Accessibility and Mobility in Urban India

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Objective

- **Measure accessibility, proximity, mobility, and congestion in Indian cities and assess their determinants**

Definitions: Accessibility and its components

1. **Uncongested mobility**: Speed in absence of traffic ('free flow' speed)
2. **Congestion**: Average delay due to traffic
3. **Mobility**: Uncongested mobility + Congestion (actual speed)
4. **Proximity**: Distance to travel destinations
5. **Accessibility**: Proximity + Mobility

In turn, accessibility, mobility, proximity, and congestion are determined by:

1. **Roads**: mileage and other features of a city's street network
2. **Other city characteristics**: Population, area, share of drivers, etc

Why do we care about accessibility?

The benefits from cities and urbanization

- Cities make workers and firms more productive
- Cities allow residents to consume a greater variety of goods at a lower price

But for this, city residents need to be able to "go places"

- Extremely large road investments involved.

Results on determinant of accessibility

- Uncongested mobility is a more important determinant of mobility than congestion
- City population worsens uncongested mobility and congestion, improves proximity, and overall no effect on accessibility
- More vehicles associated with worse congestion
- More major roads associated with better uncongested mobility and proximity
- Income associated with better uncongested mobility and worse congestion: bell shape impact on mobility

Data

1. 154 Indian cities defined using night lights
2. 23 million simulated "real time traffic" trips from Google Maps
3. All establishments in India from Google Place
4. All roads by types in India from Open Street Map.
5. Other: World Bank *Spatial Database for South Asia*

Sampling trips

- We do not have a transportation survey (and no existing transportation survey would currently satisfy our data needs)
- Instead we make up trips and measure them using Google Maps
- To obtain representative trips, we
  - Design trips that resemble actual trips
  - Use different design strategies and verify they all lead to the same results
  - Weight trips by how busy traffic (implicitly) is

Sampling trips

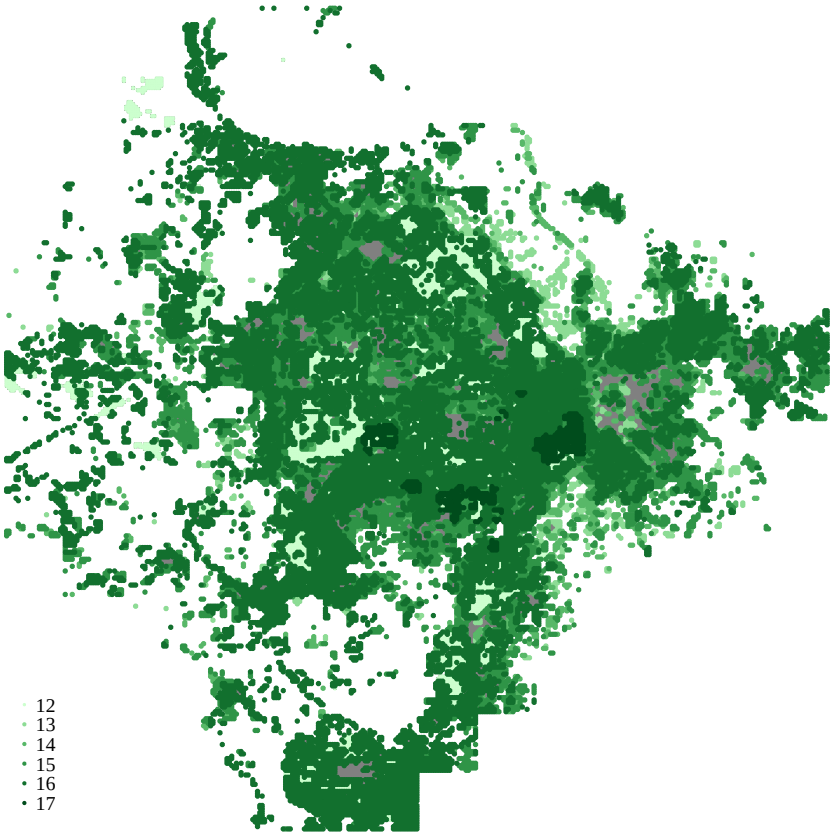
Four trip design strategies:

1. Radial trips
2. Circumferential trips
3. Gravity trips
4. Trips to "remarkable places" (using city hall as proxy for workplace)

- These strategies aim to mimic actual trips in key dimensions (lengths, destinations, etc) or some idealized travel behavior

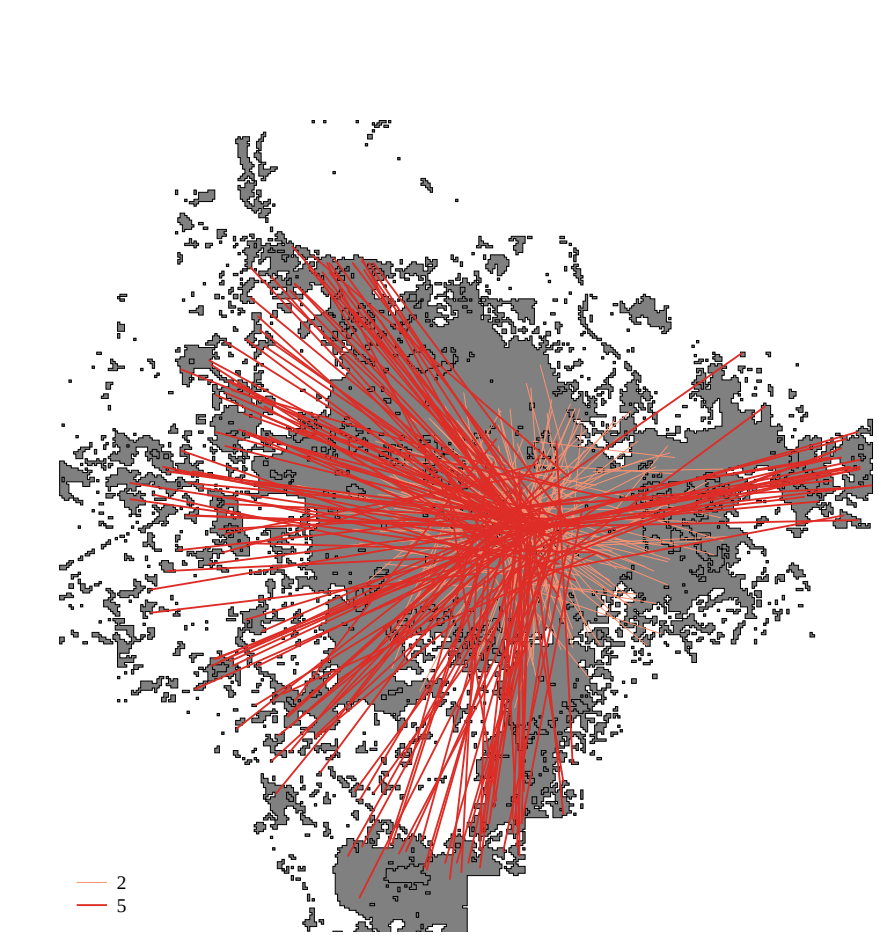
Illustration, Jamnagar in Gujarat

Google Maps representation

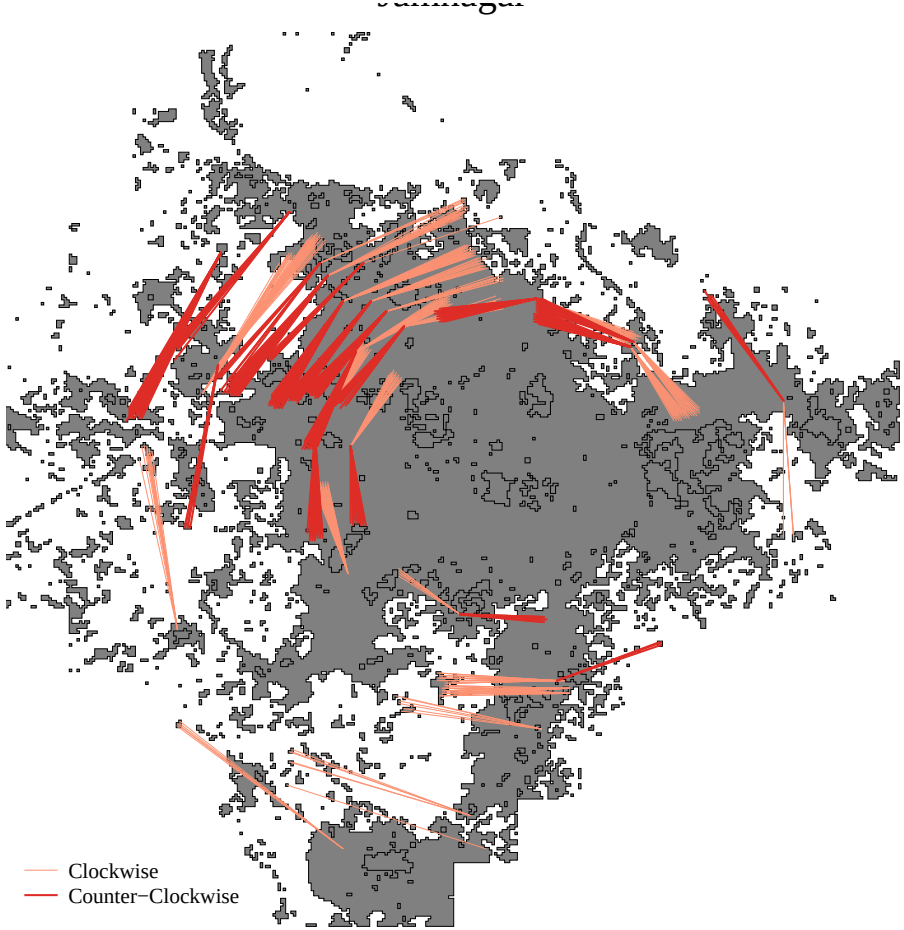


Lighted built-up areas

Illustration, Jamnagar in Gujarat

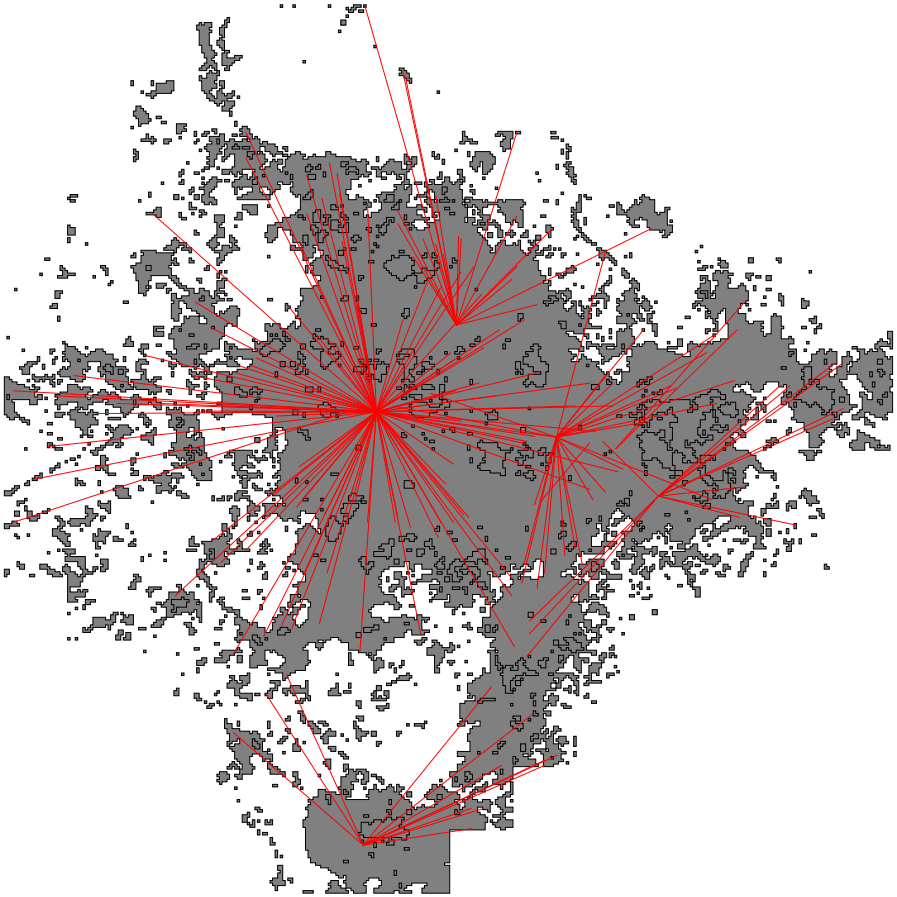


Radial trips

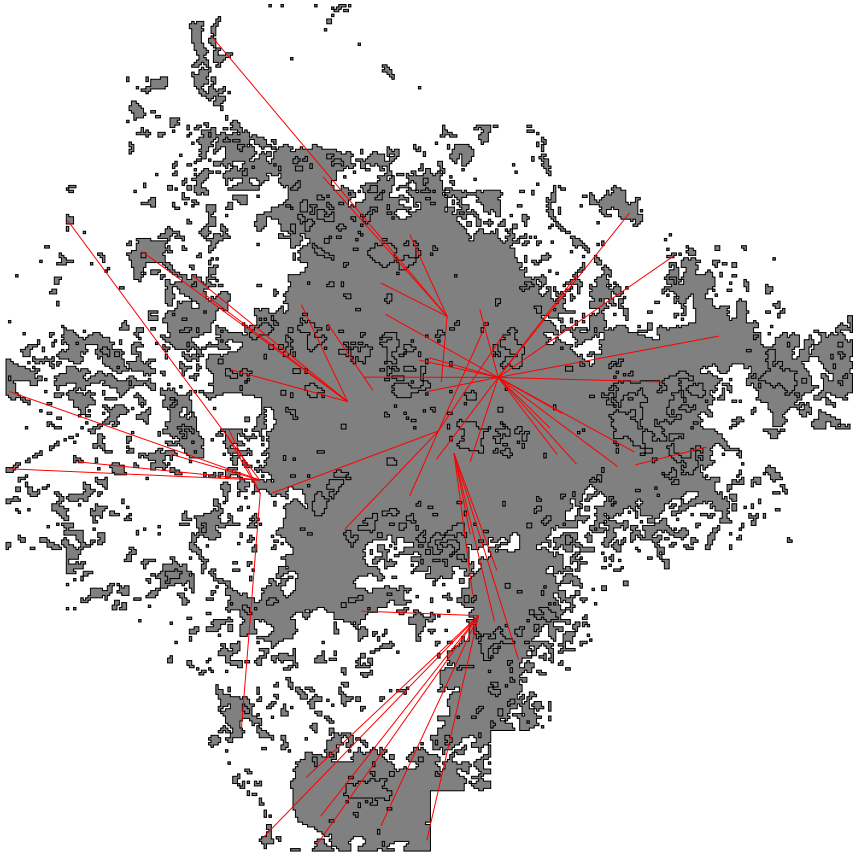


Circumferential trips

Illustration, Jamnagar in Gujarat



Trips to the mall



Trips to the hospital

Measuring mobility

