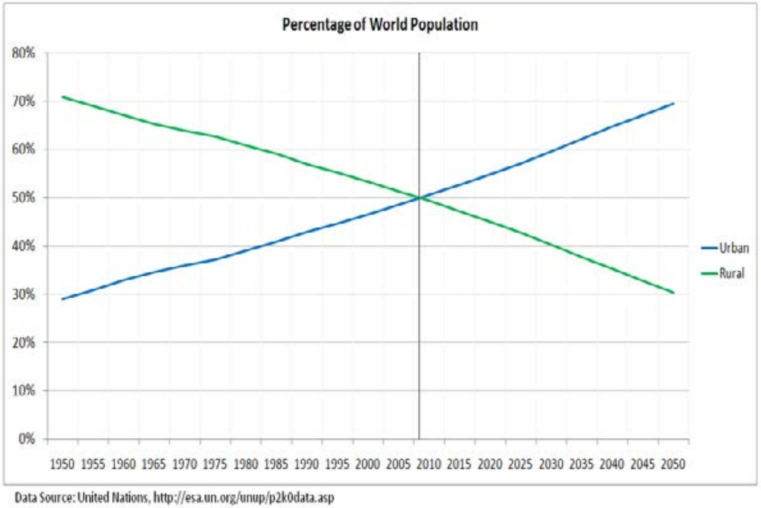
Using GIS to Make Urban Mobility More Sustainable

Harvey J. Miller
Department of Geography &
Center for Urban and Regional Analysis (CURA)
The Ohio State University

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

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

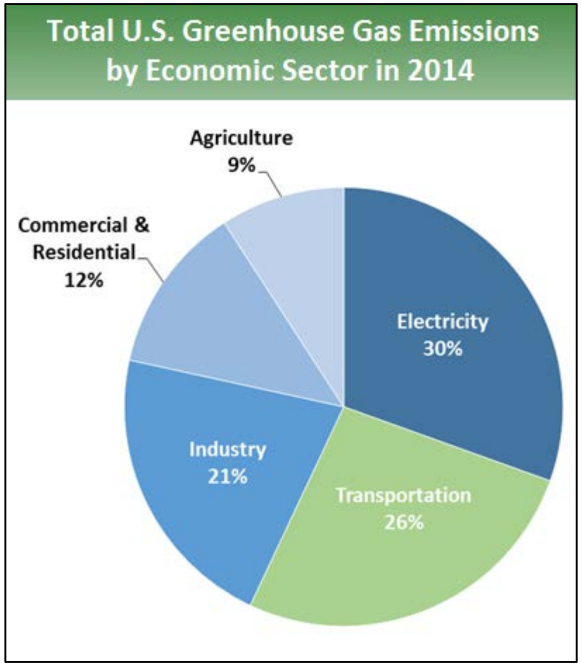
Our mobility systems are not sustainable!

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



www.epa.gov

Our mobility systems are not sustainable

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)

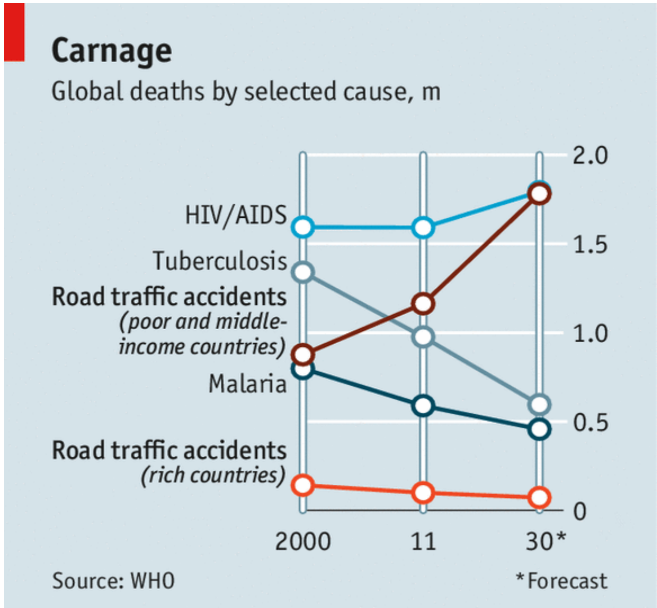

TRAFFIC ACCIDENTS

2016 Was the Deadliest Year on American Roads in Nearly a Decade

Kirsten Korosec
Feb 15, 2017

Lower gas prices and and increased motor-vehicle mileage combined with risky activities like speeding and driving while texting is proving deadly for American drivers.

fortune.com



www.economist.com

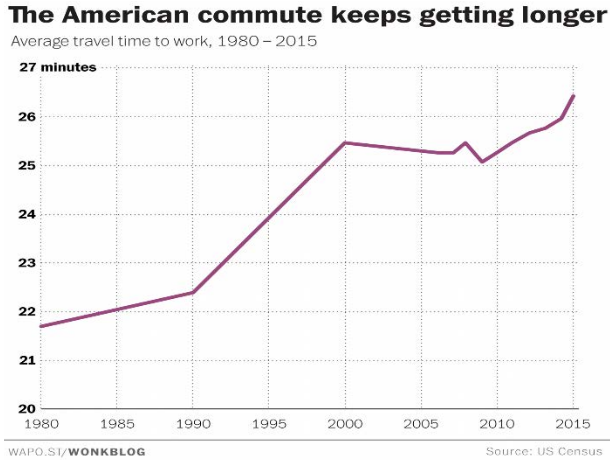
Our mobility systems are not sustainable

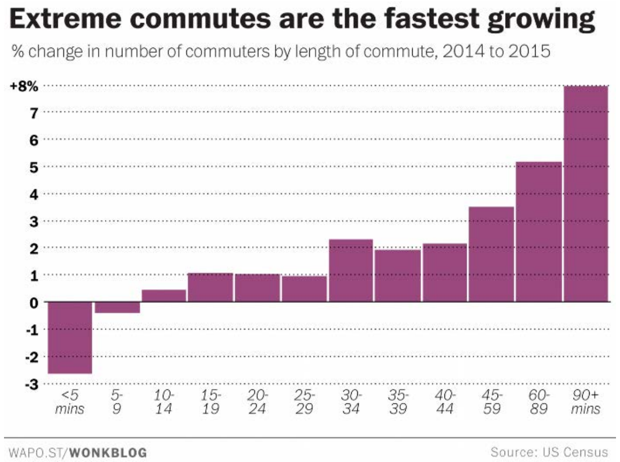
Congestion

- 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





washingtonpost.com

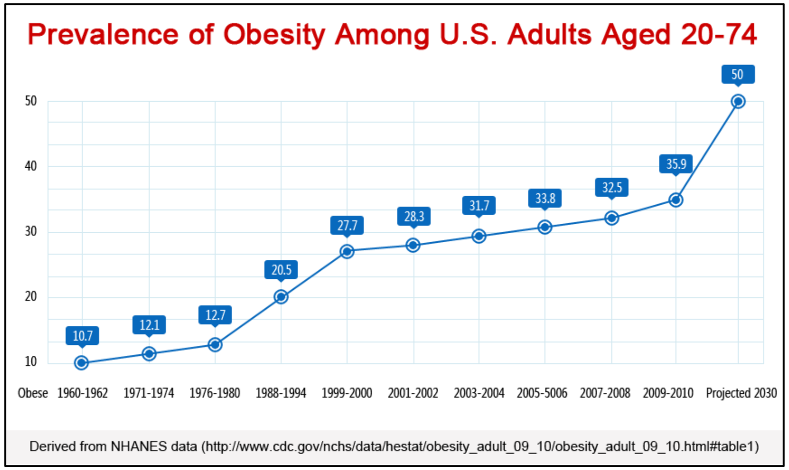
Our mobility systems are not sustainable

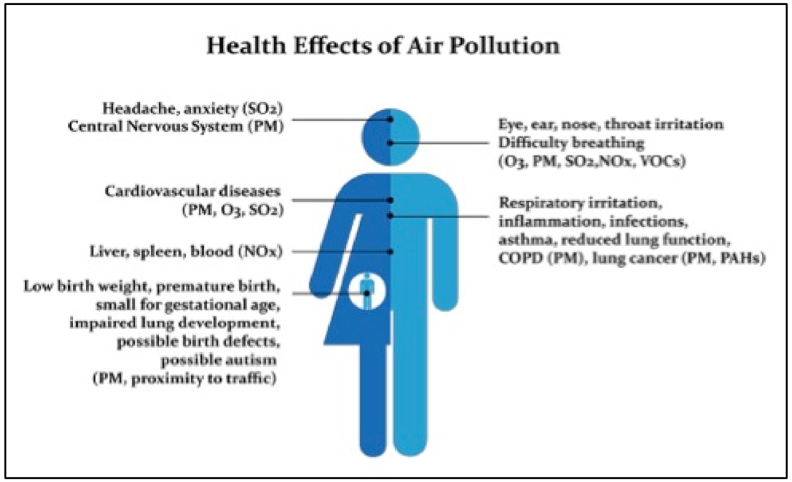
Public health

- Physically inactive lifestyles are a major public health crisis

Air quality

- Ground-level ozone, PM, SO_x, NO_x
- Wide range of bad health impacts





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Towards sustainable urban mobility

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

Banister, D. (2008). The sustainable mobility paradigm. *Transport Policy*, Vol. 15, (2), pp. 73-80.

New policy needs new measures

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

www.newsworks.org

Evidence-based policy to support sustainable mobility

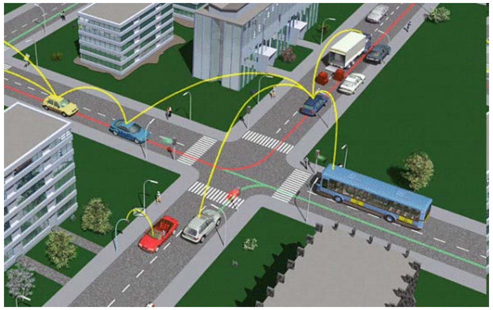
- **People-based measures** – especially social equity
- **Capture externalities** – e.g., health, air quality

www.eunews.it

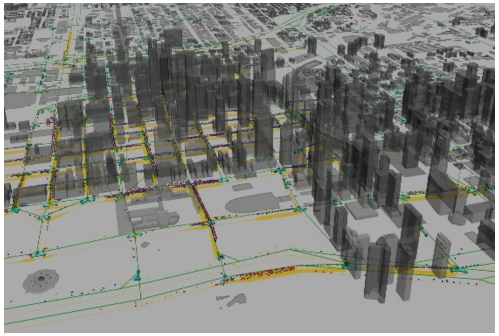
GIS opportunities

- 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”

blogs.casa.ucl.ac.uk



rtm.science.unitn.it



avl.ncsa.illinois.edu

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


MAPS Overview
Airport Line Stops
Existing Stops
Airport TRAX Route
Existing TRAX Lines
Study Area
Near Group
0 500 1,000 2,000 Meters
Data: AGRC; ESRI; Author. 2012.

