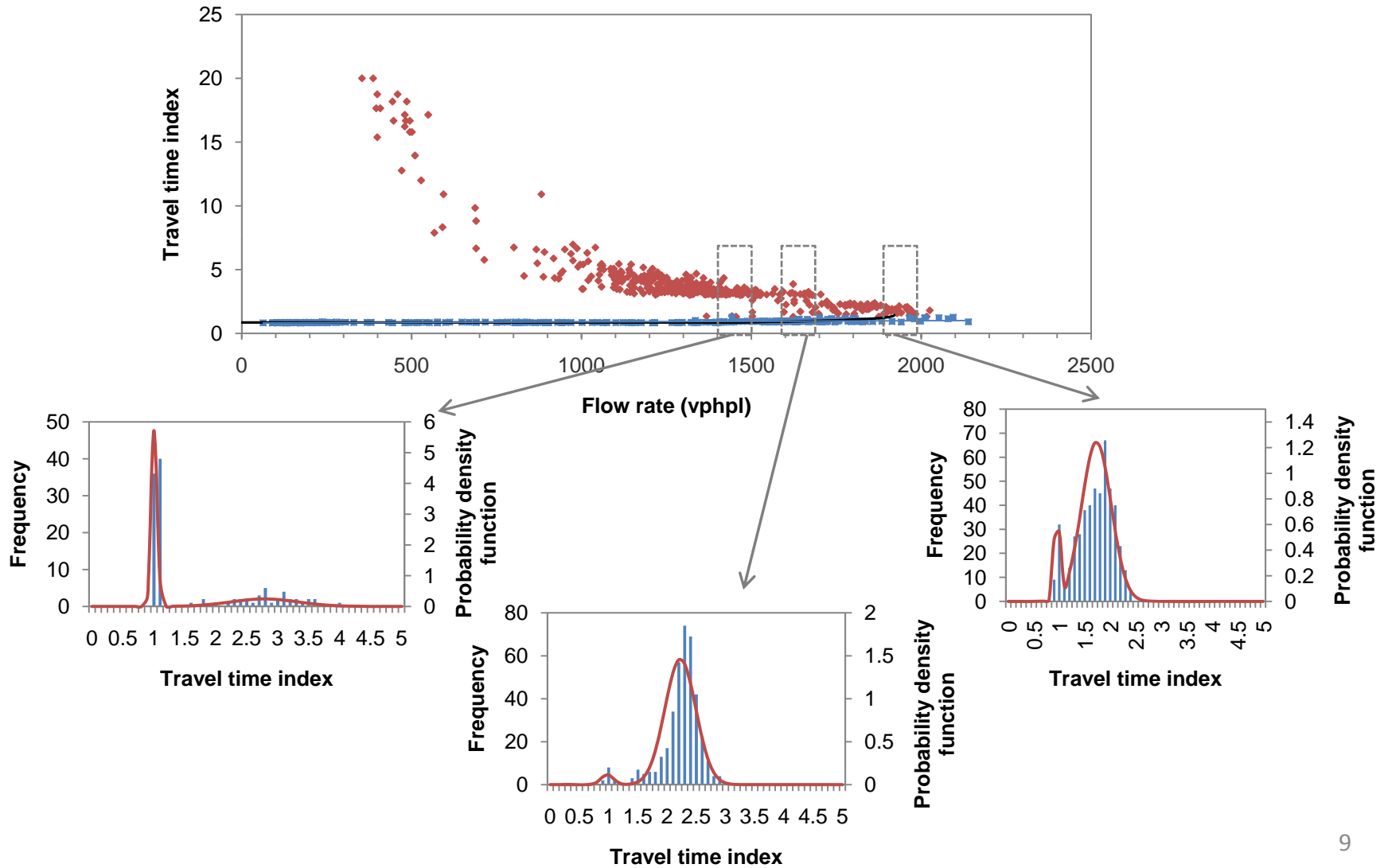
A Markov Chain Approach to Model Breakdown - Probability of Transition

- The transition probability p_{ij} pertains to the probability of moving from state i to state j .
- The transition probability matrix, $P=[p_{ij}]$, is estimated by MLE.

$$p_{ij} \geq 0, \forall i, j \in S \quad \sum_{j \in S} p_{ij} = 1, \forall i \in S$$



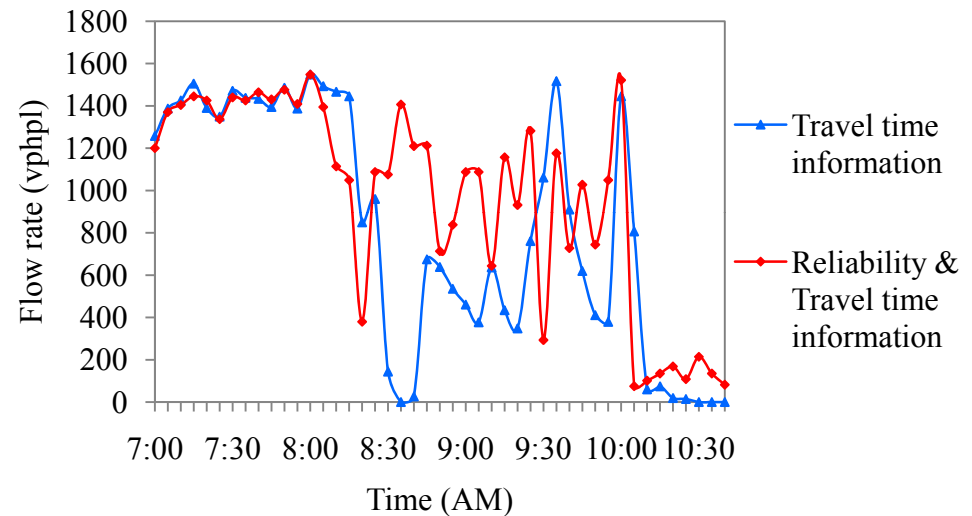
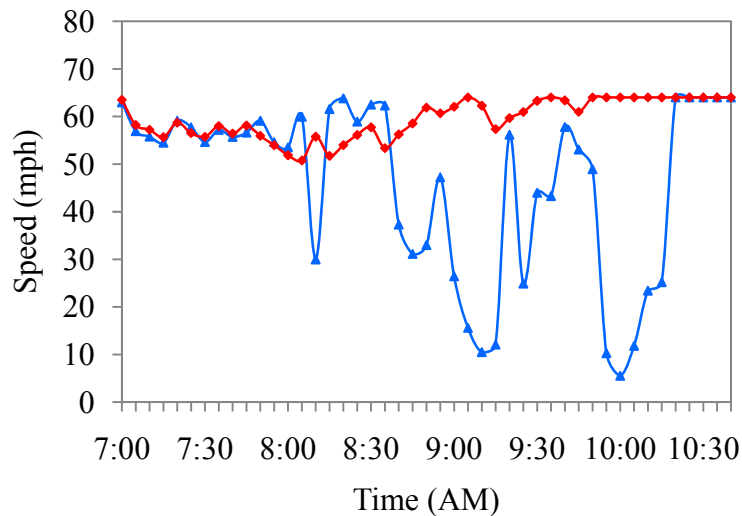
Travel Time Distribution



