Using GIS to Make Urban Mobility More Sustainable

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Sustainable urban mobility

• The future of humanity is urban
• Sustainability requires sustainable urban mobility

Dimensions

1. Economic: Cost-effective, responsive
2. Environmental: Minimize non-renewable resources and environment impacts
3. Social: Accessible, equitable, safe
Climate change

- US: Transportation is 2nd largest source of greenhouse gases
- Also dominant in China, India

Energy

- Over 90% of US transportation energy is from petroleum (US Energy Information Administration)
- 60% from light-duty vehicles (EIA)
- Cars are the least efficient way to move people
Safety

- Traffic accidents are the leading cause of death for Americans aged 5-34 (Centers for Disease Control and Prevention)

- Becoming the leading cause of death overall in poor/middle-income countries (World Health Organization)
Our mobility systems are not sustainable

Congestion
- USA: 7 billion extra hours – 42 hours per rush-hour commuter
- In major cities, drivers have to plan 2X travel time to account for irregular delays
  (Texas Transportation Institute)

Social equity
- Americans spend more on automobiles than food and health care
- Automobile monocultures creates social exclusion based on ability to pay, drive
Public health

- Physically inactive lifestyles are a major public health crisis

Air quality

- Ground-level ozone, PM, SO\textsubscript{x}, NO\textsubscript{x}
- Wide range of bad health impacts
Towards sustainable urban mobility

<table>
<thead>
<tr>
<th>Conventional planning</th>
<th>Sustainable planning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical</td>
<td>Social</td>
</tr>
<tr>
<td>Mobility</td>
<td>Accessibility</td>
</tr>
<tr>
<td>Traffic focus</td>
<td>People focus</td>
</tr>
<tr>
<td>Technocratic</td>
<td>Community-based</td>
</tr>
<tr>
<td>Economic</td>
<td>Multidimensional</td>
</tr>
<tr>
<td>Large scale</td>
<td>Local scale</td>
</tr>
<tr>
<td>Street as road</td>
<td>Street as space</td>
</tr>
<tr>
<td>Speed traffic up</td>
<td>Slow movement down</td>
</tr>
<tr>
<td>Time minimized</td>
<td>Time reasonable and reliable</td>
</tr>
<tr>
<td>Segregate activities, people, transport</td>
<td>Integrate activities, people, transport</td>
</tr>
</tbody>
</table>

New policy needs new measures

- Our main performance measure is counting cars
- Result: we plan for cars

Evidence-based policy to support sustainable mobility

- People-based measures – especially social equity
- Capture externalities – e.g., health, air quality
GIS opportunities

• Location-aware technologies
• Mobile sensors and geosensor networks
• Mobility and movement analytics
• Science and tools for exploring massive spatio-temporal data
• Tools for simulating human systems from the “bottom-up”
Examples from my research

1. **Moving Across Places Study (MAPS):** Public transit, Complete Streets and physical activity
   Barbara Brown (PI), Harvey J. Miller, Ken Smith and Carol Werner, National Cancer Institute, National Institutes of Health

2. **Green accessibility:** Measuring the environmental costs of space-time prisms in sustainable transportation planning
   Keith Bartholomew, Harvey J. Miller (PI) and Xuesong Zhou, National Science Foundation
1. Moving Across Places Study (MAPS)

Moving Across Places Study (MAPS)

- Impacts of Light Rail Transit and Complete Streets on physical activity
- Salt Lake City, Utah, USA

A quasi-experiment

- Measurements of same participants before and after planned intervention
- Case (near) and control (far) groups
1. Moving Across Places Study (MAPS)

Data collection

- Height, weight measurements; attitudinal surveys
- GPS + accelerometer wear for one week
- 2012 (before) and 2013 (after)
- Complete sample: n = 536

Data pre-processing (Westat)

- Uploaded, fused and map-matched
- Download for participant review
- **Mode detection**: Walk, bike, car, bus, LRT
Do you recall this activity?

- Monday, October 31
- 8:13 AM - 8:31 AM

- Yes
- No
- Skip activity

(My bike ride from home to work in Oct. 2011)
How important were the following goals to this activity?

