2012 ITS-NY NINETEENTH ANNUAL MEETING
June 7 – 8, 2012; Saratoga Springs, NY
Efficiency and ITS

Friday, June 8, 2012

8:30 a.m. Panel 4: Current ITS University Research and Projects
Panel Moderator: Dr. Camille Kamga, CUNY/University Transportation Research Center
“Data Mining Algorithm for the Analysis of Overweight Vehicles Using WIM Technology,” Graziano Fiorillo, The City College of New York, CUNY, Winner ITS-NY Best Student ITS Essay Contest
“Coordinated Transit Fares and Car Pricing at Congested Bottlenecks,” Dr. Eric Gonzales, Rutgers, The State University of New Jersey
“Dynamic Signal Control for Low Delay at Traffic Intersections,” Dr. Koushik Kar, Rensselaer Polytechnic Institute
“Use of the VISTA Dynamic Traffic Assignment (DTA) for Emergency Operations,” Dr. Kyriacos Mouskos, City University of New York
Data Mining Algorithm for the Analysis of Overweight Vehicles Using WIM Technology

Graziano Fiorillo
The City College of New York - CUNY
Background

• High number of Overweight vehicles cause increased damage to pavements and bridges
• Data collection is important to quantify damage
• Weigh-In-Motion (WIM) systems collect unbiased truck data
• WIM systems cannot distinguish between permit and illegal overweight vehicles
Objective

• This paper presents a methodology to obtain statistical estimates of overweight trucks and separates them into permit and illegal vehicles
• Methodology is applied to New York State data
Available Data

• WIM truck data

• Database of Divisible (DV) Permit loads
  ➢ Vehicles of legal size but overweight

• Database of Annual and Trip Special Hauling (SH) Permit
  ➢ Vehicles where the freight due to special reasons cannot be divided to be transported by vehicles of ordinary size
Use weigh-in-motion (WIM) data

- Axle weights
- Axle spacing
- Time of arrival

- 25 WIM stations in New York State

- FHWA procedures for quality control and system calibration

- Existing WIM systems cannot identify permit or illegal

<table>
<thead>
<tr>
<th>TECHNOLOGY</th>
<th>ACCURACY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bending Plate</td>
<td>0 to 12%</td>
</tr>
<tr>
<td>Capacitive Mat</td>
<td>0.5 to 1.5%</td>
</tr>
<tr>
<td>Load Cell</td>
<td>0 to 6%</td>
</tr>
<tr>
<td>Piezoelectric</td>
<td>3 to 30%</td>
</tr>
<tr>
<td>Quartz cables</td>
<td>&lt;10%</td>
</tr>
<tr>
<td>B-WIM</td>
<td>6%</td>
</tr>
</tbody>
</table>
Bending Plate Sensors

WIM Controller

Bending Plate
Examples of Special hauling vehicles
- Statistics show high variability on percentages of Overweight Vehicles

<table>
<thead>
<tr>
<th>State</th>
<th>% Exceeding Legal limits</th>
<th>High Enforcement</th>
<th>Low Enforcement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alaska</td>
<td>0.23%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arizona</td>
<td>0.53%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arkansas</td>
<td>0.29%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Colorado</td>
<td>12%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Illinois</td>
<td>~27.1%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Louisiana</td>
<td>~25%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maryland</td>
<td>1.40%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Montana</td>
<td>10.33%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>North Dakota</td>
<td>50%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oregon</td>
<td>~5%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Texas</td>
<td>3 to 4%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Utah</td>
<td>2-3%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>State</th>
<th>High Enforcement</th>
<th>Low Enforcement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Virginia</td>
<td>0.5 to 2.0 %</td>
<td>12 to 27 %</td>
</tr>
<tr>
<td>Maryland</td>
<td>1.00%</td>
<td>34%</td>
</tr>
<tr>
<td>Arizona</td>
<td>1.50%</td>
<td>30%</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>1.00%</td>
<td>20%</td>
</tr>
<tr>
<td>Idaho</td>
<td>11.90%</td>
<td>32%</td>
</tr>
<tr>
<td>Florida</td>
<td>1.40%</td>
<td>13%</td>
</tr>
<tr>
<td>Montana</td>
<td>1.00%</td>
<td>29%</td>
</tr>
</tbody>
</table>

Straus and Semmes (2006)

Taylor et al. (2000)
GVW Distribution
• Being Overweight does NOT mean ILLEGAL

• New York State Department of Transportation (NYSDOT) allows vehicles to travel overweight according to specific regulations and the payment of a Permit fee

• The objective of this study is to recognize trucks that actually are illegal from those that are not
## Analysis of WIM Data – FHWA Truck Classification

<table>
<thead>
<tr>
<th>CLASS</th>
<th>VEHICLE PROFILE</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td><img src="image1" alt="CL 5" /></td>
</tr>
<tr>
<td>6</td>
<td><img src="image2" alt="CL 6" /></td>
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<tr>
<td>7</td>
<td><img src="image3" alt="CL 7" /></td>
</tr>
<tr>
<td>8</td>
<td><img src="image4" alt="CL 8" /></td>
</tr>
<tr>
<td>9</td>
<td><img src="image5" alt="CL 9" /></td>
</tr>
<tr>
<td>10</td>
<td><img src="image6" alt="CL 10" /></td>
</tr>
<tr>
<td>11</td>
<td><img src="image7" alt="CL 11" /></td>
</tr>
<tr>
<td>12</td>
<td><img src="image8" alt="CL 12" /></td>
</tr>
<tr>
<td>13</td>
<td><img src="image9" alt="CL 13" /></td>
</tr>
</tbody>
</table>
Analysis of WIM Data – NYS Legal Weight Limits

- **NYS Formula**
  \[ W = 34,000 + 1,000 \cdot L_{TOT} \]
  \[ GVW < 71,000 lb \]

- **FBF Formula**
  \[ W = 500 \left( \frac{L \cdot N}{N - 1} + 12 \cdot N + 36 \right) \]
  \[ GVW < 80,000 lb \]

  - \( W \) = weight of axle group
  - \( L \) = length of axle group
  - \( N \) = number of axles in group

- Single Axle Weight Limit = 22,400 lb.
- Tandem Axle Weight Limit = 36,000 lb. (spacing<= 8 ft.)
- Total Gross Weight Limit = 80,000 lb.
# Analysis of WIM Data – Overweight Code (OVWC)

