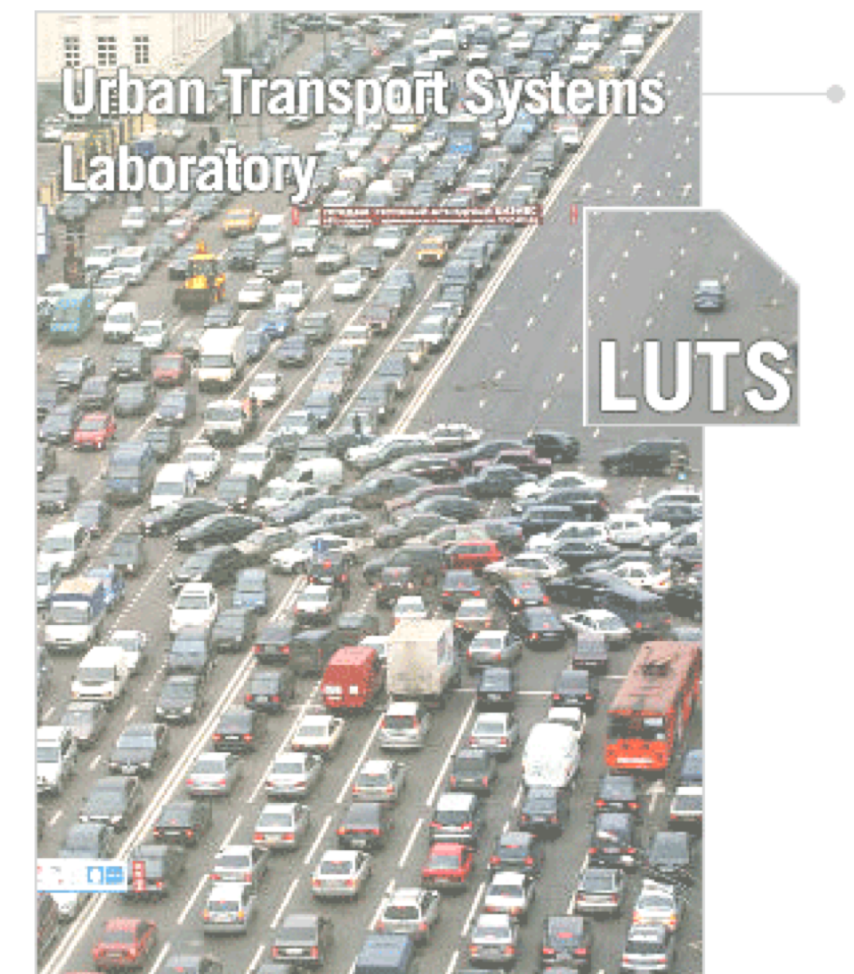


Macroscopic Fundamental Diagram: Existence, Physical Properties and Dynamic Modeling

Intro to traffic flow modeling and ITS

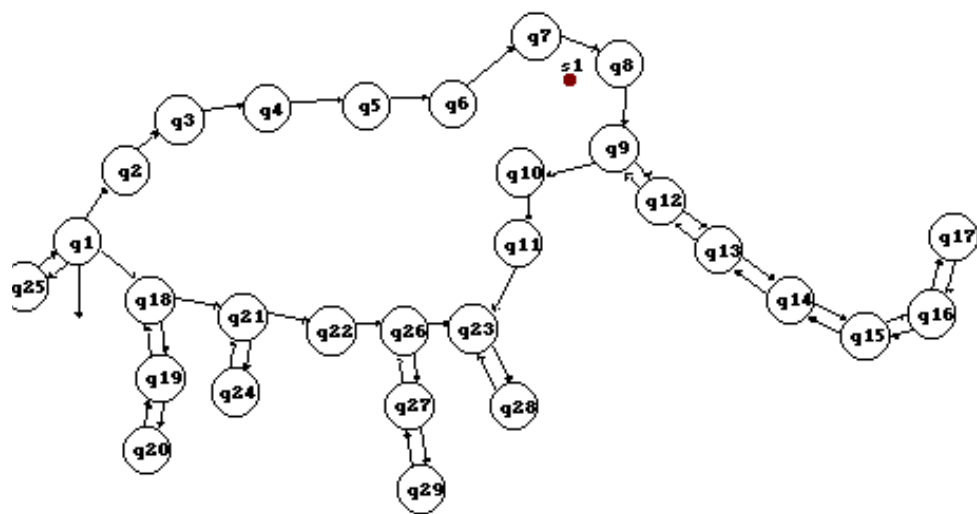
Prof. Nikolas Geroliminis



- Week 4.1
 - MFD Existence (Simulations)
 - MFD Existence (Empirical studies)
 - Estimating MFD variables
- Week 4.2
 - MFD Physical Properties
- Week 4.3
 - MFD Dynamic Modeling

WHY A NETWORK LEVEL APPROACH?

- Humans make a lot of choices - routes, destinations and driving behavior (unpredictability)
- Not a clear distinction between free-flow and congested states at link level (complexity)
- Decentralized control is not efficient for highly congested systems (controllability)



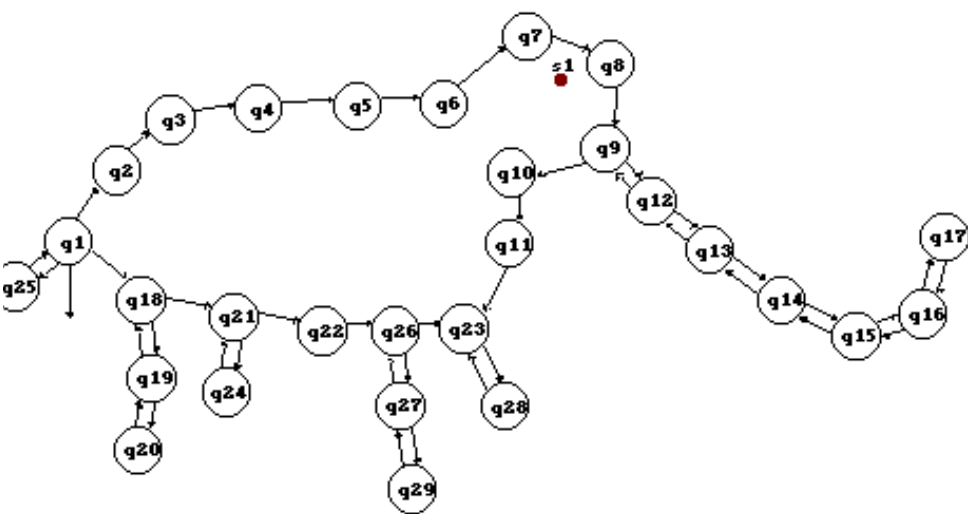
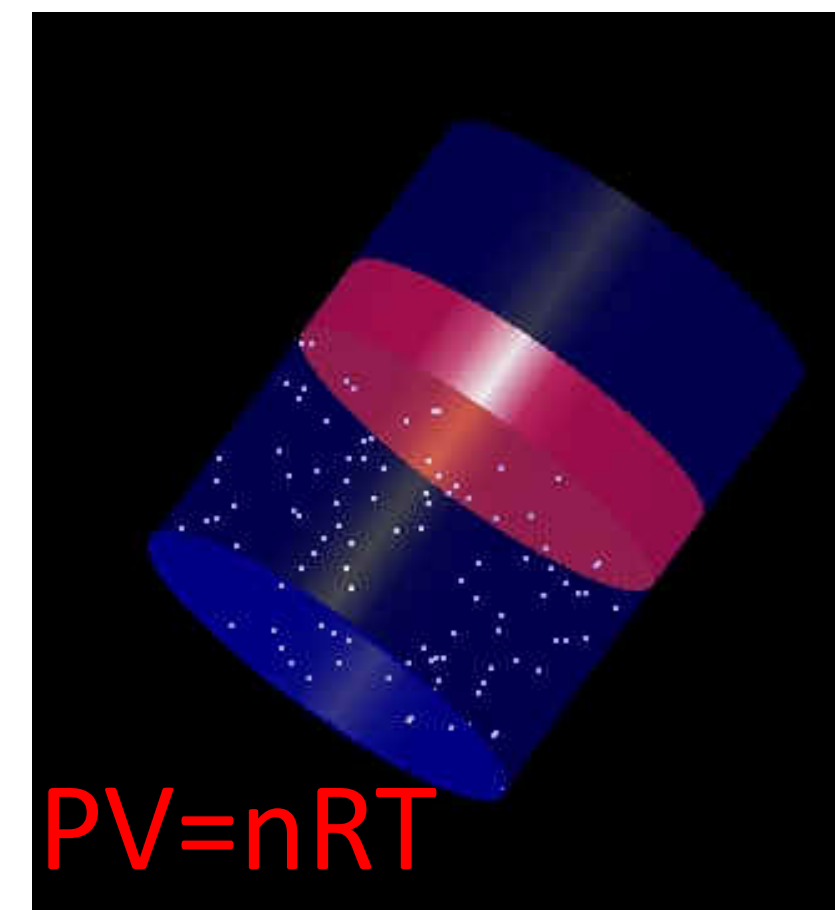
**“With four parameters I can fit an elephant,
and with five I can make him wiggle his trunk”.**
JOHN VON NEUMANN

WHY A NETWORK LEVEL APPROACH?

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- Move from PREDICTION to OBSERVATION
- Develop physically realistic models of urban congestion

