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Travel Time Prediction Using Higher Traffic Flow Models

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Outline of the presentation

- Introduction
- Background
- Methodology
- Data Collection
- Results
- Conclusions

Introduction

- Travel time is an important system performance measure.
- Availability of travel time information
    - Control traffic and reduce congestion.
    - Identification of shortest path between a pair of origin and destination.
    - Essential for various Intelligent Transportation Systems (ITS) applications such as Advanced Traveler Information Systems (ATIS), Advanced Public Transportation System (APTS) and Advanced Traffic Management Systems (ATMS).
    - Dynamic route guidance, incident detection, freeway ramp metering control etc.
- Travel time - a spatial parameter- Prediction is challenging.

Background

- Various techniques - reported in literature.
  - Data driven approach
  - Traffic flow theory based approach
- Data driven – extracts system characteristics from the huge amount of data – data intensive.
- Traffic flow theory based approach – concepts of physics – relates traffic flow variables – complete picture of the system- aggregate level- minimal data.
- Developing countries- Minimal data collection infrastructure.
- Travel time prediction using traffic flow theory based approach – Suitable.

Back ground

- Traffic flow models – Modified/Rewritten/discretized/state space – travel time prediction/estimation.
- Macroscopic traffic models – First order models- Higher order models.
  - Models: LWR, Payne, Zhang, Aw-Rascle.
- First order
  - LWR- simplest – explored to an extent.
- Higher order models
  - Payne- Negative speeds – Characteristics speed higher than vehicle speed.
  - Aw-Rascle– Answers the limitations of Payne's model -not yet explored.
- Adopted – Aw-Rascle's traffic flow model– Travel time prediction.

Aw Rascle Model

$$\frac{\partial \rho}{\partial t} + \frac{\partial(\rho v)}{\partial x} = 0$$ (Conservation equation)

$$\frac{\partial(v + p(\rho))}{\partial t} + v\frac{\partial(v + p(\rho))}{\partial x} = \frac{1}{T}(u_e(k) - u)$$ (Velocity dynamics equation)

Where,

v is speed,

ƒ is traffic density,

p is the traffic pressure and

t is the independent variables represent time.

x is the independent variables represent space.

Modelling

- Purely hyperbolic and conservative form of Aw-Rascle Model i.e. under no diffusion and no relaxation conditions (Aw & Rascle, 2000).

$$\frac{\partial \rho}{\partial t} + \frac{\partial(\rho v)}{\partial x} = 0 \qquad (1)$$

$$\frac{\partial(v + p(\rho))}{\partial t} + v\frac{\partial(v + p(\rho))}{\partial x} = 0 \qquad (2)$$

- Taking the velocity dynamics equation and modified for travel time prediction.

- Assumption
  - Equations are independent to each other

Modelling

- Adopting the pressure function suggested by Zhang et al., (2016)

$$p(k) = v_f - V(k) \quad (3)$$

- Assuming Greenshield speed-density function for *V*(*k*), eqn. (3) becomes

$$p(k) = v_f \left(\frac{k}{k_j}\right) \quad (4)$$

- Subs (4) in (2), the modified form of Aw-Rascle's velocity dynamics equation is

$$\frac{\partial\left(v + v_f\left(\frac{k}{k_j}\right)\right)}{\partial t} + v\frac{\partial\left(v + v_f\left(\frac{k}{k_j}\right)\right)}{\partial x} = 0 \quad (5)$$

Modelling

- Discretization: Finite difference method
  - Forward Time Backward Space scheme

$$\frac{\partial u}{\partial x} = \frac{u_i^t - u_{i-1}^t}{\Delta x} \quad \frac{\partial k}{\partial x} = \frac{k_i^t - k_{i-1}^t}{\Delta x}$$

$$\frac{\partial u}{\partial t} = \frac{u_i^{t+1} - u_i^t}{\Delta t} \quad \frac{\partial k}{\partial t} = \frac{k_i^{t+1} - k_i^t}{\Delta t}$$

