DEVELOPMENT OF PERFORMANCE MEASURES ON SIGNALIZED ARTERIALS

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Outline & Conclusions

- Problem Statement
- Model Formulation – Extensions
- Performance Measures
- Model Applications

- Model for Estimating Travel Times and Performance Measures on Arterials
  - Explicit consideration of traffic dynamics and signal coordination
  - Good agreement with field and simulated data
  - Readily implemented to most systems with surveillance data
  - Production of performance measures

Problem Statement (1)

- **Need**
  - **Performance measurement on arterials**
    Travel times, variability, signal progression, queue lengths
    - **Real-time monitoring**
    - **Travel time information**
    - **Corridor management**
  - **Information from surveillance systems**

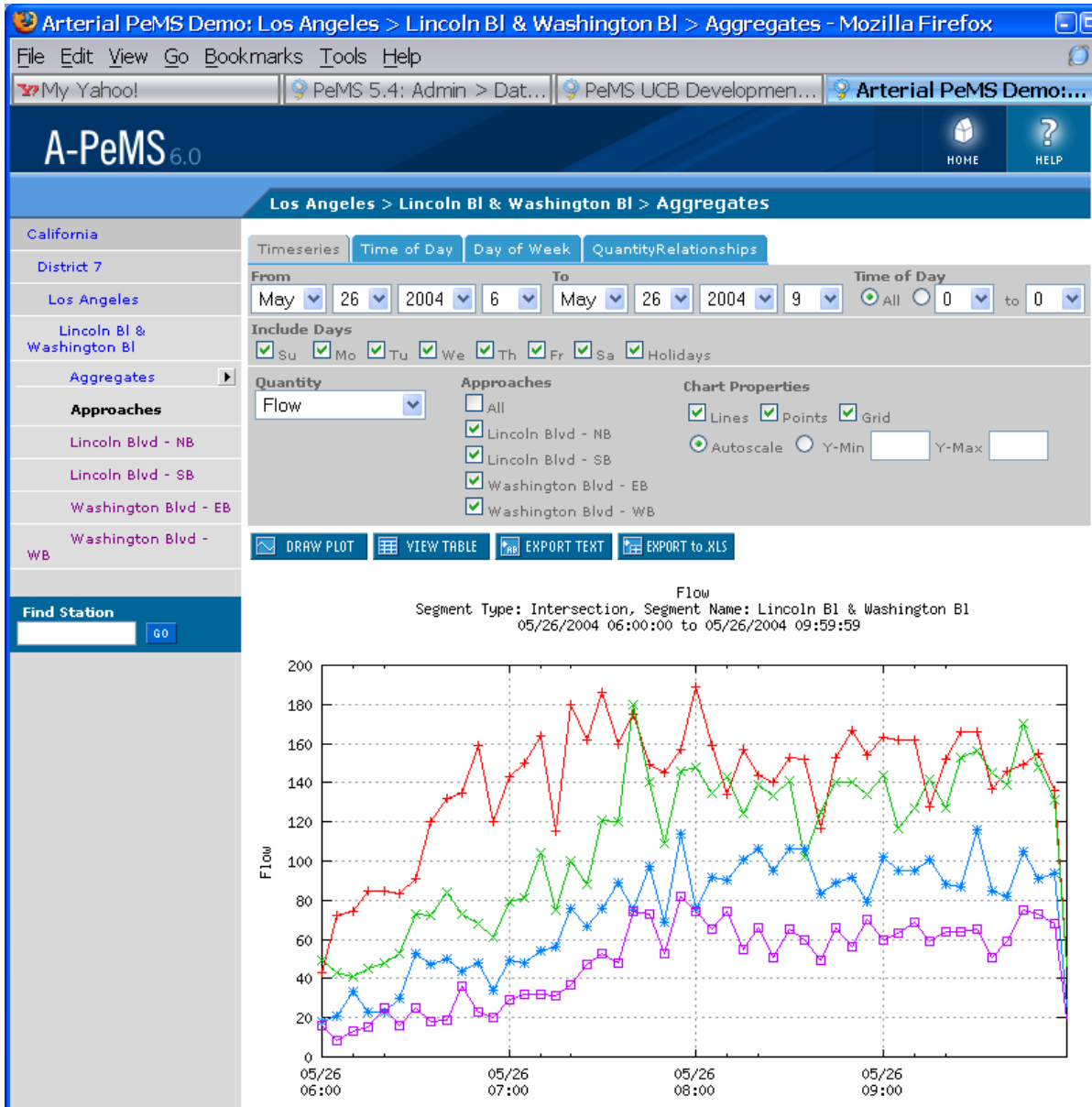
- **Previous Work**
  - **Site specific models (regression analysis)**
  - **Aggregate models (BPR, HCM)**
  - **Vehicle re-identification (limited deployments)**

Problem Statement (2)

- **Motivation**
  - Starting point:
    - Freeway Performance Measurement System (PeMS)
    - Large scale collection/storage/processing/analysis of surveillance data
  - Develop APeMS (arterial performance measurement system)
  - Estimation of travel times on signalized arterials
- **Approach**
  - Modeling of traffic dynamics
  - Considering effect of signal coordination
  - Data from surveillance systems
  - Low computational requirements