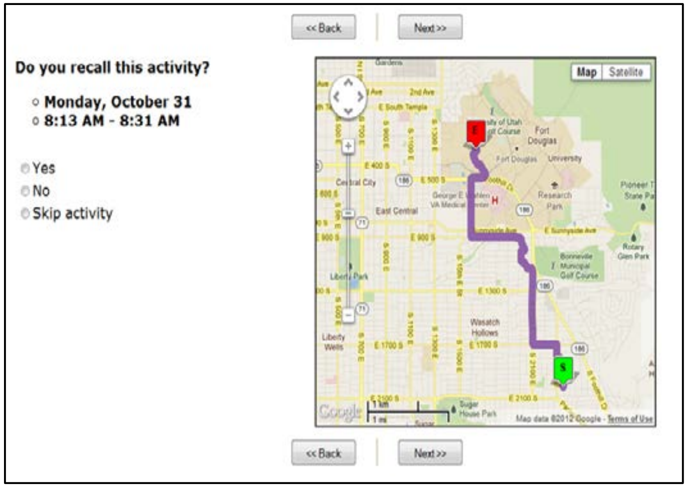
1. Moving Across Places Study (MAPS)

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



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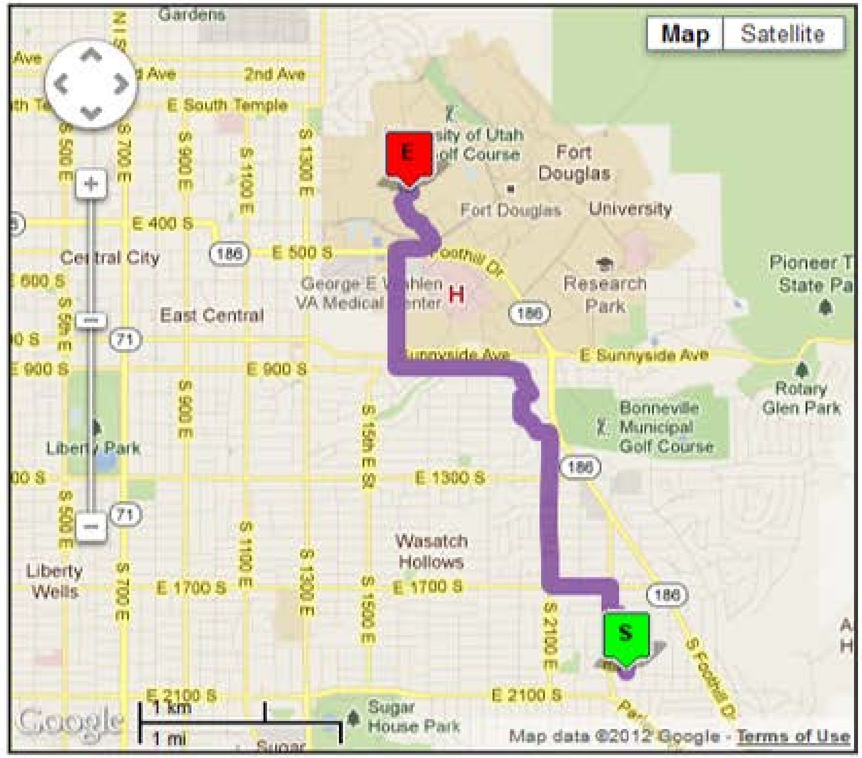
Do you recall this activity?

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

- Yes
- No
- Skip activity



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(My bike ride from home to work in Oct. 2011)

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How important were the following goals to this activity?

	Not at all important				Very Important
	1	2	3	4	5
Getting exercise	○	○	○	○	○
Getting someplace	○	○	○	○	○
Getting leisure or Recreation	○	○	○	○	○
	1	2	3	4	5

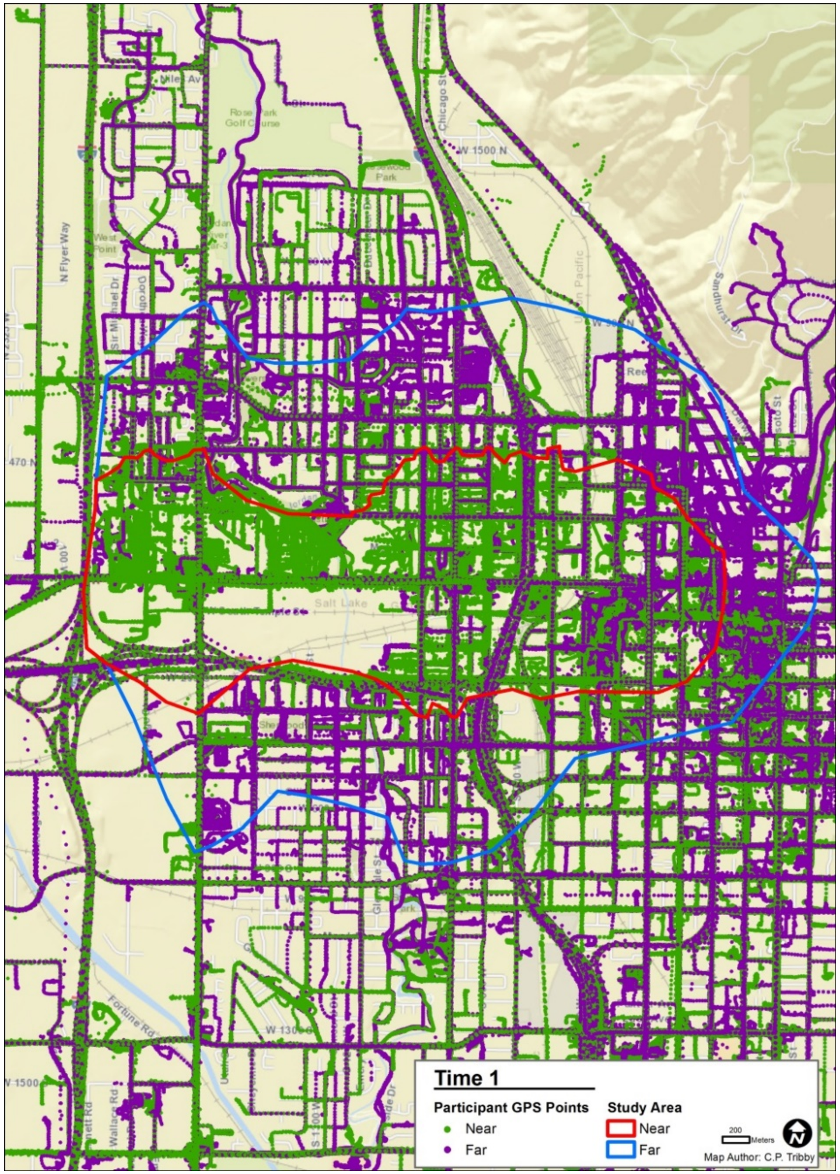
Did the place where the activity occurred feel:

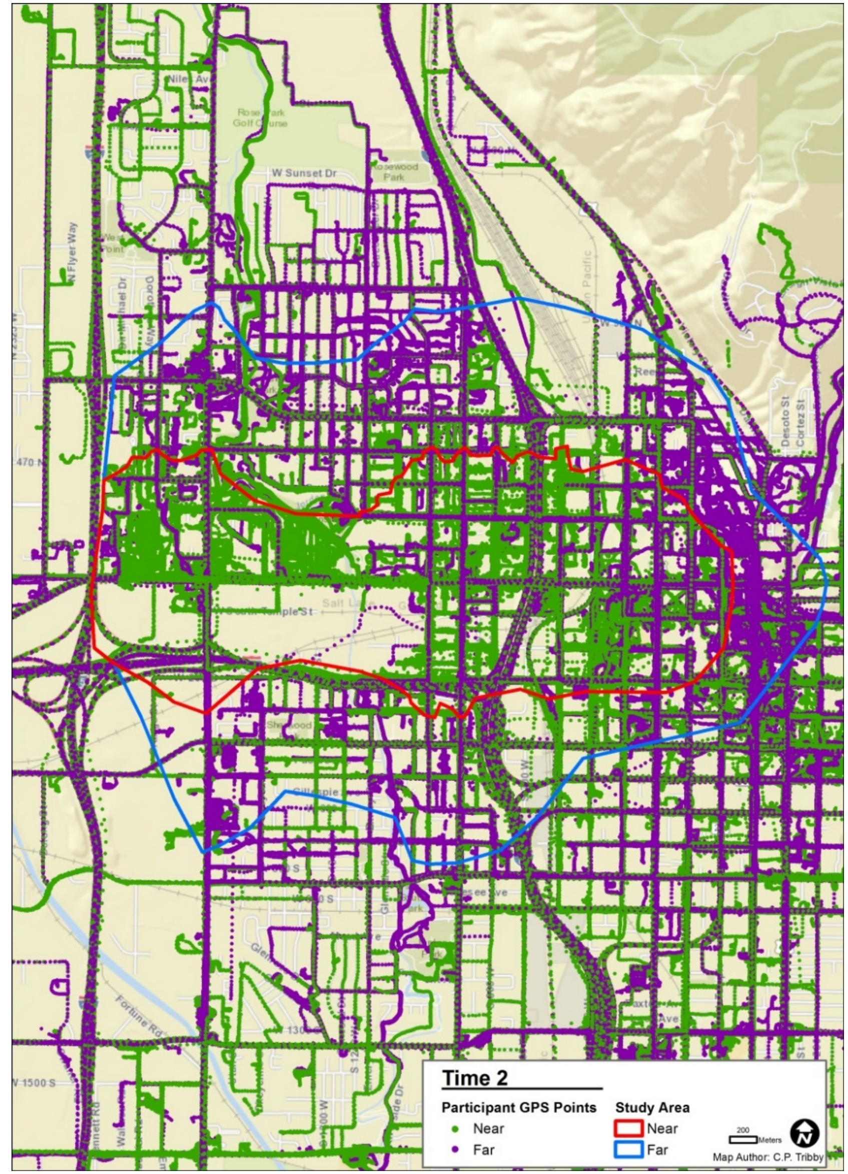
	Not at all				Very
	1	2	3	4	5
Safe from **crime**?	○	○	○	○	○
Safe from **traffic**?	○	○	○	○	○
Pleasant?	○	○	○	○	○
Easy to get to or around?	○	○	○	○	○
	1	2	3	4	5

Activity Summary

Start: Monday, October 31 8:13 AM
End: Monday, October 31 8:31 AM
From **home** to **school** alone

<< Back | Next >>





Big geographic data? Approximately 4 million GPS points for each time period!