<table>
<thead>
<tr>
<th>Weight Limit exceeded</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>None: All legal limits are met</td>
<td>OVWC=0000</td>
</tr>
<tr>
<td>NYS requirement GVW=34,000 lbs+1000 L for trucks under 71,000 lbs</td>
<td>OVWC=1000</td>
</tr>
<tr>
<td>FBF formula for trucks less than 71,000 lbs</td>
<td>OVWC=2000</td>
</tr>
<tr>
<td>FBF formula for trucks greater than 71,000 lbs</td>
<td>OVWC=3000</td>
</tr>
<tr>
<td>GVW=80,000 lbs</td>
<td>OVWC=0400</td>
</tr>
<tr>
<td>Axle weight = 22,400 lbs</td>
<td>OVWC=0050</td>
</tr>
<tr>
<td>Tandem weight = 36,000 lbs</td>
<td>OVWC=0006</td>
</tr>
<tr>
<td>Vehicles exceeding both limits 1 and 5</td>
<td>OVWC=1050</td>
</tr>
<tr>
<td>Vehicles exceeding both limits 1 and 6</td>
<td>OVWC=1006</td>
</tr>
<tr>
<td>Vehicles exceeding both limits 2 and 5</td>
<td>OVWC=2050</td>
</tr>
<tr>
<td>Vehicles exceeding both limits 2 and 6</td>
<td>OVWC=2006</td>
</tr>
<tr>
<td>Vehicles exceeding both limits 3 and 4</td>
<td>OVWC=3400</td>
</tr>
<tr>
<td>Vehicles exceeding both limits 3 and 5</td>
<td>OVWC=3050</td>
</tr>
<tr>
<td>Vehicles exceeding both limits 3 and 6</td>
<td>OVWC=3006</td>
</tr>
<tr>
<td>Vehicles exceeding both limits 4 and 5</td>
<td>OVWC=0450</td>
</tr>
<tr>
<td>Vehicles exceeding both limits 4 and 6</td>
<td>OVWC=0406</td>
</tr>
<tr>
<td>Vehicles exceeding both limits 5 and 6</td>
<td>OVWC=0056</td>
</tr>
<tr>
<td>Vehicles exceeding simultaneously limits 1, 5, 6</td>
<td>OVWC=1056</td>
</tr>
<tr>
<td>Vehicles exceeding simultaneously limits 2, 5, 6</td>
<td>OVWC=2056</td>
</tr>
<tr>
<td>Vehicles exceeding simultaneously limits 4, 5, 6</td>
<td>OVWC=0456</td>
</tr>
<tr>
<td>Vehicles exceeding simultaneously limits 3, 4, 5</td>
<td>OVWC=3450</td>
</tr>
<tr>
<td>Vehicles exceeding simultaneously limits 3, 4, 6</td>
<td>OVWC=3406</td>
</tr>
<tr>
<td>Vehicles exceeding simultaneously limits 3, 5, 6</td>
<td>OVWC=3056</td>
</tr>
<tr>
<td>Vehicles exceeding simultaneously limits 3, 4, 5, 6</td>
<td>OVWC=3456</td>
</tr>
</tbody>
</table>

Example:  
- Exceeding : FBF, GVW, Axle  
- Not Exceeding : Tandem
Analysis of PERMIT Data – Clustering

• Separate the trucks in the DV and SH permit databases into clusters

1. OVWC and FHWA
2. Number of Axles
3. Gross Weight and Total Length
Data Mining Procedure

• Assemble the WIM data file

• Assign overweight code (OVWC) to each record in the WIM file

• For each WIM record classified as Overweight compare its characteristics with the characteristics in the (DV) and (SH) databases
  
  ➢ Match (DV) and (SH) rules ➞ Assign (Comb) Label
  ➢ Match (DV) rule only ➞ Assign (DV) Label
  ➢ Match (SH) rule only ➞ Assign (SH) Label
  ➢ Does not match any rule ➞ Assign ILLEGAL (IL) Label
Data Mining Procedure – Verification Test 1

<table>
<thead>
<tr>
<th>Class</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. Trucks</td>
<td>112</td>
<td>5718</td>
<td>11933</td>
<td>276</td>
<td>207170</td>
<td>177184</td>
<td>3185</td>
<td>6805</td>
<td>48667</td>
<td>152</td>
</tr>
<tr>
<td>No. OW Trucks</td>
<td>106</td>
<td>5713</td>
<td>11919</td>
<td>263</td>
<td>206639</td>
<td>176662</td>
<td>3112</td>
<td>6021</td>
<td>4251</td>
<td>150</td>
</tr>
<tr>
<td>No. Legal Trucks</td>
<td>6</td>
<td>5</td>
<td>14</td>
<td>13</td>
<td>531</td>
<td>522</td>
<td>73</td>
<td>784</td>
<td>44416</td>
<td>2</td>
</tr>
<tr>
<td>DV</td>
<td>99</td>
<td>1540</td>
<td>4813</td>
<td>262</td>
<td>51655</td>
<td>96245</td>
<td>3111</td>
<td>5736</td>
<td>4197</td>
<td>137</td>
</tr>
<tr>
<td>DV/SH</td>
<td>7</td>
<td>4173</td>
<td>7106</td>
<td>1</td>
<td>154984</td>
<td>80417</td>
<td>1</td>
<td>285</td>
<td>54</td>
<td>13</td>
</tr>
<tr>
<td>IL</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

- Divisible Permit (DV)
  - Total Number of Overweight Trucks: 414,836 (89.9%)
  - Classified (DV): 40.4 %
  - Classified Combo (DV/SH): 59.6 %
Data Mining Procedure – Verification Test 1

<table>
<thead>
<tr>
<th>Class</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. Trucks</td>
<td>407</td>
<td>234</td>
<td>1172</td>
<td>2712</td>
<td>33109</td>
<td>13478</td>
<td>191</td>
<td>841</td>
<td>17739</td>
<td>9450</td>
</tr>
<tr>
<td>No. OW Trucks</td>
<td>21</td>
<td>172</td>
<td>992</td>
<td>159</td>
<td>8177</td>
<td>9219</td>
<td>144</td>
<td>256</td>
<td>3298</td>
<td>3308</td>
</tr>
<tr>
<td>No. Legal Trucks</td>
<td>386</td>
<td>62</td>
<td>180</td>
<td>2553</td>
<td>24932</td>
<td>4259</td>
<td>47</td>
<td>587</td>
<td>14442</td>
<td>6142</td>
</tr>
<tr>
<td>DV</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>SH</td>
<td>5 [23.8%]</td>
<td>10 [5.8%]</td>
<td>838 [84.5%]</td>
<td>156 [98.1%]</td>
<td>3312 [40.5%]</td>
<td>3035 [32.9%]</td>
<td>144 [100%]</td>
<td>236 [92.2%]</td>
<td>3280 [99.4%]</td>
<td>3308 [100%]</td>
</tr>
<tr>
<td>DV/SH</td>
<td>16 [76.2%]</td>
<td>162 [94.2%]</td>
<td>154 [15.5%]</td>
<td>3 [1.9%]</td>
<td>4865 [59.5%]</td>
<td>6184 [67.1%]</td>
<td>0</td>
<td>20 [7.8%]</td>
<td>18 [0.6%]</td>
<td>0</td>
</tr>
<tr>
<td>IL</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

- Divisible Permit (SH)
  - Total Number of Overweight Trucks : 25,746 (32.4 %)
  - Classified (SH) : 55.6 %
  - Classified Combo (DV/SH) : 44.4 %
Data Mining Procedure – Verification Test 1

• Illegal Sample (IL)
  - Total Number of Trucks 259
  - Classified (DV) 6.2 %
  - Classified (SH) 24.3 %
  - Classified Combo (DV/SH) 59.4 %
  - Classified (IL) 10.1 %
Data Mining Procedure – Verification Test 2