Reliability and System Management

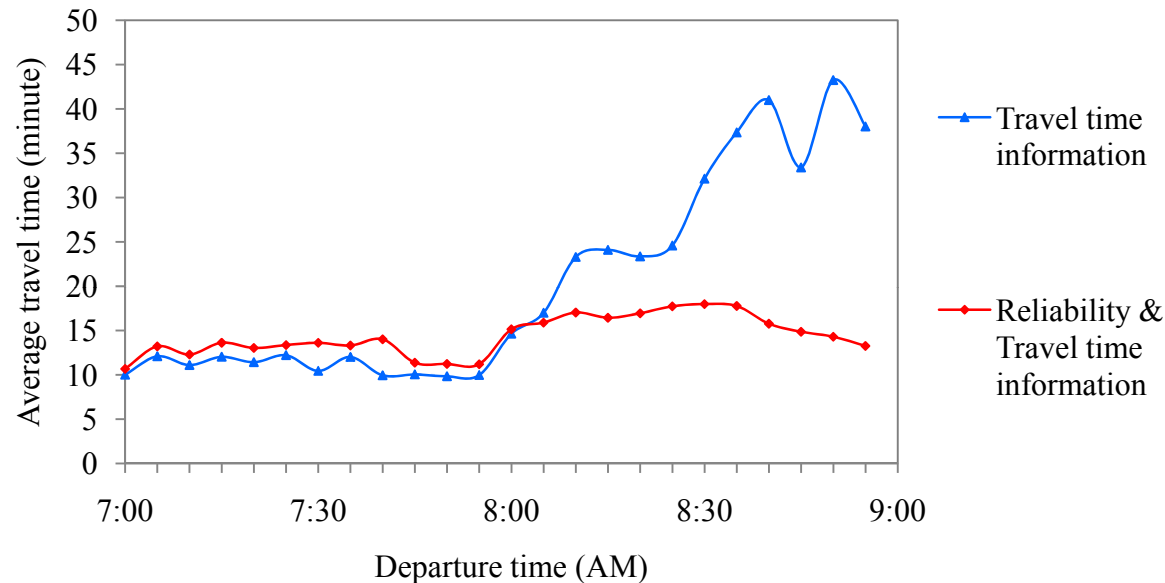
- Traffic physics: human behavior causes unreliability– inherent randomness, collective effects
- Management affects travel time reliability:
 - INFORMATION affects reliability
 - PRICING affects reliability
 - INTEGRATED TRAFFIC MANAGEMENT affects reliability

ANTICIPATORY INFORMATION AFFECTS RELIABILITY



- Providing travel reliability information contributes to delaying the onset of breakdown and alleviating its extent
- Higher and more stable flow is observed under the reliability scenario, indicating an increase in freeway throughput

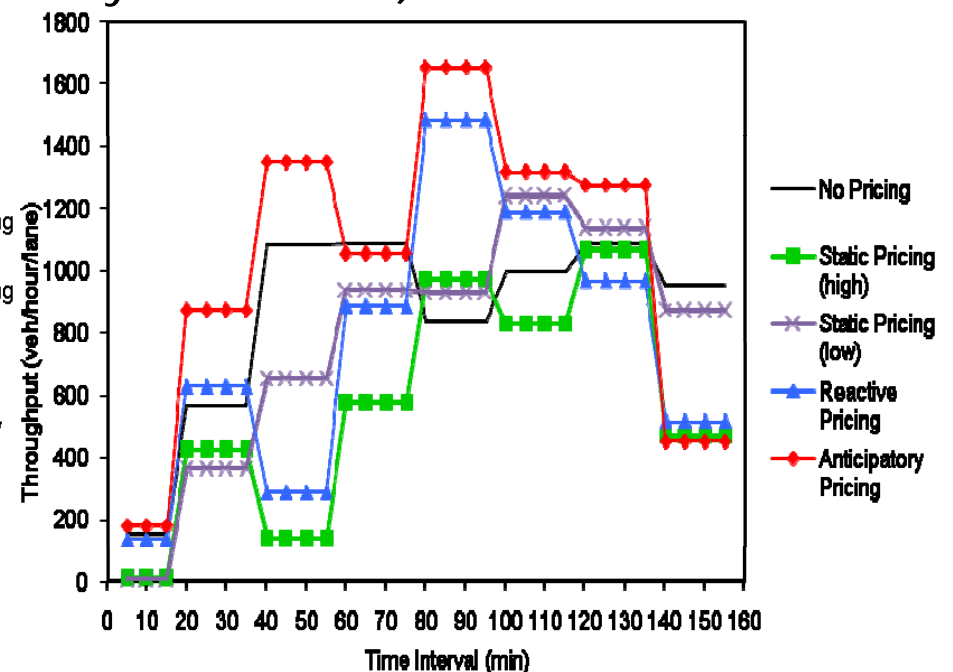
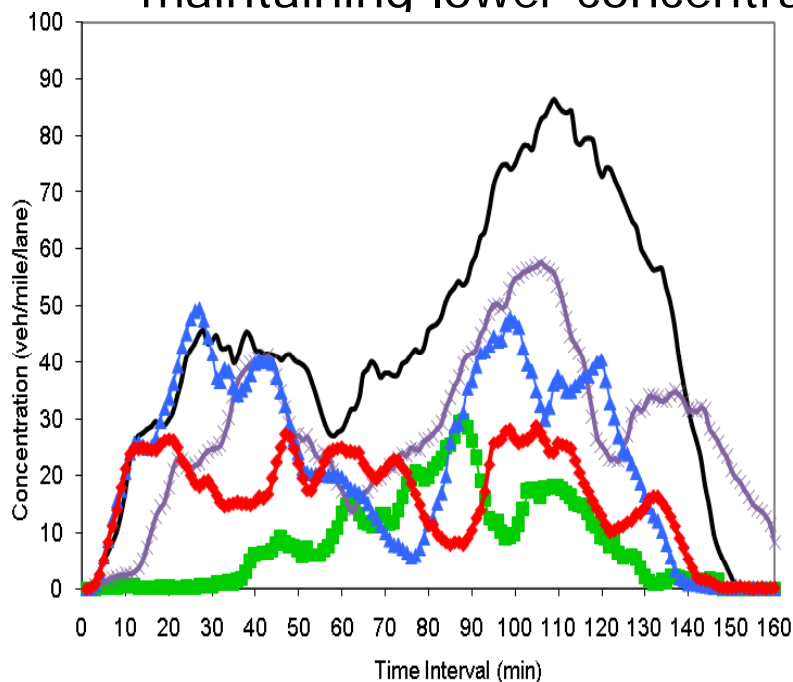
Effectiveness: Average Travel Time