Public transit user

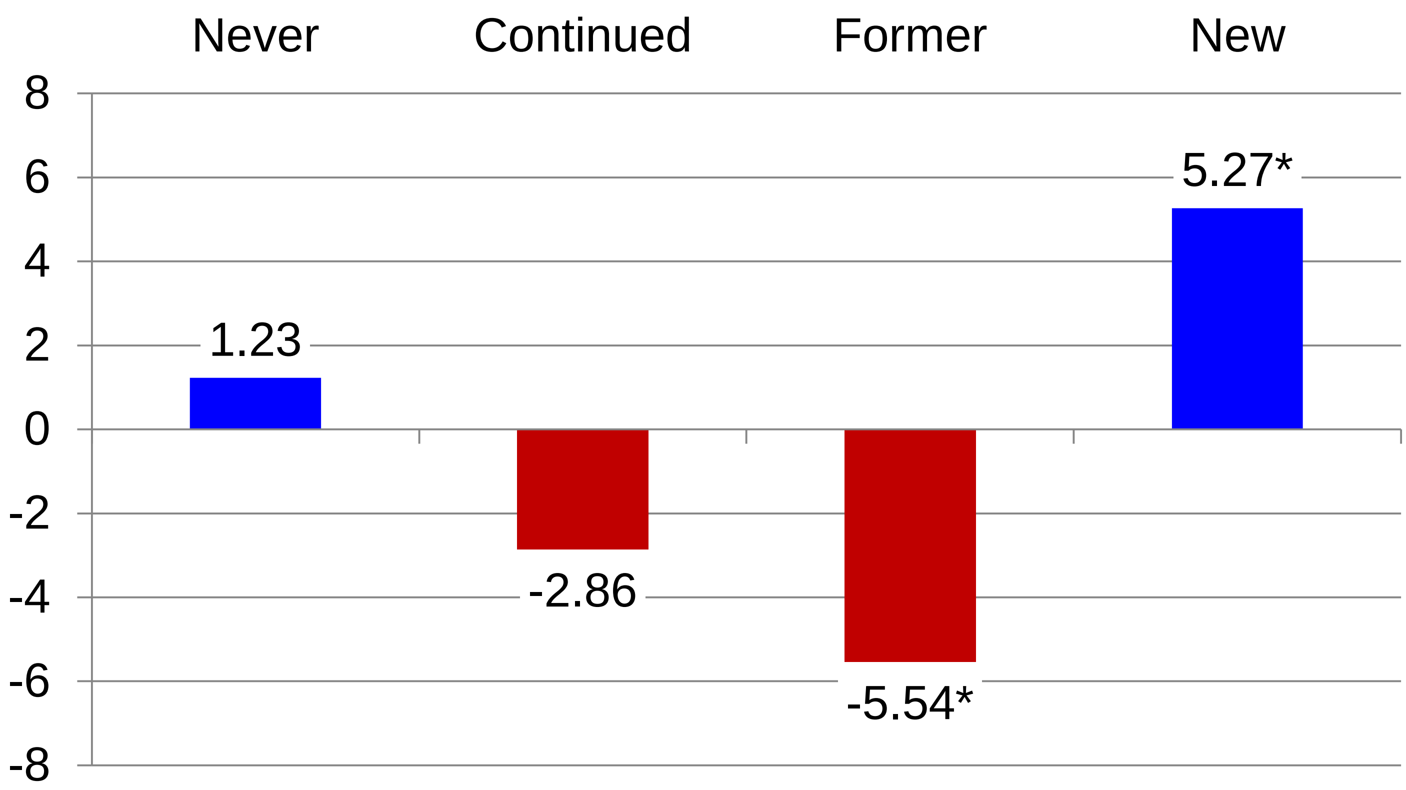
Participant who rode either bus or LRT at least once during data collection week

Transit groups (below)

Transit group	N	Public transit user in: 2012?	2013?
Never	391	No	No
Continued	51	Yes	Yes
Former	42	Yes	No
New	52	No	Yes

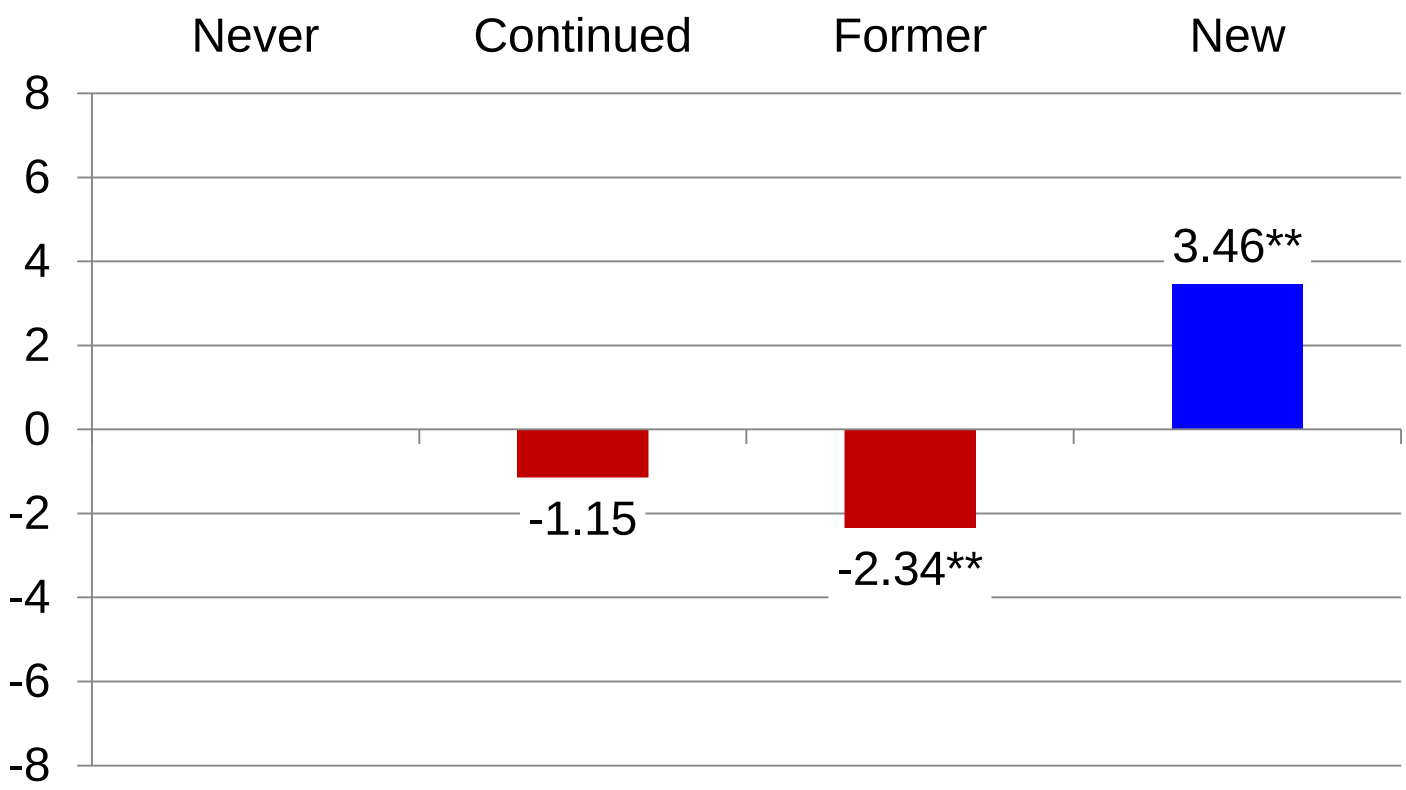
Changes in PA-Total time by group

(within-person differences, 2013 - 2012)



Average time: Minutes per 10 hr. wear period
PA: Min 1000 cpm in min 5 minute bout
Within group differences: * $p < 0.1$

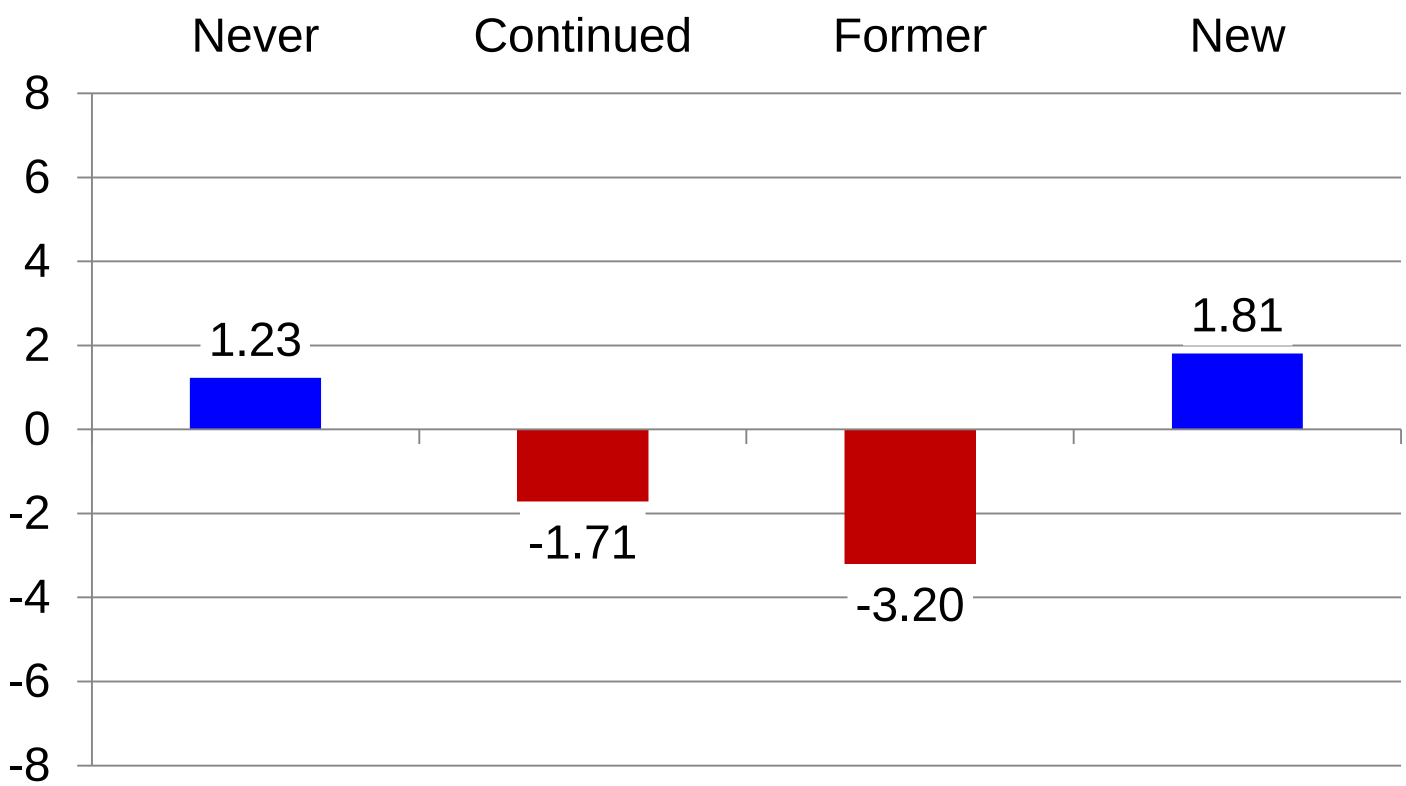
Changes in PA-Transit time by group
(within-person differences, 2013 - 2012)



