Statistical Modeling and Analysis for Travel Time Estimation of Urban Arterial Traffic

Michigan Engineering Industrial and Operations Engineering

Data Fusion Lab

Project Sponsor: Bureau of Transportation Statistics-US Department of Transportation

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Motivation

Estimation and prediction of travel time has significant impact on traffic planning, management, and control:

- As the primary measure of the level of service in an urban arterial
- To determine design traffic volumes on roadway in urban transportation planning model
- To adaptively control signal timing and detect incidents

State-of-the-Art

Stochastic modeling with the following assumptions:

- No vehicles entering and existing the roadway between detectors
- The probability distribution of travel time is invariant between detectors
- Short-term estimates and predictions is made for 5-15 minutes

Simulation modeling and analysis:

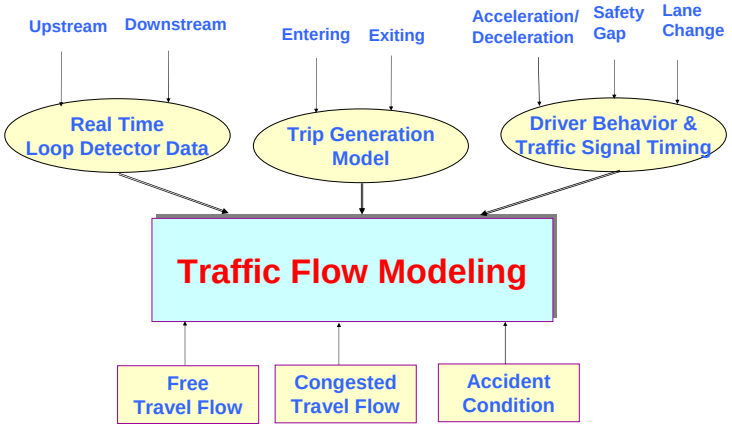
- Need to predetermine all distributions and parameters for traffic flow, vehicle volumes, driver behaviors, etc.
- No guideline for validation of simulation results
- Hard to implemented in real time traffic control

Objectives & new features

To develop an effective model and statistical analysis techniques for travel time estimation for urban arterial traffic with the following new features:

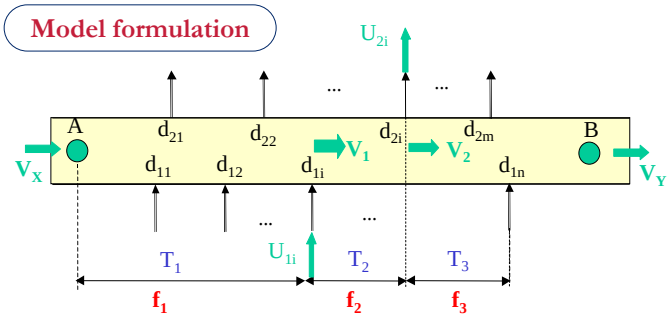
- Travel time estimation is performed based on real time loop-detector data with the resolution of one second
- The effects of vehicle volume and the location of entrances and exists are modeled explicitly by using varying probability distributions of travel time between detectors
- The effect of trip generation factors is integrated in the traffic flow model

Proposed approaches

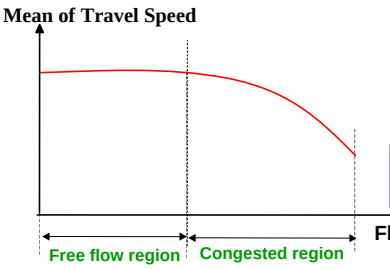


Accomplishments

Model formulation



- **Different travel time distribution through entrances/exits**
- **Effect of travel flow on travel speed**



$$\hat{V}_1(t) = \sum_{\tau=0}^{T_1} \hat{f}_1(\tau) \cdot V_X(t-\tau)$$

$$\hat{V}_2(t) = \sum_{\tau=0}^{T_2} \hat{f}_2(\tau) \cdot \left[\hat{V}_1(t-\tau) + U_{1i}(t-\tau)\right]$$

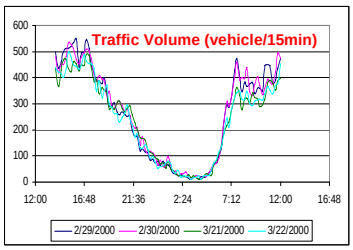
$$\hat{V}_Y(t) = \sum_{\tau=0}^{T_3} \hat{f}_3(\tau) \cdot \left[\hat{V}_2(t-\tau) - U_{2i}(t-\tau)\right]$$

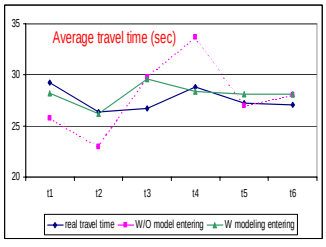
- **V_X and V_Y are measured by real time loop detectors**
- **U_{1i} and U_{2i} are obtained from trip generation model**
  - **trip generation factor identification**
  - **hierarchical clustering of U_{1i} and U_{2i}**
- **f_1, f_2, and f_3 are adaptively estimated by Least-square estimation**

Travel time distribution estimation

$$\min_{f_1,f_2,f_3} \sum_{t=(T_B+b)/\Delta}^{t=(T_F+a)/\Delta} [e(t)]^2 = \sum_{t=(T_B+b)/\Delta}^{t=(T_B+a)/\Delta} \left[V_Y(t) - \hat{V}_Y(t)\right]^2$$

$$\text{suject to } f_k \geq 0, \text{ and } \sum_{t=a_k}^{b_k} f_k(t) = 1;\ k = 1,2,3$$





Impact of Work

Provide short-term travel time estimation for real time traffic control and early incident detection.

Reference

Guo, H. and Jin, J., "Modeling and Cross Correlation Analysis for Travel Time Estimation in Urban Arterial Traffic," to appear in *Transportation Research Record A*.

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