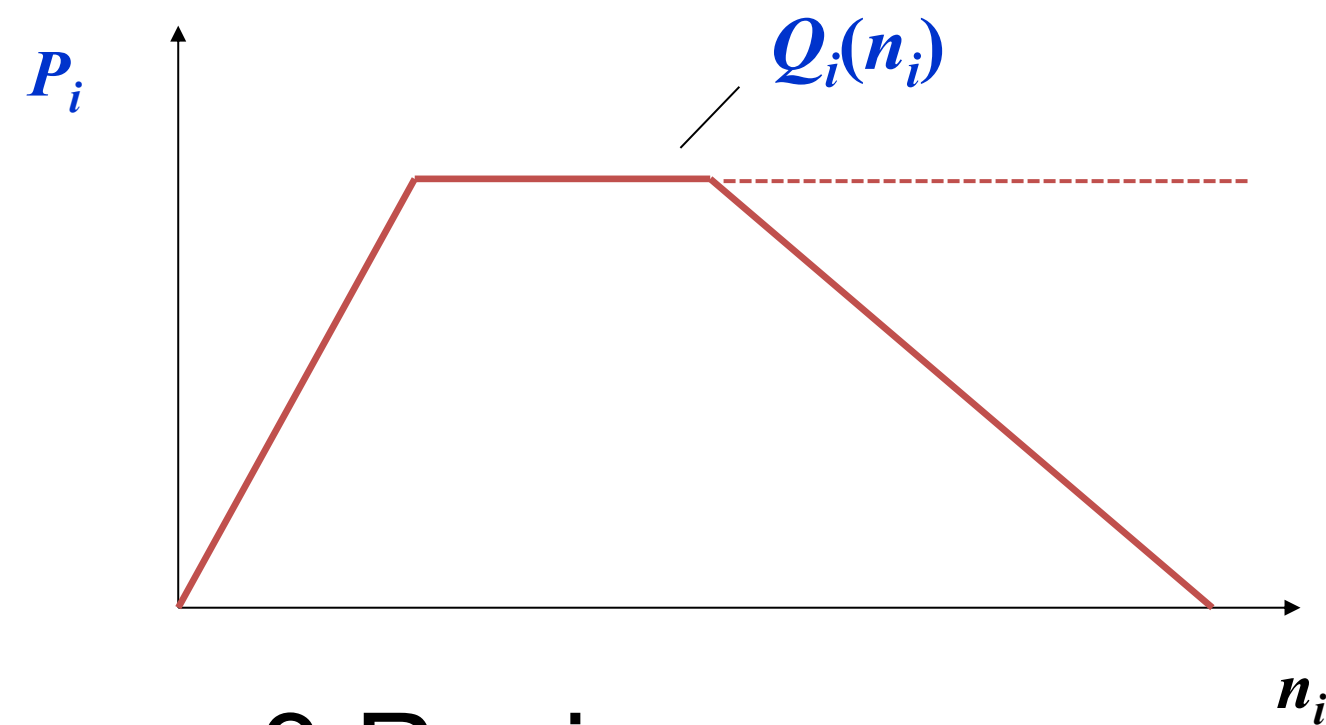
PROPOSE → **MONITOR** → **MODIFY**



“With four parameters I can fit an elephant,
and with five I can make him wiggle his trunk”.
JOHN VON NEUMANN

Fundamental Diagram (FD) for a link i

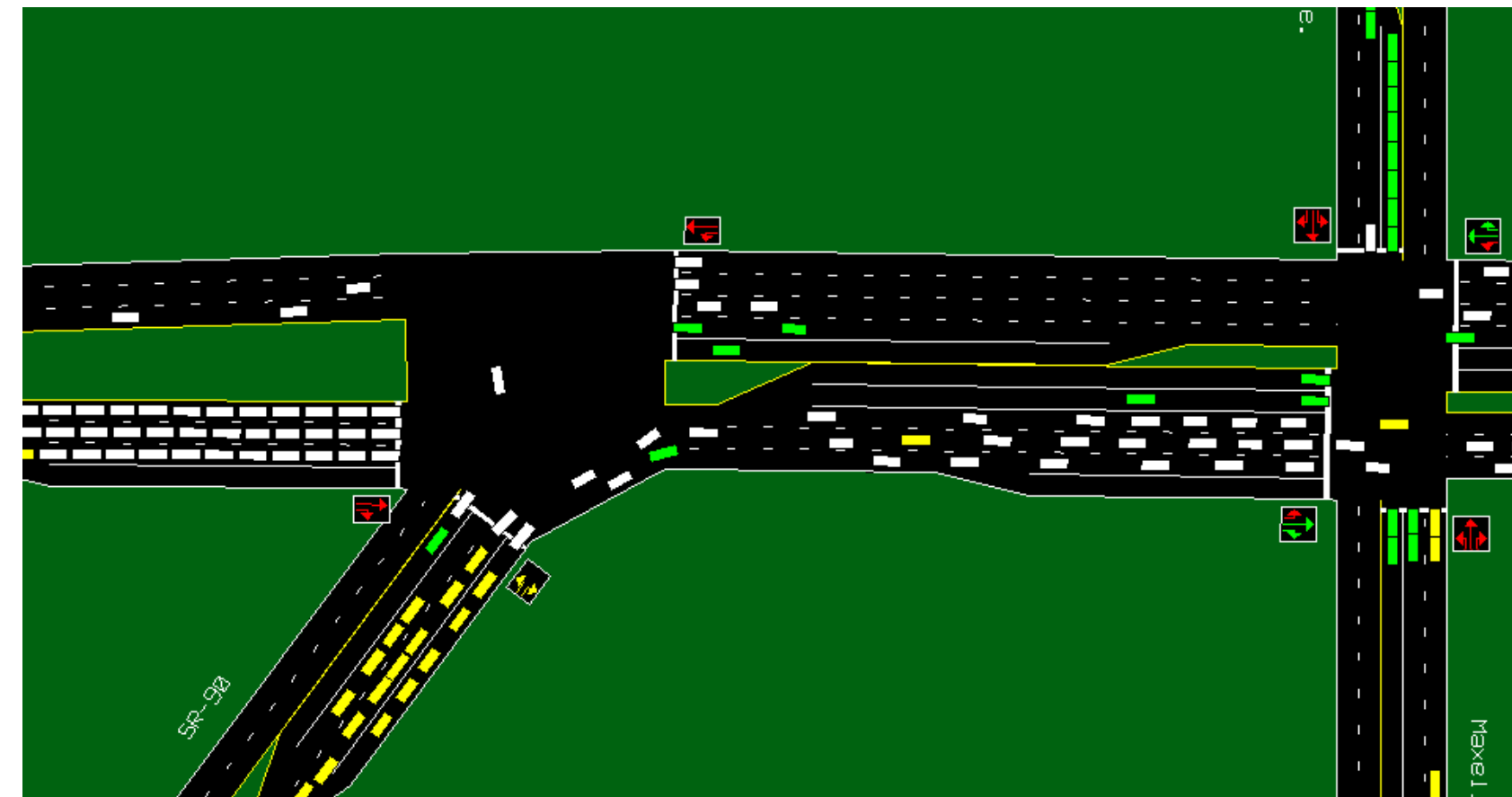
- Accumulation : n_i (vehs)
- Travel Production : P_i (veh-km/hr) - VKT
- Output-Trip completion rate O_i (vehs/hr)



- 3 Regimes
I : Undersaturated
II : Efficient

III : Oversaturated

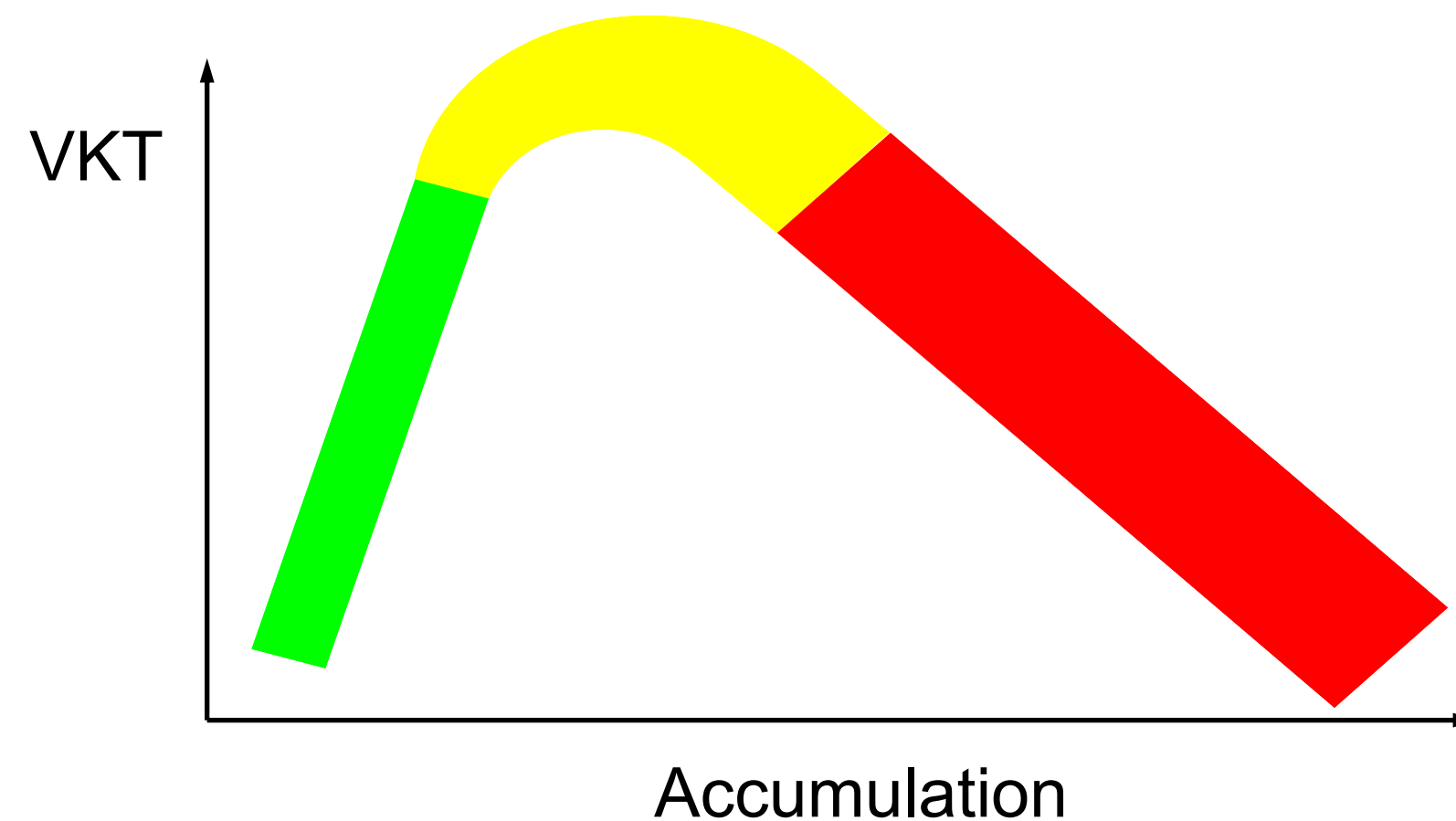
Growing queues from the downstream link block the arrivals



