Outline

- Context
- Research Process & Methods
- Results
- Conclusions
Context
Projected growth in CO₂ emissions from cars and light duty trucks (assuming stringent nationwide vehicle - 45 mpg - and fuel standards - 15% less carbon intensity).
VMT, GHG and the Built Environment

Seattle, WA

Source: Frank et al., 2007

The Netherlands

Source: Grazi et al., 2008
Assessing Relationships
Assessing Relationships

Urban Form
\[\rightarrow\]
Activity Patterns
\[\rightarrow\]
Vehicle GHG
\[\rightarrow\]
SES
Assessing Relationships

Urban Form → Activity Patterns → Vehicle GHG

Urban Form → SES → Vehicle GHG

Urban Form → Activity Patterns
Assessing Relationships

a) Structural equation framework

b) Traditional OLS regression framework
Conceptual Modeling Framework

- **Socio-Demographics**: Age, gender, youth in household, household income, vehicle access
- **Activity Patterns**: Tour complexity, location of stops
- **Vehicle Use**: Daily vehicle kilometers traveled by activity-tour type
- **Built Environment**: Density, neighbourhood walkability, regional accessibility, etc.
- **GHG Emissions**: Daily per-capita vehicle GHG emissions by activity-tour type
Research Process & Methods
What associations are meaningful / significant?

What are the relative effects between SES and BE on VKT and GHG?

Do associations between BE and GHG vary by activity-tour type?

Policy Implications?
Operationalizing Activity-Tours

Home-Based Work/School Activity-Tour (HBWS)  
(Complex, Multi-Stop Tour)

Home-Based Other Activity-Tour (HBO)  
(Simple, One-Stop Tour)
Modeling VKT and GHG Emissions

HBO TOUR #1

\[
\begin{align*}
0.31 \text{ kgCO}_2\text{e/km} & \times 13 \text{ km} \\
& = 4.03 \text{ kgCO}_2\text{e} \\
& \div 2 \text{ occupants} \\
& = 2.02 \text{ kgCO}_2\text{e}
\end{align*}
\]

HBO TOUR #2

HBO TOUR #3
• Net residential density
• Commercial density
• Intersection density
• Land use mix
Walkability calculated by summing normalized distribution (z-score) of each urban form variable for all postal code centroids.
Measuring Regional Accessibility

- Network distance (in KM) to nearest town/regional centre
- Distance (in km) to self-reported place of work and/or school
Results
Total Daily kgCO$_2$e by Activity Tour Type

- **HBWS Tours**: 10,617 kgCO$_2$e (65%)
- **HBO Tours**: 5,560 kgCO$_2$e (35%)

**Mean Tour Distance**
- HBWS = 26.9 km
- HBO = 15.2 km

**Primary Mode**
- HBWS = Auto Drive Alone (46.6%)
- HBO = Auto Shared Ride (51.3%)
Local Walkability and Vehicle GHG

- Most walkable neighbourhoods > 2.26 on walk index;
- least walkable neighbourhoods < -2.08 on walk index.
Regional Accessibility and Vehicle GHG

- Most accessible distance to town / regional centre < 0.8 km, least accessible > 4.45 km.

- Most accessible distance to work < 5 km; least accessible > 18 km.
Two Statistical Models

Built Environment SES Activity Patterns

Vehicle GHG’s related to Home-Based Work / School Tours

Built Environment SES Activity Patterns

Vehicle GHG’s related to Home-Based Other Tours
HBO Activity-Tour Statistical Model

(+) significant
\( (p > 0.05) \) positive effect

(-) significant
\( (p > 0.05) \) negative effect

Model fit measures
RMSEA = 0.044
CFI = 0.990
SRMR = 0.014
**HBO Activity-Tour Model (Total Effects)**