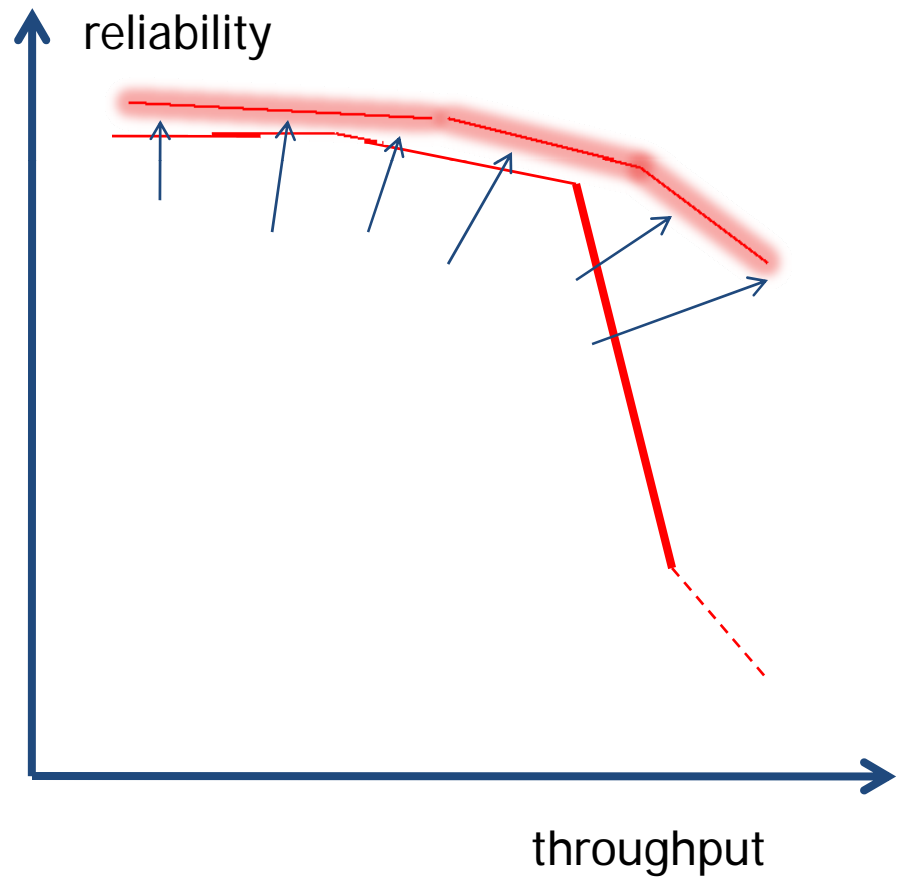
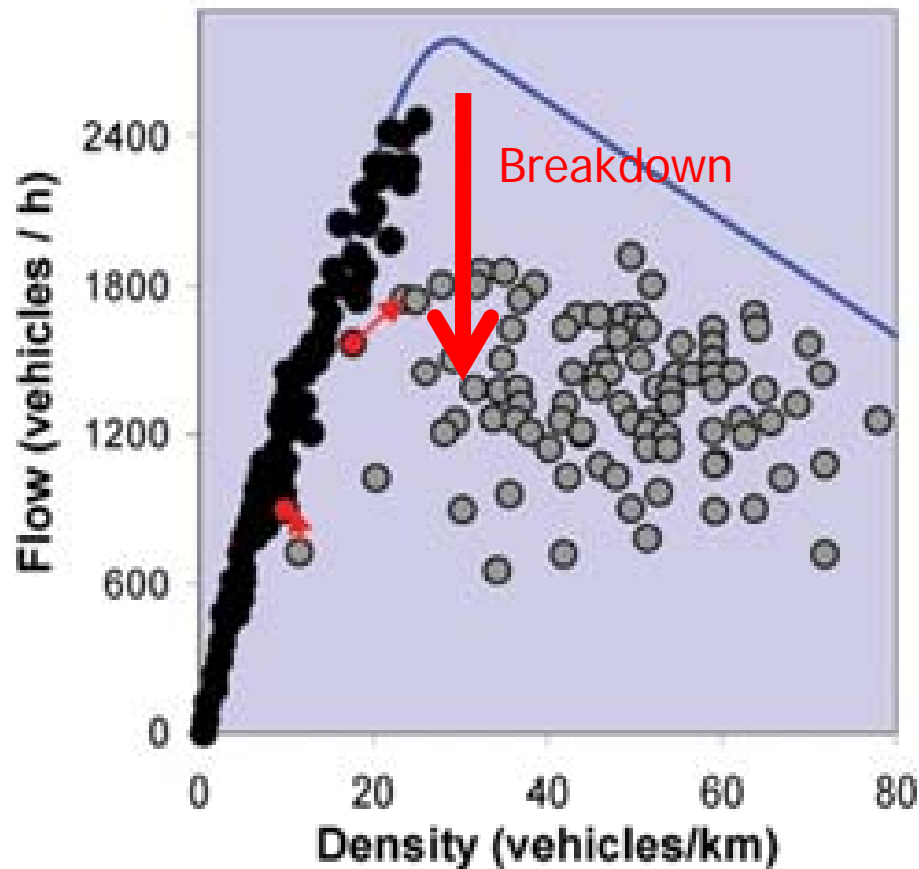
- Scenarios:
 - only anticipatory travel time information is provided
 - both anticipatory travel time and reliability information is available
- Significant time savings are observed when **travel reliability information** is provided in addition to **travel time information**