Theory: Generalization to networks

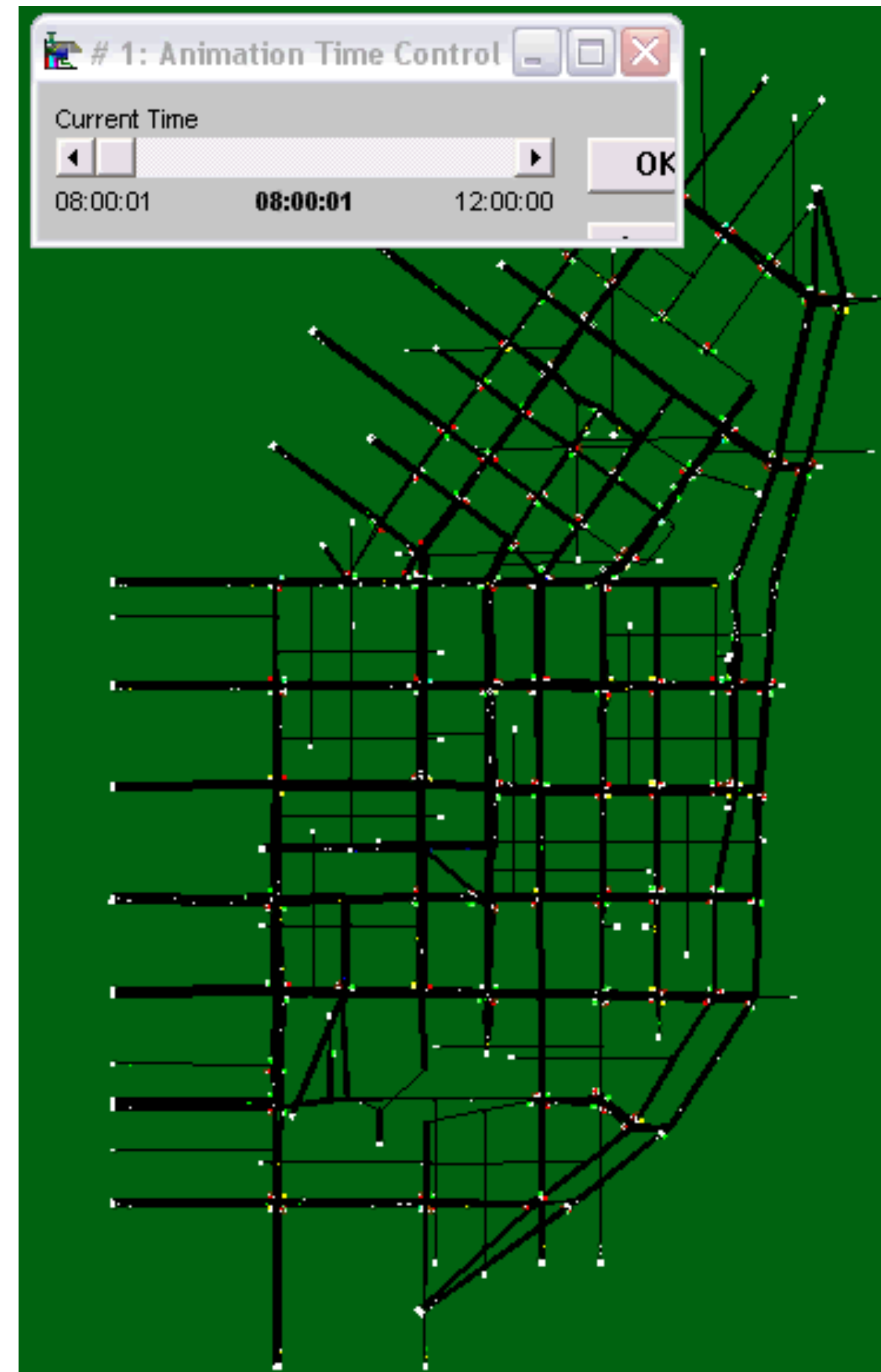
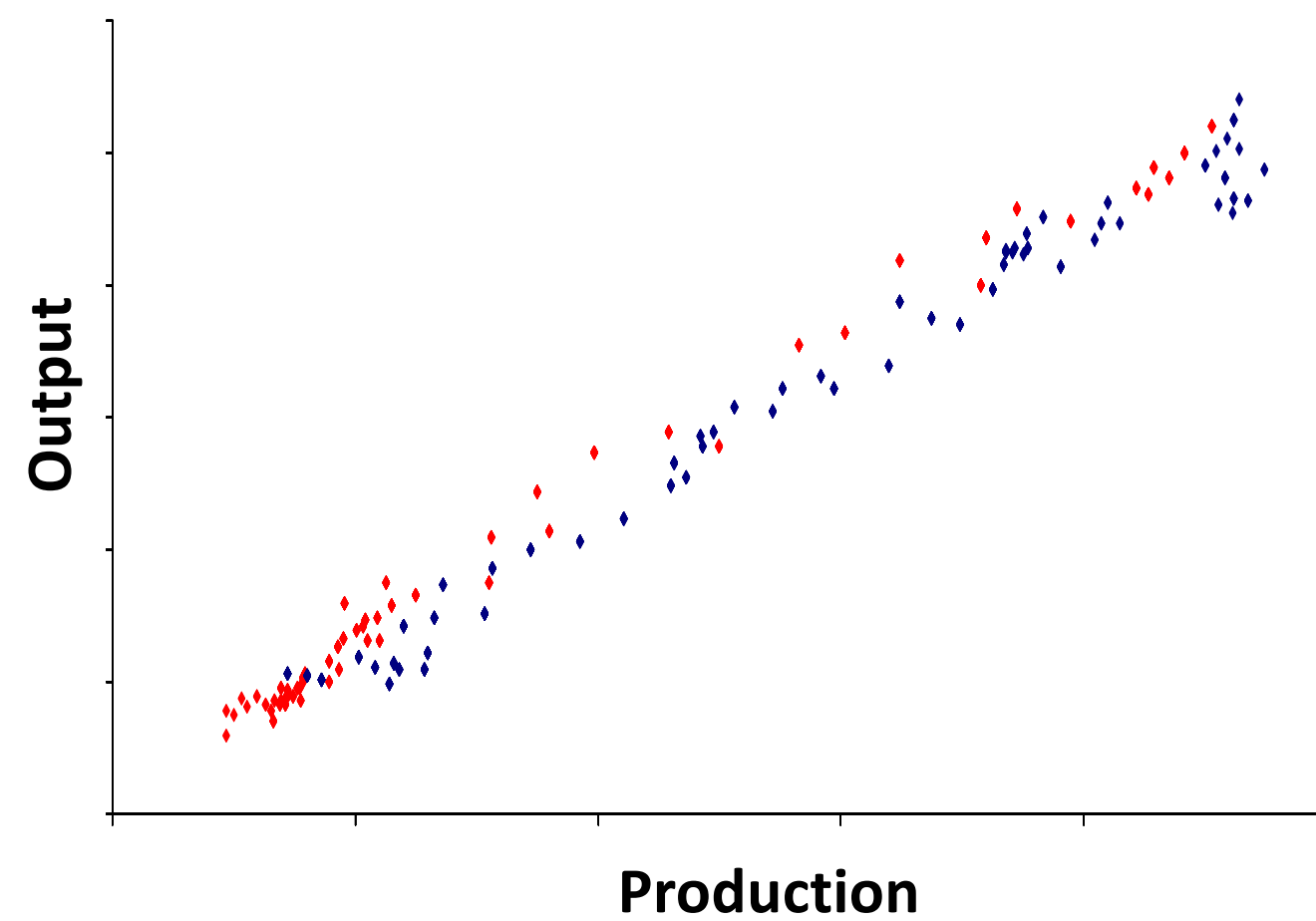
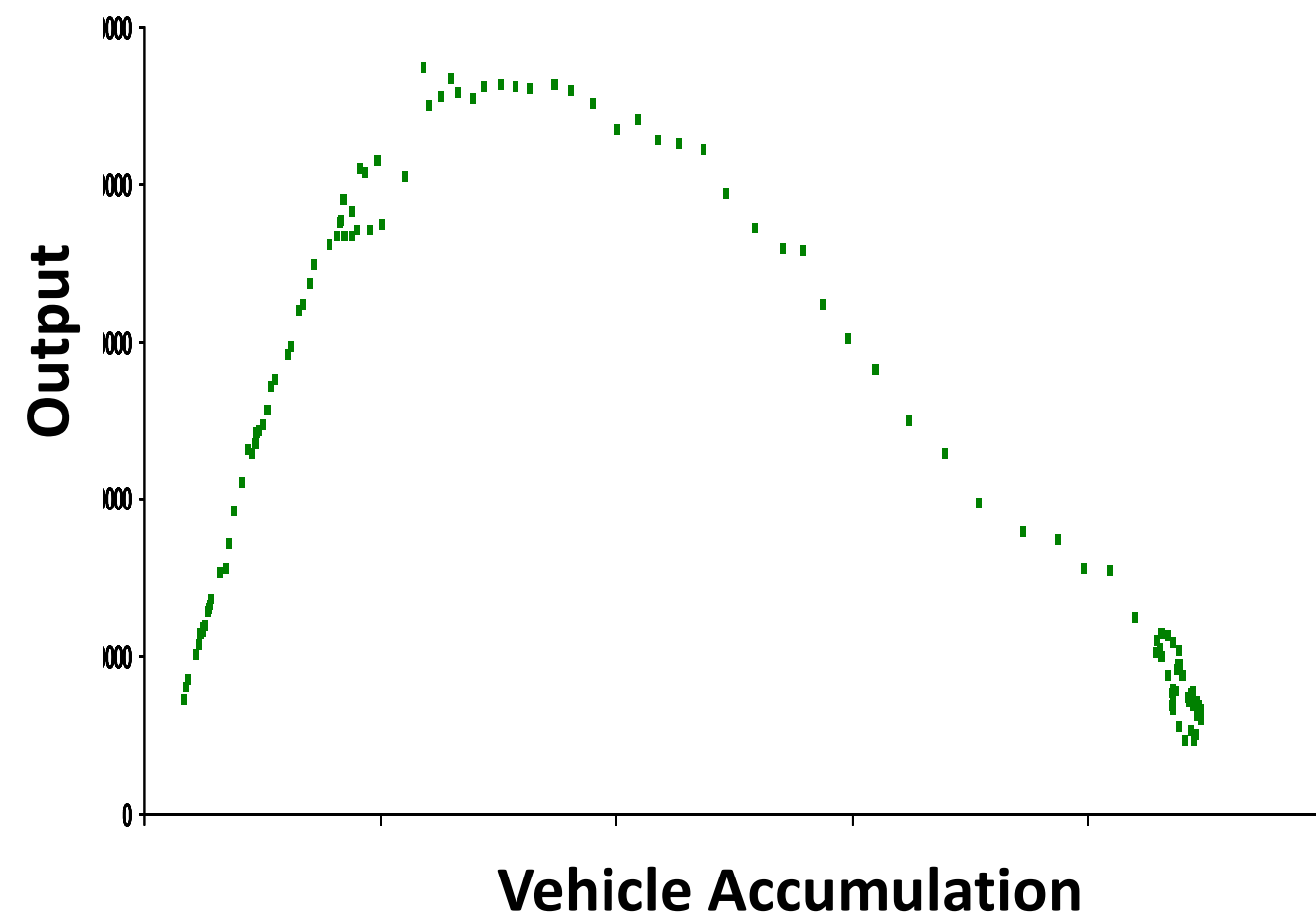
$$P = \sum P_i = \sum Q_i(n_i) \cong Q(\sum n_i)$$