- **NYSDOT 2009/10**: 361,000
- **OVWC**: 4.0%
- **Sample GVW> 80k**: 989

**NYSDOT** (989 vehicles)
- IL: 49.6%
- DV: 49.2%
- SH: 1.2%

**ALGORITHM** (5,327 vehicles)
- IL*: 25.9%
- DV*: 17.8%
- SH*: 2.8%

- **WIM Sample**: 243,874
- **OVWC**: 5.9%
- **Sample GVW> 80k**: 5,327
Data Mining Procedure – Verification Test 2

\[ \Pr(DV) = \frac{\Pr(DV^*)}{1 - \Pr(Comb \mid DV)} \]

\[ \Pr(SH) = \frac{\Pr(SH^*)}{1 - \Pr(Comb \mid SH)} \]

\[ \Pr(IL) = \frac{\Pr(IL^*)}{1 - \Pr(Comb \mid IL)} \]

\[ \frac{\Pr(DV^*)}{1 - \Pr(Comb \mid DV)} + \frac{\Pr(SH^*)}{1 - \Pr(Comb \mid SH)} + \frac{\Pr(IL^*)}{1 - \Pr(Comb \mid IL)} = 1 \]
Data Mining Procedure – Verification Test 2

Bayesian updating to correct for illegals that look like permits

$$\Pr(IL/SH) = \frac{\Pr(SH/IL) \times \Pr(IL)}{\Pr(SH/IL) \times \Pr(IL) + \Pr(SH/SH) \times \Pr(SH)}$$

$$\Pr(IL/DV) = \frac{\Pr(DV/IL) \times \Pr(IL)}{\Pr(DV/IL) \times \Pr(IL) + \Pr(DV/DV) \times \Pr(DV)}$$
Final Result – Verification Test 2

NYSDOT (989 vehicles)
- IL: 49.6%
- DV: 49.2%
- SH: 1.2%

ALGORITHM (5,327 vehicles)
- IL: 61.6%
- DV: 37.4%
- SH: 1.0%
### Final Result – Verification Test 2

<table>
<thead>
<tr>
<th>Overweight Type</th>
<th>No. of trucks</th>
<th>Original data mining Percentages</th>
<th>Updating of unknown permits</th>
<th>Bayes updating of Illegal trucks</th>
<th>NYSDOT Overweight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Divisible (DV)</td>
<td>949</td>
<td>17.8%</td>
<td>44.0%</td>
<td>37.4%</td>
<td>49.2%</td>
</tr>
<tr>
<td>Special Hauling (SH)</td>
<td>150</td>
<td>2.8%</td>
<td>5.1%</td>
<td>1.0%</td>
<td>1.2%</td>
</tr>
<tr>
<td>Unknown Permit (DV/SH)</td>
<td>2,848</td>
<td>53.5%</td>
<td>0%</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Illegal (IL)</td>
<td>1,380</td>
<td>25.9%</td>
<td>50.9%</td>
<td>61.6%</td>
<td>49.6%</td>
</tr>
</tbody>
</table>
Accuracy depends on overlap in DV and SH databases

- Overlap = 1
- Overlap ≠ 0
- Overlap = 0

Accuracy vs. Overlap graph:

- Accuracy decreases as overlap decreases.
- Accuracy is maximized when overlap is 1.
- Accuracy is minimized when overlap is 0.
Conclusions

• A data mining procedure can be used to estimate the number of illegal trucks

• The procedure provides a statistical distribution of overweight permit and illegal vehicles. There is good agreement of Special Hauling and Divisible load permits with the analysis performed by NYSDOT

• The WIM station must be well calibrated to avoid biased records

• The accuracy of the algorithm is strongly dependent on overlap between permit databases (DV) and (SH)
Acknowledgements

- NYSDOT project C-08-13
- Prof. Michel Ghosn of the City College of New York
- Mr. Chris Scharl of NYSDOT
THANK YOU
Coordinated Transit Fares and Car Pricing at Congested Bottlenecks

ITS-NY Annual Meeting: Current ITS University Research and Projects
8 June 2012

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Problem of Interest

**Congested roadways** can benefit from demand management strategies. Technologies allow us to implement congestion pricing strategies for cars and transit.

Look at **coordinated pricing** of cars and transit when people can choose:

- when to travel
- which mode to use

Consider **efficiency** and **equity** of feasible pricing strategies.

**Result:** A trade-off exists. Technologies provides flexibility to choose.
No Toll or Fare

Cars
EXAMPLE Un-tolled Bridge

Transit
EXAMPLE Fare-free Transit Service

Queensboro Bridge, New York City

Staten Island Ferry, New York City

Rutgers Transit, New Brunswick, NJ
Fixed Toll or Fare

**Cars**
**EXAMPLE** Tolled Bridge

*Henry Hudson Bridge, New York City*

**Transit**
**EXAMPLE** Fixed Transit Fares

*Subway, New York City*
Variable Toll or Fare

Cars

**EXAMPLE** Time-Dependent Toll

Stockholm Congestion Charge, Sweden

**EXAMPLE** Dynamic HOT Lane Toll

SR 167, King County, Washington

Transit

**EXAMPLE** Peak/Off-Peak Fares

Metro, Washington, DC
Morning Commute, Bottleneck  

(Vickrey, 1969)

Given:

- ORIGIN (Home)
- DESTINATION (Work)

BOTTLENECK

Capacity = $\mu$
Morning Commute, Bottleneck (Vickrey, 1969)

Given:

Commuters wish to reach work on-time, $\lambda$

Schedule penalty for being early or late (units of equivalent travel delay)

Penalty

Schedule Deviation

$L$

$\mu$
Morning Commute, Bottleneck (Vickrey, 1969)

Given:

- ORIGIN (Home)
- DESTINATION (Work)
- BOTTLENECK Capacity = $\mu$

Commuters wish to reach work on-time, $\lambda$

Schedule penalty for being early or late (units of equivalent travel delay)

Commuters choose when to travel to minimize their generalized cost:

\[ \text{Cost} = \text{Uncongested Trip Cost} + \text{Queuing Delay} + \text{Schedule Penalty} \]
User Equilibrium: Un-priced Cars

(Vickrey, 1969; et al)
User Equilibrium: Un-priced Cars

(Vickrey, 1969; et al)

User Cost

\[ T_C(1 - \mu/\lambda) \]

\( t_A \)  \( t_1 \)  \( \bar{t} \)  \( t_2 \)  \( t_F \)

User Choices:

- User Cost (hrs)
- Schedule Penalty
- Delay
- Penalty

Departure Time
User Equilibrium: Un-priced Cars

(Vickrey, 1969; et al)

User Cost (hrs)

$T_C(1 - \mu/\lambda)$

$\Delta z$

Schedule Penalty

Delay

User-Experienced Cost

$e$

$T_C$ $L$

User Choices

Departure Time

Efficiency

Total Cost, $Z =$ Uncongested Mode Costs + Delay + Schedule Penalty

Equity

$\Delta z =$ Maximum User Cost – Minimum User Cost
System Optimum: Variable-priced Cars

(Vickrey, 1969; et al)

Optimal time-dependent toll for cars **eliminates queuing delay**, but leaves users with the same experienced costs.

