Advanced Modeling System for Forecasting Regional Development, Travel Behavior, and the Spatial Pattern of Emissions

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Presentation outline

• Research team members
• Research questions
• Study area
• Modeling approach
• Progress highlights
• Next steps
Land use and travel behavior modeling
UNC CTP, NCSU ITRE, ODU

Emissions estimation
NCSU ITRE and CE

Air quality modeling
UNC Institute for the Environment

Outreach and partnerships
UNC
Motivation

• Built form related to how we travel
  – Walking
    • Distance to destinations
    • Mixed uses of land
      – Specific uses
    • Density
  – Miles traveled
  – Trip purpose
    • Shopping trips
    • Work trips
Motivation

• Link development patterns and regional air quality, through travel
  – Develop behavioral models that reflect built form influences
  – Couple travel demand and emissions models at appropriate spatial and temporal scales
  – Improve ability to represent real-world driving cycles and microscale influences at high temporal and spatial resolution
  – Account for advanced technologies and alternative fuels
Key research questions

• Can regional development patterns, over 50 years, influence quantity and spatial pattern of emissions from transportation in the Charlotte (NC) area?
  – Type of development
  – Intensity of development
  – Location of development

• How would different development patterns affect…
  – Ozone
  – Fine PM
  – Other quality of life indicators
Modeling approach

• Classify built environment
  – Walking and transit-supportive environments
• Develop models sensitive to such environments
  – Land demand
  – Travel demand
• In future scenarios compare behaviors, emissions, air quality
Modeling steps -scenarios

1. Built form
   TRANSECT

2. Integrated transport-land model

3. Emissions estimates

4. Air quality

5. Built form
   TRANSECT

6. Integrated transport-land model

7. Future scenarios

8. Emissions estimates

9. Air quality
Study area - Charlotte

- Growing metro area in NC
- Data-rich
- Designated 8-hour ozone non-attainment area
- SEQL + ReVA
- Future transit metropolis?
Mecklenburg County

- **Rapid population increase**
  - 22% from 1990 to 2000
  - > 600k in 2005

- **Even faster land consumption**
  - Density
    - 1950: 6.98 person/acre
    - 2000: 3.60 person/acre
Built form Transect

- Provides continuum of built environments and development possibilities
- Classifies neighborhoods based on
  - Land use (uses, densities, open space)
  - Demographics + employment
  - Travel (street design and circulation, accessibility, and alternative modes)
  - Housing
  - Recreation
Built form Transect

- Data factor-analyzed
  - walkability
  - accessibility
  - agglomeration
  - property value
  - industry

- Cluster analysis of factors
Cluster types

- Type 1 (Red)
  - One, unique CBD block group
  - Mostly office
  - High local/regional accessibility
  - High improvements to total parcel value ratio (commercial uses)
Cluster types

- Type 3 (Yellow Blue)
  - Some mixing of land uses
  - High local/regional accessibility
  - Roughly the second ring
Cluster types

- Type 6 (Dark Blue)
  - Single family residential is dominant
  - High levels of green space
  - Limited local/regional accessibility
  - Bridge between rural and suburban
TRANUS

- Integrated transportation-land development model
  - Cross-sectional equilibrium, spatial input-output
  - Production, household, land sectors
The activities-land use system

Productive sectors
Household sectors
Land

Production costs
Commodity flows
Travelers flows
Equilibrium prices of land

Consumption of land

Source: Modelistica, 2004
Economic flows generate transportation flows

Zone 256 supplies labor

Zone 258 demands labor
Structure of pax transport model

- Pax flows
- Disaggregate modal split
- Probabilistic assignment
Trips per person for i-j pair, given an economic exchange between i and j

Passenger flows

Accessibility decile
Modal split

• Mode choice $f$ (built form)

• 2002 regional travel survey
  – Home-based work travel
    • Transit & walking environments for O and D
      – Trips from walk-friendly to walk-friendly zones 7 times higher odds by walking
        » Comes from high and middle income groups