ANTICIPATORY PRICING AFFECTS RELIABILITY

- Concentrations averaged over links along the congested portion of toll road, weighted by the link length
- Throughput measured at downstream of where traffic breaks down in base case (no pricing)
- Anticipatory pricing strategy can provide higher throughput while maintaining lower concentration (steady traffic flow)



Throughput vs. Reliability



Reliability and System Management

- Traffic physics: human behavior causes unreliability– inherent randomness, collective effects
- Management affects travel time reliability
 - ➔ So what are we exactly evaluating?
Well managed or poorly managed future systems?
- Psychology: user response and adaptation affects reliability

Behavioral Considerations

- “Indifference band” of arrival times in congested situations:
People not only adjust their decisions but also adjust indifference band in response to experienced fluctuations in performance
- In real systems, users cope with complexity using simple rules: buffer time, safety margin– confounded with perception/judgment
- Conventional SP exercises limited in uncovering underlying preferences; games, laboratory experiments, experimental economics more promis
- Strong interactive effects that suggest that system may be in dynamic disequilibrium rather than stationary equilibrium
- Risk attitudes: risk seekers prefer variability– experimental evidence (Bogers, 2009) that some drivers prefer routes with high variability hoping to attain lower travel times...
- Assumption of users facing stationary and known (and understood...) distribution of travel times highly questionable

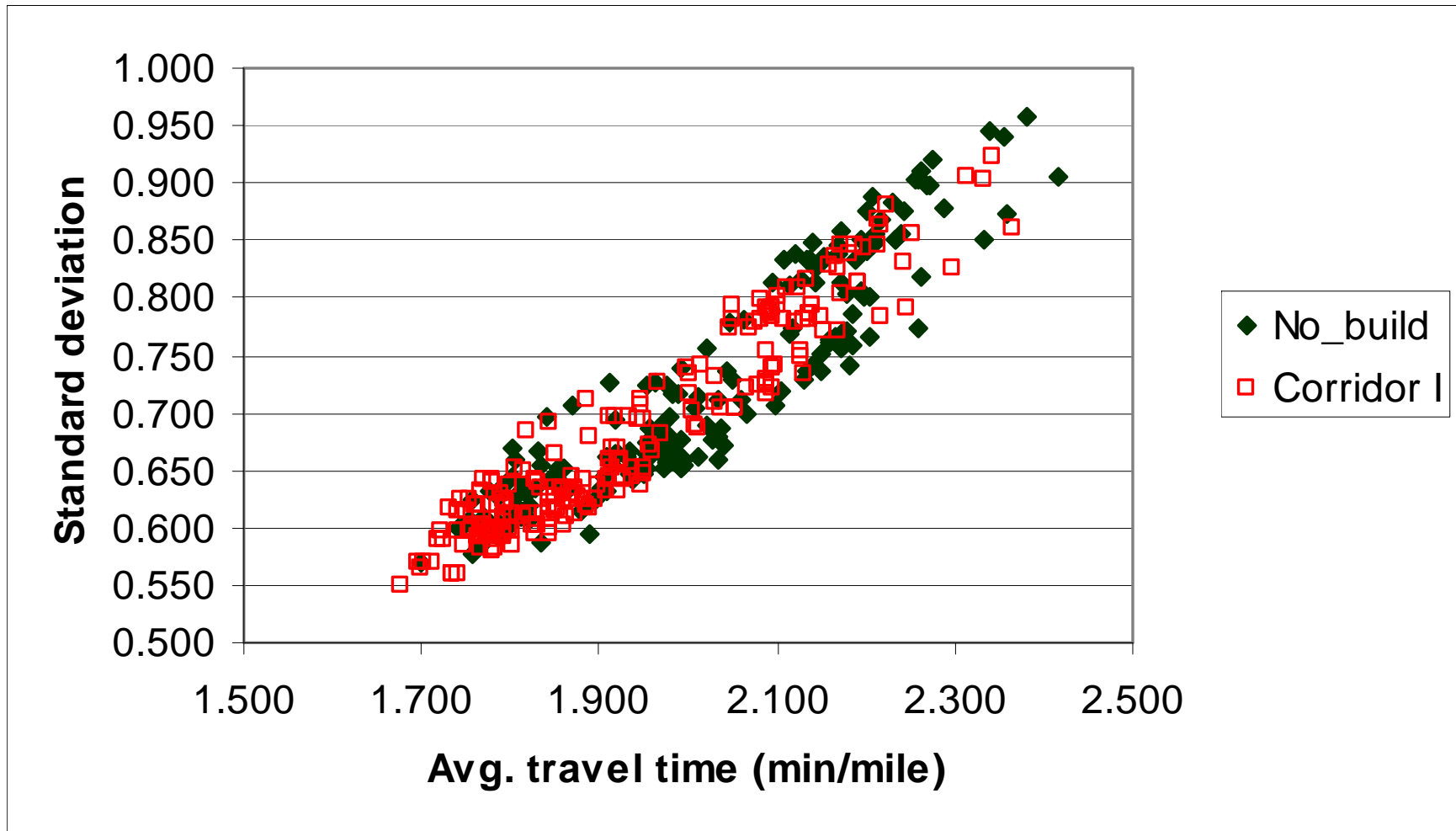
Network Traffic Physics

- Strong correlation between travel times in different parts of the network
 - Adjacent links are likely to experience high delays in the same general time period than unconnected links
 - Difficult to capture these correlation patterns when only link level measurements are available
 - Difficult to derive path-level and OD-level travel time distributions from the underlying link travel time distributions
 - Link-level relations not robust