**EFFICIENCY** improved  
**EQUITY** not changed
Adding Transit Choice  

(Gonzales and Daganzo, 2011)

Given:

Identical generalized cost for all transit riders, $z_T$

Generalized cost of on-time car trip without delay, $z_C$

Wardrop’s equilibrium:

If both modes are used, Car User Cost = Transit User Cost

If only car is used, Car User Cost $\leq$ Transit User Cost
Compare Pricing Strategies

Definition: **Prices** are the car toll or transit fare charged to users in addition to the generalized cost of the trip.

1. **User Equilibrium**: Un-priced Cars and Transit

2. **System Optimum**: Time-Dependent Prices for Cars and Transit

3. **Fixed Prices**: Time-Independent Prices for Cars and Transit

4. **Fixed Car Toll, Time-Dependent Transit Fares**: e.g., Un-priced Cars and Time-Dependent Transit Fares
1. User Equilibrium: Cars and Transit

(Gonzales and Daganzo, 2011)

Assuming that users pay generalized cost of mode chosen; no additional car tolls or transit fare subsidies.
2. Optimal Prices: Cars and Transit

(Gonzales and Daganzo, 2011)

Delays can be eliminated with “optimal,” time-dependent prices.

System optimum achieved by any car toll, $c(t)$, satisfying the following:

\[
d\frac{c(t)}{dt} = \begin{cases} 
  e & \text{EARLY} \\
  -L & \text{LATE} \\
  -L < \frac{c(t)}{dt} < e & \text{ON-TIME}
\end{cases}
\]

Transit fare must be set to maintain Wardrop equilibrium:

\[
\text{ON-TIME } \quad T(t) = c(t) - T
\]
### 2. Optimal Prices: Cars and Transit

(Gonzales and Daganzo, 2011)

Case illustrated: off-peak toll = 0, transit cost per user is $z_T$.

<table>
<thead>
<tr>
<th>User Cost (hrs)</th>
<th>Car Only</th>
<th>Car and Transit</th>
<th>Car Only</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T(1 - \mu/\lambda)$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Delta z_{SO}$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$T$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$e$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$-L$</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Diagram:**
- **User Cost** (hrs)
- **Departure Time**
- **Car Toll**, $C(t)$
- **Transit Fare**, $T(t)$
- **Schedule Penalty**
- **Early**
- **On-Time**
- **Late**
3. Fixed Prices: Cars and Transit

Car toll and transit fare are time-independent:
e.g., car price, $C = 0$, transit fare is fixed with subsidy at $T$. 

![Graph showing user cost and departure time with early, on-time, and late schedule times, indicating car toll and transit fare costs.](image-url)
4. Fixed Car Toll, Variable Transit Fare

Car toll is time-independent and transit fare is time-dependent: e.g., car price, $C = 0$, transit fare is $\gamma(t)$. 

\[ T_4(1 - \mu/\lambda) \]

\[ T_4 = \Delta z_4 \]

User Cost (hrs)

Car Toll, $\$C$

Transit Fare, $\gamma(t)$

Departure Time

\[ t_A, t_1, t_B, t_E, t_2, t_F \]
Numerical Example

Peak Commute Demand: \( N = 10,000 \) trips in 1 hour

Bottleneck Capacity: \( \lambda = 6,000 \) vehicles/hour

Earliness Penalty: \( e = 0.5 \) hours of queueing/hour early

Lateness Penalty: \( L = 2 \) hours of queueing/hour early

Difference of Free-Flow Generalized Mode Costs: \( T = z_T - z_C = 0.2 \) hours
Comparison of Efficiency and Equity

- **System Optimum:** Car Only
- **User Equilibrium:** Car Only

1. User Equilibrium: Car and Transit
2. Optimal Prices: Car and Transit
3. Fixed Prices
4. Fixed Toll, Variable Fare
Comparison of Efficiency and Equity

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Total System Cost (veh-hrs)</th>
<th>User Cost Difference (hrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Optimal Prices</td>
<td>680</td>
<td>EFFICIENCY 0.2</td>
</tr>
<tr>
<td>4. Fixed Toll, Variable Fare</td>
<td>782</td>
<td>EQUITY 0.03</td>
</tr>
<tr>
<td>3. Fixed Prices</td>
<td>800</td>
<td></td>
</tr>
</tbody>
</table>

1. User Equilibrium: Car and Transit
2. Optimal Prices: Car and Transit
3. Fixed Prices
4. Fixed Toll, Variable Fare
Flexibility of Coordinated Pricing

Technologies allow us to:
- Inform Users
- Collect Fares
- Collect Data
- Set the “Right” Prices

In many cases, a trade-off exists between efficiency and equity.

Technologies provide flexibility to achieve efficiency and equity objectives in pricing cars and transit.
Questions

Coordinated Transit Fares and Car Pricing at Congested Bottlenecks
ITS-NY Annual Meeting: Current ITS University Research and Projects
Eric J. Gonzales
eric.gonzales@rutgers.edu
Dynamic Signal Control for Low Delay at Traffic Intersections

Presenter:
Koushik Kar (RPI)

Joint work with:
Abouzar Ghavami (RPI), Satish Ukkusuri (Purdue)
Traffic signal control is an important and challenging issue in transportation networks

- Effective signal control can substantially reduce waiting times at traffic signals

Signal control done through controlling the phase selections and their lengths (times)

Traditionally, signal control done through following a fixed (static) schedule

- The fixed schedule could vary with time of the day, or day in week

Lot of recent interest in dynamic signal control with real-time traffic information

- Finding increasing deployment in different forms
- Question: can dynamic signal control substantially reduce vehicle delay (waiting time) in traffic intersections?
Related Work

- Long history of work on traffic signal control
- Queuing analysis/models have been widely used
- Some examples:
  - *Webster ’58, Allsop ’72*: Optimal cycle length and phase time assignments, capacity calculation
  - *Pierce & Webb ’90, Azimirad et al ’10*: Learning or AI based adaptive signal control algorithms
  - *Hu, Tan & Ong ’97, Mirchandani & Zou ’97*: Queuing analysis of signalized intersection
  - *Wunderlich, Liu and Urbanik ’08, Varaiya ’10*: Queue-length dependent signal control policies
Queue-length dependent Dynamic Signal Control

- We focus on dynamic signal control algorithms that take into account the number of vehicles waiting in each lane
  - Can be estimated via loop detectors, sensors, cameras
  - Can possibly do smarter control if the traffic signal knew vehicle destinations, speed and location of vehicles that might arrive shortly (but at greater information exchange, less driver privacy)

- We analyze a *maximum weighted signal-control (MWS)* and its variant, compare with traditional fixed time control
  - MWS has been subject of recent interest (Wunderlich, Liu and Urbanik ’08, Varaiya ’10)
  - Shown to attain maximum throughput, without knowledge or assumptions on the traffic arrival process
  - Also well-studied in context of wireless networks (Tassiulas ’92)

- Our focus is *average delay, and not throughput!*
Collision-free Sets

- **Collision graph of 4-Way intersection**
  - Free right turns assumed

Collision-free sets (Phases):

\[
\Gamma_1 = \{NT, ST\}, \quad \Gamma_2 = \{ET, WT\}, \quad \Gamma_3 = \{NL, SL\}, \quad \Gamma_4 = \{EL, WL\}, \\
\Gamma_5 = \{NT, NL\}, \quad \Gamma_6 = \{ET, EL\}, \quad \Gamma_7 = \{ST, SL\}, \quad \Gamma_8 = \{WT, WL\}.
\]
Signal Control Algorithms

- **Fixed Time scheduling (FTS) (static)**
  - Keep repeating a specific pattern of phases
  - The phase length (time) can differ across phases (chosen “optimally” based on average traffic rates)

- **Maximum Weighted Scheduling (MWS) (dynamic)**
  - Choose the phase (collision free set of lanes) with the longest aggregate queue-length
  - Phase length of each chosen phase is the same

- **Adaptive-length MWS (aMWS) (dynamic)**
  - Choose the phase (collision free set of lanes) with the longest aggregate queue-length (like MWS)
  - Length of the chosen phase depends on the sum of the aggregate queue-lengths of the phase
**Modeling and Parameters**

- **Inter-vehicle passing time, $D$:**
  - The distance between the front of two successive vehicles in line.