A-PeMS Pilot Implementation

- **Navigate via GIS or through listings of arterials and intersections**
- **Standard plots of measured quantities vs. time**
- **Example: Traffic flows versus time on all intersection approaches**

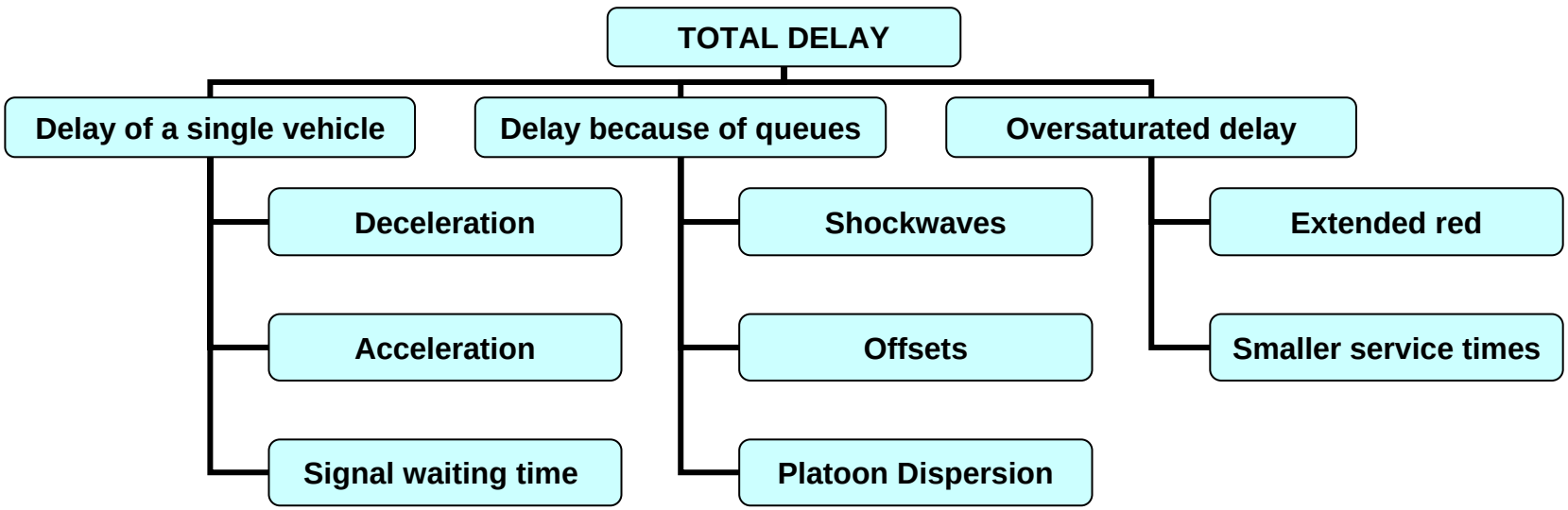


Model Structure[1]

Link travel time = Running Time + delay at the Signal

Data:

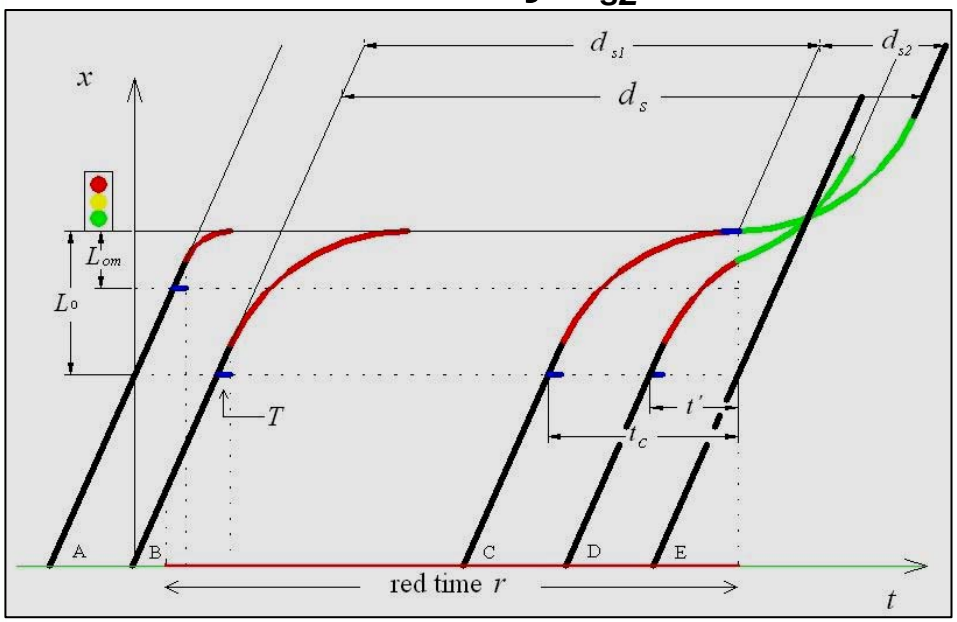
- **Signal status & settings (cycle, length, splits, offsets)**
- **Counts, occupancy (and speed) from mid-block (system) detectors**