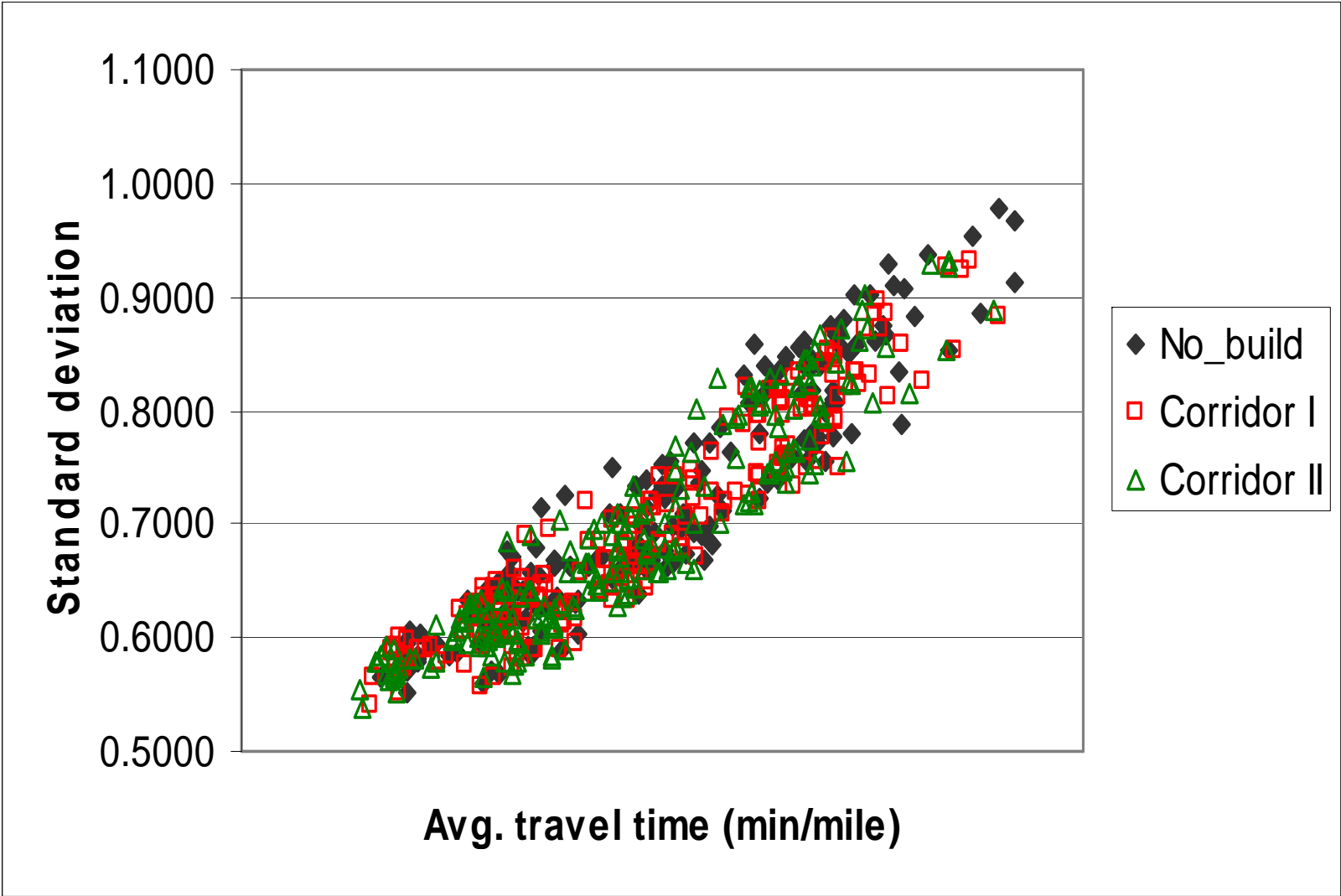
Travel Time Reliability

Standard Deviation vs. Average Travel Time

(Greater Washington, DC network: OD level variability)



Derived from static assignment model results under ergodicity assumptions



Irvine Network



- Network

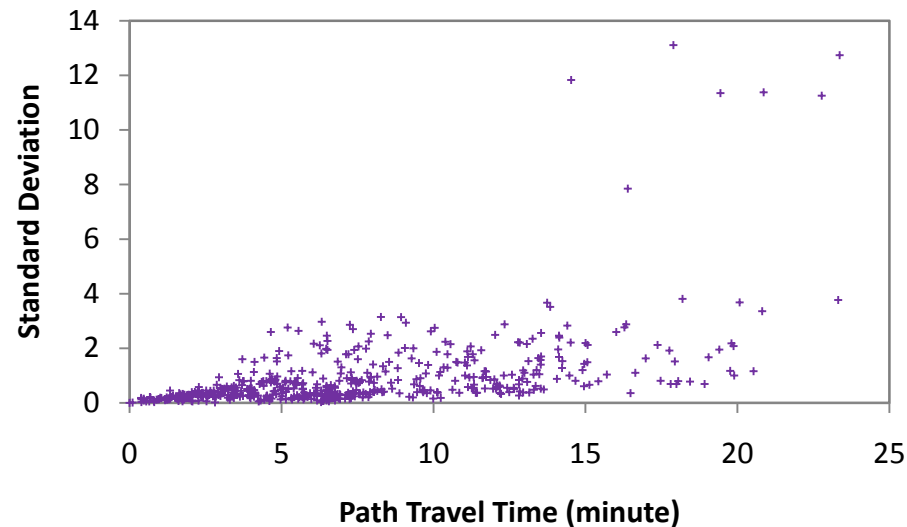
- Freeways I-405, I-5, state highway 133
- 326 nodes
- 626 links
- 61 TAZs