- **Lag:**
  - The time taken by the head-of-line driver to start moving after the signal turns green (3-5 secs typical), due to driver reaction time, intersection clearance.
Fixed Time Scheduling (FTS)

- The collision-free set (phase) $\Gamma_k$ is scheduled turn by turn with fixed and pre-assigned phase time, $S_k$, $S_{min} \leq S_k \leq S_{max}$.

- The average delay of FTS can be calculated (approximated) in terms of the average traffic rates, the phase times, $S_k$, $D$ and $Lag$. 
Maximum Weighted Scheduling (MWS)

- The collision-free set chosen is the one that has the maximum number of vehicles waiting (maximum backlog)
  - Weight of collision-free set $I_k$ at time $\tau = \sum_{ij \in I_k} Q_{ij}(\tau)$
  - Phase time fixed at $\Delta$

- The average delay is upper bounded in terms of average traffic rates, $D$, $Lag$ and $\Delta$
  - Uses delay analysis techniques typically used in constrained queuing networks
Adaptive-length MWS (aMWS)

- In aMWS a collision-free set is chosen based on maximum backlog, \( \sum_{i,j \in \Gamma_k} Q_{ij}(\tau) \)

- The assigned phase time for chosen collision-free set \( \Gamma_k \):

\[
S_k(\tau) = \max\{S_{\text{min}}, \min\{( \sum_{i,j \in \Gamma_k} Q_{ij}(\tau) \times D)^{r_1}, \max_{i,j \in \Gamma_k} Q_{ij}(\tau) \times D)^{r_2}, S_{\text{max}}\}\}
\]

\((0 \leq r_1, r_2 < 1)\)

- Motivated by a scheduling algorithm proposed for constrained queuing networks by in Tassiulas & Bhattacharya ’95
4-Way Intersection *without Lag*, Balanced load:

- \( \frac{\lambda_{iT}}{\lambda_i} = 0.5 \)
- \( \frac{\lambda_{iL}}{\lambda_i} = 0.2 \)
- \( \frac{\lambda_{iR}}{\lambda_i} = 0.3 \)
- \( S_{\text{min}} = 15 \text{ sec} \)
- \( S_{\text{max}} = 60 \text{ sec} \)
- \( r_1 = r_2 = 0.99 \)
- \( D = 2 \text{ Sec} \)
- \( \text{Lag} = 0 \text{ Sec} \)
- \( W_R = 5 \text{ Sec} \)

Average *Delay* vs. Traffic Load

(RS: theoretical delay for FTS based on randomized approximation)
Simulation Results (cont’d)

- 4-Way Intersection *without Lag*, Balanced load:

![Graph showing average latency vs. traffic load]

\[
\frac{\lambda_{iT}}{\lambda_i} = 0.5 \\
\frac{\lambda_{iL}}{\lambda_i} = 0.2 \\
\frac{\lambda_{iR}}{\lambda_i} = 0.3 \\
S_{\text{min}} = 15 \text{ sec} \\
S_{\text{max}} = 60 \text{ sec} \\
r_1 = r_2 = 0.99 \\
D = 2 \text{ sec} \\
\text{Lag} = 0 \text{ sec} \\
W_R = 5 \text{ sec}
\]

Average *Latency* vs. Traffic Load
4-Way Intersection *with Lag* = 5 sec, Balanced Load:

Average *Delay* vs. Traffic Load

\[
\frac{\lambda_i T}{\lambda_i} = 0.5 \\
\frac{\lambda_i L}{\lambda_i} = 0.2 \\
\frac{\lambda_i R}{\lambda_i} = 0.3 \\
S_{\text{min}} = 15 \text{ sec} \\
S_{\text{max}} = 60 \text{ sec} \\
r_1 = r_2 = 0.99 \\
D = 2 \text{ Sec} \\
\text{Lag} = 5 \text{ Sec} \\
W_R = 5 \text{ Sec}
\]
Real Traffic Intersection Modeling

- Real 4-way intersection topology, San Mateo, CA:

(Source: Google Maps)

The real traffic data was obtained from: Zhang and Lou, “Robust signal timings for arterials under day-to-day demand variations”, Journal of Transportation Research, 2010.
Simulation Results

- Real 4-Way Intersection, \textit{with Lag} = 5 sec, Unbalanced Load (obtained through measurement):

\begin{align*}
\frac{\lambda_i T}{\lambda_i} &= 0.5 \\
\frac{\lambda_i L}{\lambda_i} &= 0.2 \\
\frac{\lambda_i R}{\lambda_i} &= 0.3 \\
S_{min} &= 15 \text{ sec} \\
S_{max} &= 60 \text{ sec} \\
r_1 &= r_2 = 0.99 \\
D &= 2 \text{ Sec} \\
Lag &= 5 \text{ Sec} \\
W_R &= 5 \text{ Sec}
\end{align*}

Average \textit{Delay} vs. Traffic Load
Conclusion and Future Work

- Without “lag effects”, dynamic backlog-dependent scheduling policies like MWS and aMWS lead to lower delay than FTS at all loads.

- In presence of lag effects, MWS performance suffers at high loads due to “capacity loss”
  - Unless the fixed phase time is made large (bad idea)

- aMWS results in near-minimal delay at all loads and scenarios simulated
  - Bottomline: Adaptive phase choices in backlog-dependent dynamic scheduling should be accompanied with adaptive choices of phase times as well.

- Extension of this study to a network of intersections remains to be done in future work.
Thank You!
Use of VISTA DTA for Emergency Operations

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Associate Director, CUNY ITS UTMSC
Email: mouskos@utrc2.org

ITS-NY
Saratoga Springs, NY
June 08, 2012
Outline

• Introduction to VISTA DTA
• Framework to model emergencies using DTA
• Case study: Star-Trans European Commission Project
• Case Study: Use of DTA to support emergency operations (evacuation) in Alabama
What is Simulation-based Dynamic Traffic Assignment?