<table>
<thead>
<tr>
<th>Goal</th>
<th>Not at all important</th>
<th>Very Important</th>
</tr>
</thead>
<tbody>
<tr>
<td>Getting exercise</td>
<td>1 2 3 4</td>
<td>5</td>
</tr>
<tr>
<td>Getting someplace</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Getting leisure or Recreation</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
</tbody>
</table>

Did the place where the activity occurred feel:

<table>
<thead>
<tr>
<th>Feel</th>
<th>Not at all</th>
<th>Very</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safe from crime</td>
<td>1 2 3 4</td>
<td>5</td>
</tr>
<tr>
<td>Safe from traffic</td>
<td>1 2 3 4</td>
<td></td>
</tr>
<tr>
<td>Pleasant</td>
<td>1 2 3 4</td>
<td></td>
</tr>
<tr>
<td>Easy to get to or around</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
</tbody>
</table>
Big geographic data? Approximately 4 million GPS points for each time period!
Public transit user
Participant who rode either bus or LRT at least once during data collection week

Transit groups (below)

<table>
<thead>
<tr>
<th>Transit group</th>
<th>N</th>
<th>Public transit user in:</th>
<th>2012?</th>
<th>2013?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Never</td>
<td>391</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Continued</td>
<td>51</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Former</td>
<td>42</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>New</td>
<td>52</td>
<td>No</td>
<td>Yes</td>
<td></td>
</tr>
</tbody>
</table>
Changes in PA-Total time by group
(within-person differences, 2013 - 2012)

Never | Continued | Former | New
--- | --- | --- | ---
1.23 | -2.86 | -5.54* | 5.27*

Average time: Minutes per 10 hr. wear period
PA: Min 1000 cpm in min 5 minute bout
Within group differences: * p < 0.1
Changes in PA-Transit time by group
(within-person differences, 2013 - 2012)

<table>
<thead>
<tr>
<th>Never</th>
<th>Continued</th>
<th>Former</th>
<th>New</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>3.46</strong></td>
<td><strong>-2.34</strong></td>
<td></td>
</tr>
<tr>
<td><strong>-1.15</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Average time: Minutes per 10 hr. wear period
PA: Min 1000 cpm in min 5 minute bout
Within group differences: ** p < 0.05
Changes in PA-Other time by group
(within-person differences, 2013 - 2012)

<table>
<thead>
<tr>
<th>Group</th>
<th>Average time (minutes per 10 hr. wear period)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Never</td>
<td>1.23</td>
</tr>
<tr>
<td>Continued</td>
<td>-1.71</td>
</tr>
<tr>
<td>Former</td>
<td>-3.20</td>
</tr>
<tr>
<td>New</td>
<td>1.81</td>
</tr>
</tbody>
</table>

Average time (minutes per 10 hr. wear period);
PA: Min 1000 cpm in min 5 minute bout
Within group differences: None significant
# Summary

<table>
<thead>
<tr>
<th>User behavior (2013 vs. 2012)</th>
<th>PA-Total</th>
<th>PA-Transit</th>
<th>PA-Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Did not change (Never; Continuing)</td>
<td>No change</td>
<td>No change</td>
<td>No change</td>
</tr>
<tr>
<td>Stopped using transit (Former)</td>
<td>Decrease</td>
<td>Decrease</td>
<td>No change</td>
</tr>
<tr>
<td>Started using transit (New)</td>
<td>Increase</td>
<td>Increase</td>
<td>No change</td>
</tr>
</tbody>
</table>

No confounding factors
No substitution for non-transit PA
→ LRT generated new PA
BMI changes by transit ridership (difference 2013 - 2012)

**p<.01 Never = control group
Walkability audit

Irvine Minnesota Inventory (IMI)
160 attributes / 6 dimensions
• Accessibility
• Attractiveness
• Traffic safety
• Crime safety
• Density
• Pedestrian access

Block-level survey by research assistants
1000+ block faces in the neighborhood
2012 and 2013
Inter-rater reliability good
Published results (selected)


2015. Public transit generates new physical activity: Evidence from individual GPS and accelerometer data before and after light rail construction in a neighborhood of Salt Lake City, Utah, USA. *Health and Place*, 26, 8 - 17.