<table>
<thead>
<tr>
<th>Exogenous Variables</th>
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<th>Endogenous Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% TOURS SIMPLE (SQRT)</td>
<td>% STOPS NEAR HOME (SQRT)</td>
<td>VKT (SQRT)</td>
<td>VEHICLE GHG (SQRT)</td>
</tr>
<tr>
<td>AGE</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FEMALE</td>
<td>-0.092</td>
<td></td>
<td>0.014</td>
<td>0.013</td>
</tr>
<tr>
<td>PERSONS&lt;18</td>
<td><strong>0.116</strong></td>
<td>0.077</td>
<td>0.041</td>
<td>0.057</td>
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<tr>
<td>VEHICLE ACCESS</td>
<td></td>
<td></td>
<td><strong>0.254</strong></td>
<td><strong>0.243</strong></td>
</tr>
<tr>
<td>HH INCOME</td>
<td></td>
<td></td>
<td>0.048</td>
<td>0.046</td>
</tr>
<tr>
<td>NEIGHBRHD WALK</td>
<td>0.004</td>
<td><strong>0.122</strong></td>
<td>-0.141</td>
<td>-0.126</td>
</tr>
<tr>
<td>DIST TO CENTRE (SQRT)</td>
<td>-0.002</td>
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<td>0.074</td>
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<tr>
<td>TRANSIT AVLBLTY (SQRT)</td>
<td>0.003</td>
<td>0.083</td>
<td>-0.069</td>
<td>-0.097</td>
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<tr>
<td>% TOURS SIMPLE (SQRT)</td>
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<td></td>
<td>-0.151</td>
<td>-0.144</td>
</tr>
<tr>
<td>% STOPS NEAR HOME (SQRT)</td>
<td>0.036</td>
<td>-0.191</td>
<td>-0.192</td>
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</tr>
<tr>
<td>VKT (SQRT)</td>
<td></td>
<td></td>
<td></td>
<td>0.955</td>
</tr>
</tbody>
</table>

| $R^2$                      | 0.021                | 0.049                | 0.252               | 0.912               |

**NOTE:** Standardized regression coefficients. Estimates interpreted as ‘magnitude of effect’. All coefficients significant at the 95% confidence interval. **Bold** coefficients modeled as strongest parameter estimate for the given endogenous variable. n = 1,370.
HBWS Activity-Tour Statistical Model “A”

(+): significant (p > 0.05) positive effect

(-): significant (p > 0.05) negative effect

Model fit measures
RMSEA = 0.066
CFI = 0.986
SRMR = 0.009
## HBWS Activity-Tour Model “A” (Total Effects)

<table>
<thead>
<tr>
<th>Exogenous Variables</th>
<th>Endogenous Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TOUR CMPLXTY (LGn)</td>
</tr>
<tr>
<td>AGE</td>
<td>-0.059</td>
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<tr>
<td>FEMALE</td>
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<tr>
<td>PERSONS&lt;18</td>
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<tr>
<td>VEHICLE ACCESS</td>
<td>0.067</td>
</tr>
<tr>
<td>HH INCOME</td>
<td></td>
</tr>
<tr>
<td>NEIGHBRHD WALK</td>
<td></td>
</tr>
<tr>
<td>DIST TO WRK/SCHL (SQRT)</td>
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</tr>
<tr>
<td>TRANSIT AVLBLTY (SQRT)</td>
<td></td>
</tr>
<tr>
<td>TOUR CMPLXTY (LGn)</td>
<td></td>
</tr>
<tr>
<td>VKT (SQRT)</td>
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</tr>
</tbody>
</table>

\[ R^2 = 0.007 \quad 0.570 \quad 0.996 \]

**NOTE:** Standardized regression coefficients. Estimates interpreted as 'magnitude of effect'. All coefficients significant at the 95% confidence interval. **Bold** coefficients modeled as strongest parameter estimate for the given endogenous variable. \( n = 1,713 \).
HBWS Activity-Tour Statistical Model “B”

(+): significant (p > 0.05) positive effect

(-): significant (p > 0.05) negative effect

Model fit measures:
- RMSEA = 0.078
- CFI = 0.975
- SRMR = 0.022

Andrew Devlin, BES (Pl.) | MA Thesis Defense | UBC Institute for Resources Environment & Sustainability | 4 December 2009
### HBWS Activity-Tour Model “B” (Total Effects)

