Transportation Planning & Tailpipe Emissions -

Where are we and where are we going?

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Acknowledgements
- Eric Jackson and Britt Holmén
- National Science Foundation
- New England University Transportation Center

Outline
- Transportation Planning
- Tailpipe Emissions
- Connecting our models
- The Vermont Transportation Research Center
- What are tailpipe emissions and how do we reduce them?

Transportation Planning / Modeling
Old Paradigm

- Land Use and Activities
- Travel Demands
- Infrastructure

- No feedback loops
- Limited design options - lack of diversity
- Non-optimal and expensive

Transportation Planning / Modeling
New Paradigm

- Transportation Services
- Land Use & Activities
- Mobility
Transportation Planning / Modeling

New Paradigm

Land Use & Activities

Transportation Services ↔ Mobility

- feedback loops - interactions
- multimodal
- optimal solutions require more complex analysis … and better data

Environmental Impacts of Transportation

Tailpipe Emissions - What is that?

Vehicle Emissions - What are They?

- Tailpipe
  - Hydrocarbons (HC)
  - Nitrogen Oxides
  - Carbon Monoxide
  - Carbon Dioxide
  - Particulate Matter

- Evaporative (HC)

  \[ HC + NOx + \text{Sunlight} = \text{Ozone} \]

  Public Health

  Health

  Greenhouse Gas

  Haze, Health

- Running Emissions
- Soak Emissions
- Start Emissions

Vehicle Emissions - What are They?

- Tailpipe
  - Hydrocarbons (HC)
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  - Carbon Monoxide
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IDEAL Gasoline Combustion

**IN OXYGEN ATMOSPHERE:**
Assume Gasoline Composition = \(C_7H_{13}\)

\[ C_{7}H_{13} + 10.25O_2 \leftrightarrow 7CO_2 + 6.5H_2O \]

COMPLETE COMBUSTION!

Real-world Fuel Combustion

AIR is not 100% oxygen ~21 vol.% \(O_2\) 79 vol.% \(N_2\)

Internal combustion engines do not always result in complete combustion of fuel.

INCOMPLETE COMBUSTION PRODUCES POLLUTANTS!

\[ \text{Fuel} + (O_2 + 3.76N_2) \leftrightarrow \text{CO}_2 + \text{H}_2\text{O} + [\text{CO} + \text{HC} + \text{NO}] \]

"Regulated" Pollutants

Gasoline Engines

Diesel Engines

Air Toxics - Unregulated Emissions

**Why Do We Care?**
• Carcinogens
• Non-cancer health effects: reproductive & neurological
  *No tailpipe regulations, currently.*

**What are they?**
MSATs (Mobile Source Air Toxics):
- Benzene: known human carcinogen
- Formaldehyde
- Acetaldehyde, Acrolein: probable human carcinogens.
- 1,3-butadiene
- Diesel particulate & organic gases
- Methyl tertiary butyl ether (MTBE): fuel additive

Diesel and Light-duty Exhaust Particles

PM vs PN

Diesel Particle Size Distribution

Peak in Number Distribution ~ 20nm
Particle Size & Lung Deposition

The human lungs cannot easily reject ultrafine particles!

Spatial and Durational Environmental Effects

Ultrafine Particles
Dp < 100 nm

Nanoparticles
Dp < 50 nm

After D. Kittelson 1998

The human lungs cannot easily reject ultrafine particles!

Integrated Transportation and Environmental Models

- Planning/Demand Models
- Traffic Simulation
  - Function of average link speed
time resolved and vehicle-based speed

Current On-road Emissions Models

- Mobile (EPA)
- EMFAC
  - Regional models based on vehicle class, average speeds and road class
- MOVES (EPA)
- Measure
- CMEM
  - Emissions models developed based on operating mode but are still under development

The Minivan Experiments
The Minivan Experiments

• Space
• Power
• Vibrations

Hybrids

GPS Receivers

○ Mounted on Roof
○ Position and Velocity
○ 1 Record per Second

ScanTool

○ OBD II
○ Velocity
○ 4 Records per Second

GPS for Measuring Vehicle Operating Mode

<table>
<thead>
<tr>
<th>Mode</th>
<th>Garmin GPS</th>
<th>Geollogger GPS</th>
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<tr>
<td>Idle</td>
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<td>97</td>
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<tr>
<td>Acceleration</td>
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<td>Cruise</td>
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<td>Deceleration</td>
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<td>88</td>
</tr>
<tr>
<td>Overall</td>
<td>96</td>
<td>93</td>
</tr>
</tbody>
</table>

Accelerometers

○ Mounted on Roof
○ 1 Axis and 3 Axis
○ Acceleration
○ 10 Records per Second
**CT Emissions Test Route**
- 17 miles
- Multiple Road Types
- 13 miles (rural arterial)
- 1 mile (divided highway)
- 3 miles (local roads)
- Speed limits
  - 25-65 mph

**Data Collection**
- October 11th - 31st, 2006
- 22 Drivers Recruited
  - Each drove two circuits
- 986 miles of data
- 105,735 seconds of data

**Consistency**

**Emissions Factor vs Speed**
What affects tailpipe emissions?

- Second by second operation
- Road type
- Driver
- Vehicle
- Traffic control
- Temperature and humidity
- Fuel

How can we reduce tailpipe emissions?