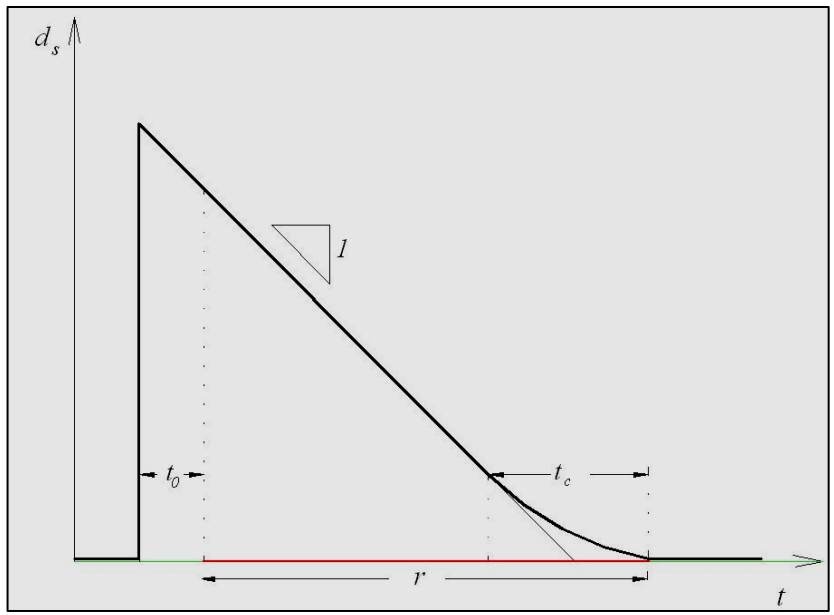
[1] Skabardonis and Geroliminis, 16th ISTTT, Maryland, 2005

I. Delay of a Single Vehicle

- **Deceleration plus idle delay d_{s1}**
- **Acceleration delay d_{s2}**



Delay of a single vehicle as a function of time

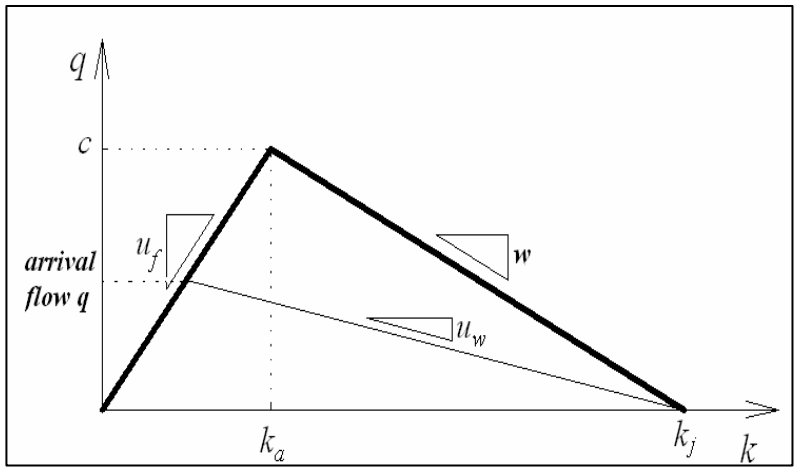


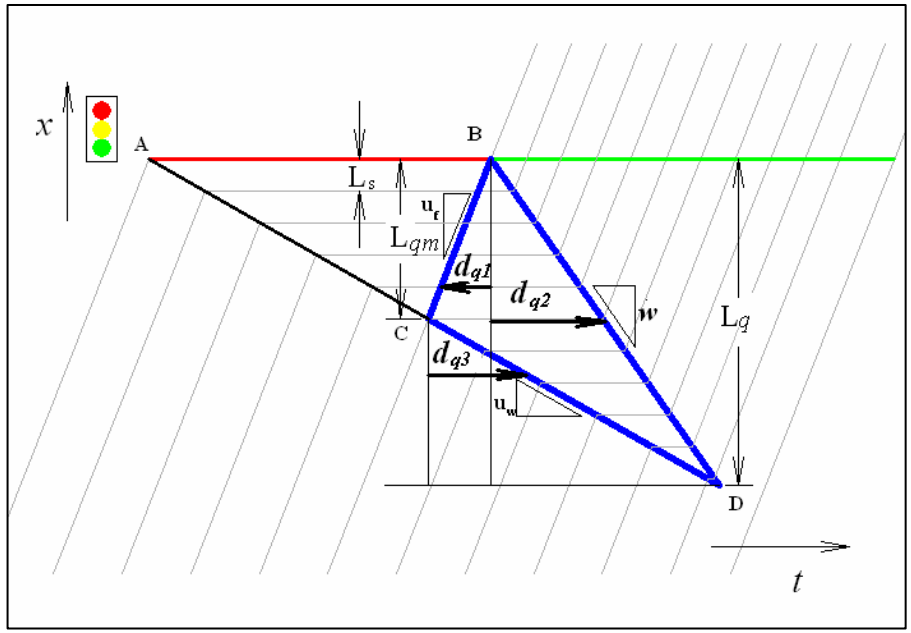
$$d_s(t)=\begin{cases} r-t+T+\dfrac{u_f}{2\gamma_\alpha} & , T+\dfrac{u_f}{2\gamma_{dm}}<t<r-\dfrac{u_f}{2\gamma_d} \\ 0.5\left(\dfrac{\gamma_d\cdot\gamma_\alpha+\gamma_d^2}{\gamma_\alpha u_f}\right)\left(r-t+T+\dfrac{u_f}{2\gamma_d}\right)^2 & , r-\dfrac{u_f}{2\gamma_d}<t<r+T+\dfrac{u_f}{2\gamma_d} \\ 0 & , \text{o.w.} \end{cases}$$