AGGREGATE BEHAVIOR
=
SCALED UP VERSION OF LINK BEHAVIOR



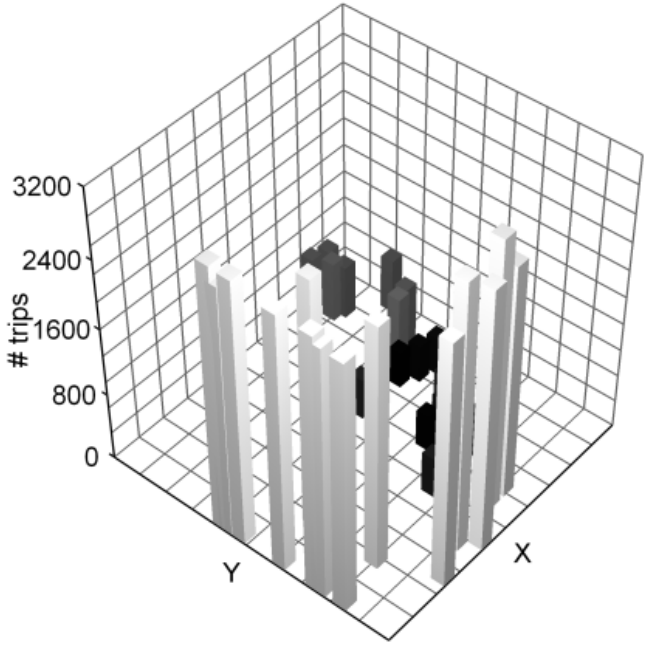
- An MFD exists
- Trip completions / Network flow \cong Constant

MFD (Simulation evidence)

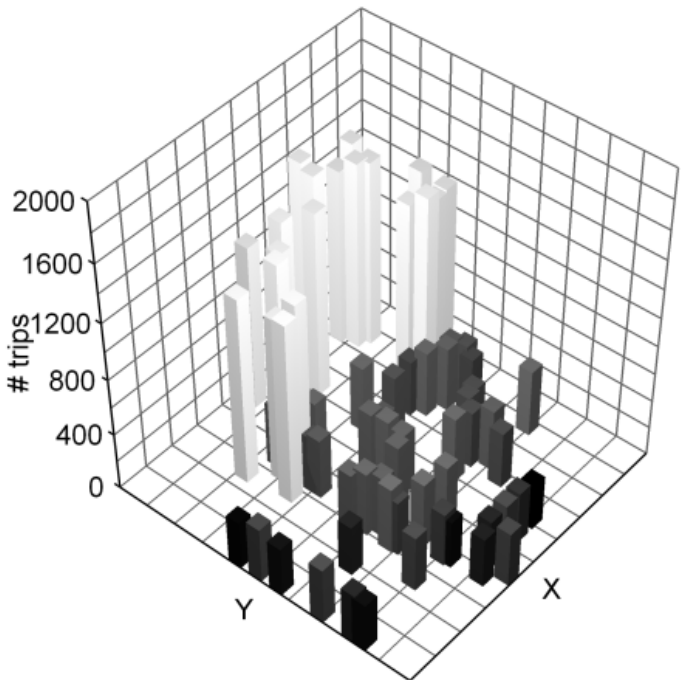


MFD – Sensitivity to demand

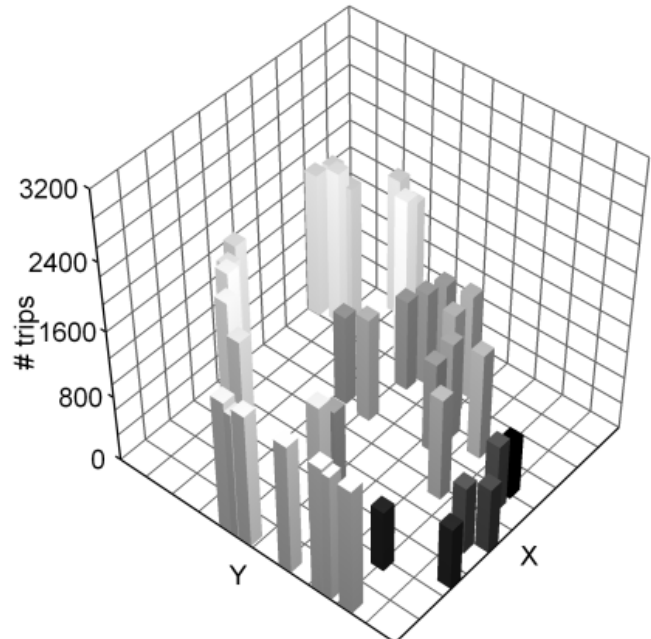
**DESTINATIONS
PER NODE**



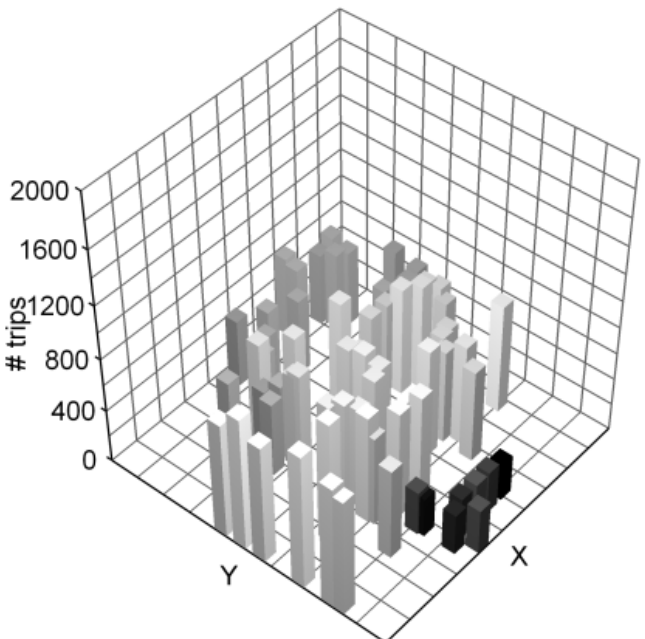
**ORIGINS
PER NODE**



**DESTINATIONS
PER NODE**



**ORIGINS
PER NODE**

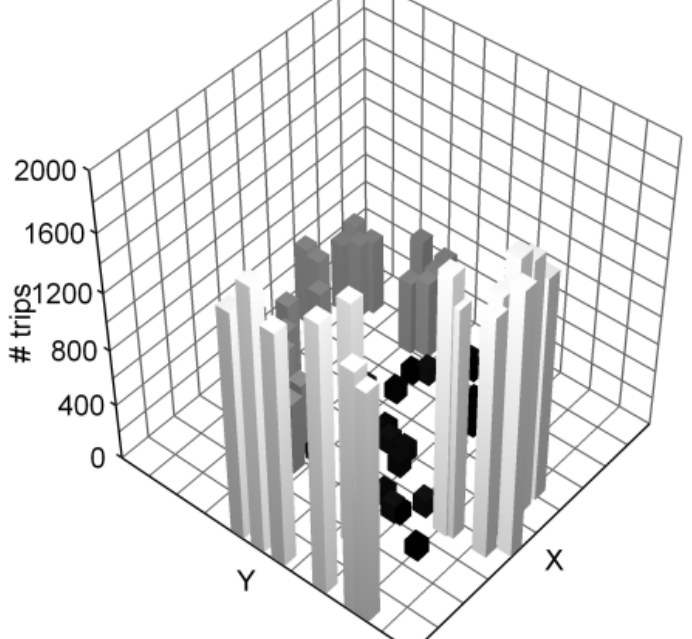
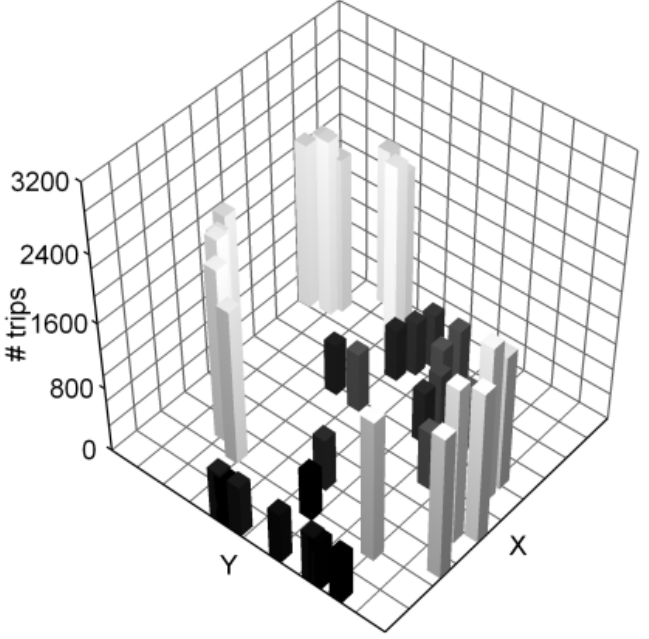
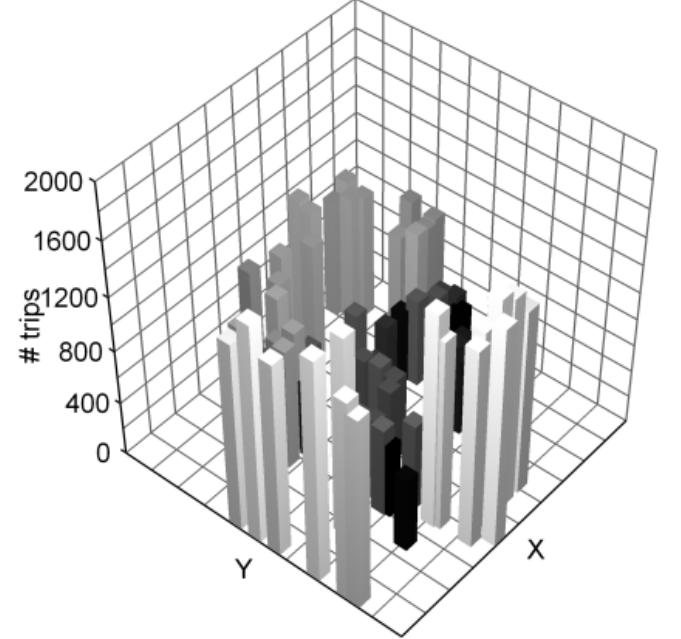
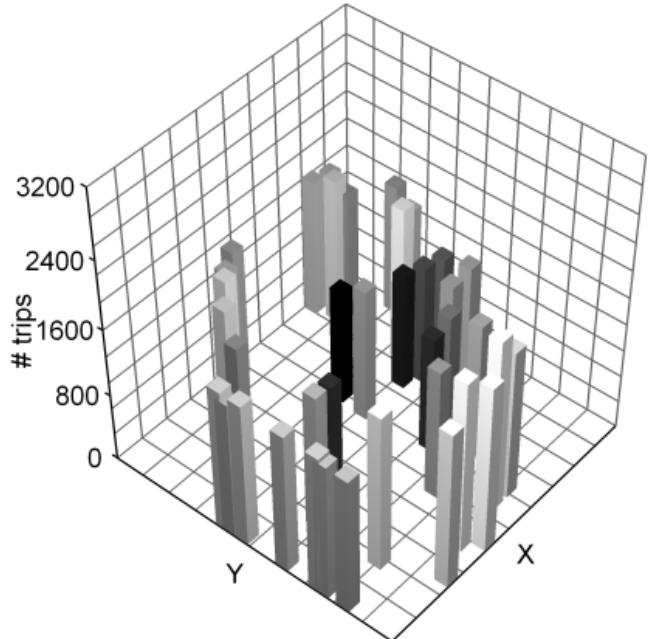