Where,
t is the time index
i is the space index

  - Discretizing the eqn. (5) and rewriting as (6)

$$u_i^{t+1} = u_i^t - \left(\left(\frac{v_f k_i^{t+1}}{k_j}\right) - \left(\frac{v_f k_i^t}{k_j}\right)\right) - \left(\frac{\Delta t}{\Delta x}\right) u_i^t \left[(u_i^t - u_{i-1}^t) + \left(\left(\frac{v_f k_i^t}{k_j}\right) - \left(\frac{v_f k_{i-1}^t}{k_j}\right)\right)\right]$$

$$u_i^{t+1} = u_i^t - \left(\frac{v_f}{k_j}(k_i^{t+1} - k_i^t)\right) - \left(\frac{\Delta t}{\Delta x}\right) u_i^t \left[(u_i^t - u_{i-1}^t) + \left(\frac{v_f}{k_j}(k_i^t - k_{i-1}^t)\right)\right] \quad (6)$$

Implementation

- Assumptions
  - First sections(Entry) speed and density values – initial conditions.
  - Overtaking of vehicles are permitted
  - Stability Condition of the numerical scheme: $\left(\frac{\Delta x}{\Delta t}\right) > v_f$

  (vehicle travelling at V_f cannot travel more than one time step)
- Adopting the discretized form of conservation eqn. suggested by Kumar et al., (2011).

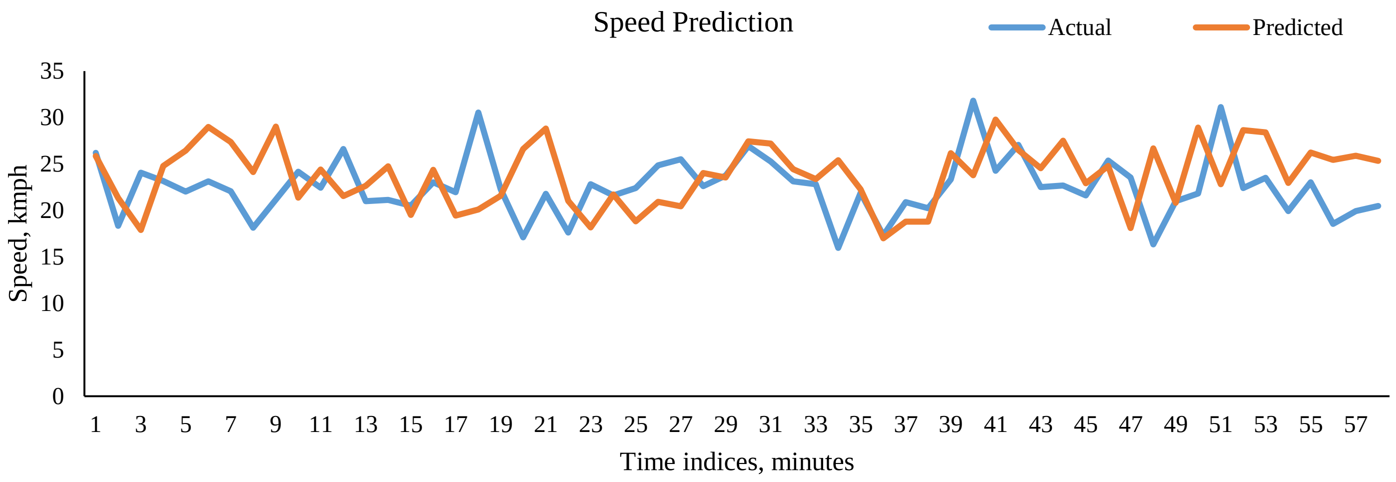
$$k_i^{t+1} = k_i^t \left(1 - \left(\frac{\Delta t}{\Delta x}\right) v_f \left(1 - \frac{k_i^t}{k_j}\right)\right) - k_{i-1}^t \left(\left(\frac{\Delta t}{\Delta x}\right) v_f \left(1 - \frac{k_{i-1}^t}{k_j}\right)\right)$$