• Little transit effects
Modal split

• 2002 regional travel survey
  – Other home based trips
    • Trips from walk-friendly to walk-friendly zones 1.5 times higher odds of choosing walking
    • Trips from transit-friendly to transit-friendly zones 3.12 higher odds of choosing transit
  – Non-home based trips
    • Trips from walk-friendly to walk-friendly zones have 7 times higher odds of choosing walking
Future scenarios

• Business as usual and smart growth

Source: Metrolina COG
Future scenarios and land use

• New zoning around rail stations
  – Density bonuses
  – Incentives for dense development (reflected in land price)

• Down-zoning and land conservation in wedges
Smart growth scenario
Current status

• TRANUS calibrated to baseline (Y2000)
• Second baseline implemented and run
  • Transit improvements baseline (light rail, BRT, CRT)
  • No population, technology, employment changes
• Scenarios (Y2050) being implemented
• Emissions calculated
  – Baseline
  – For Triangle case (2005 vs 2030) to assess technology/fuel contributions to emissions changes
Link-based emissions model

- Vehicle fuel and technology
- Facility type
- Ambient conditions
- Vehicle mean speed for link
- Vehicle class and age
- Vehicle fleet distribution
- Emission control standards and programs

Source: Frey et al 2008
Conceptual approach for emission factors & inventory estimation

- Meteorology
- Facility type
- Average cycle speed
- Vehicle class & age
- Vehicle fuel & technology
- I/M program, standards
- Year

Speed- and facility-specific link emission rates for a given technology

Travel demand modeling

Basic emission rates
Technology correction factors (if necessary)

Link-based vehicle volume/travel time

Emission factor for a given technology

On-Road Mobile Source Emission Inventory

Source: Frey et al 2008
Link-based emissions model

• For each
  – Average link-based speed
  – Facility type
    • Freeway, arterial, ramp, local & collector
  – Technology class
    • Gasoline, diesel, E85, HEV, CNG cars etc

\[ EF = \left( BER \times \alpha \right) \times TCF \times SCF \]
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Vehicle Fuel &amp; Technology</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic Emission Rates</td>
<td>LDGV, LDDV, HDDT, HDDB</td>
<td>MOBILE6</td>
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<tr>
<td>Speed Correction Factors</td>
<td>LDGV, HDDT</td>
<td>NCSU PEMS</td>
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<tr>
<td></td>
<td>HDDB</td>
<td>EPA PEMS</td>
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<td></td>
<td>LDDV</td>
<td>Portugal PEMS</td>
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<td>Fuel Economy</td>
<td>LDGV</td>
<td>EPA</td>
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<td>LDDV, HEV, CNG Cars</td>
<td>Fuel Economy Guide by EPA &amp; DOE</td>
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<tr>
<td>Technology Correction Factors</td>
<td>E85, HEV, CNG Cars</td>
<td>EPA Certification Tests</td>
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<tr>
<td></td>
<td>B20 trucks, CNG Buses</td>
<td>Literature*</td>
</tr>
<tr>
<td>Travel Patterns</td>
<td>TRANUS for Charlotte/Triangle Region Model</td>
<td>ITRE, NCSU</td>
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</tbody>
</table>

* There were no data available for alternative heavy-duty vehicle technologies. Their TCFs are based on literature estimates for B20 versus diesel heavy-duty trucks, and NG versus diesel buses.

Source: Frey et al 2008
Example of link-based tailpipe emission factors: Arterials, CY 2005

Source: Frey et al 2008
Emissions inventory

\[ TE = \sum_{ct}^{CT} \left( EF_{ct} \cdot t_{ct} \cdot vol_{ct} \right) \]

Where:
- \( ct \) = combination of vehicle class and technology;
- \( EF_{ct} \) = link-based emission factor for vehicle class (\( ct \)) (g/sec);
- \( t_{ct} \) = average link travel time of vehicle class (\( ct \)) (second);
- \( vol_{i,ct} \) = travel volume of vehicle on link for vehicle class (\( ct \)) (vehicles/hr);
- \( TE \) = total emissions for a single link (g/hr).