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)

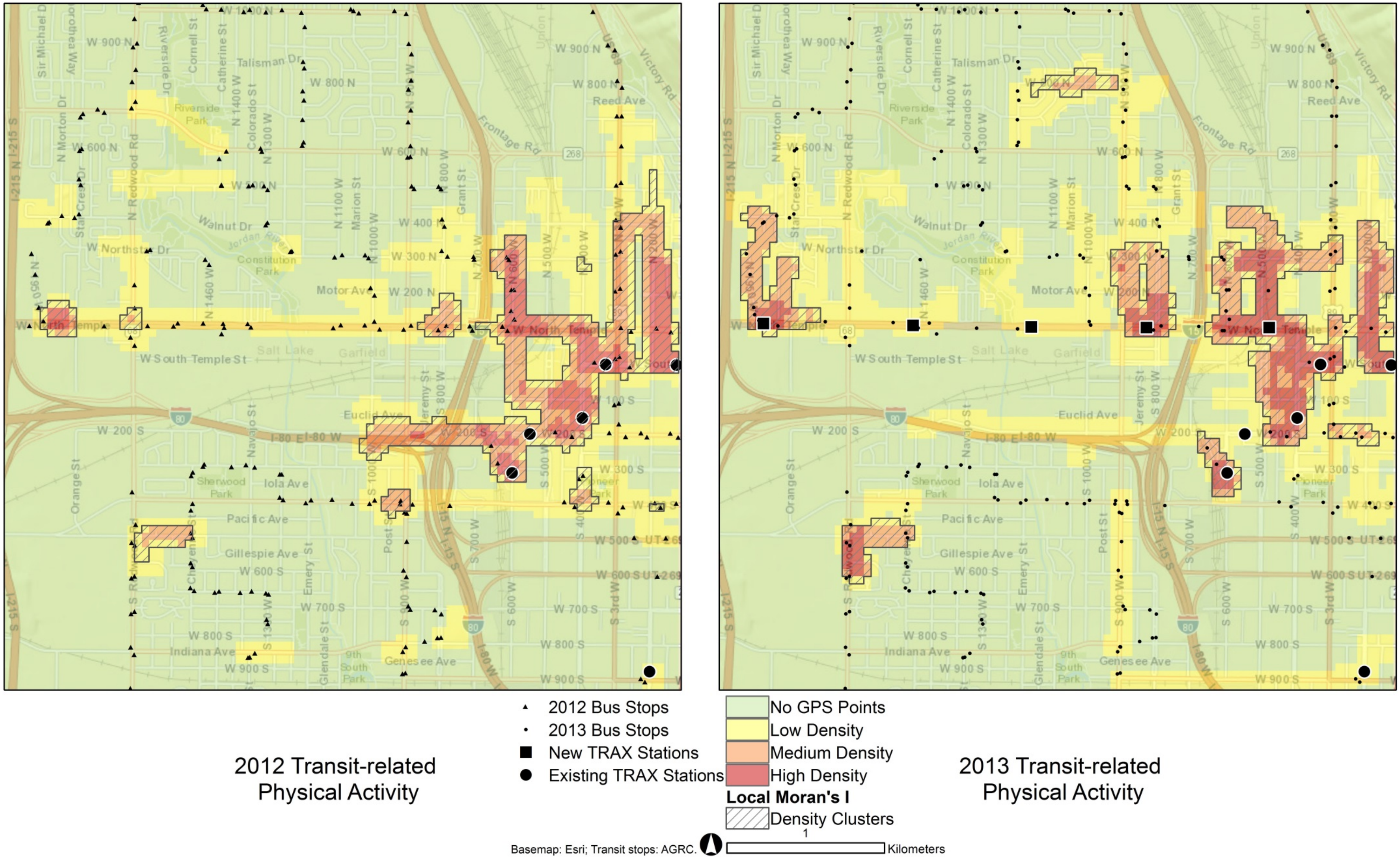


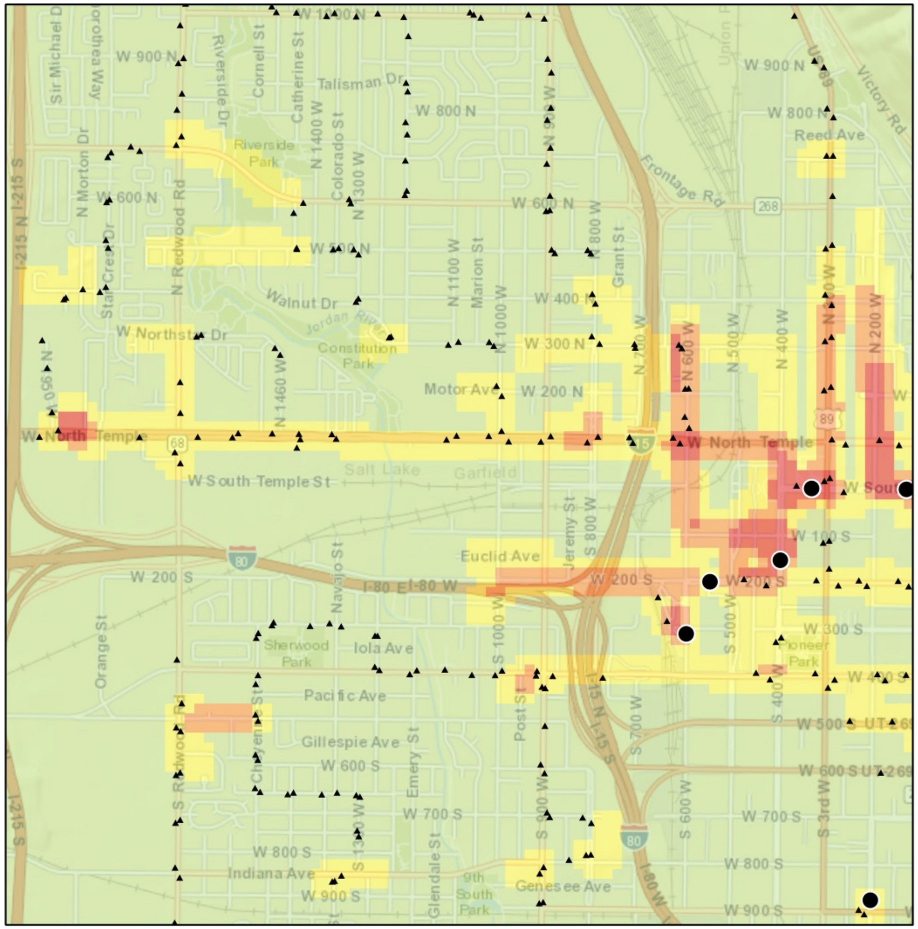
Average time (minutes per 10 hr. wear period);
PA: Min 1000 cpm in min 5 minute bout
Within group differences: None significant

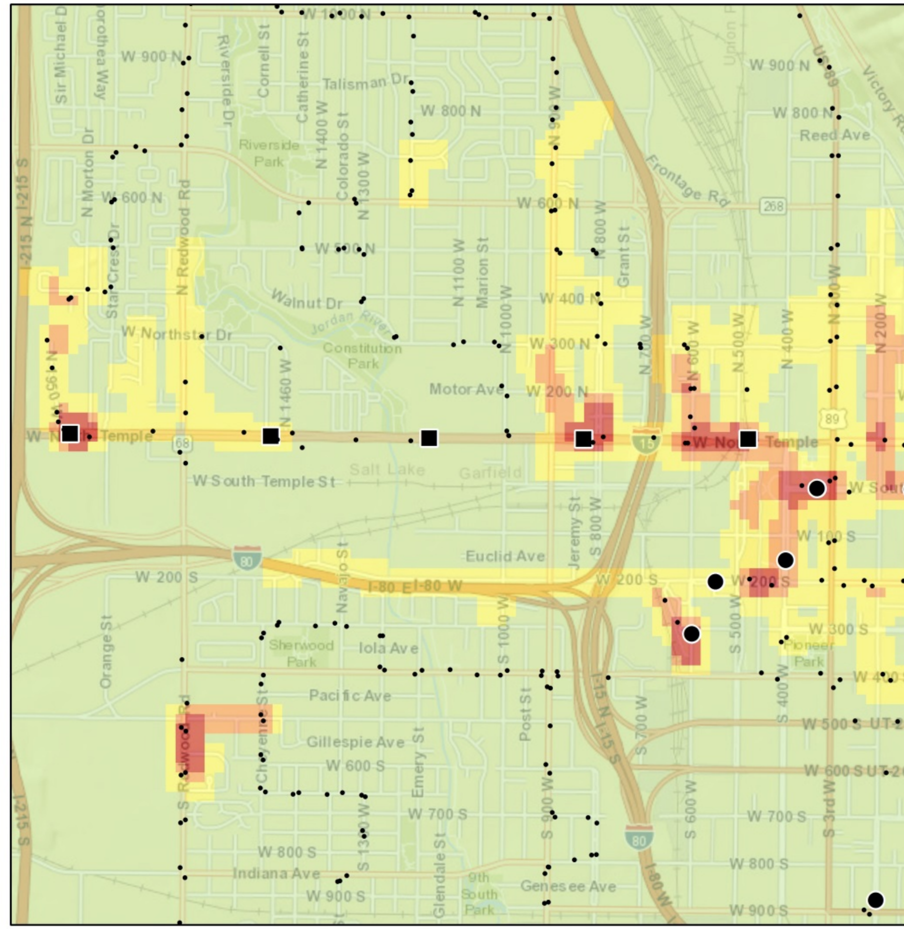
Summary

User behavior (2013 vs. 2012)	**PA-Total**	**PA-Transit**	**PA-Other**
Did not change (Never; Continuing)	No change	No change	No change
Stopped using transit (Former)	Decrease	Decrease	No change
Started using transit (New)	Increase	Increase	No change