II. Delay because of Queues

Model the temporal and spatial formation of queues based on LWR theory

Assume triangular q-k diagram





$$d_q^n = d_q^{n-1} + L_s \cdot \begin{cases} \frac{1}{w} + \frac{1}{u_f}, & \text{if } nL_s \le L_{qm} \\ \frac{1}{w} - \frac{1}{u_w}, & \text{if } L_{qm} < nL_s \le L_q \end{cases}$$

Effect of Signal Coordination (Offsets)

Adjustment of phase times at the downstream signal

- **green time**

$$g' = g - \left(L/u_f - o \right)$$

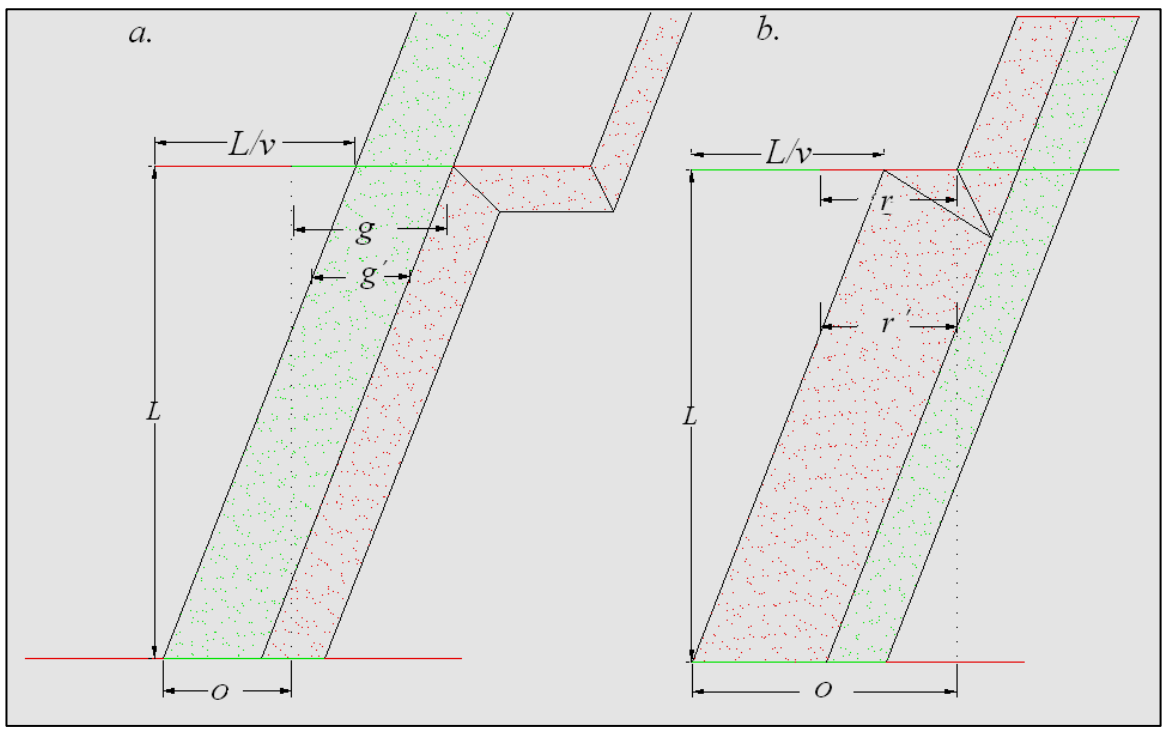
$$r' = r$$

- **red time**

$$g' = g$$

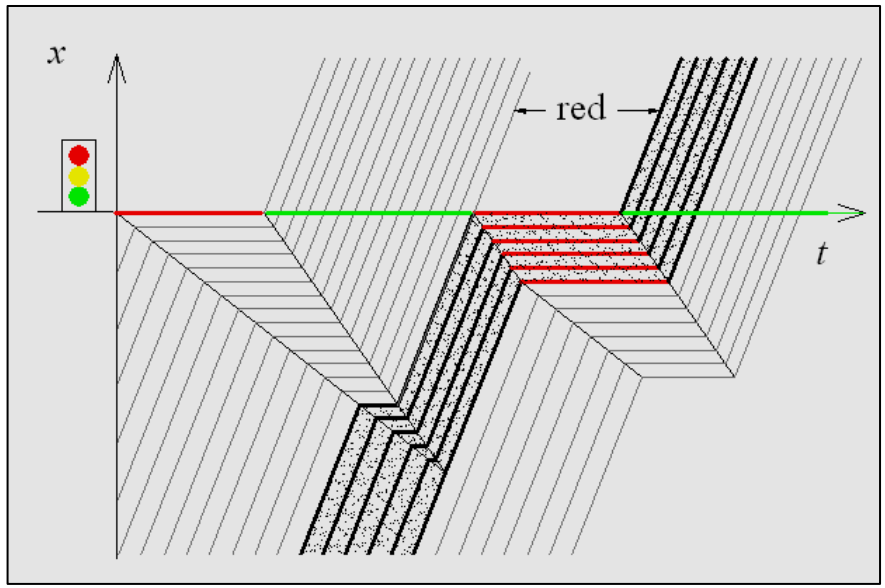
$$r' = r - \left(o - L/u_f \right) + t_q$$

$$t_q = \min\left(\frac{n_q \cdot L_s}{w} + \frac{n_q \cdot L_s}{u_f}, g \right)$$