Evolution from the Static Traffic Assignment (4th step in the planning process)

Given:
- Infrastructure
- Traffic Control
- Origin/Destination of Vehicles, and a
- Traffic Simulator

It Computes the *Spatio-Temporal* Path for every User so that:

*No user can switch path and improve either his departure or his arrival time (Dynamic User Equilibrium)*
Simulation-based DTA Models

• Main Models:
  – DYNASMART
  – DYNAMIT
  – Visual Interactive System for Transport Algorithms (VISTA)
  – DYNAMEQ
  – AIMSUN
  – DynusT
  – Transmodeller
BASIC DTA Solution APPROACH

shortest path (Per OD pair & time)

Move some vehicles to the shortest path

Compute cost on each path

Check if all ODT paths have equal and minimum cost

Does the DTA model Reaches Convergence?

If Yes then it is usable for comparing scenarios

If No then it is not usable for comparing scenarios

DONE
Mesoscopic Simulator RouteSIM: Notation of the Cell Transmission Model

(i) ordinary cell   (ii) diverging cell   (iii) merging cell
(iv) source cell    (v) sink cell
VISTA - Overall Framework/Functional Components

- Java GIS
- Web Browser
- CORBA
- JDBC
- Web Server
- Data Warehouse
- Management Module
- RouteSim
- TDSP
- DTA
- Assignment
- OD. Est.
- Report

Communications Layer
- Interface
MODELING EMERGENCY OPERATIONS USING VISTA
Visual Interactive System for Transport Algorithms

- VISTA Transport Group Inc., Austin, Texas
- VISTA Uses:
  - New York, New Jersey, Alabama, Chicago-IL, Austin Texas, Lefkosia Cyprus, Athens Greece, Bologna, Italy, Saarbrucken, Germany
  - Infrastructure planning, Incident Management, Evacuation modeling, Evaluate location of Dynamic Message Signs, Emergency Operations, Traffic Operations, Transit route planning, Environmental Impacts
VISTA DTA Input Needs

• **Infrastructure Data:** GIS, roadway geometry, capacity, number of lanes
• **Traffic control:** signal timing, intersection geometry, speed limit, vehicle class prohibitions, lane designation
• **Bus data:** routes and schedules
• **Traffic flow data for calibration:** traffic counts, travel times/speeds, OD matrix surveys, vehicle location data per vehicle class
VISTA DTA Calibration

• Estimation of the Dynamic OD matrix per 15-minute time interval
  – ideally for a 24-hour time period such that each vehicle has a start and an end during simulation

• Calibration:
  – Estimated traffic flows to be less than 20% of observed traffic counts
  – Estimated travel times to be less than 20% of observed travel times
VISTA Incident Scenario Modeling

Input Data

• Cordon Links characteristics:
  – # of lanes closed, capacity reduction, closure duration
  – vehicle class prohibitions

• Emergency(ER) Dispatching Routes OR origin-destination of ER vehicles

• User defined Evacuation Route(s) OR origin-destination of evacuation vehicles (then model proposes)

• Bus Detour(s) or Model proposed

Results

• Model computes performance data (tables)
• Model suggests optimal evacuation routes and ER vehicle routes (output in GIS format)
• Animation of incident conditions using simulator
<table>
<thead>
<tr>
<th><strong>Project Name</strong></th>
<th><strong>STAR-TRANS</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Project Full Title:</strong></td>
<td>Strategic Risk Assessment and Contingency Planning in Interconnected Transportation Networks</td>
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<td><strong>Project Type:</strong></td>
<td>FP7 Theme 4 (ICT) &amp; Theme 10 (Security)</td>
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<tr>
<td><strong>Project Start Date:</strong></td>
<td>November 1st, 2009</td>
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<tr>
<td><strong>Project Duration:</strong></td>
<td>30 Months</td>
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<td><strong>Project Budget:</strong></td>
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<td><strong>Consortium:</strong></td>
<td>11 organizations from 7 Countries</td>
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<tr>
<td>Consortium</td>
<td></td>
</tr>
<tr>
<td>------------</td>
<td></td>
</tr>
<tr>
<td><strong>1</strong></td>
<td>INTRASOFT International S.A.</td>
</tr>
<tr>
<td><strong>2</strong></td>
<td>National Center for Scientific Research Demokritos – Environment Research Laboratory</td>
</tr>
<tr>
<td><strong>3</strong></td>
<td>Center for Security Studies</td>
</tr>
<tr>
<td><strong>4</strong></td>
<td>Confederation of Organizations in Road Transportation Enforcement</td>
</tr>
<tr>
<td><strong>5</strong></td>
<td>QinetiQ S.A.</td>
</tr>
<tr>
<td><strong>6</strong></td>
<td>Fraunhofer Institute for Transportation and Infrastructure Systems</td>
</tr>
<tr>
<td><strong>7</strong></td>
<td>Center for Research and Technology Hellas – Information &amp; Telematics Institute</td>
</tr>
<tr>
<td><strong>8</strong></td>
<td>Metropolitan Police Service</td>
</tr>
<tr>
<td><strong>9</strong></td>
<td>CTL Cyprus Transportation Logistics Ltd.</td>
</tr>
<tr>
<td><strong>10</strong></td>
<td>SQUARIS Ltd.</td>
</tr>
<tr>
<td><strong>11</strong></td>
<td>SRM, Bologna, Italy</td>
</tr>
</tbody>
</table>
DTA model & Star-Trans IAT framework

User-specified Incident characteristics

Network & operational changes

Desired output

IAT

Base conditions model
Calibrated outside the framework (takes hours to run)

Scenario Model

Algorithms to compute new traffic conditions & output
VISTA-IAT Scripts

Implement network changes

Simulate traffic patterns after incident
• Can make different assumptions regarding driver’s behavior and information provision

Find best ER & evacuation routes given new traffic patterns

Compute the performance of ER vehicles, evacuation vehicles & detoured buses

Generates output tables, results, animation & other outputs
Athens Incident Scenario Data Sources

• OASA VISUM Data
  – Morning one-hour Peak static OD matrix from the VISUM model
  – estimate a 15-min dynamic OD matrix
  – GIS network
  – Link characteristics
  – Bus Routes and Schedules
  – incorporate all data into VISTA

• Demokritos/KEMEA Compiled Data
  – Emergency Vehicles Locations (POIs Fire Brigade, Police, Ambulance
  – Defined Athens Scenario Related Data
  – incorporate all data into the IAT software
DTA model & IAT framework

- Athens VISTA DTA Base Model: developed first within the IAT-VISTA framework
User Input

- Incident: Bomb threat at Doukissis Plakentias metro station
- Start time of the incident (8.10am)
- Duration of the incident (8.10-10.00am)
- Cordon Link around the incident (8.35am)
- Fully or partially closed links/concerning the number of lanes (All lanes closed)
- Fully or partially closed links/concerning the type of vehicles (All vehicles forbidden, except from ER and Evacuation vehicles)
Athens Incident Data(2)

- Vehicle class prohibitions (roadways in pink): autos, buses
- Emergency vehicles are allowed to go through
Athens Emergency (ER) Vehicles Dispatching

**Model proposed routes**
Model chooses the time-dependent shortest route based on time-dependent link travel times per ER vehicle to the incident location.