- Demand

- Two hours morning peak (7-9AM)

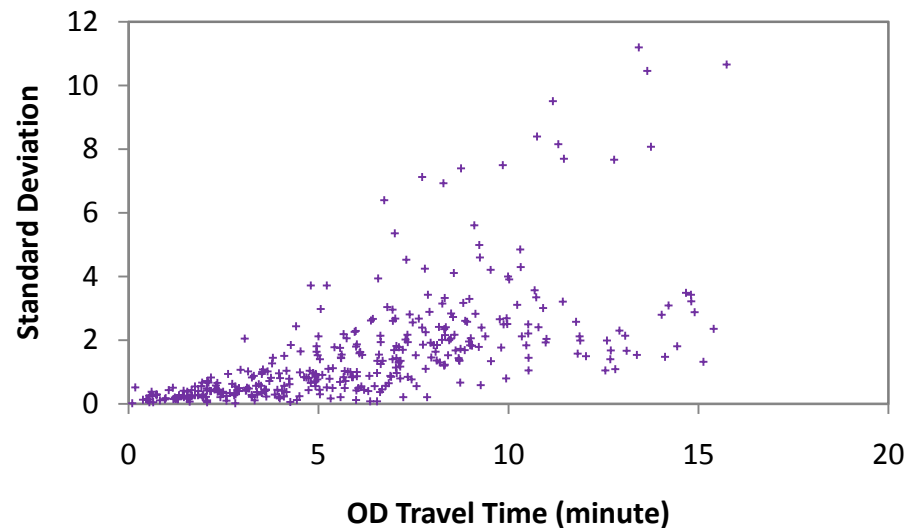
Path Travel Time and Standard Deviation

- Each data point represents the mean and standard deviation of travel times for all the vehicles (over the entire planning horizon) traveling on one path.
- Only paths with more than 10 vehicles are considered



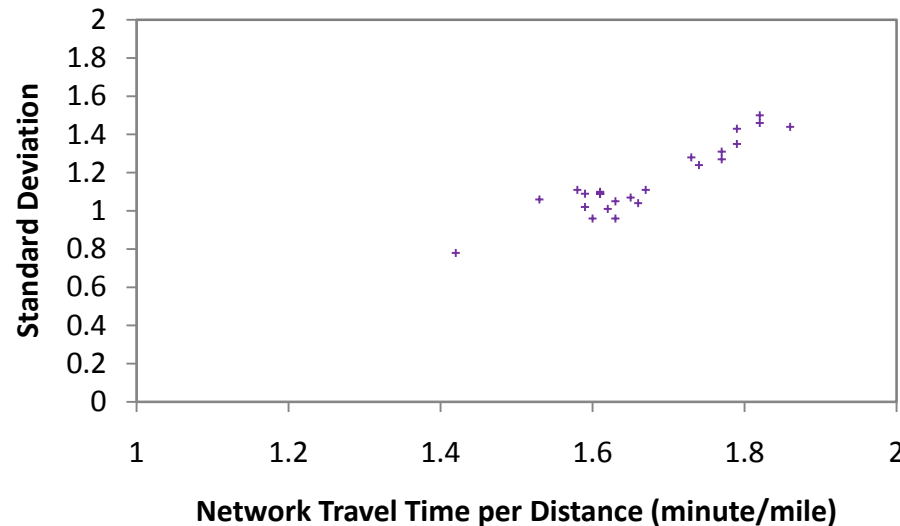
OD Travel Time and Standard Deviation

- Each data point represents the mean and standard deviation of travel times for all the vehicles (over the entire planning horizon) traveling between one OD pair.



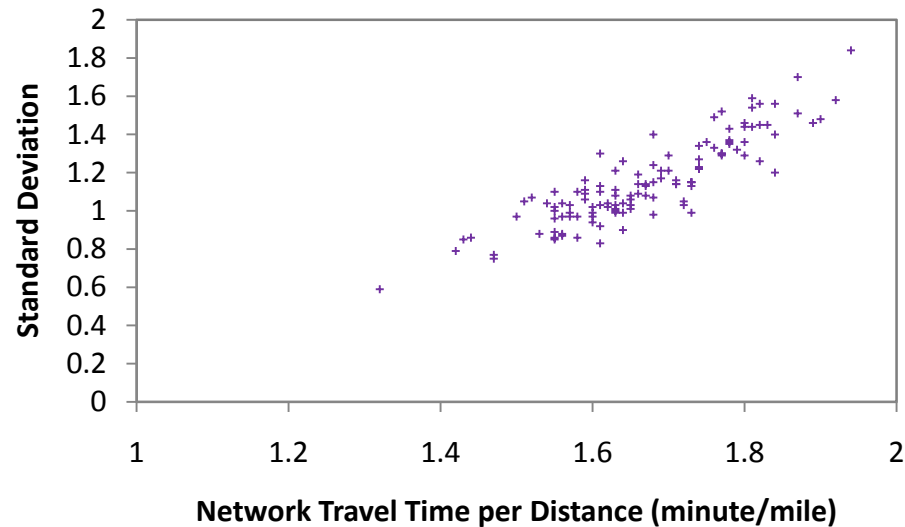
Network Travel Time per Unit Distance and Standard Deviation (5 minute interval)

- Each data point represents the mean and standard deviation of travel times **per mile** for all vehicles departing in 5-minute interval.
- 24 data points for 2-hour demand



Network Travel Time per Distance and Standard Deviation (1 minute interval)

- Each data point represents the mean and standard deviation of travel times **per mile** for all vehicles departing in 1-minute interval.
- 120 data points for 2-hour demand