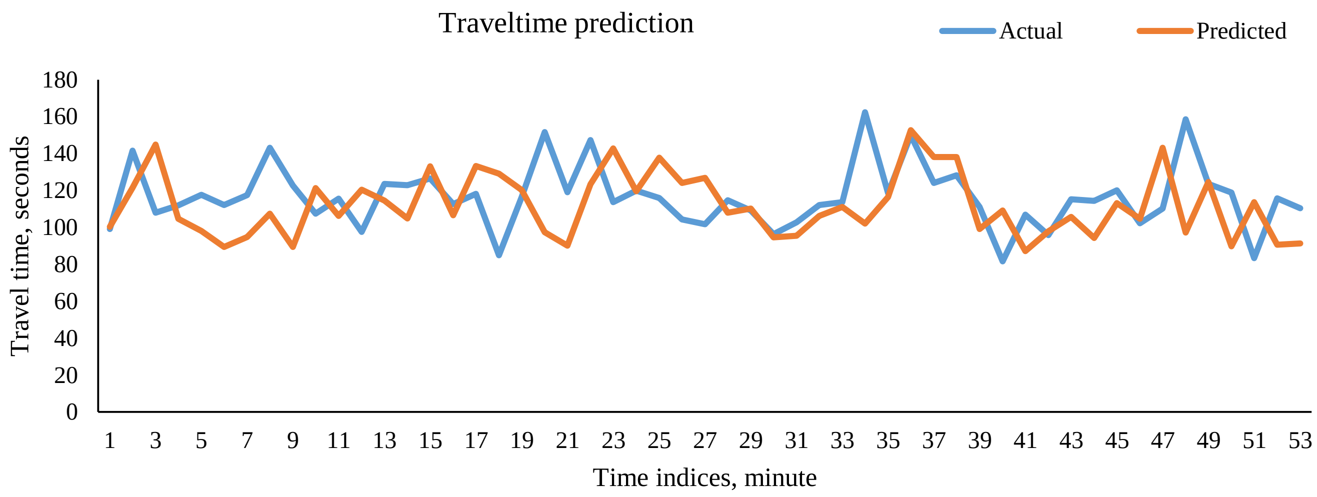
Implementation

- Study stretch : Rajiv Gandhi Salai (IT Corridor), Chennai, India.
  - Section 1: Location A to Location B
  - Section 2 : Location B to Location C
  - Total Length: 1.72 km
  - Six lane highway road
  - Only direction of traffic considered
- Road stretch similar to the field test bed was created in VISSIM using a satellite image
- Five hours simulation – implementation
- Density and speed values for both section 1 and 2 - Collected