1) Reduce the amount of travel
   - Transit including effective routing and innovative rural service
   - Bicycles and walking
   - Mixed use developments and strong village centers
   - Telecommunications
   - Car sharing, car-pooling, taxi systems and ride sharing

2) More energy efficient vehicles
   - Hybrid and Plug-in hybrid vehicles
   - Smaller vehicles
   - Transit including cleaner fuels and non-traditional vehicles

3) Different energy, potentially lower Carbon Fuels for all vehicles

4) Driving Behavior – “eco-driving”
University of Vermont Transportation Research Center

- Founded 2006
- Transdisciplinary teams spanning 6 Colleges
- Transportation
  - Integrated models
  - Tailpipe emissions
  - Tourism travel
  - Seasonal variations
  - Efficiency

New Model Components:
- carbon footprint
- stormwater
- air quality
- security / robustness
- groundwater impact
- local freight
- plants

What will the transportation and land system look like in 20 years?

How accurate are existing models and how are they most effectively integrated?

New Model Components:
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What will the transportation and land system look like in 20 years?

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University Transportation Center Signature Focus #1
Transportation and Land Use Models:

- Founded 2006
- Transdisciplinary teams spanning 6 Colleges
- Transportation
  - Integrated models
  - Tailpipe emissions
  - Tourism travel
  - Seasonal variations
  - Efficiency

What will the transportation and land system look like in 20 years?

How accurate are existing models and how are they most effectively integrated?

University Transportation Center Signature Focus #2
Emissions and Performance of Alternative Vehicles in Northern Climates

- How do hybrid versus non-hybrid vehicle emissions and performance differ in the winter and in hilly terrain?
- How do tailpipe emissions vary with biodiesel fuel properties?
- How can emissions science be communicated to influence individual behavior and serve the public interest?
- Unique UVM focus: on-board sensors, particle number emissions, low-cost sensors and public communication.

Partners: Vermont Agency of Natural Resources; Resource Systems Group (RSG), Inc.; ReSource Systems Group (RSG), Inc.; Udall Foundation; UVM Parking and Transportation

University Transportation Center Signature Research Focus #1
Sustainable Transportation for Tourism

- Development of DOT traffic level of service measures for tourism areas.
- Does ECO-LABELING of green tourism increase economic and community benefits?
- Do tourist travel experiences impact their routine travel choices?
- What social and economic factors affect tourism travel demand?

Partners: Udall Foundation; Lamoille Valley Transportation

University Transportation Center Signature Research Focus #2
Sustainable Transportation for Tourism

- How does the built environment impact mobility and quality of life, especially for rural residents and including unserved demand?
- How do climate and season impact walking and biking for both purposeful and recreational trips?
- Project connects transportation, quality of life and active living.

Partners: New England Transportation Institute (NETI); Resource Systems Group (RSG), Inc.

University Transportation Center Signature Research Focus #3
Seasonality and Built Environment Impacts

- How does the built environment impact mobility and quality of life, especially for rural residents and including unserved demand?
- How do climate and season impact walking and biking for both purposeful and recreational trips?
- Project connects transportation, quality of life and active living.

Partners: New England Transportation Institute (NETI); Resource Systems Group (RSG), Inc.

University Transportation Center Signature Focus #4
Transportation Energy Efficiency

- Definition and metrics
- Agent-based modeling of adoption of PHEVs by region
- The relationship between travel and electricity demand

External Partners: Vermont Law School, Central Vermont Public Service, Green Mountain Power and Burlington Electric Department

Partners: New England Transportation Institute (NETI); Resource Systems Group (RSG), Inc.; Agency of Transportation; Green Mountain Coffee Roasters

University Transportation Center Signature Focus #5
Transportation Energy Efficiency

- Definition and metrics
- Agent-based modeling of adoption of PHEVs by region
- The relationship between travel and electricity demand

External Partners: Vermont Law School, Central Vermont Public Service, Green Mountain Power and Burlington Electric Department

Partners: New England Transportation Institute (NETI); Resource Systems Group (RSG), Inc.; Agency of Transportation; Green Mountain Coffee Roasters
UVM Transportation Research Center

Transportation Services ↔ Land Use & Activities

Mobility

www.uvm.edu/transportationcenter