**User Input**
- Type of vehicle
- Origin Stations For Dispatching of ER vehicles
- Departure time of the ER Vehicle (e.g. 2min, 10min after the incident)

**Strategic planning (future)**
- Collect actual ER vehicle link/route travel time data under actual incident and non-incident conditions – **Calibrate model**
- Try various Origin Stations for ER vehicles and evaluate routes
- Select “optimal” locations for ER vehicles based on historical incident data
- Keep updating/calibrating periodically
Origin and Destination Nodes Proposed for ER-police dispatching
Athens ER-Police Dispatching (2)

- Model proposed path for ER-Police dispatching
Athens ER- Ambulance Dispatching(1)

- Origin and Destination Nodes proposed for ER-Ambulance dispatching
Athens ER- Ambulance Dispatching(2)

- Model proposed path for ER-Ambulance dispatching
Athens ER-Fire Brigade Dispatching (1)

• Origin and Destination Nodes proposed for ER-Fire Brigade dispatching
Athens ER-Fire Brigade Dispatching(2)

- Model proposed path for ER-Fire Brigade dispatching
Athens Evacuation Route(1)

**Model proposed route**
Model chooses the shortest route based on time-dependent link travel times

**User Input**
- Type of vehicle (Bus)
- Closest safe node for Evacuation (Chalandri Metro Station)
- Start time and duration of the Evacuation Vehicle (8.35-10.00am)
- Frequency of the Evacuation Vehicle (10min)

**Strategic Planning (future)**
- Prepare evacuation routes for various strategic locations
- Evaluate/select best evacuation routes periodically
- Calibrate model continuously
Athens Evacuation Route(2)

- Model proposed route for the Evacuation Route
Athens Bus Detour

User Input
• Run the incident scenario without the Bus Detour
• Check the travel times of the links close to the incident after simulation
• Run the model to find the best possible Bus Detour (from the cordon bus-route cutoff points or use the ones provided by the transit agency)

Strategic Planning (future)
• Calibrate model using actual bus travel times
• Evaluate various bus routes based on real incidents
• Select best bus detours for locations with historically frequent incidents
• Keep updating
Athens Bus Detour(2)

• Bus Detour for Bus Route(No120) originally through incident
Athens Result Tables

- General Performance Data for Athens Base Case & Incident Scenario
- Performance data for the Bus Evacuation Route
- Travel time difference using the Bus Detour
- Performance data for the Emergency Vehicle Routes
Athens Result Tables

- Differences in travel times and other performance data between Athens Base Case & Incident Scenario

<table>
<thead>
<tr>
<th>network</th>
<th>average system ttime(min)</th>
<th>ttime of diverted veh(min)</th>
<th>% of network links</th>
</tr>
</thead>
<tbody>
<tr>
<td>incident scenario</td>
<td>55,9</td>
<td>85,6</td>
<td>0,78</td>
</tr>
<tr>
<td>base case</td>
<td>17,4</td>
<td>21,5</td>
<td>0,1</td>
</tr>
</tbody>
</table>

- **BUS EVACUATION ROUTE** - Travel times and other performance data for the Bus Evacuation Route

<table>
<thead>
<tr>
<th>origin</th>
<th>destination</th>
<th>type</th>
<th>start time(min)</th>
<th>avg travel time(min)</th>
<th>length(m)</th>
<th>speed(km/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Doukissis Plakentias Station</td>
<td>Chalandri Metro Station</td>
<td>Evacuation Bus</td>
<td>35</td>
<td>0,9</td>
<td>890</td>
<td>59,5</td>
</tr>
</tbody>
</table>

- **BUS DETOUR** - Travel time difference between Athens Base Case & Incident Scenario for a random Bus Route using the Bus Detour

<table>
<thead>
<tr>
<th>Bus Route</th>
<th>Network Travel Time Time(min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Case</td>
<td>Incident Scenario</td>
</tr>
<tr>
<td>Bus No120</td>
<td>20,58</td>
</tr>
</tbody>
</table>
### Athens Result Tables (3)

**EMERGENCY VEHICLES ROUTE - Travel time & other performance data for the Emergency Vehicles Routes of the Athens**

<table>
<thead>
<tr>
<th>origin</th>
<th>destination</th>
<th>type</th>
<th>departure</th>
<th>travel time (min)</th>
<th>length (m)</th>
<th>speed (km/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EKAB1</td>
<td>Doukissis Plakentias Station</td>
<td>ambulance</td>
<td>12</td>
<td>6,6</td>
<td>2907</td>
<td>25,7</td>
</tr>
<tr>
<td>EKAB2</td>
<td>Doukissis Plakentias Station</td>
<td>ambulance</td>
<td>20</td>
<td>7,5</td>
<td>3585</td>
<td>29,0</td>
</tr>
<tr>
<td>9th FIRE STATION OF ATHENS</td>
<td>Doukissis Plakentias Station</td>
<td>fire brigade</td>
<td>12</td>
<td>10</td>
<td>5570</td>
<td>33,8</td>
</tr>
<tr>
<td>9th FIRE STATION OF ATHENS</td>
<td>Doukissis Plakentias Station</td>
<td>fire brigade</td>
<td>20</td>
<td>10,2</td>
<td>5570</td>
<td>32,2</td>
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<tr>
<td>4th FIRE STATION OF ATHENS</td>
<td>Doukissis Plakentias Station</td>
<td>fire brigade</td>
<td>12</td>
<td>9,8</td>
<td>14195</td>
<td>86,9</td>
</tr>
<tr>
<td>4th FIRE STATION OF ATHENS</td>
<td>Doukissis Plakentias Station</td>
<td>fire brigade</td>
<td>20</td>
<td>9,8</td>
<td>14195</td>
<td>86,9</td>
</tr>
<tr>
<td>P.S.XALANDRI</td>
<td>Doukissis Plakentias Station</td>
<td>police</td>
<td>12</td>
<td>7,4</td>
<td>3832</td>
<td>30,6</td>
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<tr>
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<td>Doukissis Plakentias Station</td>
<td>police</td>
<td>20</td>
<td>7,4</td>
<td>3832</td>
<td>30,6</td>
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<tr>
<td>P.S.VRILISIA</td>
<td>Doukissis Plakentias Station</td>
<td>police</td>
<td>12</td>
<td>7,2</td>
<td>3533</td>
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<tr>
<td>P.S.VRILISIA</td>
<td>Doukissis Plakentias Station</td>
<td>police</td>
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<td>6,3</td>
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<td>P.S.AG.PARASKEVI</td>
<td>Doukissis Plakentias Station</td>
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<td>12</td>
<td>3,2</td>
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<td>P.S.AG.PARASKEVI</td>
<td>Doukissis Plakentias Station</td>
<td>police</td>
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<td>3</td>
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<td>P.S.GERAKAS</td>
<td>Doukissis Plakentias Station</td>
<td>police</td>
<td>12</td>
<td>5,3</td>
<td>7340</td>
<td>83,7</td>
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<tr>
<td>P.S.GERAKAS</td>
<td>Doukissis Plakentias Station</td>
<td>police</td>
<td>20</td>
<td>5,3</td>
<td>7340</td>
<td>83,7</td>
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<tr>
<td>GADA&amp;TEEM</td>
<td>Doukissis Plakentias Station</td>
<td>police</td>
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<td>11,2</td>
<td>15805</td>
<td>85,3</td>
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<tr>
<td>GADA&amp;TEEM</td>
<td>Doukissis Plakentias Station</td>
<td>police</td>
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<td>83,7</td>
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<tr>
<td>SWAT</td>
<td>Doukissis Plakentias Station</td>
<td>police</td>
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<td>9,7</td>
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<td>83,7</td>
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<tr>
<td>SWAT</td>
<td>Doukissis Plakentias Station</td>
<td>police</td>
<td>20</td>
<td>9,7</td>
<td>13562</td>
<td>83,7</td>
</tr>
</tbody>
</table>
IAT-VISTA Athens Scenario Animation(2)
IAT-VISTA Athens Scenario Animation(4)
Towards a VISTA-IAT Tool for Strategic Planning under Emergency Conditions (Future)