SCENARIO 1

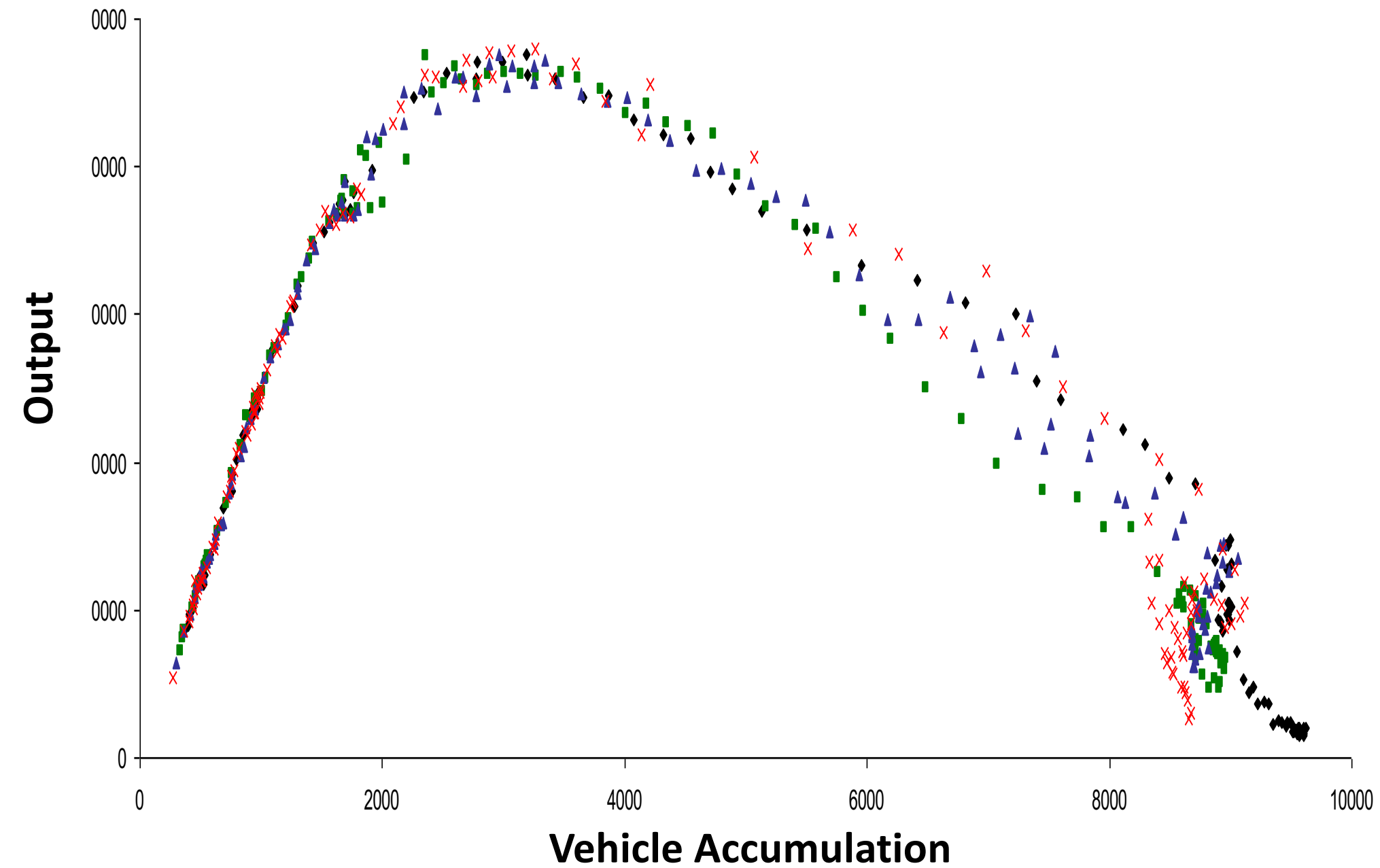
SCENARIO 3

SCENARIO 2

SCENARIO 4



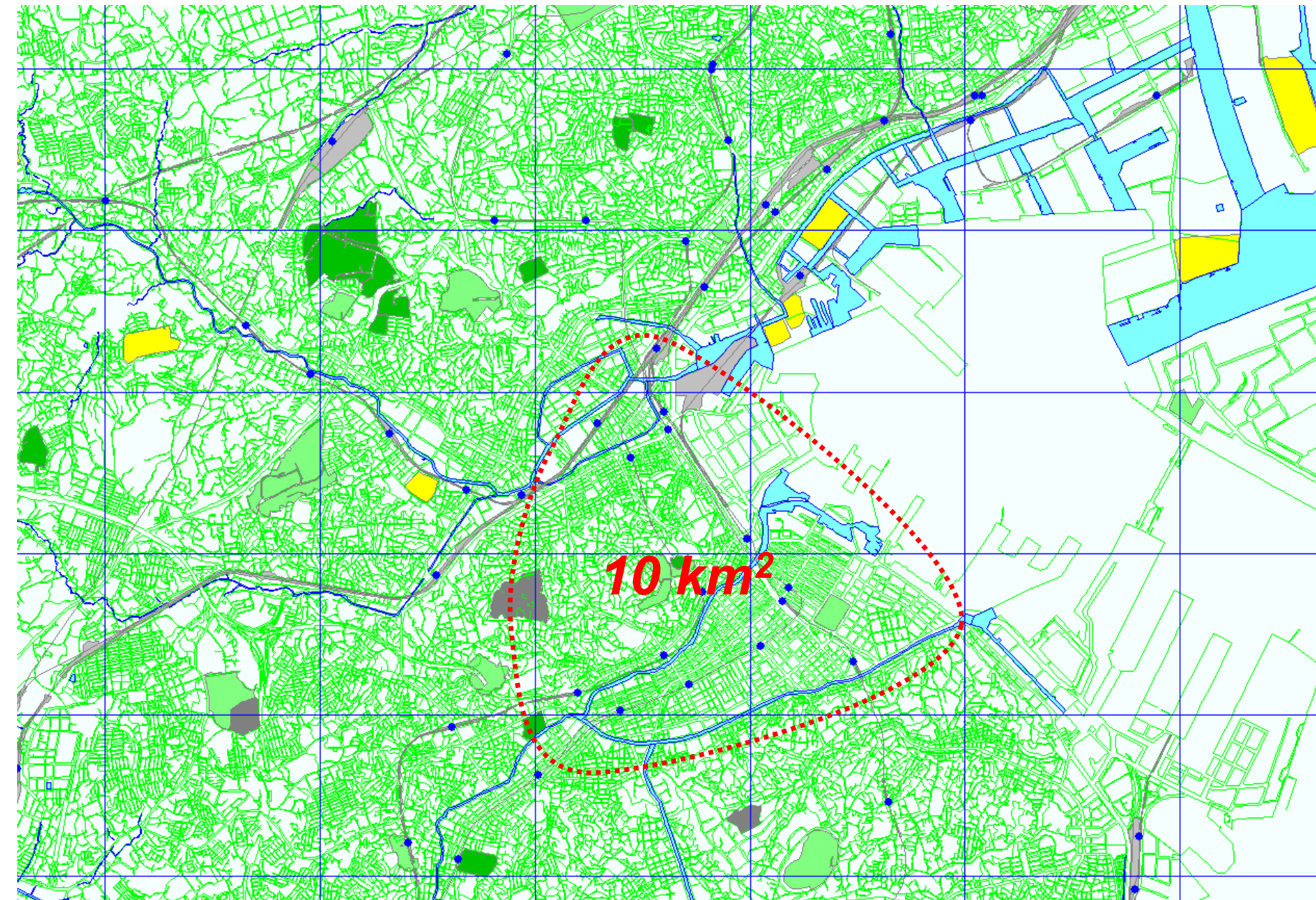
MFD – Sensitivity to demand



MFD is a property of the infrastructure
INDEPENDENT OF O-D TABLES

Real World Experiment: Site Description

- Fixed sensors
 - 500 ultrasonic detectors
 - Occupancy and Counts per 5min
- Mobile sensors
 - 140 taxis with GPS
 - Time and position
 - Other relevant data (stops, hazard lights, blinkers etc)
- Geometric data
 - Road maps (detector locations, link lengths, intersection control, etc.)



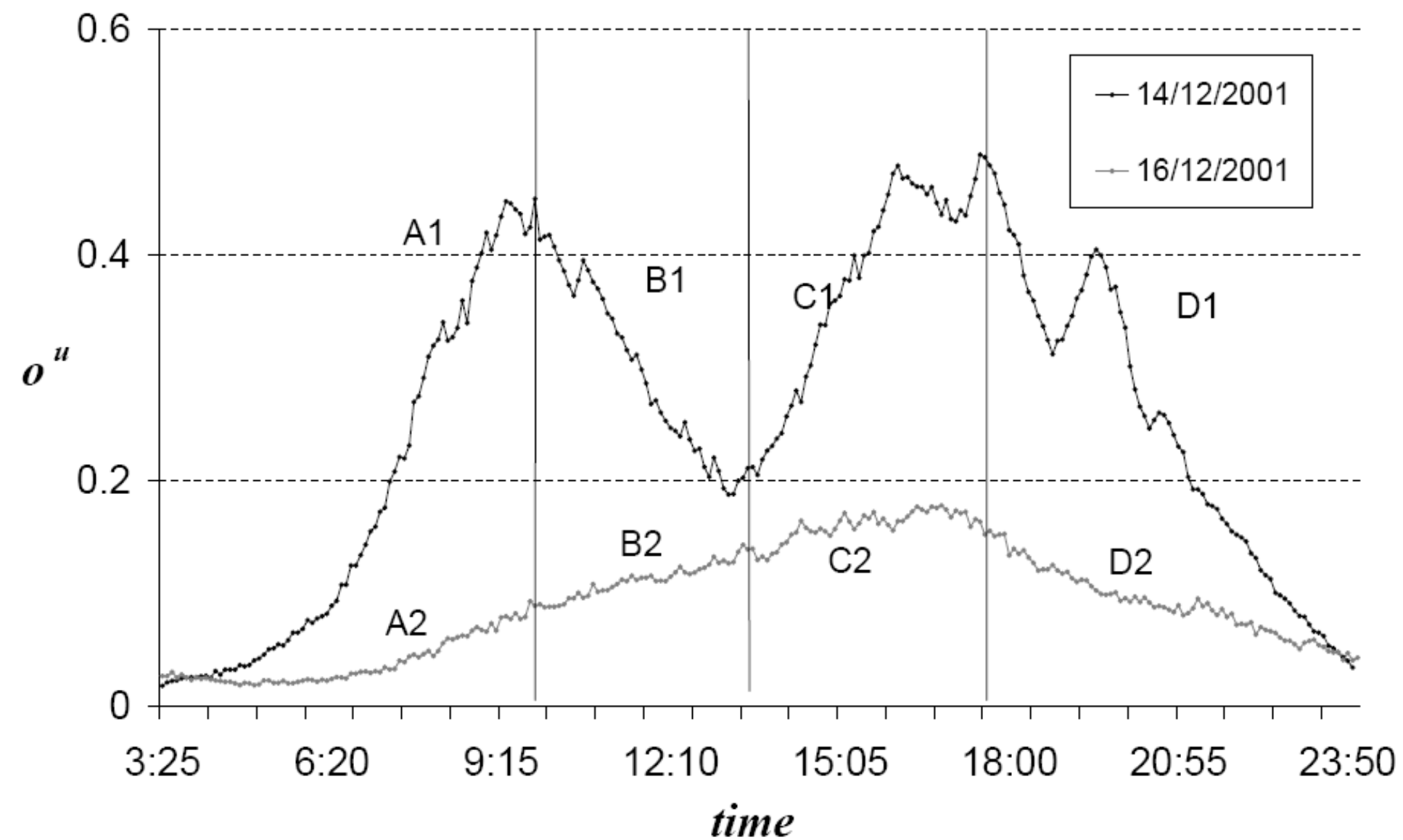
(Dec. 2001 data)