Network Travel Time per Distance with Sampling Vehicles

- Each data point represents the mean and standard deviation of travel times **per mile** for all vehicles departing in 1-minute interval.
- 120 data points for 2-hour demand

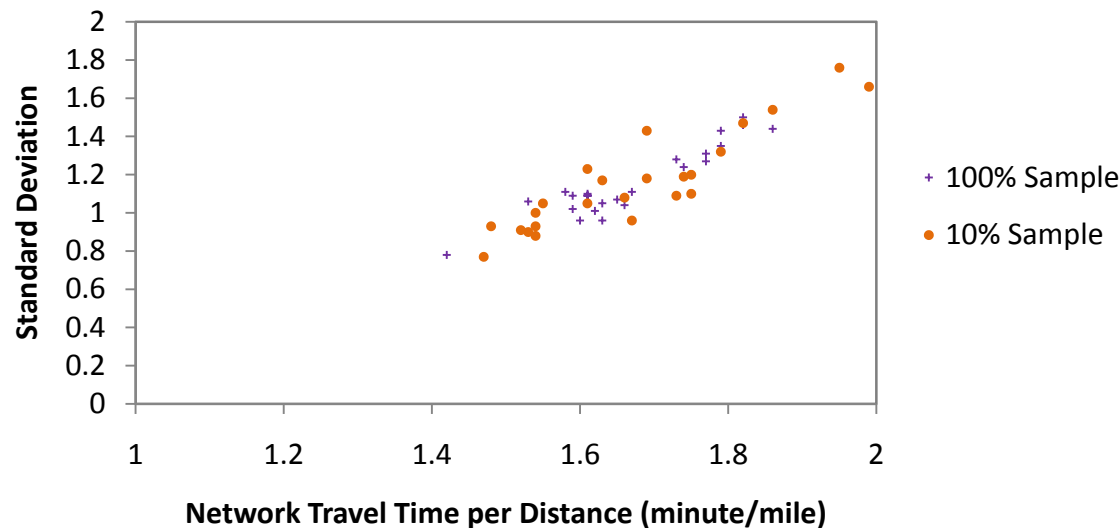


CHART Network



- **Network**

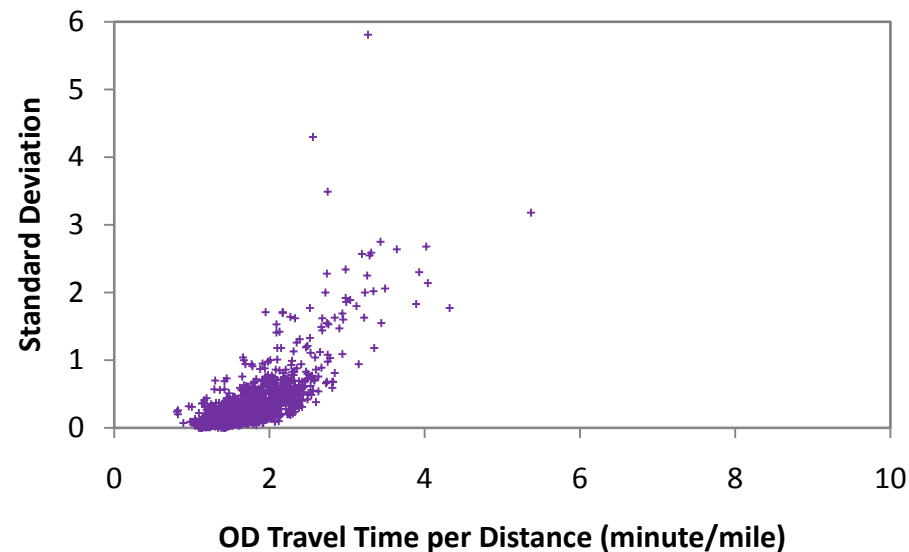
- I-95 corridor between Washington, DC and Baltimore, MD, US
- 2241 nodes
- 3459 links
- 111 TAZ zones

- **Demand**

- Two hours morning peak (7-9AM)

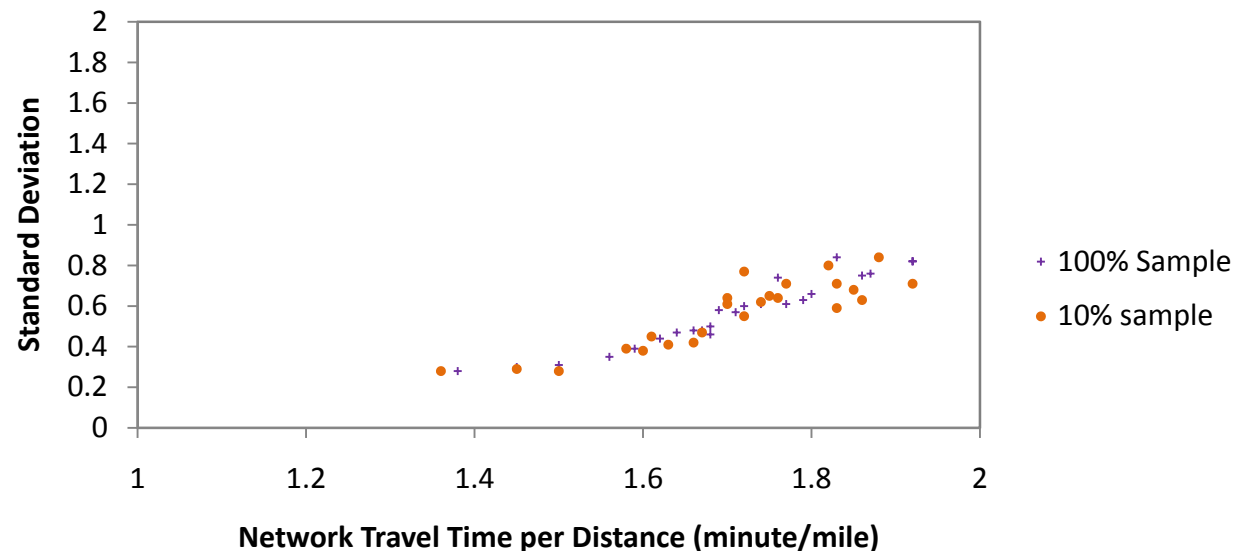
OD Travel Time **per Unit Distance** and Standard Deviation

- Each data point represents the mean and standard deviation of travel times **per mile** for all the vehicles (over the entire planning horizon) traveling between one OD pair.