No confounding factors
No substitution for non-transit PA
→ **LRT generated new PA**


2012 Bus Stops
2013 Bus Stops
New TRAX Stations
Existing TRAX Stations
No GPS Points
Low Density
Medium Density
High Density
Local Moran's I
Density Clusters
1
Kilometers
Basemap: Esri; Transit stops: AGRC.
2012 Transit-related Physical Activity
2013 Transit-related Physical Activity





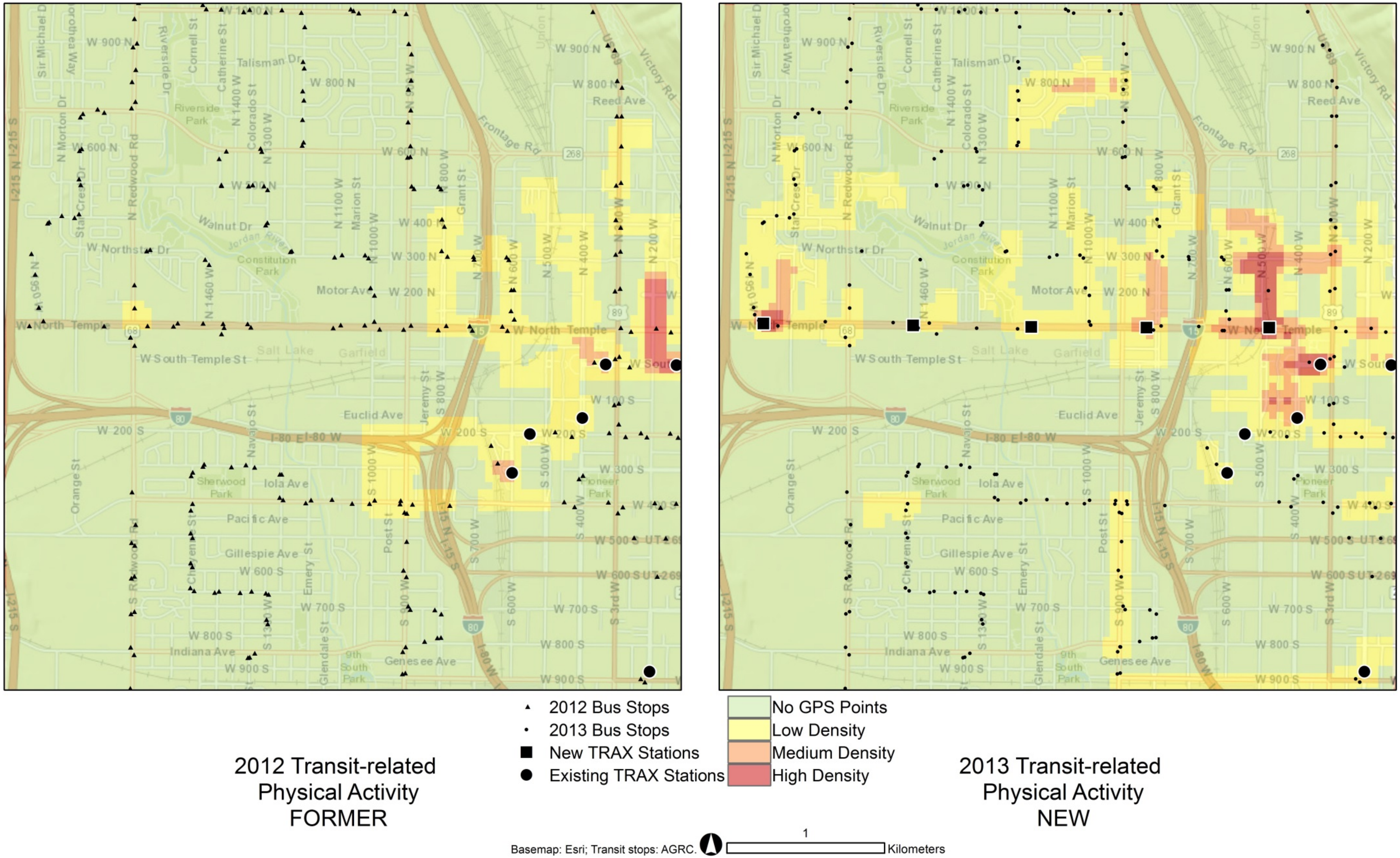
- ▲ 2012 Bus Stops
- • 2013 Bus Stops
- ■ New TRAX Stations
- ● Existing TRAX Stations

- No GPS Points
- Low Density
- Medium Density
- High Density

2012 Transit-related Physical Activity CONTINUED

2013 Transit-related Physical Activity CONTINUED

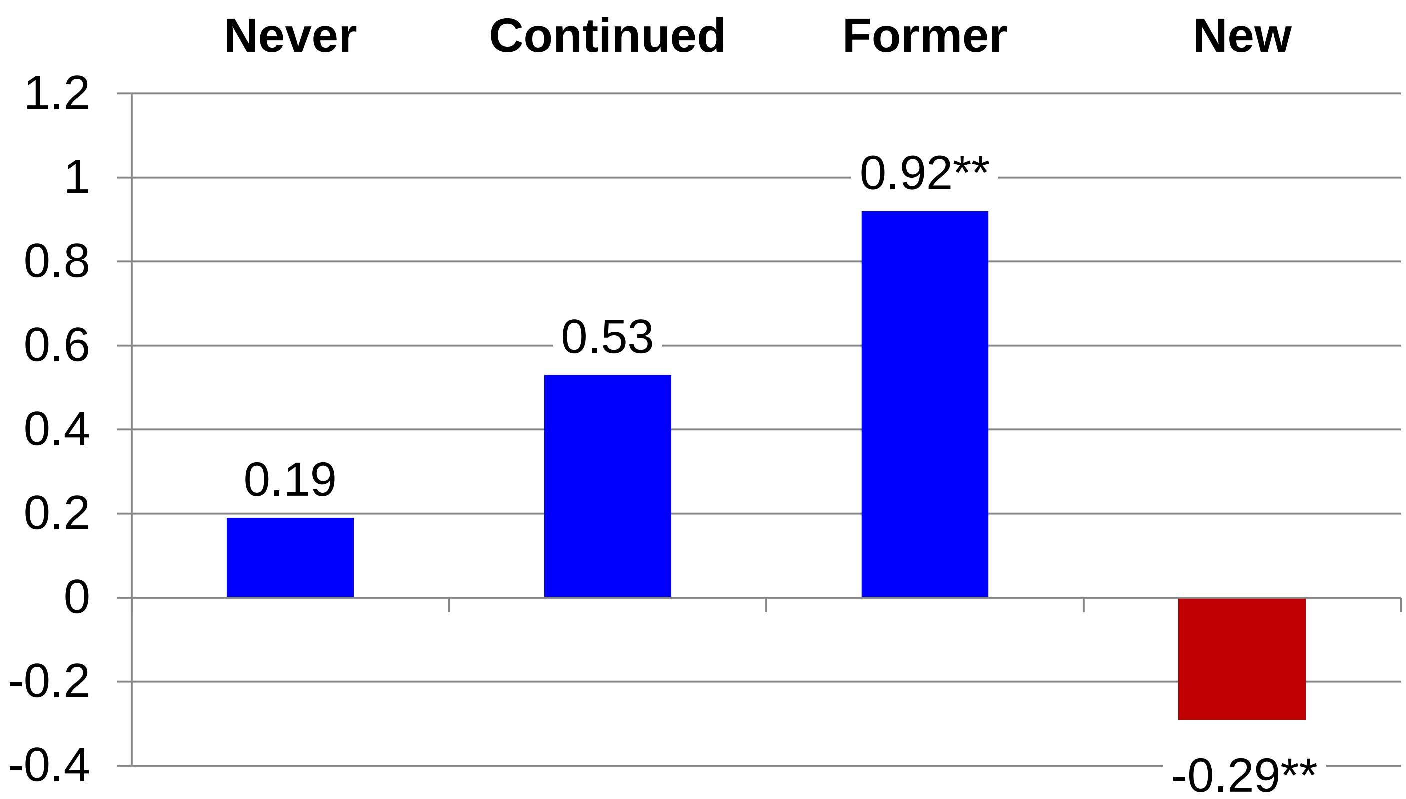
Basemap: Esri; Transit stops: AGRC. 1 Kilometers



2012 Transit-related Physical Activity FORMER

2013 Transit-related Physical Activity NEW

BMI changes by transit ridership (difference 2013 - 2012)



**p<.01 Never = control group

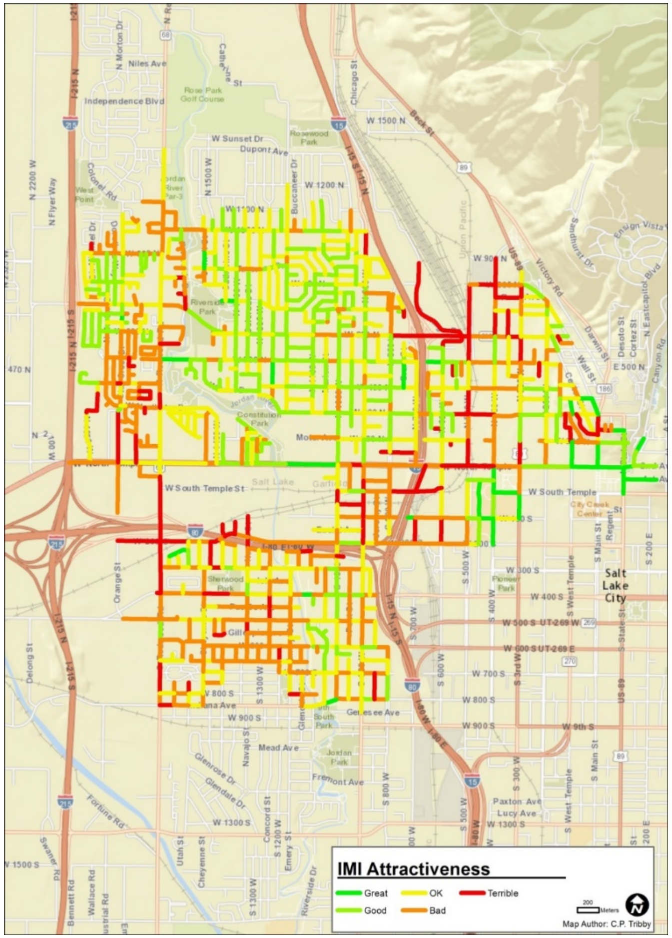
1. Moving Across Places Study (MAPS)

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. Transit use, physical activity, and body mass index changes: Objective measures associated with Complete Street light rail construction. **American Journal of Public Health**, 105, 1468-1474.