Geroliminis, N. & Daganzo, C.F. (2008). Existence of urban-scale macroscopic fundamental diagrams: Some experimental findings, *Transportation Research part B*, 42 (9), 759-770

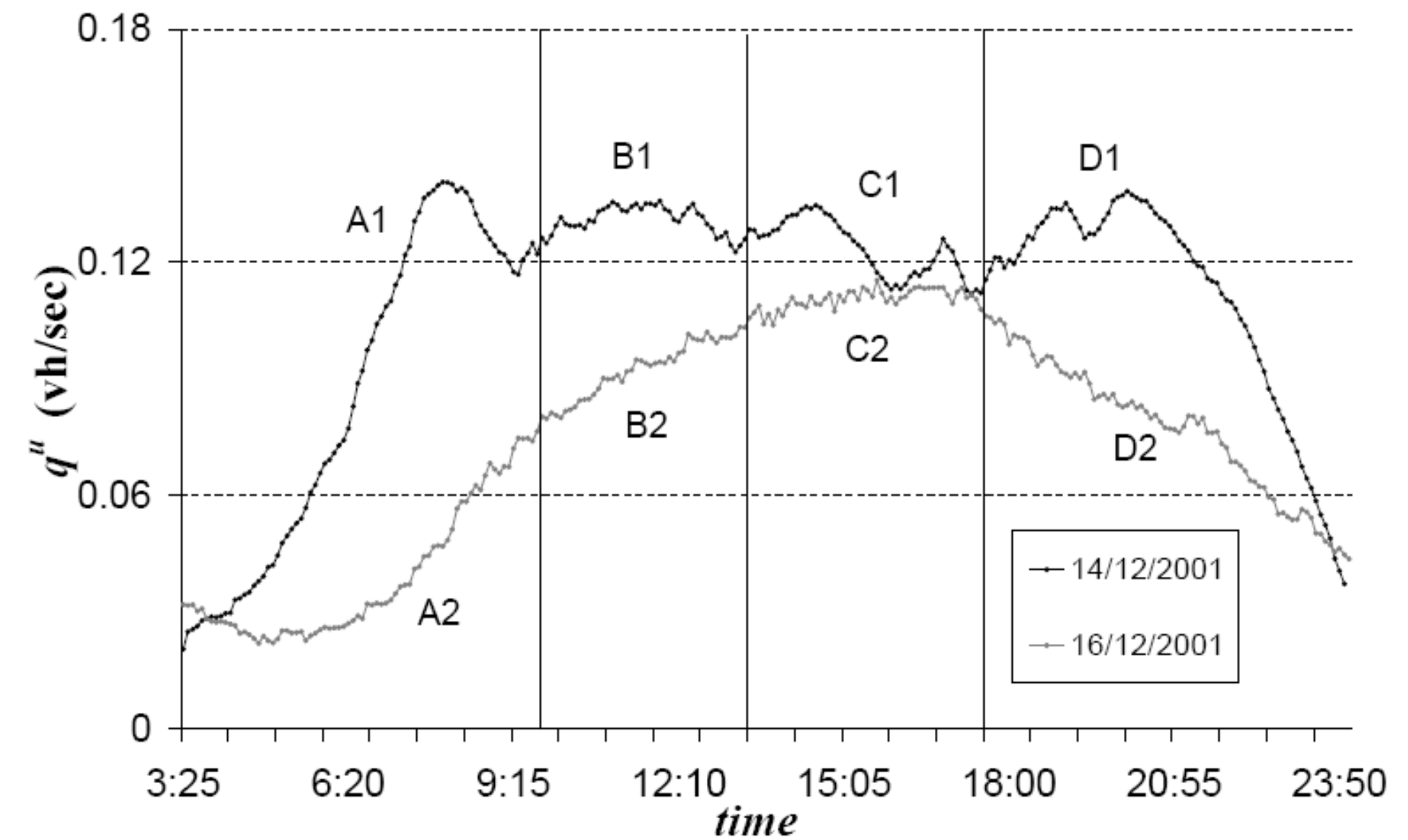
Single Detectors



Space-Mean Flow and Occupancy

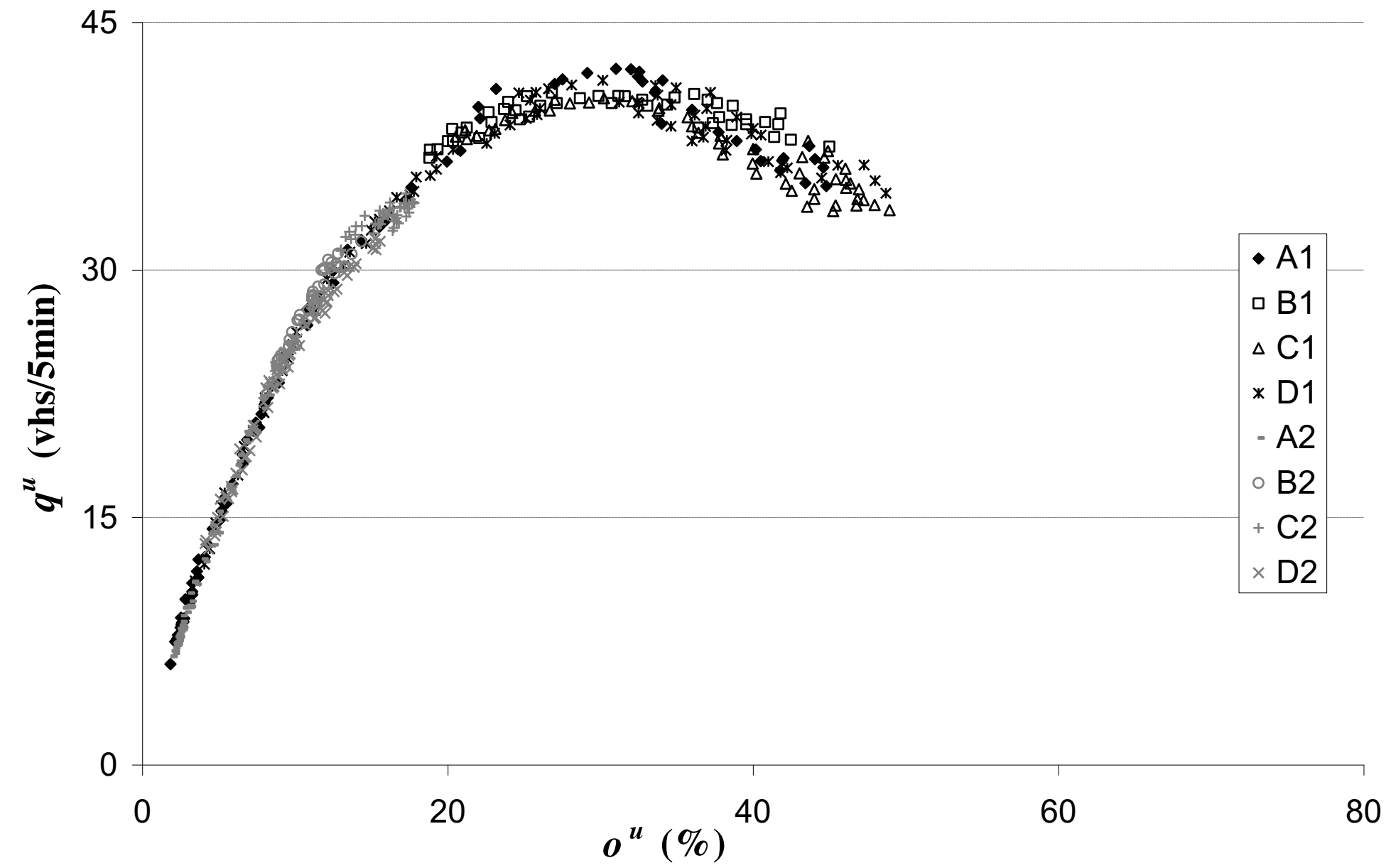


Average Occupancy
by time-of-day



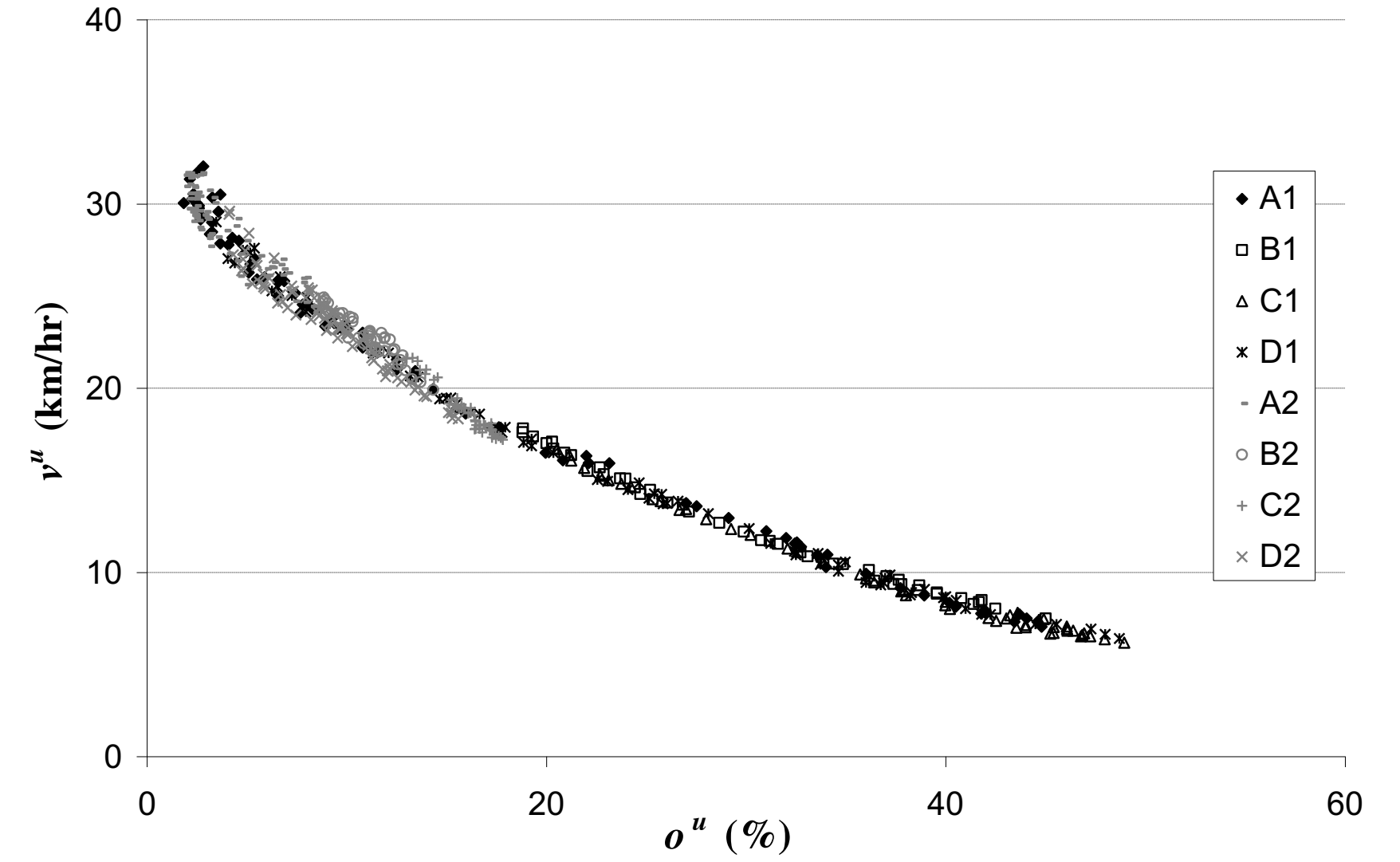
