3. Emission-based traffic responsive signal control system

Research Objectives

- Given the lack of a real-time signal control system that minimizes total emissions of cars and buses by utilizing modal-based emission estimation:
  
  - Develop an analytical model to estimate emissions using macroscopic traffic stream characteristics and modal emission estimation
  
  - Design a traffic responsive signal control system that minimizes total emissions of cars and buses at isolated intersections.
Assumptions

- Impact of bus stops on auto and transit operations are ignored
- Transit vehicles travel in mixed lanes along with autos
- Vehicles arrive at a constant rate
- Analytical models developed:
  - to infer trajectories given certain macroscopic characteristics such as arrival rate and saturation flow
  - assuming that auto and transit vehicle arrival times are known in real-time
ITS Technologies for real-world implementation

- Sensing Systems (detectors)
  - Vehicle arrival rates
  - Travel times
- Automated Vehicle Location (AVL) Systems
  - Bus dwell times at stops → travel times → arrival times

Source: http://www.precisiontrafficsafety.com/products/sensys/
Source: www.tc.umn.edu
Mathematical Program

\[
\text{Min} \quad \text{Total Emissions of Cars and Buses}
\]

subject to:

\((\text{Minimum green for each phase and lane group})\)

\((\text{Constant cycle length})\)
Methodology

- Estimate the total time spent on each vehicle operating mode for cycles $T$ and $T+1$ as a function of the green times of cycle $T$ and $T+1$.

- Estimate emission rates for each vehicle operating mode.

- Optimize green times of cycle $T$ by minimizing total emissions for both autos and transit vehicles for cycles $T$ and $T+1$. 
Methodology
Modal Emission Rate Estimation

- Speed
- Acceleration
- Link’s grade

→ VSP (Vehicle Specific Power) value

→ VSP mode

→ emission rate

• Assumptions:
  o Link’s grade = 0
  o Constant cruising speed = 45 (km/hr)
  o Constant acceleration/deceleration rates
    - Cars: acceleration rate = 3 \( \frac{m}{s^2} \) and deceleration rate = 4 \( \frac{m}{s^2} \)
    - Buses: acceleration rate = 2 \( \frac{m}{s^2} \) and deceleration rate = 2 \( \frac{m}{s^2} \)
## Emission Rates

<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>Operating Mode</th>
<th>NO\textsubscript{x} (mg/s)</th>
<th>HC (mg/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline Autos</td>
<td>Acceleration</td>
<td>7.7</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td>Deceleration</td>
<td>0.9</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>Cruising</td>
<td>1.2</td>
<td>0.4</td>
</tr>
<tr>
<td></td>
<td>Idling</td>
<td>0.3</td>
<td>0.4</td>
</tr>
<tr>
<td>Diesel Buses</td>
<td>Acceleration</td>
<td>263.5</td>
<td>2.1</td>
</tr>
<tr>
<td></td>
<td>Deceleration</td>
<td>45.0</td>
<td>1.3</td>
</tr>
<tr>
<td></td>
<td>Cruising</td>
<td>133.3</td>
<td>1.7</td>
</tr>
<tr>
<td></td>
<td>Idling</td>
<td>45.0</td>
<td>1.3</td>
</tr>
</tbody>
</table>
Test Site: Mesogeion & Katechaki Avenues, Athens, Greece
Results: Comparison with Vehicle-based optimization

Effect of Auto Demand

% Change in Emission (HC) from Vehicle-based to Emission-based Optimization

Intersection Flow Ratio \((Y)\)

Auto demand increases
Findings

- Reduction in overall emissions and transit emissions
- The lower the auto demand, the higher the overall reduction in emissions
- Results depend on the vehicle technology and emission factors
Current and Future Work

- Real-time signal control system with TSP that accounts for stochasticity in transit vehicle arrivals
- Real-time signal control system to minimize person delay and emissions
- Prediction algorithms for vehicle arrivals using low resolution AVL data
- Extension of real-time signal control systems to networks
Thank you

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