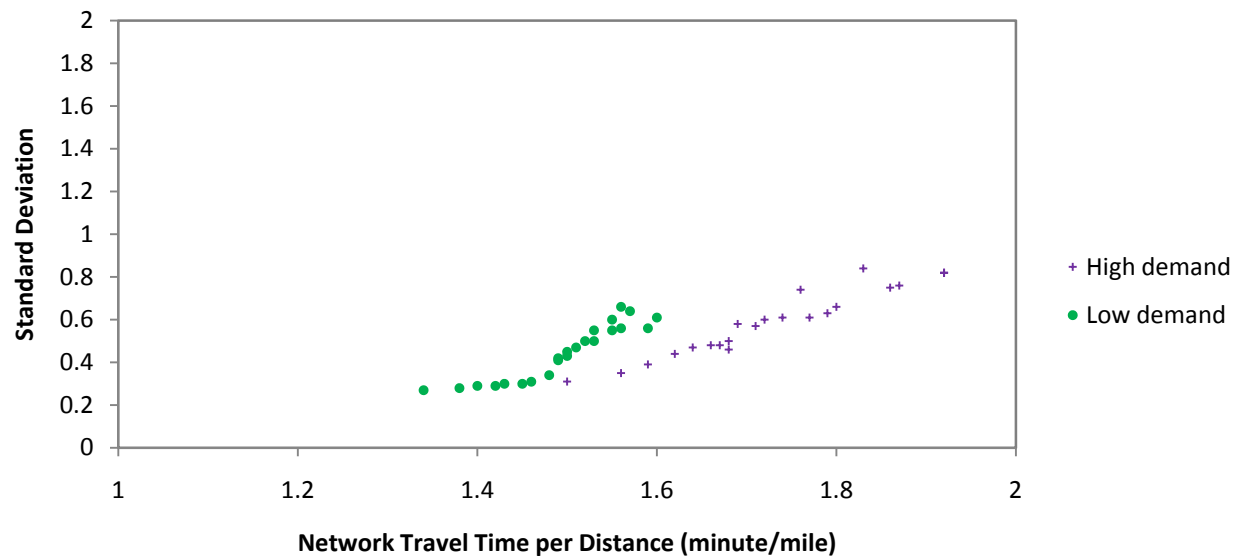
Network Travel Time per Unit Distance with Sampling Vehicles

- Each data point represents the mean and standard deviation of travel times **per mile** for all vehicles departing in 5-minute interval.
- 24 data points for 2-hour demand



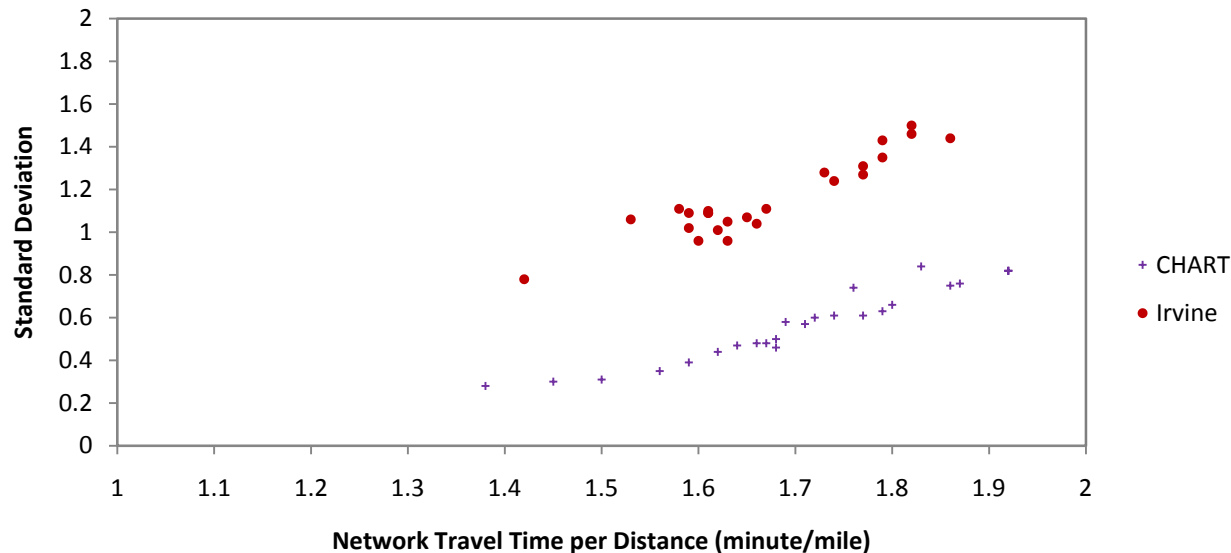
Network Travel Time per Unit Distance with Different Demand Level (Congestion Level)

- Low demand: 80% of the peak hour demand
- High demand: 100% of the peak hour demand



Network Travel Time per Unit Distance with Different Networks

- The mean travel time per mile range is comparable, which indicates similar congestion level
- CHART network shows lower variation in travel times



Concluding Comments

- Many things could be done in the short term to reflect reliability considerations; robust relation between SD and Mean of trip time PER MILE
- DTA plus robust analytical relations on supply side, w. Vovsha's approaches to utility valuation provide low hanging fruit

Concluding Comments

- Required: a more fundamental perspective on project and system evaluation that recognizes:
 - Traffic physics and role of system management: controllability and opportunities for intervention
 - Short and long term dynamics of user judgment and behavior
 - Network spatial and temporal dynamics
 - Relevance of “external” events (accidents, weather) to evaluation frame of reference
 - Connection between individual attitudes towards risk and social preferences