Average Flow by
time-of-day

Average flow



Average occupancy

Average speed



Average occupancy

Fusing taxi and detector data

An MFD exists on the part of the network covered by detectors. What about the whole network?

1. Filter for passenger-carrying taxis
2. Estimation of accumulation and speed
3. Results

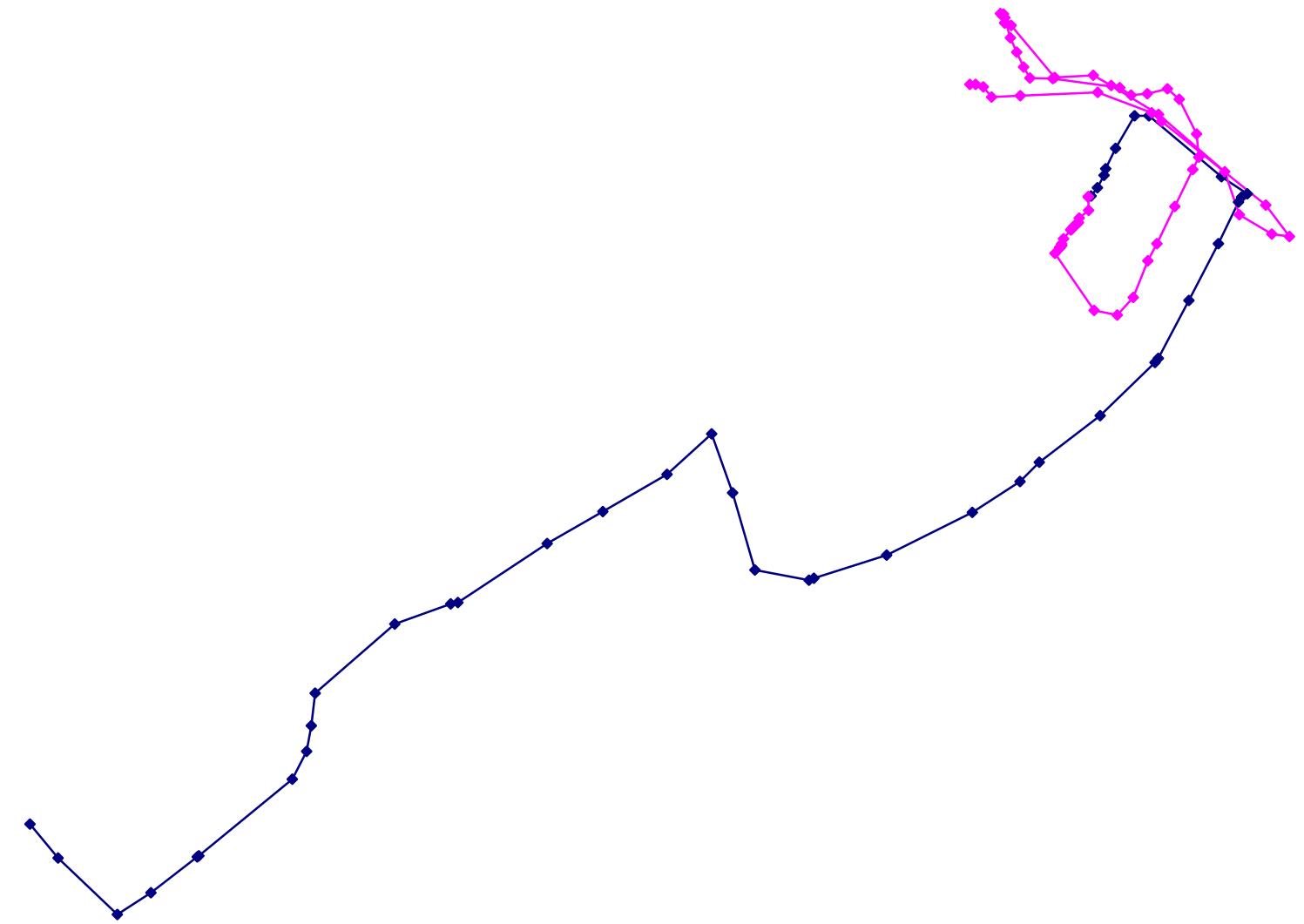
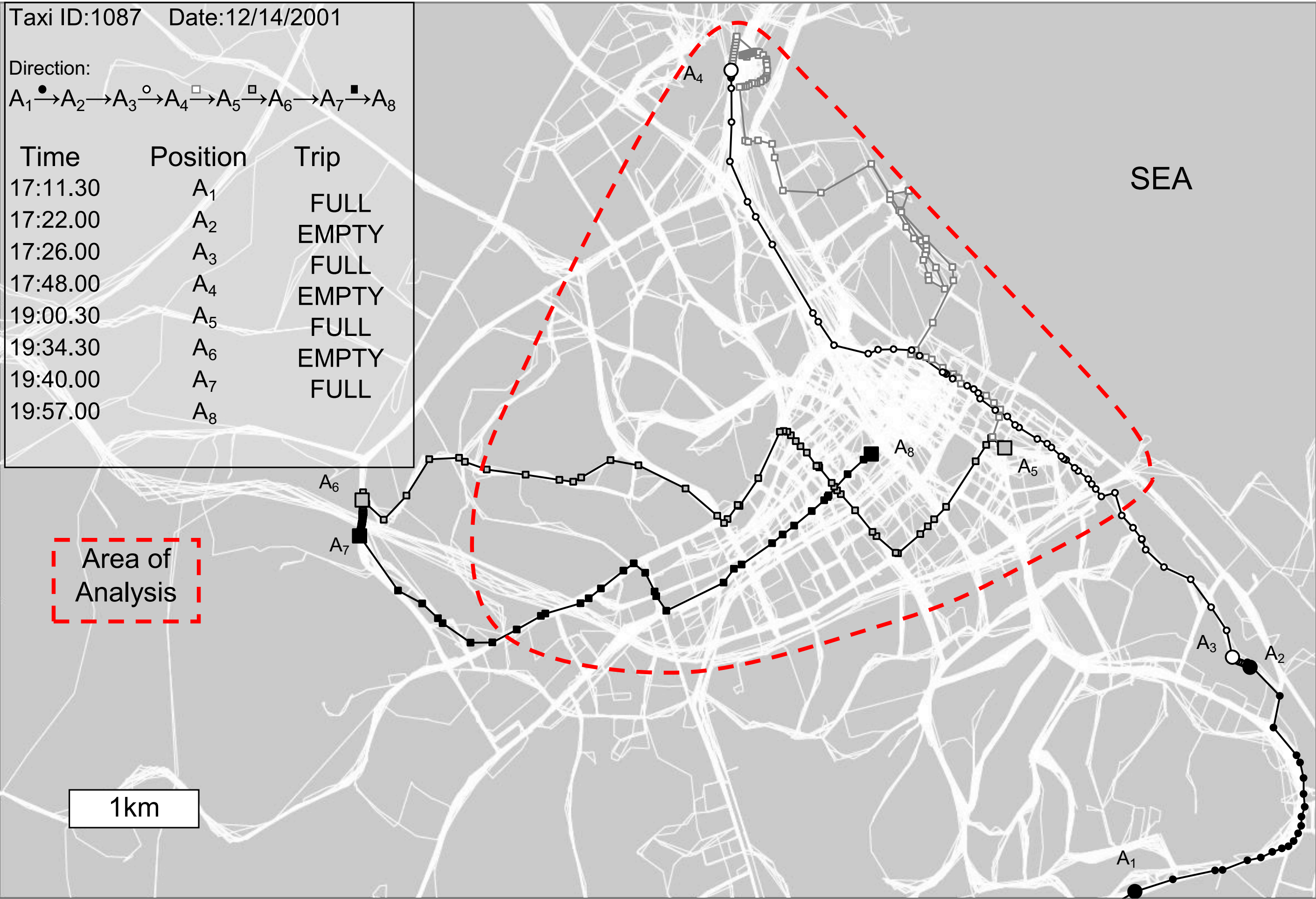