• Develop a first Calibrated detailed Dynamic Traffic Assignment (DTA) model
• Develop a Full Integration with a Customized IAT (Input and Output)
• Develop a Daily-Calibrated DTA Model using online traffic flow, incident, traffic control, infrastructure, environmental data
• Products:
  – Continuous estimation of Traffic conditions (online)
  – Specific OD/transit route reports per ER unit and transport agency (updated frequently/continuously)
EVALUATION OF LANE-REVERSAL PLANS FOR I-65 IN ALABAMA

Virginia P. Sisiopiku, PhD
University of Alabama at Birmingham

Kyriacos C. Mouskos, PhD
City College of New York

Curtis Barrett
VTG Inc., USA
Problem Statement

- Hurricanes are prevalent in the Atlantic Ocean and Gulf of Mexico.
- Governments and transportation planning agencies must prepare and plan for evacuation of residents.
- Contra-flow operations is a strategy for evacuation but feasibility & operationality require further study as reservations exist.
## Saffir-Simpson Hurricane Scale (NOAA, 2007)

<table>
<thead>
<tr>
<th>Category</th>
<th>Wind Speed (mph)</th>
<th>Estimated Storm Surge (ft)</th>
<th>Damage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>74 – 95</td>
<td>4 – 5</td>
<td>Minimal</td>
</tr>
<tr>
<td>2</td>
<td>96 – 110</td>
<td>6 – 8</td>
<td>Moderate</td>
</tr>
<tr>
<td>3</td>
<td>111 – 130</td>
<td>9 – 12</td>
<td>Extensive</td>
</tr>
<tr>
<td>4</td>
<td>131 – 155</td>
<td>13 – 18</td>
<td>Extreme</td>
</tr>
<tr>
<td>5</td>
<td>&gt; 155</td>
<td>&gt; 18</td>
<td>Catastrophic</td>
</tr>
</tbody>
</table>
AL Experience with Contra-Flow

- ALDOT has a detailed plan for reverse laning of I-65 for hurricane evacuation.
  - Evacuation routes and termini
  - Plan implementation procedures and requirements

- Plan was fully implemented successfully in the past since 2004 (e.g. Hurricane Ivan; Hurricane Dennis, etc)
Evacuation Zones
Some Characteristics

• Study network had over 4,300 nodes and 10,000 links.
• Car demand exceeded 1,000,000 veh
• Evacuee demand: 35,000 veh for low intensity and 106,349 veh for high intensity storms.
• The network was run for 26 hrs to capture the evacuation patterns before, during, and after lane reversal operations for evacuation for every iteration of every scenario considered in the study.
# Network-Wide Results

## Low Intensity Hurricanes (Category 1, 2)

<table>
<thead>
<tr>
<th></th>
<th>Loaded Vehicles</th>
<th>Entered Total TT (H)</th>
<th>AVG TT (M)</th>
<th>Entered Veh. VMT (Miles)</th>
<th>AVG Speed (Miles/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NL - No Reversal</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All Vehicle</td>
<td>1087810</td>
<td>167547</td>
<td>9.24</td>
<td>8828190</td>
<td>52.69</td>
</tr>
<tr>
<td>Evacuee</td>
<td>35045</td>
<td>50156</td>
<td>85.87</td>
<td>3248543</td>
<td>64.77</td>
</tr>
<tr>
<td>Car</td>
<td>1052765</td>
<td>117390</td>
<td>6.69</td>
<td>5579647</td>
<td>47.53</td>
</tr>
<tr>
<td><strong>PL - Partial Reversal 16 Hours</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All Vehicle</td>
<td>1082432</td>
<td>163843 [-2.2%]</td>
<td>9.08</td>
<td>8668139</td>
<td>52.91</td>
</tr>
<tr>
<td>Evacuee</td>
<td>35045</td>
<td>49994 [-0.3%]</td>
<td>85.59</td>
<td>3250823</td>
<td>65.02</td>
</tr>
<tr>
<td>Car</td>
<td>1047387</td>
<td>113849 [-3.0%]</td>
<td>6.52</td>
<td>5417316</td>
<td>47.58</td>
</tr>
<tr>
<td><strong>FL - Full Reversal 16 Hours</strong></td>
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<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>All Vehicle</td>
<td>1082432</td>
<td>164057 [-2.1%]</td>
<td>9.09</td>
<td>8662865</td>
<td>52.80</td>
</tr>
<tr>
<td>Evacuee</td>
<td>35045</td>
<td>50038 [-0.2%]</td>
<td>85.67</td>
<td>3245882</td>
<td>64.87</td>
</tr>
<tr>
<td>Car</td>
<td>1047387</td>
<td>114019 [-2.9%]</td>
<td>6.53</td>
<td>5416983</td>
<td>47.51</td>
</tr>
</tbody>
</table>

Note: in []: % change from no reversal
# Network-Wide Results
## High Intensity Hurricanes (Category 3,4,5)

<table>
<thead>
<tr>
<th></th>
<th>Loaded Vehicles</th>
<th>Entered Total TT (H)</th>
<th>AVG TT (M)</th>
<th>Entered Veh. VMT (Miles)</th>
<th>AVG Speed (Miles/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NH - No Reversal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All Vehicle</td>
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<td>36.24</td>
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<tr>
<td>Evacuee</td>
<td>106349</td>
<td>398109</td>
<td>224.61</td>
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<td>47.38</td>
</tr>
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<td>675093</td>
<td>73912</td>
<td>6.57</td>
<td>3514095</td>
<td>47.54</td>
</tr>
<tr>
<td>PH - Partial Reversal 16 Hours</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All Vehicle</td>
<td>778748</td>
<td>468251 [-0.8%]</td>
<td>36.08</td>
<td>22278233</td>
<td>47.58</td>
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<tr>
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<td>223.47</td>
<td>18856652</td>
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<tr>
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<td>72161 [-2.4%]</td>
<td>6.44</td>
<td>3421581</td>
<td>47.42</td>
</tr>
<tr>
<td>FH - Full Reversal 16 Hours</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All Vehicle</td>
<td>778748</td>
<td>391547 [-17.0%]</td>
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<td>319364 [-19.8%]</td>
<td>180.18</td>
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<td>72183 [-2.3%]</td>
<td>6.44</td>
<td>3420090</td>
<td>47.38</td>
</tr>
</tbody>
</table>

Note: in []: % change from no reversal
National Disaster Observer, Volume XXXII • Number 6 July 2008,
QUESTIONS AND COMMENTS