Source: Frey et al 2008
Emissions implementation to Research Triangle

- **Baseline scenario (2005)**
  - With and without alternative technologies-fuels

- **Future scenario (2030)**
  - With and without alternative technologies-fuels
  - With and without VMT growth (33%) and speeds decrease (28%)
  - Fleet renewal (to Tier 2 vehicles)
Triangle region transportation network

Source: Frey et al 2008
### Emission inventory scenarios & fleet characterization

<table>
<thead>
<tr>
<th>Vehicle Class</th>
<th>Fuel &amp; Tech.</th>
<th>Fleet Penetration of Each Vehicle Class (%)</th>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Present Scenario (2005)</td>
<td>Baseline</td>
<td>Alternative</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Future Scenario (2030)</td>
<td>Baseline</td>
<td>Alternative</td>
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<tr>
<td>Car</td>
<td>LDGV</td>
<td>100</td>
<td>100</td>
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<tr>
<td></td>
<td>E85</td>
<td>0</td>
<td>0</td>
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<td></td>
<td>HEV</td>
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<td></td>
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<td></td>
<td>CNG</td>
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<td></td>
<td>EV &amp; Fuel Cell</td>
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<td>0.1</td>
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<tr>
<td>Truck</td>
<td>HDDT</td>
<td>100</td>
<td>100</td>
<td>73</td>
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<tr>
<td></td>
<td>B20 Trucks</td>
<td>0</td>
<td>0</td>
<td>27</td>
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<tr>
<td>Bus</td>
<td>HDDB</td>
<td>100</td>
<td>100</td>
<td>73</td>
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<tr>
<td></td>
<td>CNG Bus</td>
<td>0</td>
<td>0</td>
<td>27</td>
</tr>
</tbody>
</table>

Source: Frey et al 2008
Regional emissions during weekday morning peak hour

Total Transportation Network Emissions (tons)

<table>
<thead>
<tr>
<th>Scenario</th>
<th>HC</th>
<th>CO</th>
<th>NO\textsubscript{x}</th>
<th>CO\textsubscript{2}</th>
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</thead>
<tbody>
<tr>
<td>Present: Baseline</td>
<td>0.854</td>
<td>34.50</td>
<td>4.63</td>
<td>1376</td>
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<tr>
<td>Present: Alternative</td>
<td>0.788</td>
<td>29.75</td>
<td>4.48</td>
<td>1326</td>
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<tr>
<td>Future, No Growth: Baseline</td>
<td>0.153</td>
<td>9.69</td>
<td>0.39</td>
<td>1200</td>
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<tr>
<td>Future, No Growth: Alternative</td>
<td>0.148</td>
<td>8.36</td>
<td>0.37</td>
<td>1166</td>
</tr>
</tbody>
</table>

Source: Frey et al 2008
Next steps

• Complete similar estimation for Meck County scenarios
  – Incorporate fuel/technology, VMT changes, and URBAN FORM

• Air quality modeling, given emissions
Conclusions

• Calibrated integrated transport & land use model
  – Sensitive to environment --unique
  – Insight into behavior, technology and air pollution

• Neighborhood typology in accordance with theory
Conclusions

• Confirmed empirically relevance of environment
  – Travel mode choice
  – Residential location decisions
  – Implemented relevance in TRANUS framework
Conclusions

• Small market penetration of advanced vehicles and fuels do not appear to alter fleet emissions substantially

• Fleet turnover to Tier 2 vehicles substantially reduces emissions of HC, CO and NO\textsubscript{x}

• Modest improvements in fuel economy could be offset by VMT growth/average speed reductions
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