Illustration of filter results



Estimation of accumulations and speeds

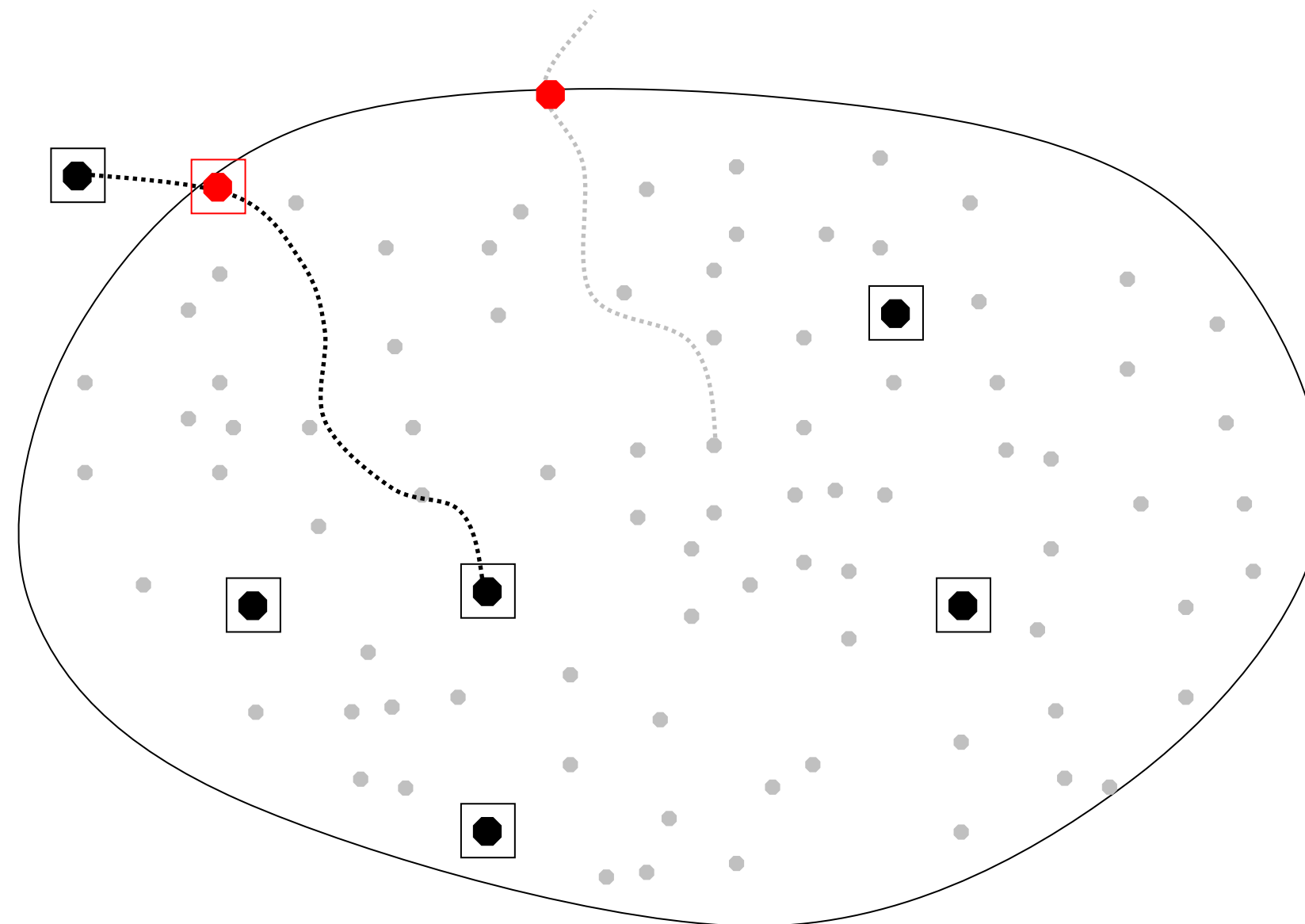
Conjecture: Passenger carrying taxis use the same parts of the network as cars

Then:

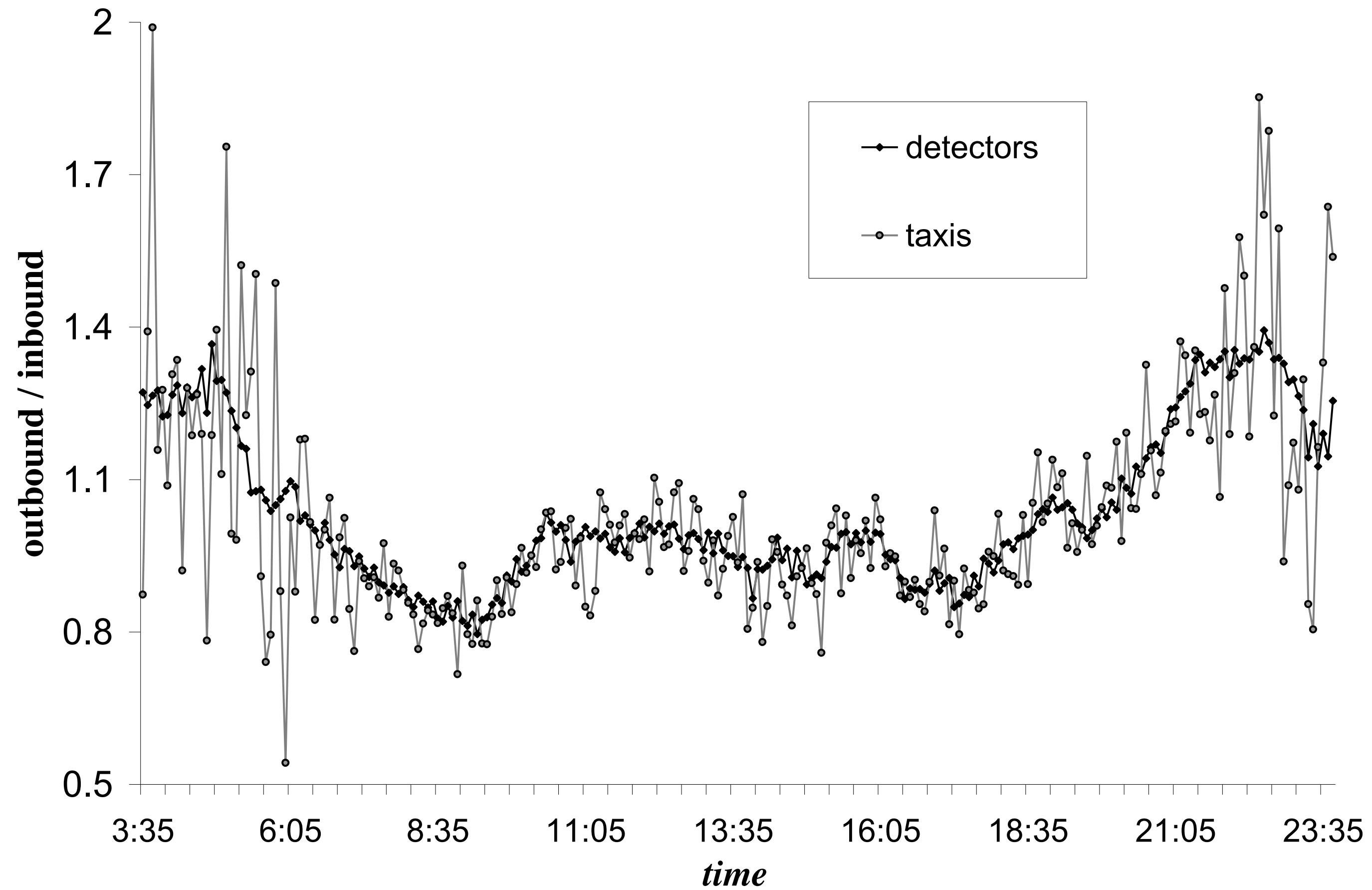
$$u(t) \approx \bar{u}_{taxi}(t)$$

$$n(t) \approx n_{taxi}(t) \cdot \Phi(t)$$

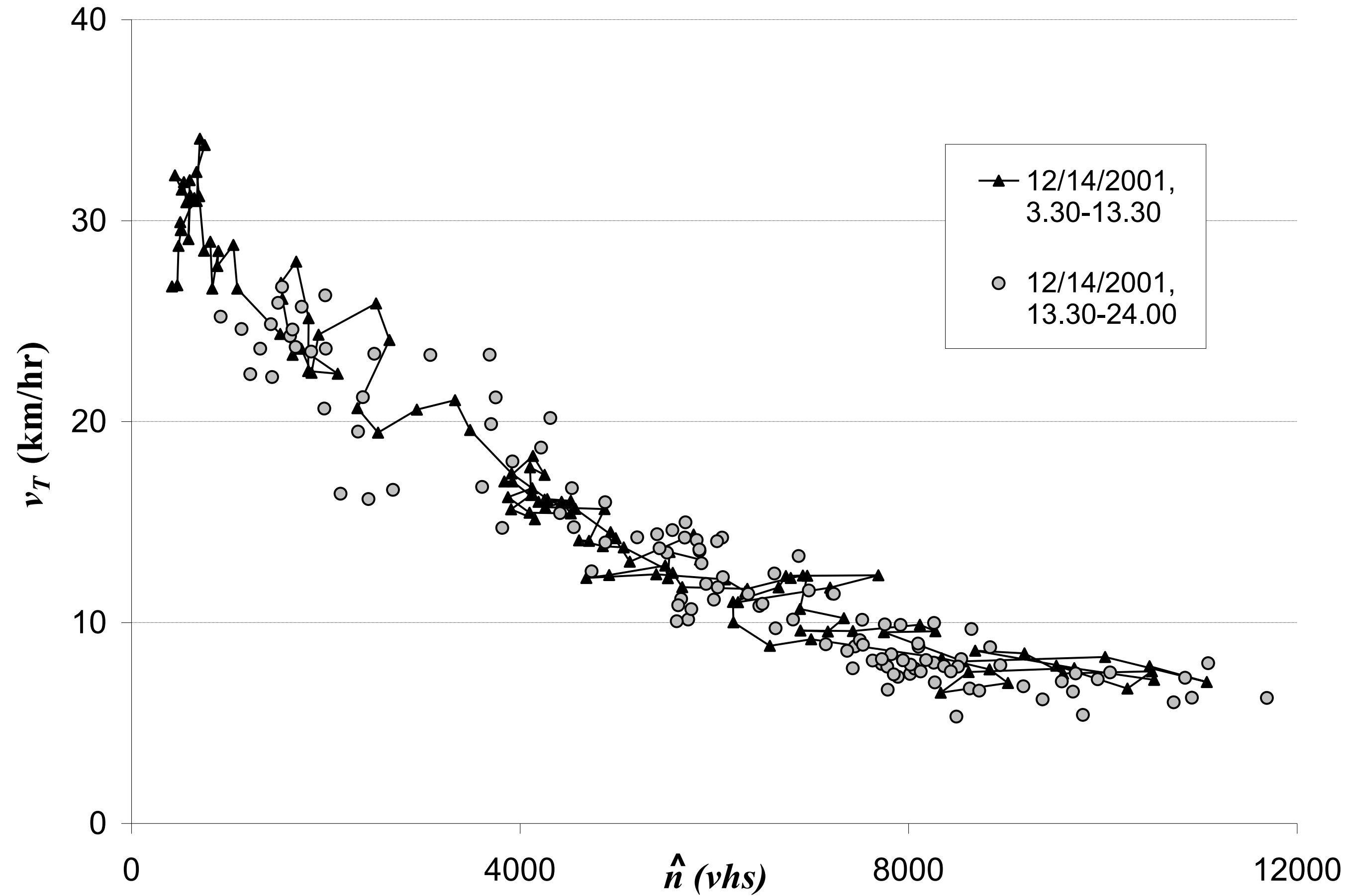
$$\Phi(t) = \frac{\dot{\square}_{\bullet}}{\square_{\bullet}} \approx \frac{\dot{\square}_{\bullet}}{\square_{\bullet}}$$



Full taxis vs. cars



Taxi and detector data: Results



Taxi and detector data: Results