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.

2016. Assessing built environment walkability using activity space summary measures. **Journal of Transport and Land Use**, 9, 1-21.

2016. A complete street intervention for walking to transit, non-transit walking, and bicycling: A quasi-experimental demonstration of increased use. **Journal of Physical Activity & Health**. doi: 10.1123/jpah.2016-0066.

2016. Analyzing walking route choice through built environments using random forests and discrete choice techniques. **Environment and Planning B: Planning and Design.** doi: 10.1177/0265813516659286

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

2. Green accessibility

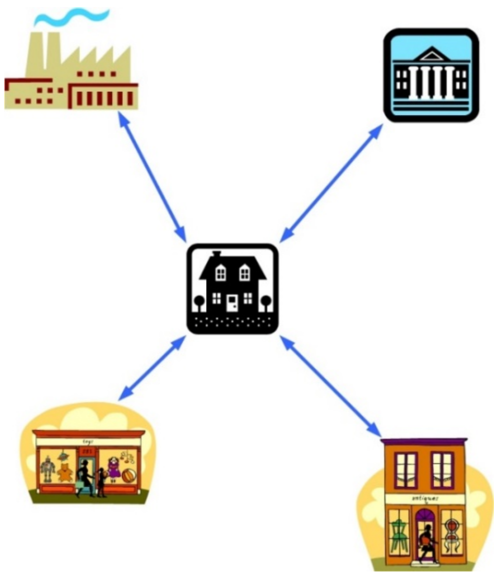
Accessibility

- 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



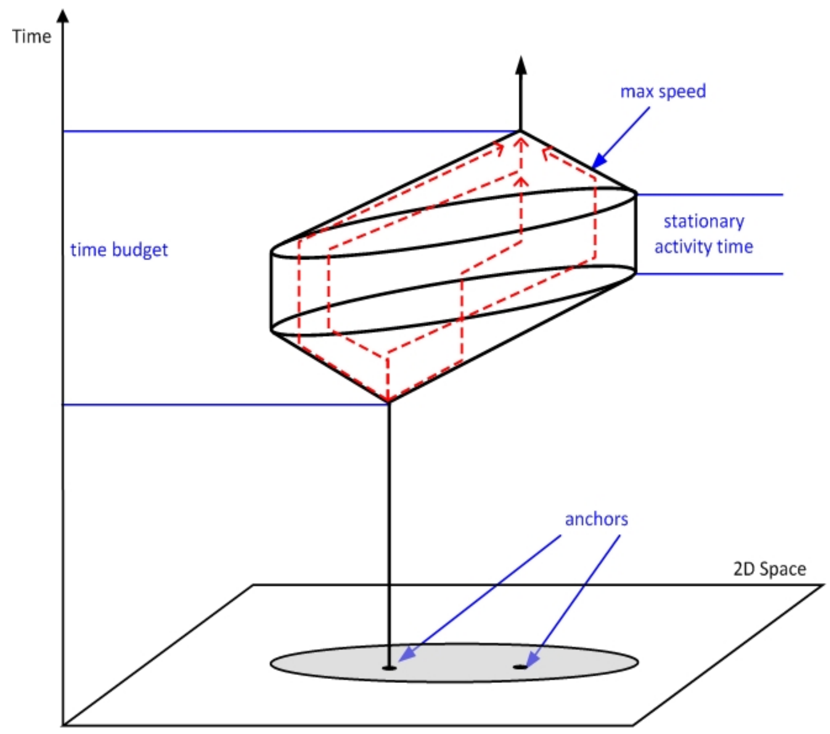
Classic accessibility measure: Count the number of activities near home (or work)

Space-time prisms

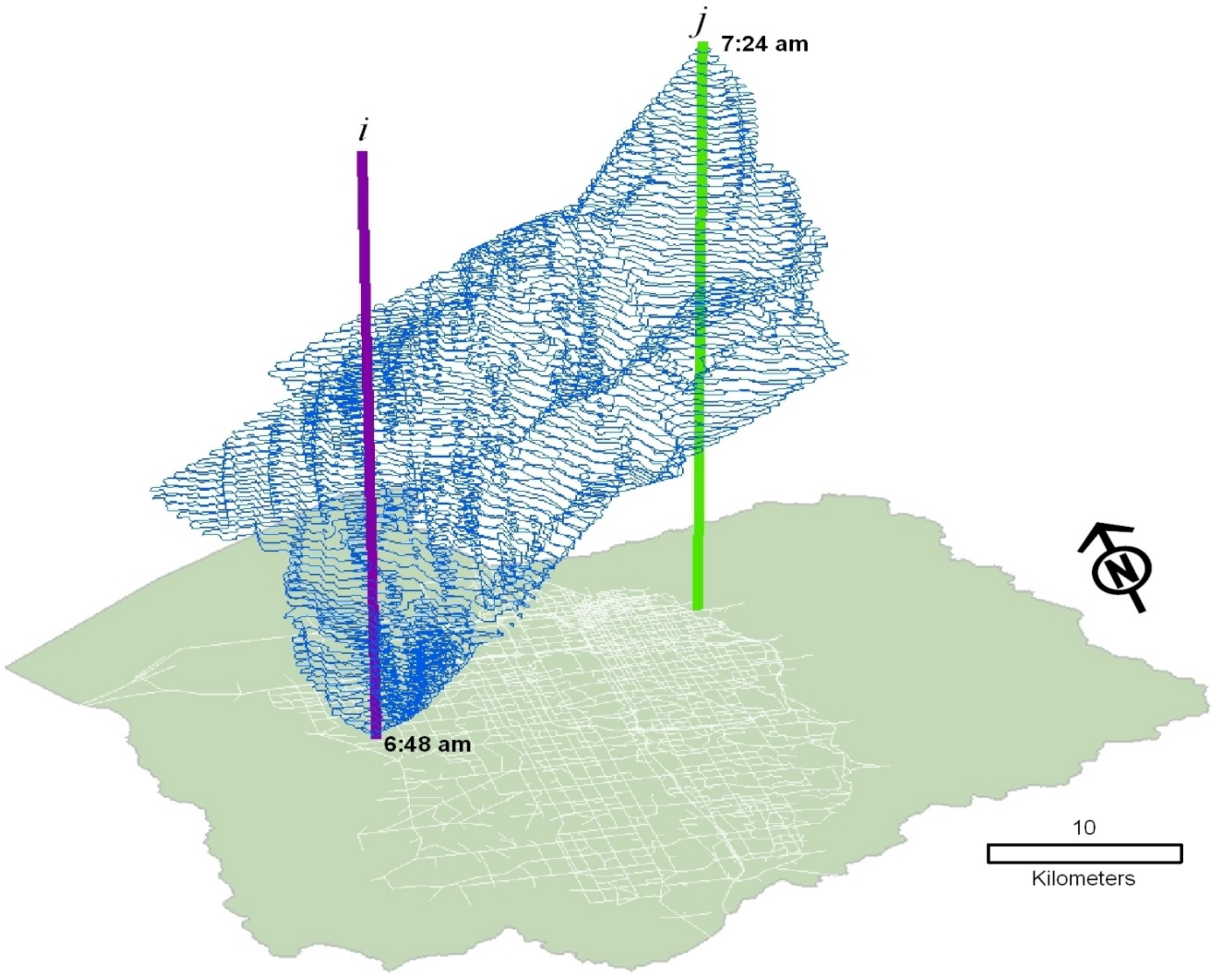
Envelope of all possible space-time paths between two locations and times given maximum speed and any stationary time

A socially sensitive measure of accessibility

Considers both location and time constraints

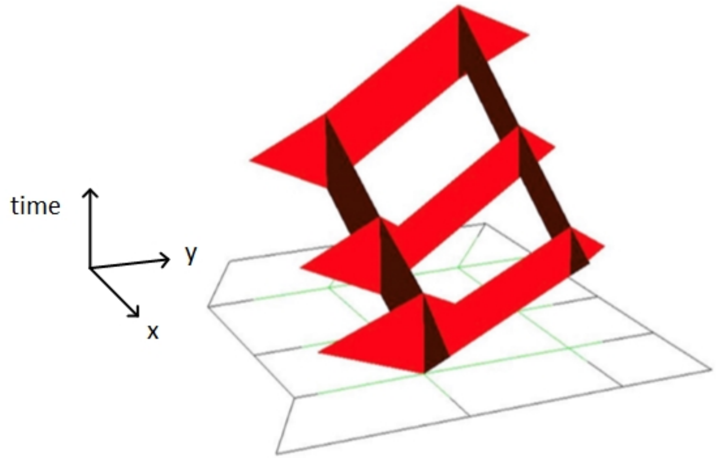


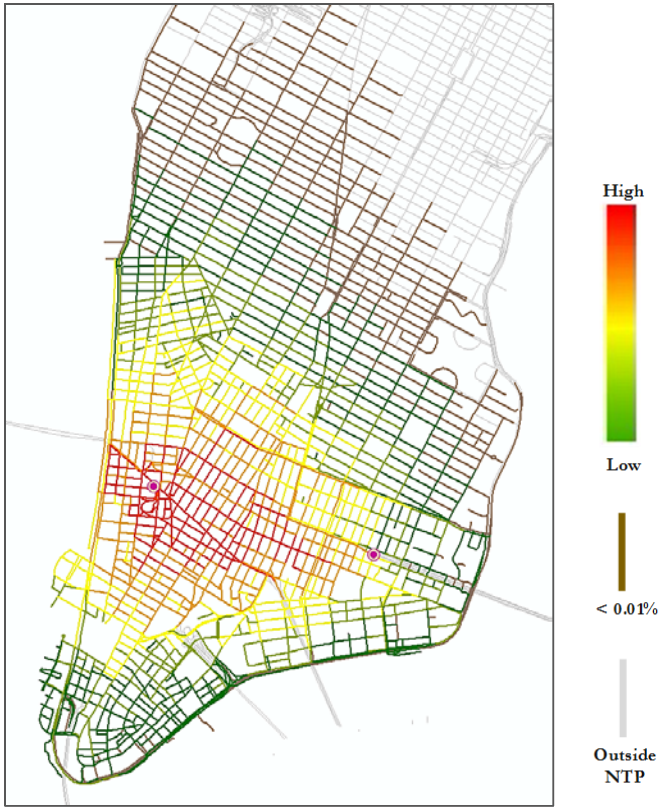
A space time prism (STP) in continuous space