<table>
<thead>
<tr>
<th>Exogenous Variables</th>
<th>Tour Complexity (LGn)</th>
<th>% Stops Near Home (SQRT)</th>
<th>VKT (SQRT)</th>
<th>Vehicle GHG (SQRT)</th>
</tr>
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<tbody>
<tr>
<td>AGE</td>
<td></td>
<td></td>
<td>0.077</td>
<td>0.075</td>
</tr>
<tr>
<td>FEMALE</td>
<td>0.092</td>
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<td>-0.061</td>
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<tr>
<td>PERSONS&lt;18</td>
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<td>0.126</td>
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<tr>
<td>VEHICLE ACCESS</td>
<td></td>
<td>-0.117</td>
<td>0.285</td>
<td>0.278</td>
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<tr>
<td>HH INCOME</td>
<td></td>
<td></td>
<td>0.066</td>
<td>0.064</td>
</tr>
<tr>
<td>NEIGHBRHD WALK</td>
<td></td>
<td>0.036</td>
<td>-0.078</td>
<td>-0.076</td>
</tr>
<tr>
<td>DIST TO WRK/SCHL (SQRT)</td>
<td><strong>0.141</strong></td>
<td>-0.140</td>
<td><strong>0.555</strong></td>
<td><strong>0.574</strong></td>
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<tr>
<td>TRANSIT AVBLTY (SQRT)</td>
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<td><strong>0.205</strong></td>
<td>-0.024</td>
<td>-0.023</td>
</tr>
<tr>
<td>TOUR CMPLXTY (LGn)</td>
<td></td>
<td></td>
<td>0.105</td>
<td>-0.112</td>
</tr>
<tr>
<td>% STOPS NEAR HOME (SQRT)</td>
<td></td>
<td>-0.002</td>
<td>-0.115</td>
<td>0.102</td>
</tr>
<tr>
<td>VKT (SQRT)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[
R^2 = 0.039, 0.067, 0.642, 0.953
\]

**NOTE:** Standardized regression coefficients. Estimates interpreted as ‘magnitude of effect’. All coefficients significant at the 95% confidence interval. **Bold** coefficients modeled as strongest parameter estimate for the given endogenous variable. \( n = 496 \).
Conclusions
General Conclusions

• SEM analysis framework yielded **anticipated (theory-based) results** and builds on previous findings by explicitly accounting for indirect and mediating effects between key variables in generating parameter estimates.

• The strength of associations between built environment variables, vehicle use and emissions **varies by activity-tour type and characteristics.**

• Influence of the built environment may be **overwhelmed by vehicle access** in some instances, notably for non-work/school activity tours.

• Policies balancing “**carrots**” (e.g. strong land use regulation, accessible and affordable transit alternatives) and “**sticks**” (e.g. vehicle, parking, road pricing) required.
Barriers to VKT Reduction

- Densities continue to decrease (beyond urban core);
- Vehicle ownership/access increasing (through 2006);
- Perceived vs. objective perspectives of time;
- Scattered employment trends;
- Sociocultural connections to private vehicle; and
- Built environment slow to transform.
Study Limitations (Selected)

• Cross-sectional study design;

• Work-based tours and work place urban form characteristics not included in analyses;

• Inability to model GHG emissions using detailed congestion-based speeds, actual trip path and specific vehicle and fuel type;

• High co-linearity between urban form variables; and

• Standardized parameter estimates preclude ability quantify predicted change in GHG emissions associated with increases in walkability or regional accessibility.
Future Research (Selected)

• Control for residential and travel attitudes and preferences (self-selection);

• Assess effects of travel time and costs per mode on daily travel-related GHG;

• Multiple-group research design (i.e. across independent categories like income or regional location, etc);

• Comparative analysis between SEM and OLS analytical approaches in same study design (i.e does one yield better estimates? What are better estimates?); and

• Develop and assess feasibility of GHG impact assessment tools and models (i.e. iPLACES, HealthScape).
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- Ms. Christina DeMarco (External)
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