Vehicle Automation and its Role in Energy and Emissions

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presented at the:

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Approaches to Minimize Energy and Emissions Impacts of Transportation:

- **Build cleaner, more efficient vehicles:**
  - make vehicles lighter (and smaller) while maintaining safety
  - improve powertrain efficiency
  - develop alternative technologies (e.g., hybrids, fuel-cell, electric vehicles)

- **Develop and use alternative fuels:**
  - Bio and synthetic fuels (cellulosic ethanol, biodiesel)
  - electricity

- Decrease the total amount of driving: **VMT reduction methods**

- Improve transportation system efficiency through **automation**
Three regimes on how to reduce on-road energy and emissions through automation

- Increase capacity of roadways through automation eliminates congestion.
- Platooning reduces aerodynamic drag.
- Elimination of stop and go traffic.
vehicle activity
(velocity trajectory and grade if available)

Comprehensive Modal Emissions Model

calibration parameters

fuel consumption

emissions

Fuel consumption = 464 g = 0.17 gallons
Fuel price = $2.7/gallon
Travel fuel cost = 0.5 dollars

Travel time = 10 minutes
Travel distance = 3.7 miles
Travel speed = 21.9 mph

NOx emission = 1.5 g
(NOx emission fee = X dollars/g)
(Travel NOx emission cost = 1.5X dollars)
Initial Energy and Emissions Analysis of Automated Highway Systems:

- sponsored by NAHSC/PATH
- CO₂ and fuel are linearly related
- used energy/emissions model with typical driving activity

reference:
Fuel Saved by Trucks Driving in Close-Formation Platoons (PATH et al., 2003)
Energy and Emissions Analysis of Heavy Duty Trucks:

- sponsored by PATH, U.S. EPA, CARB
- CO₂ and fuel are linearly related
- measured (and modeled) energy/emissions of heavy duty trucks

### Follow Truck raw data

<table>
<thead>
<tr>
<th>spacing</th>
<th>Avg CO₂ gm/s</th>
<th>Avg NOx gm/s</th>
<th>Avg fuel gm/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>inf M</td>
<td>33.44</td>
<td>0.2004</td>
<td>10.57</td>
</tr>
<tr>
<td>10 M</td>
<td>30.91</td>
<td>0.1975</td>
<td>9.78</td>
</tr>
<tr>
<td>8 M</td>
<td>30.78</td>
<td>0.1938</td>
<td>9.74</td>
</tr>
<tr>
<td>6 M</td>
<td>29.58</td>
<td>0.1926</td>
<td>9.36</td>
</tr>
<tr>
<td>4 M</td>
<td>27.50</td>
<td>0.1982</td>
<td>8.70</td>
</tr>
</tbody>
</table>

**reference:**

System Architecture of Dynamic Eco-Driving

Embedded Road Sensor Data

Traffic Management Center
Traffic Management Center
Traffic Management Center
Traffic Performance Measurement System (PeMS)

Wireless Communications Provider

Vehicle Data

Internet

System Server

Instrumented Vehicles

in-vehicle device:

<table>
<thead>
<tr>
<th>MPG</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current Trip Total:</td>
<td>Distance (mi):</td>
<td>6.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Travel time (min):</td>
<td>10.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>
Dynamic Eco-Driving Field Experiments: Example Results

same travel time results:

<table>
<thead>
<tr>
<th>Energy/Emissions</th>
<th>Non-ISA</th>
<th>ISA</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO2 (g)</td>
<td>5439</td>
<td>4781</td>
<td>-12%</td>
</tr>
<tr>
<td>CO (g)</td>
<td>97.01</td>
<td>50.47</td>
<td>-48%</td>
</tr>
<tr>
<td>HC (g)</td>
<td>3.20</td>
<td>1.90</td>
<td>-41%</td>
</tr>
<tr>
<td>NOx (g)</td>
<td>6.28</td>
<td>3.97</td>
<td>-37%</td>
</tr>
<tr>
<td>Fuel (g)</td>
<td>1766</td>
<td>1534</td>
<td>-13%</td>
</tr>
</tbody>
</table>

reference:

**Single Intersection Optimization with Signal Phase and Timing Information**

Advanced signal information can help reduce intersection-influenced fuel consumption by 14% for cars and 12% for trucks.

<table>
<thead>
<tr>
<th>LDV24</th>
<th>Fuel</th>
<th>CO₂</th>
<th>CO</th>
<th>HC</th>
<th>NOₓ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle 1</td>
<td>27.8</td>
<td>87.5</td>
<td>0.378</td>
<td>0.013</td>
<td>0.011</td>
</tr>
<tr>
<td>Vehicle 2</td>
<td>70.6</td>
<td>222.4</td>
<td>0.990</td>
<td>0.045</td>
<td>0.063</td>
</tr>
<tr>
<td>Vehicle 3</td>
<td>64.5</td>
<td>203.1</td>
<td>0.873</td>
<td>0.034</td>
<td>0.067</td>
</tr>
<tr>
<td>% 3 vs 2</td>
<td>-8.7</td>
<td>-8.7</td>
<td>-11.8</td>
<td>-24.8</td>
<td>+6.4</td>
</tr>
<tr>
<td>(2-1)</td>
<td>42.9</td>
<td>134.9</td>
<td>0.612</td>
<td>0.032</td>
<td>0.052</td>
</tr>
<tr>
<td>(3-1)</td>
<td>36.7</td>
<td>115.6</td>
<td>0.496</td>
<td>0.021</td>
<td>0.056</td>
</tr>
<tr>
<td>% (3-1) vs (2-1)</td>
<td>-14.3</td>
<td>-14.3</td>
<td>-19.0</td>
<td>-34.7</td>
<td>+7.8</td>
</tr>
</tbody>
</table>

**Reference:**
Dynamic Eco-Driving on Signalized Corridors

<table>
<thead>
<tr>
<th>LDV24</th>
<th>Without</th>
<th>With</th>
<th>% Diff. in Avg.</th>
<th>p-value of t-test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Avg.</td>
<td>S.D.</td>
<td>Avg.</td>
<td>S.D.</td>
</tr>
<tr>
<td>Fuel (g/mi)</td>
<td>118.3</td>
<td>13.2</td>
<td>103.8</td>
<td>9.3</td>
</tr>
<tr>
<td>CO₂ (g/mi)</td>
<td>371.0</td>
<td>41.2</td>
<td>318.8</td>
<td>25.3</td>
</tr>
<tr>
<td>TT (sec)</td>
<td>456.7</td>
<td>60.7</td>
<td>451.9</td>
<td>56.9</td>
</tr>
</tbody>
</table>

references:


Summary and Conclusions:

- Automation can have a significant impact on environment/energy through better vehicle control, better traffic operations, and better information systems.

Vehicle Systems:

- Automation (lateral and longitudinal control, platooning, etc.)
- Closed loop systems: Smart Engines, HEV energy management

Traffic Operations:

- Congestion mitigation
- Smoother traffic flow

Information Systems:

- Environmental Friendly Navigation
- Dynamic Eco-Driving
- Speed Management Systems

Energy/Emissions Savings: Each automation strategy can potentially save 5 – 15%; all strategies can be additive for greater savings.