III. Oversaturation Delay

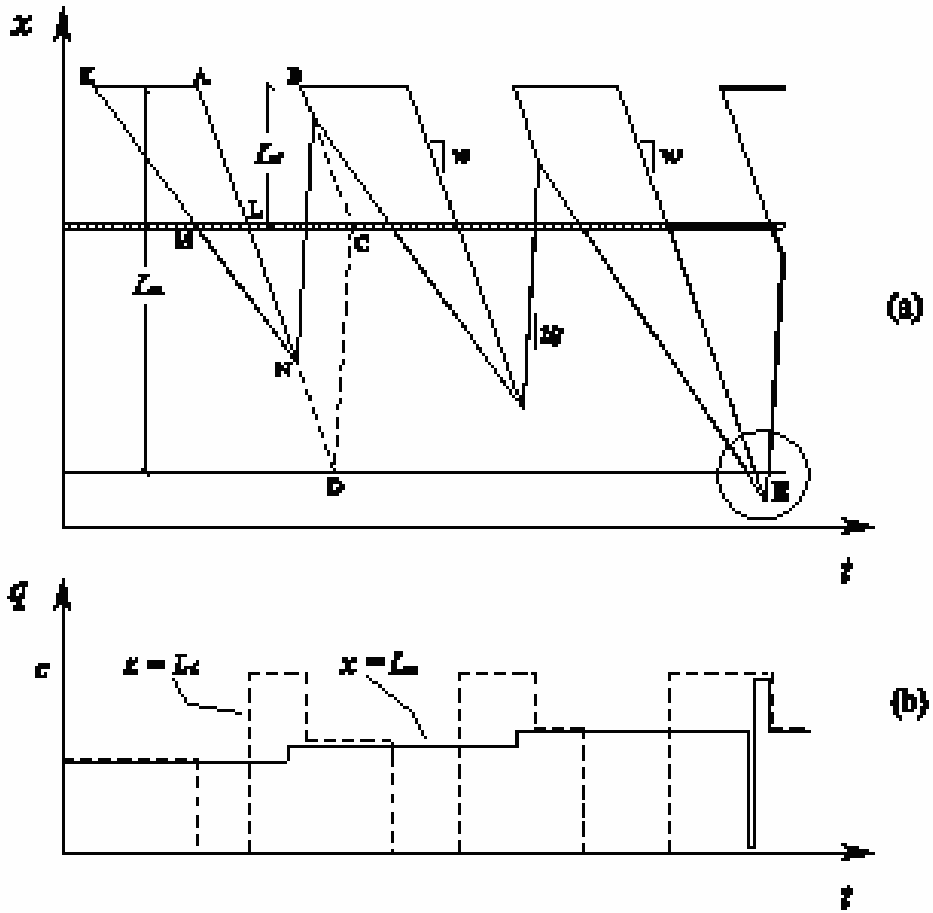
- **Arrival rate/cycle > service rate**
- **The delay of the vehicles that are not served during the cycle they arrive must be increased by one "red interval"**
- **The green time of the next cycle is decreased by the time interval needed to serve these vehicles**



Model Extensions (I)

- Long queues
  - Detectors not sufficiently upstream
  - Predict arrival rates at distance L_m

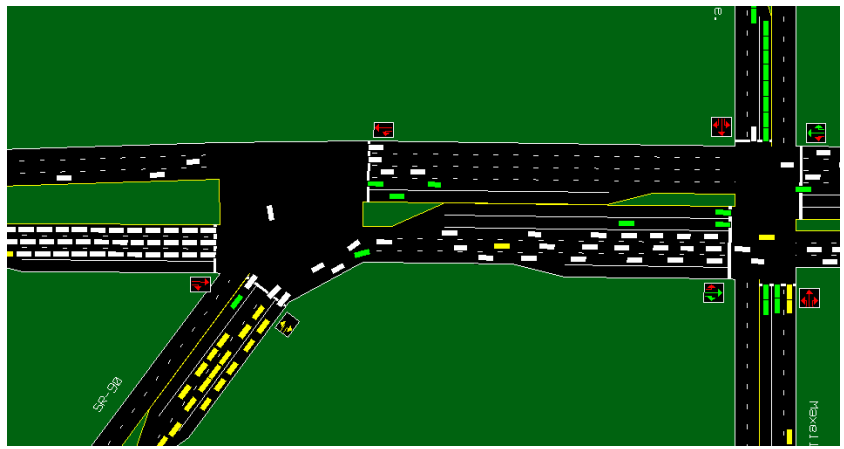
$$L_m = \frac{c}{k_j} \cdot g + L_d$$



Model Extensions (II)