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?

www.theatlanticcities.com

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

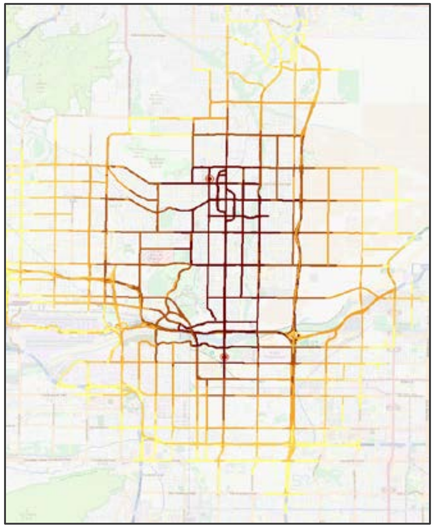
Application: Emissions in Phoenix, AZ

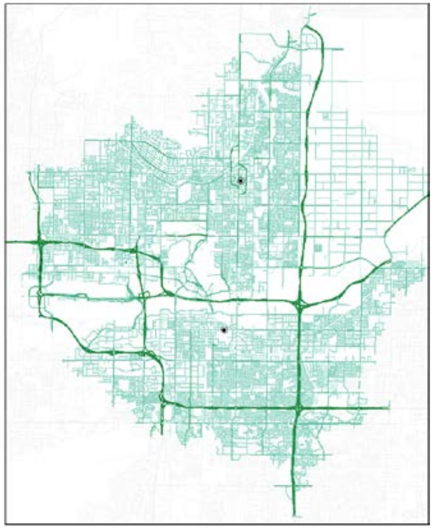
- Model expected locations and speeds within NTP
- Estimate expected emissions (MOVESLite)
- Validate using primary data from instrumented vehicles

NTP model: Continuous-time semi-Markov process

Where?
edge visit probabilities

How fast?
edge speed profiles





Energy consumption and emission model

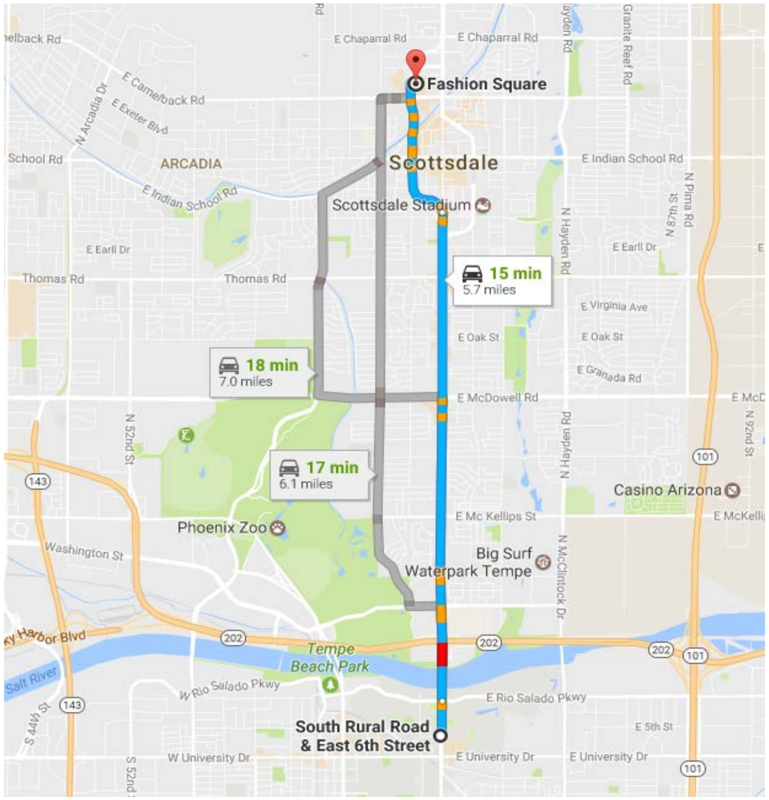
Vehicle specifics
(vehicle model; engine type; etc.)

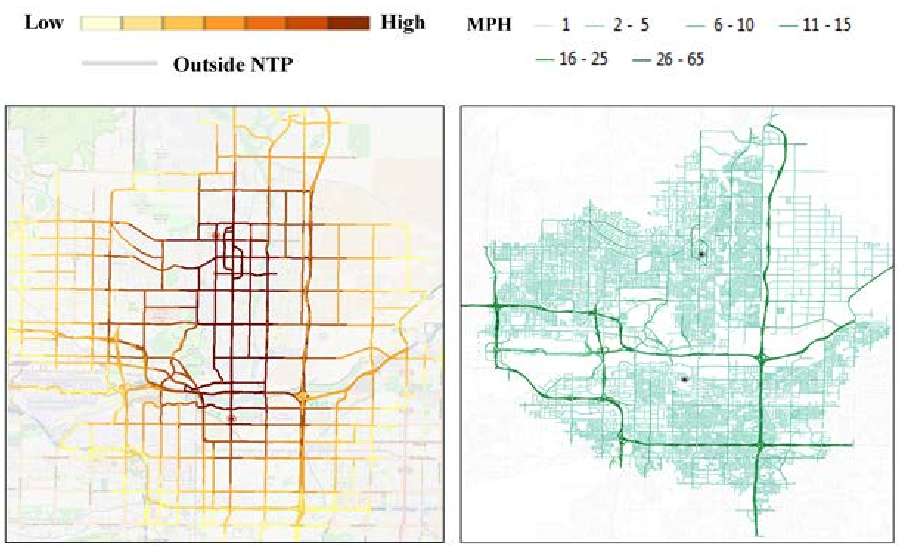
MOVESLite
Energy and emission simulator

Outputs:

1) Expected energy & emissions for entire prism;

2) Spatial distribution over time





Visit Probabilities

Mean speed distribution

Experimental prism: **Origin:** ASU Tempe campus. **Destination:** Scottsdale Fashion Square Mall. **Time budget:** 25 min. **Maximum speed**: Varies by network arc

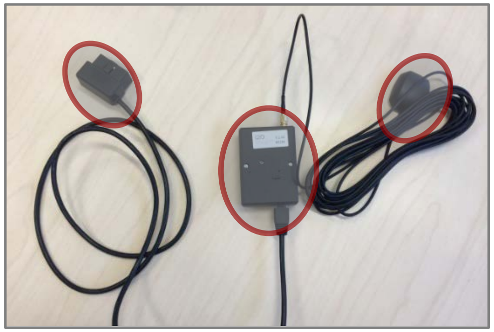
Primary Data Collection for model validation

Route Design

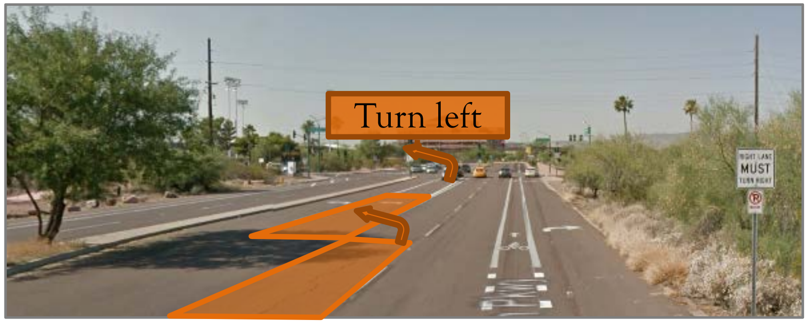
40 trips along 5 designated routes within 25 minutes

Data Collection

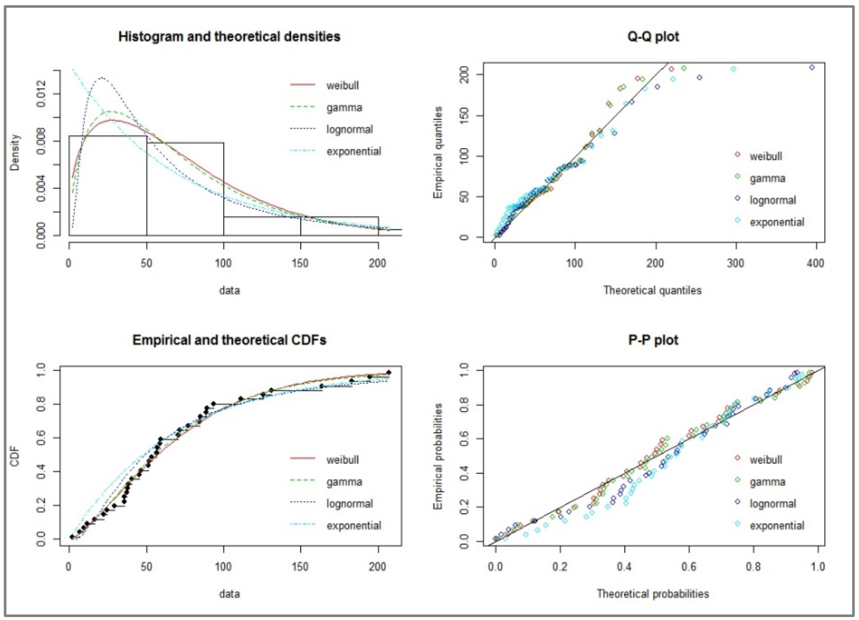
Second-by-second (location, speed, engine performance) via GPS-enabled **Onboard Diagnostic** (OBD) devices