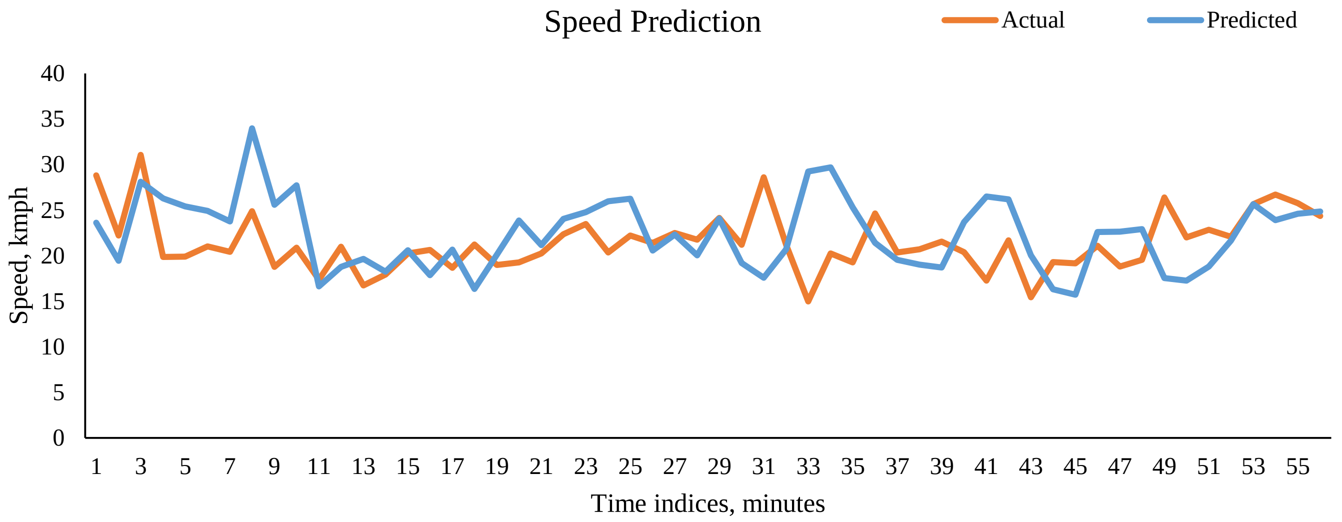
Figure: Test bed

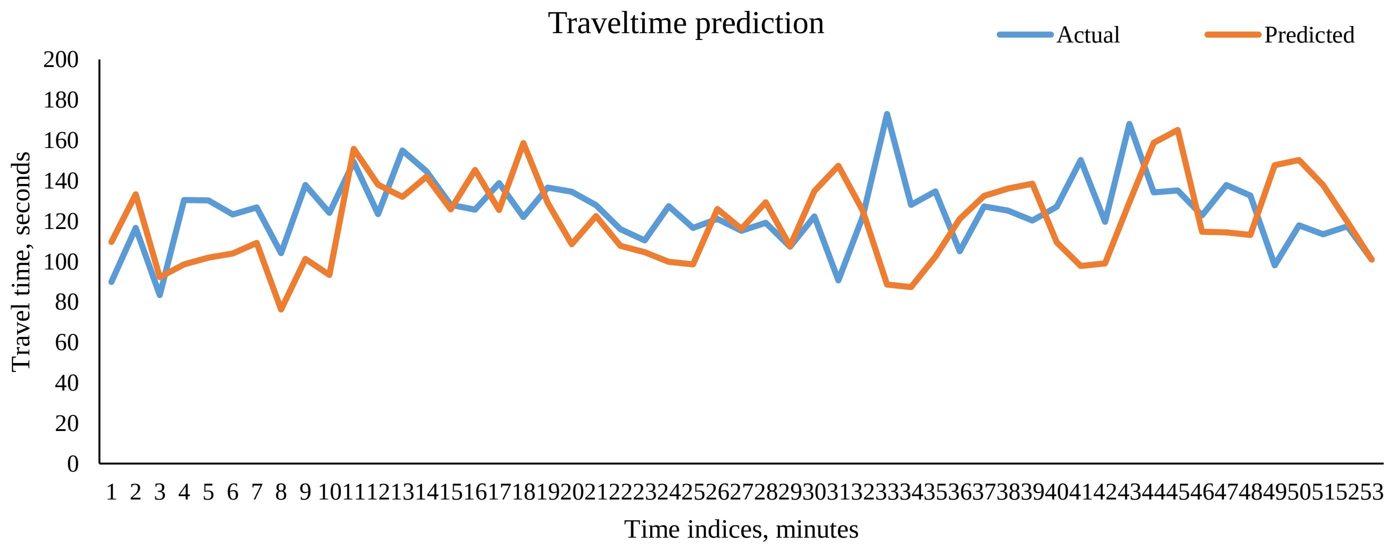
Results – Sample 1



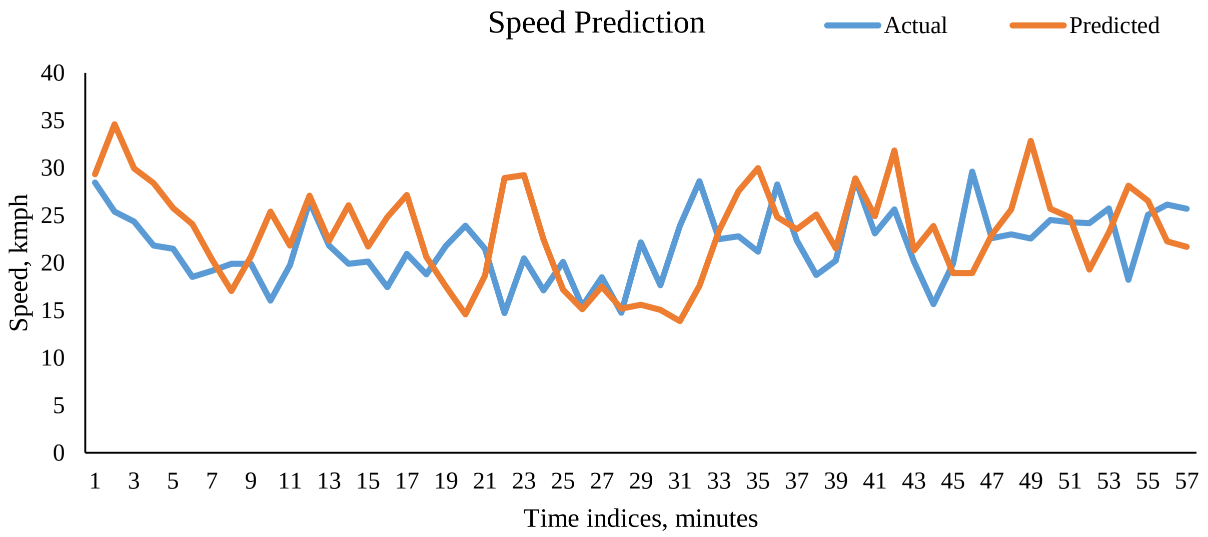


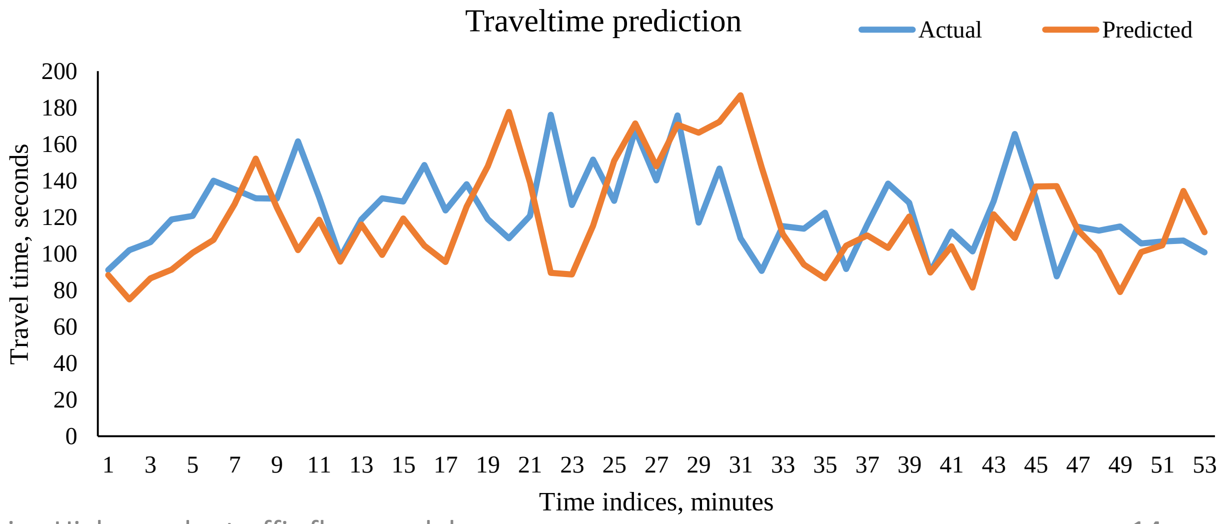
Results – Sample 2





Results – Sample 3





Conclusions

- Explored the possibility of travel time prediction using higher order traffic flow model equations.
- MAPE-15% to 21% - Satisfactory
- Model is very sensitive towards the input – variations in output - higher errors in certain places
- Initial implementation - need refinements – better predictions

Future scope

- Exponential speed density relationship.
- State space representation integrated with filtering algorithm for real time prediction.
- Possibility of using another source of data in the correction step.
- Finite Volume discretization

Thank you.