- Spillovers
  - Identify conditions

$$o_{sp} = \frac{L_{eff} \cdot \bar{q}}{u_f} + \frac{r}{C}$$



  - Adjust available green times

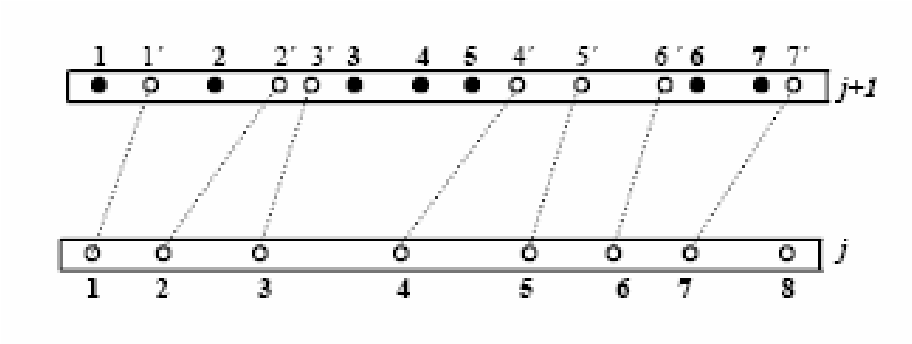
$$g_{eff}^{t+1} = \frac{N_{meas}^{t+1}}{c}$$

QUEUES DISCHARGE AT SMALLER THAN THE CAPACITY RATES

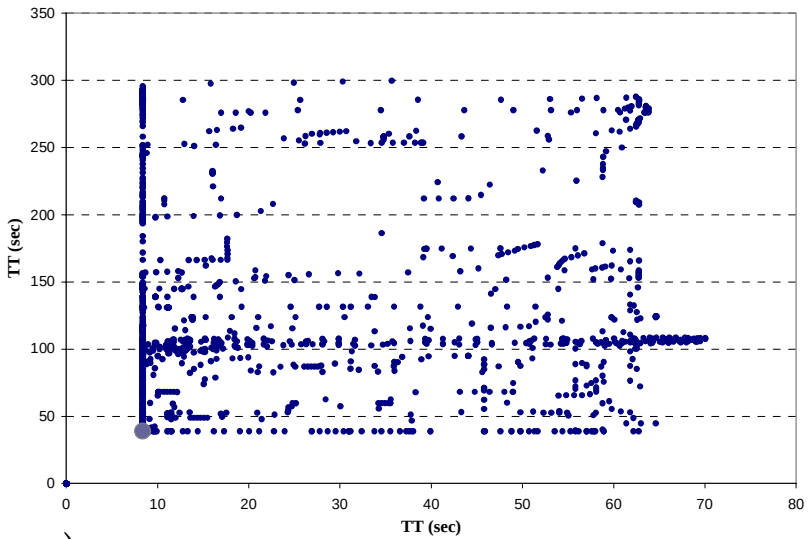
Vehicle reidentification

- Methodology for matching individual vehicles

$$t'_j = t_j + T_j\left(t_j\right) + \frac{L_{j+1} - L_j}{u_f}$$



- Maximum acceptance error between the measured and estimated arrival time of a vehicle



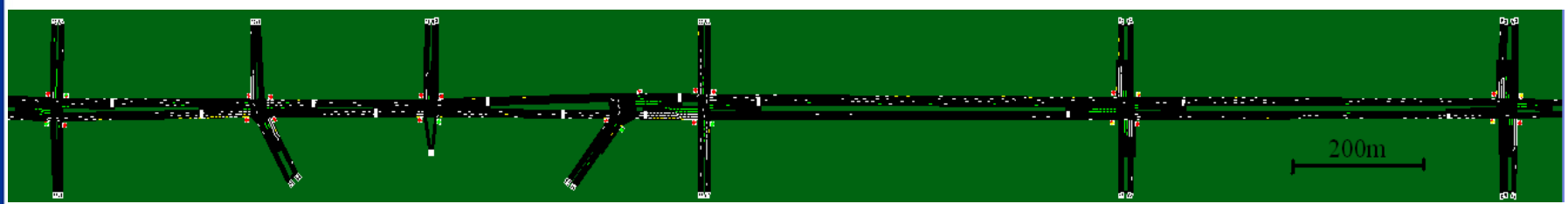
$$T_{j,1}\left(t'_j\right) = T_{j+1}\left(t'_j\right) + T_j\left(t_j\right)$$

$$T_{j,n}\left(t'_{j+n-1}\right) = T_{j+n}\left(t'_{j+n-1}\right) + T_{j,n-1}\left(t'_{j+n-2}\right) \quad \text{for} \quad t_k = t'_{k-1} \quad \forall k = 2,3,\ldots,n$$

Model Application (1)