Complete list (with links): u.osu.edu/miller.81/research/
Accessibility

• Beyond mobility
• Ability to participate in activities
  Employment, education, health care, shopping, recreation, socializing …

Fundamental to cities & transportation

A valuable measure in sustainable mobility planning

2. Green accessibility

Classic accessibility measure: Count the number of activities near home (or work)
Space-time prisms

Envelope of all possible space-time paths between two locations and times given maximum speed and any stationary time

A socially sensitive measure of accessibility

Considers both location and time constraints
A more realistic space-time prism: Travel from western to eastern Salt Lake City with a 35 minute time budget
2. Green accessibility

Network-time prisms (NTP):
Space-time prism within transportation network

- **Above:** Small example in space-time
- **Right:** NTP spatial footprint with visit probabilities for a vehicle 5 minutes after leaving Holland Tunnel in Manhattan
NTPs and sustainable mobility

Evaluation measure

- Plans, policies, investments
- What are the accessibility impacts on diverse social groups?

A bigger prism is good!

- More accessibility to opportunities

But, a bigger prism is also bad!

- Higher environmental costs (e.g., energy consumption, emissions)
Research objective

Estimate and validate environmental costs of a NTP
  • A single space-time path (e.g., GPS trajectory) is easy
  • NTP: Many paths, only one realized

Application: Emissions in Phoenix, AZ
  • Model expected locations and speeds within NTP
  • Estimate expected emissions (MOVESLite)
  • Validate using primary data from instrumented vehicles
NTP model: Continuous-time semi-Markov process

Where? edge visit probabilities

How fast? edge speed profiles

Energy consumption and emission model

Vehicle specifics (vehicle model; engine type; etc.)

MOVESLite Energy and emission simulator

Outputs:
1) Expected energy & emissions for entire prism;
2) Spatial distribution over time
Experimental prism: **Origin:** ASU Tempe campus. **Destination:** Scottsdale Fashion Square Mall. **Time budget:** 25 min. **Maximum speed:** Varies by network arc
Primary Data Collection for model validation

Route Design
40 trips along 5 designated routes within 25 minutes

Data Collection
Second-by-second (location, speed, engine performance) via GPS-enabled Onboard Diagnostic (OBD) devices

Detailed instructions to research assistants
Results

Calibrated mobility level: lognormal distribution

Expected CO₂ emissions:
Simulated vs measured CO2 for all edges (g/s)
Expected CO₂ emissions over time within the NTP (g/s)
## 2. Green accessibility

<table>
<thead>
<tr>
<th>Direction</th>
<th>Potential Network Path Area (km)</th>
<th>CO₂ Emissions (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>max speed +5 MPH</td>
</tr>
<tr>
<td>ASU to Scottsdale Mall</td>
<td>1782.48</td>
<td>2291.75 (+ 28.6 %)</td>
</tr>
<tr>
<td>Scottsdale Mall to ASU</td>
<td>1800.92</td>
<td>2315.29 (+ 28.6 %)</td>
</tr>
</tbody>
</table>

**Scenario 1: changes in speed limits**
2. Green accessibility

Scenario 2: changes in mobility levels

Original Mobility Level

20% Increase

20% Decrease
2. Green accessibility

Published results (so far)


Links to papers: u.osu.edu/miller.81/research/
Conclusion

- We cannot have sustainability without sustainable urban transportation
- Our current transportation systems are unsustainable
- We need (among other things):
  1. Evidence that shows the health benefits of active transportation, including public transport
  2. Methods to estimate social + environmental externalities of mobility
Human systems are complex

• Policy and planning interventions have unintended consequences
• Fostering sustainable mobility is a good example

Geographic data collection is much easier

• Allows researchers to design and execute real-world experiments, with stronger support for causality
• Opportunities for natural/quasi experiments are happening all the time!

Next step: Geographic information observatories

• Persistent observation of geographic data to support opportunistic observation, experimentation and shared decision-making
Contact

• Email: miller.81@osu.edu
• Web: u.osu.edu/miller.81
• Twitter: @MobileHarv

Support

• Complete the streets 3 ways: Effects on Activity and BMI (1R01CA157509-01), Obesity Policy Research: Evaluation and Measures, National Institutes of Health.
• Green accessibility: Measuring the environmental costs of space-time prisms in sustainable transportation planning” (BCS-1224102), Geography and Spatial Sciences and Environmental Sustainability programs, National Science Foundation.

Students

• Calvin Tribby, PhD.  Now: Cancer Prevention Fellow, NCI, NIH
• Ying Song, PhD.  Now: Assistant Professor, University of Minnesota

Thank you!