Temporal and Spatial Freeway Work Zone Delay Estimation Using Probe–vehicle Data

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Outline

- Background
- Model Development
- Case Study
- Conclusions
- Future Enhancements
Background

- Accurate and reliable estimates of traffic impacts associated with work zone lane closures
- Issues in traditional volume/capacity formulae and deterministic traffic queuing method
- Integration of probe-vehicle data into the traffic impact analysis model
- Development of Work zone Interactive Management Application-Planning (WIMAP-P) model and software
## Work Zone Delay Estimation Approaches

<table>
<thead>
<tr>
<th>Approaches</th>
<th>Detailed Information</th>
<th>Selected References</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Parametric Approach</strong></td>
<td>Deterministic queuing theory</td>
<td>Abraham et al. (1981); Dudek and Richards (1982); Chien and Schonfeld (2001)</td>
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<td></td>
<td>Shockwave theory</td>
<td>Lighthill and Whitham (1955); Richards (1956); Wirasinghe (1978)</td>
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<tr>
<td><strong>Non-parametric Approach</strong></td>
<td>ANN (Artificial Neural Network)</td>
<td>Karim Adeli (2003); Jiang and Adeli (2003); Ghosh-Dastidar and Adeli (2006)</td>
</tr>
<tr>
<td><strong>Simulation Approach</strong></td>
<td>VISSIM, CORSIM</td>
<td>Chien et al. (2002); Chitturi et al. (2004); Edara et al. (2013)</td>
</tr>
</tbody>
</table>
Seasonal Average Speeds (I-280, Exit 15)

I-280 EB, Exit 15 (Newark, NJ)

I-280 WB, Exit 15 (Newark, NJ)

(Speed data source: INRIX)
Artificial Neural Network (ANN)

- Analyze transportation data and recognize patterns
- Classify transportation data with proper boundaries
Data Collection

OpenReach
- Work zone related information in 2014

INRIX
- Travel time/speed covering interstate highways in 2014

Plan4Safety
- Crash records location and time in 2014

Straight Line Diagram
- Roadway geometric information (2014)
Data Collection (cont’d)

- Qualified historical work zones on New Jersey Interstate Highways in 2014 for model development

<table>
<thead>
<tr>
<th>No. of Lanes per Direction</th>
<th>2-lane Closure</th>
<th>1-lane Closure</th>
<th>Shoulder Closure</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>10</td>
<td>177</td>
<td>31</td>
</tr>
<tr>
<td>3</td>
<td>35</td>
<td>108</td>
<td>32</td>
</tr>
<tr>
<td>4 and more</td>
<td>7</td>
<td>20</td>
<td>10</td>
</tr>
</tbody>
</table>
Configuration of WIMAP-P ANN Model

Inputs | One Hidden Layer (10 Neurons) | Output
--- | --- | ---
Normal speed of segment $i$ at time $j$ |  | Estimated speeds upstream of the work zone
Work zone length | | |
Work zone duration | | |
Work zone starting time | | |
Open lane ratio | | |

<table>
<thead>
<tr>
<th>No. of Lanes per Direction</th>
<th>RMSE (mph)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-lane</td>
<td>3.9</td>
</tr>
<tr>
<td>3-lane</td>
<td>5.1</td>
</tr>
<tr>
<td>4-lane</td>
<td>4.3</td>
</tr>
</tbody>
</table>
Case Study

- Work zone location: I-287 Northbound MP 12.5 ~ 13.1
- Total number of lanes: 3
- Number of closed lanes: 1
- Date/time:
  June 19, 2014
  from 10:30 am to 1:30 pm
Freeway Work Zone Planning

Parameter Inputs:

- **Route Name:** I-287
- **Start & End Milepost Range:** 0 to 67.54
  - **Starting Milepost:** 12.5
  - **Ending Milepost:** 13.1
- **Direction:** South to North
- **Number of Total Lanes:** 3
- **Number of Closed Lanes:** 1 Lane Closed
- **Expected Start Date:** 06/19/2014
- **Expected Start Time:** 10:30:00
- **Expected End Date:** 06/19/2014
- **Expected End Time:** 13:30:00
- **Value of Passenger Car Time ($/veh-hr):** 12.75
- **Value of Truck Time ($/veh-hr):** 21.25

[Show Result]

[Show Report]
Case Study

- Determine and display the spatial and temporal speeds of an expected lane closure activity;

![Estimated Speed Heat Map](image1)

- Compare recurrent speed and estimated work zone speed in the upstream of work zone;
Case Study

Recurrent Speed Heat Map

Estimated Speed Heat Map

Historical Speed Heat Map (June 19, 2014)
Case Study

Historical Average Upstream Delay (min/veh)

Estimated Average Upstream Delay (min/veh)

Congested Length (mi)

- Blue: Actual congested length
- Orange: Estimated congested length

Work Zone Duration

Time of Day

Mileposts

Direction of Travel

10:30 10:45 11:00 11:15 11:30 11:45 12:00 12:15 12:30 12:45 13:00 13:15 13:30 13:45 14:00 14:15 14:30 14:45 15:00 15:15

Congested Length (mi)

0.0 1.0 2.0 3.0 4.0 5.0

New Jersey Institute of Technology
Case Study

- If the volume counts at the work zone are available, we can also estimate:
  - Vehicle emission cost
  - Road user cost
Conclusions

- The WIMAP-P ANN model developed utilizing probe-vehicle speed data to estimate the upstream speeds and delay under planned work zone lane closure conditions.

- The main data used are: OpenReach, INRIX, Plan4Safety, and SLD.

- In addition, the model can assist transportation engineers:
  - To evaluate congestion impacts by planned work zones.
  - To develop traffic management plans mitigating congestion.
  - To facilitate work zone sketch planning and scheduling.
  - To determine lane rental charges.
Future Enhancements

- Incorporate traffic flow data where available
- Develop an innovative Big Data management framework to cover wide range of data sources
- Estimate emission and road user costs
- Develop a corridor-based model
Q&A