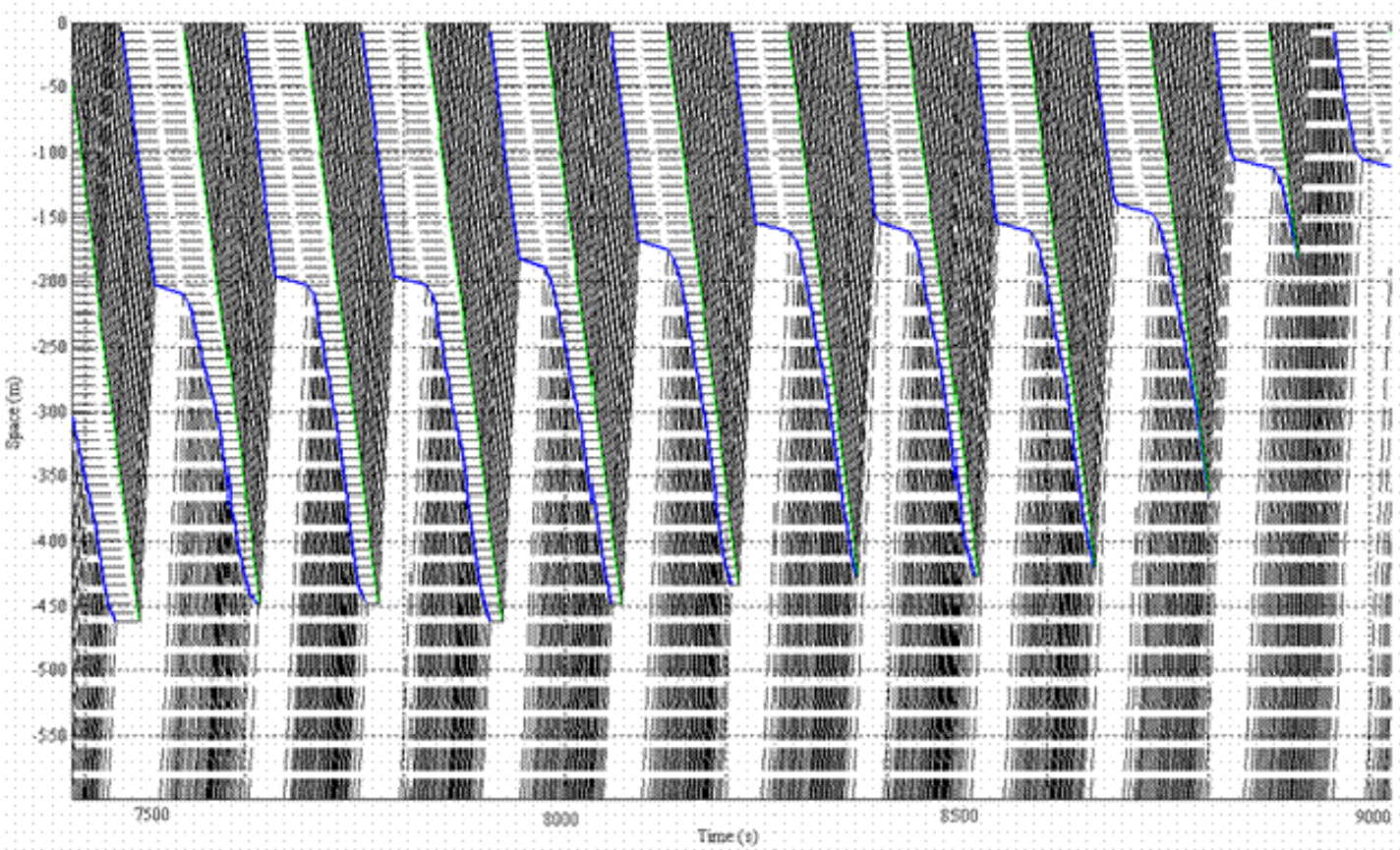
Lincoln Avenue, Los Angeles

- Seven intersections (2.3 Km, 1.4 miles)
- Traffic data (*counts*, *occupancy*) from midblock loop detectors part of the LADOT ATSAC system
- Multiphase traffic responsive signal operation (C=100-150sec)
- Probe vehicle travel times (at 7 min headways)
- Simulation of the test section