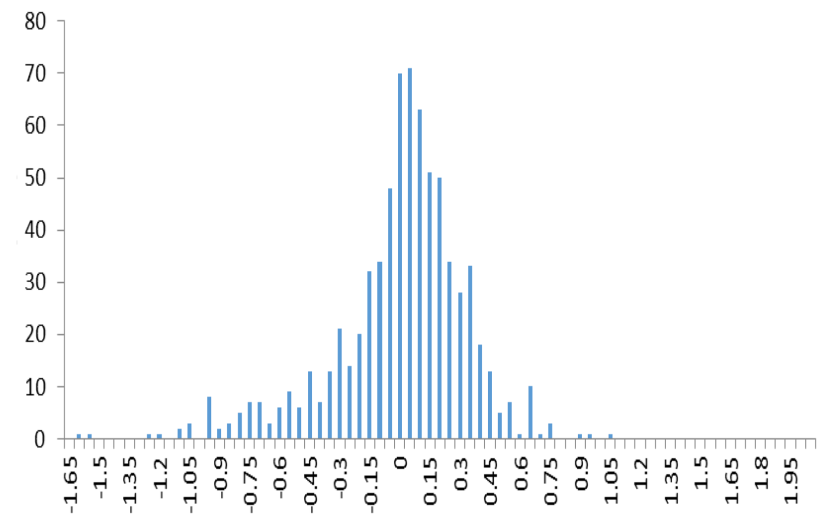


Detailed instructions to research assistants



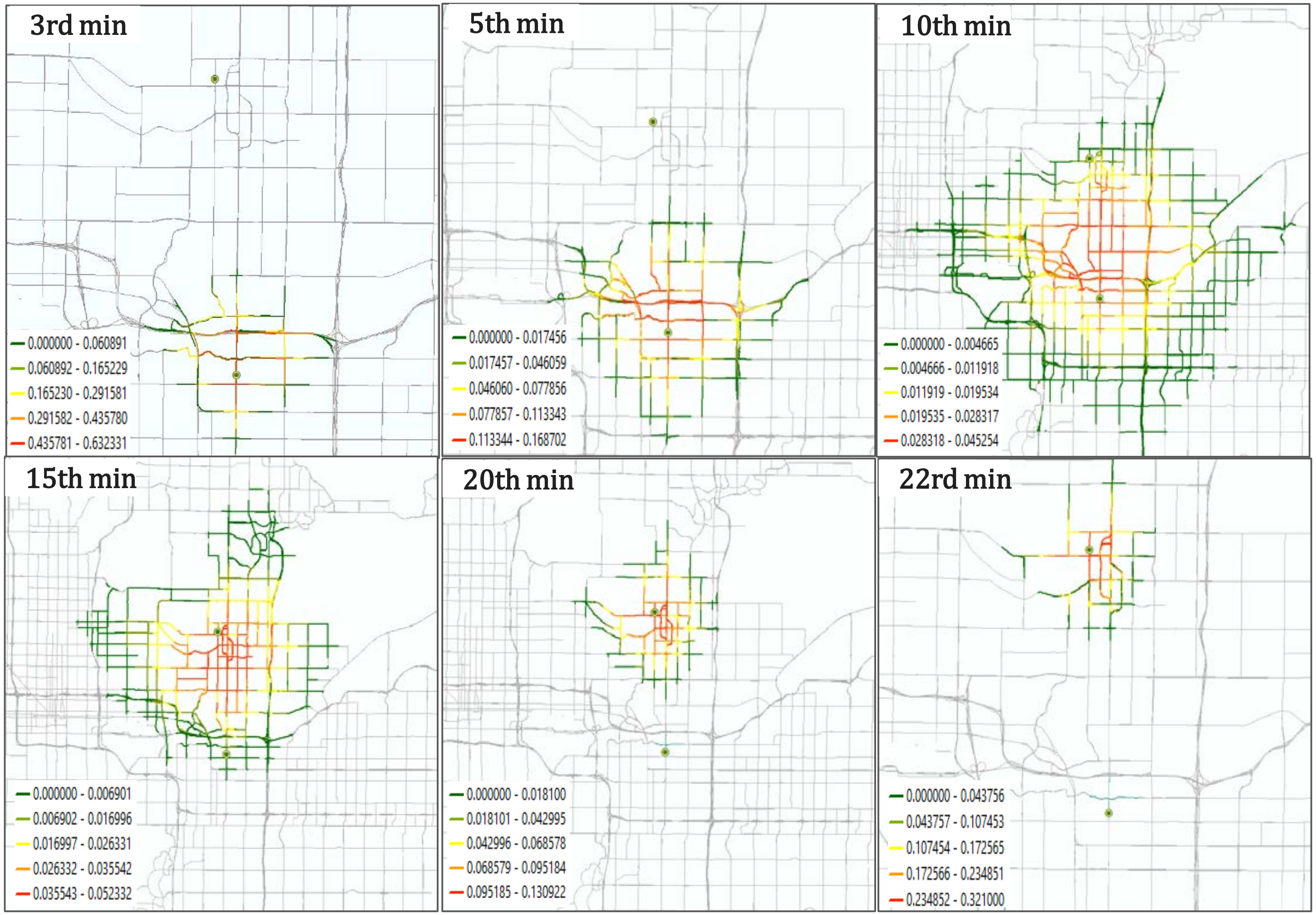
Results





Calibrated mobility level:
lognormal distribution

Expected CO_2 emissions:
Simulated vs measured CO2 for all edges (g/s)

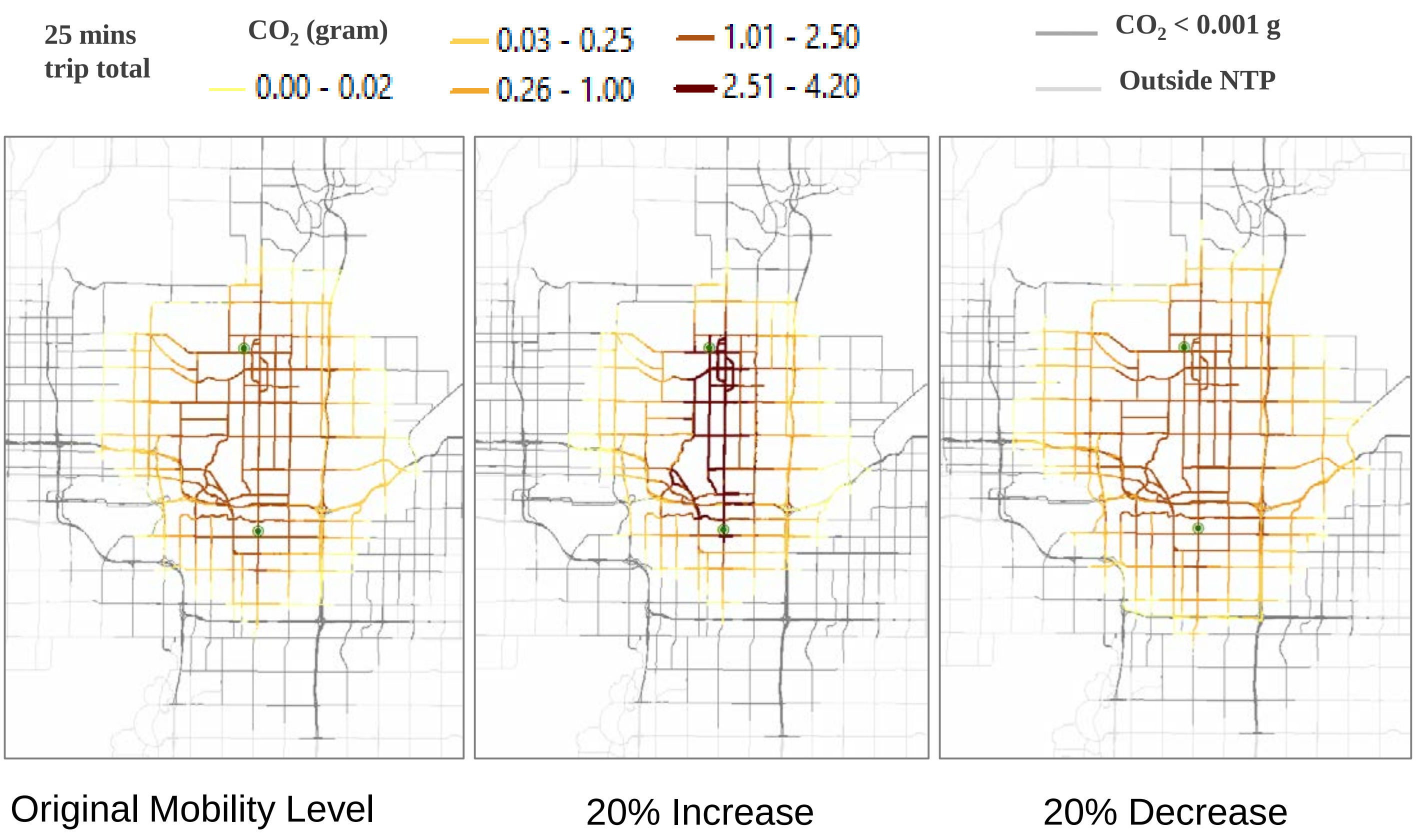


Expected CO_2 emissions over time within the NTP (g/s)

Direction	Potential Network Path Area (km)			CO_2 Emissions (g)		
	Baseline	max speed +5 MPH	max speed – 5 MPH	Baseline	max speed +5 MPH	max speed -5 MPH
ASU to Scottsdale Mall	1782.48	2291.75 **(+ 28.6 %)**	1440.30 **(- 19.2 %)**	6048.42	6231.88 **(+ 3.0 %)**	5391.32 **(- 10.9 %)**
Scottsdale Mall to ASU	1800.92	2315.29 **(+ 28.6 %)**	1466.61 **(- 10.9 %)**	6045.53	6231.23 **(+ 3.1 %)**	5398.66 **(- 10.7 %)**

Scenario 1: changes in speed limits

2. Green accessibility



Scenario 2: changes in mobility levels

Published results (so far)

2014. Simulating visit probability distributions within planar space-time prisms. **International Journal of Geographical Information Science**, 28, 104-125.

2015. Transportation network design for maximizing space-time accessibility. **Transportation Research B**, 81, 555-576.

2016. Modeling visit probabilities within network time prisms using Markov techniques. **Geographical Analysis**, 48, 18-42.

2016. Estimating the most likely space-time paths, dwell times and path uncertainties from vehicle trajectory data: A time geographic method. **Transportation Research C**, 66, 176-194.

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

To the future!

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

Thank you!

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