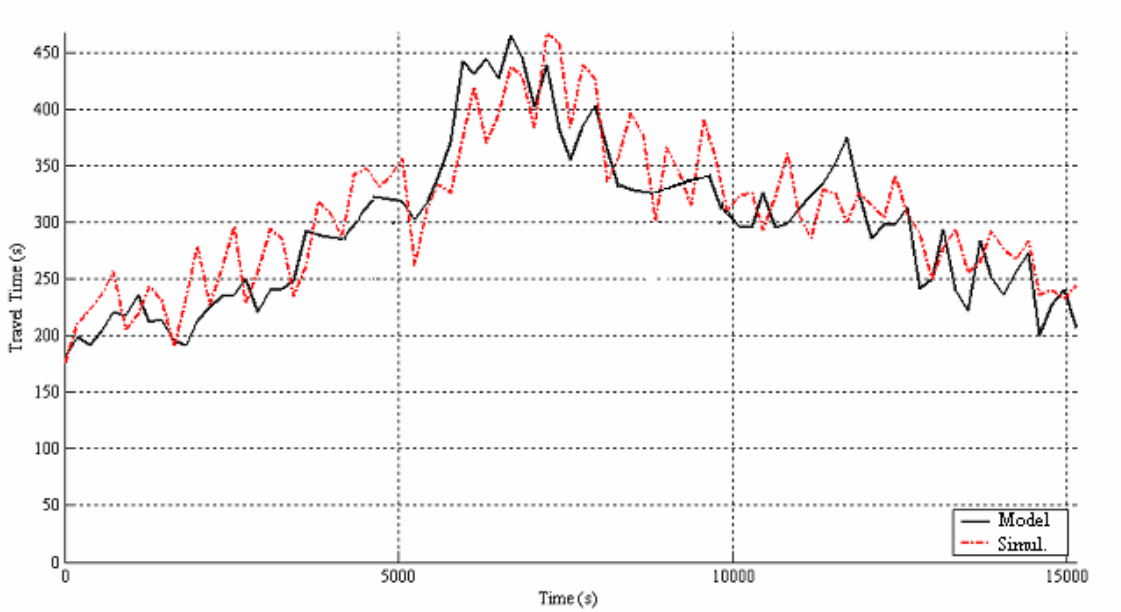


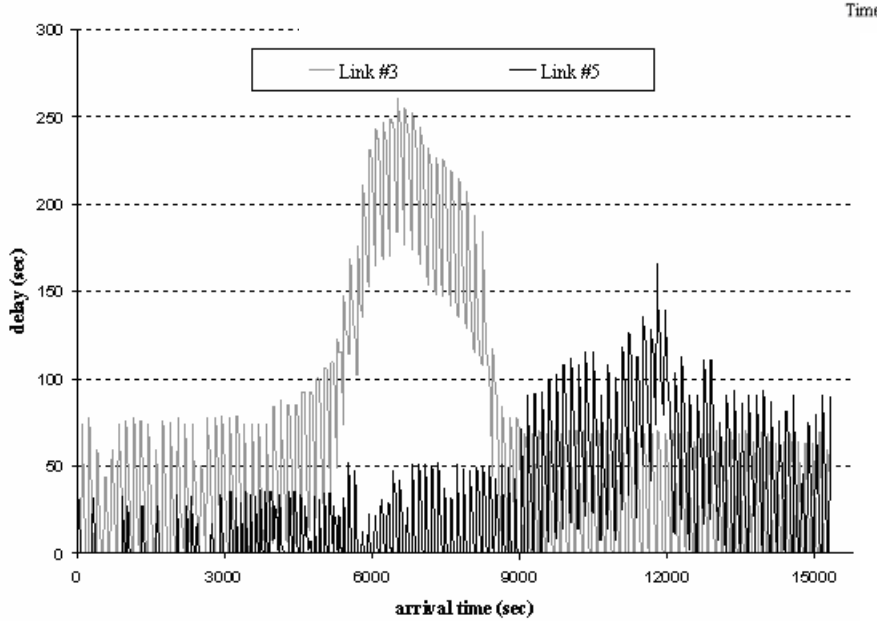
Model Application (2)

Lincoln Avenue: Draw Trajectories



Model Application (3)

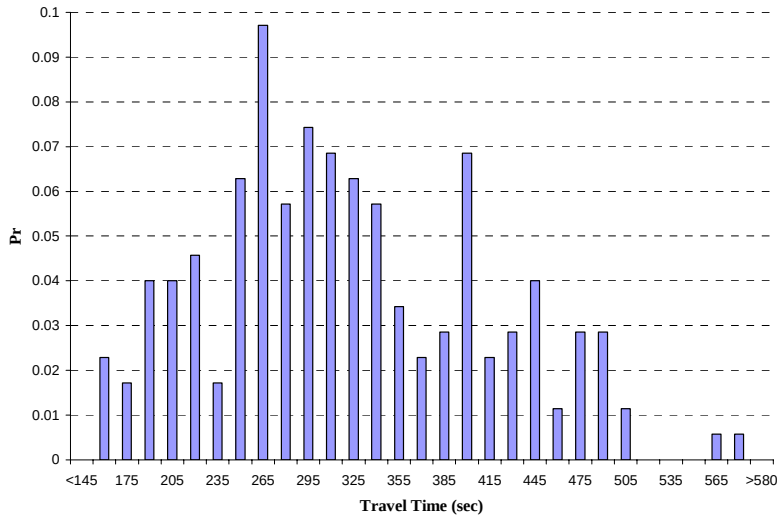




- Capture:
  - Different demand
  - high delays
  - queue spillovers

Performance Measures

- Disaggregate and aggregate Delay estimation
- Quality of signal progression
- Travel Time Variability
- Travel Time Correlation



$$\mathbf{C}_{ij} = \begin{bmatrix} 1 & .17 & .08 & -.03 & .02 & .01 \\ & 1 & .02 & -.04 & .02 & .02 \\ & & 1 & -.24 & -.09 & .08 \\ & & & 1 & .13 & -.07 \\ & & & & 1 & -.29 \\ & & & & & 1 \end{bmatrix}$$

Correlation of TT betweens links *i* and *j*

$$\mathbf{G}_{ij} = \begin{bmatrix} .39 & .15 & .08 & .01 & 0 \\ & .32 & .12 & .02 & 0 \\ & & .21 & .02 & 0 \\ & & & .10 & .04 \\ & & & & .04 \end{bmatrix}$$

Pr{ a vehicle passes with zero delay all links from *i* to *j+1* }

CTM in Arterials

- Difficulties
  - Limited space
  - Turning movements effect
  - Time-dependent capacity
  - Need for time and space desegregation

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