From a representative sample of trips to a unique city-level mobility index:

$$\log speed_i = \alpha X_i' + mobility_{c(i)} + \epsilon_i \,, \tag{1}$$

- Include: trip length, distance to center, trip type, time of day, day of week, and weather in X
- Similarly estimate $uncongestedMob_c$ and $congestion_c$ for each city by using log speed in absence of traffic and the difference between log speed and log speed in absence of traffic as dependent variables
- Equality $mobility_c = uncongestedMob_c - congestion_c$ exactly satisfied, useful for decompositions

Measuring accessibility

- **Currently**: Google's most prominent destination in search for remarkable places (airport, grocery store, etc)
- Obtain proximity (inverse distance) and accessibility (inverse travel time) to this destination

- **Work in Progress**: Map all Google Places establishments in India to measures:
  - Closest destination of a given type
  - Number of destinations passed on 5 kilometer or 10 minute trips (variety)

Measuring accessibility

$$-\log time_i = \alpha X_i^1 + accessibility_{c(i)} + \epsilon_i \quad (2)$$

$$-\log distance_i = \alpha X_i^2 + proximity_{c(i)} + \epsilon_i \quad (3)$$

- Include: time of day, day of week, weather, and destination indicators in X
- $accessibility_c = proximity_c + mobility_c$ is not exactly satisfied (but we can estimate a regression with $R^2 = 0.98$)

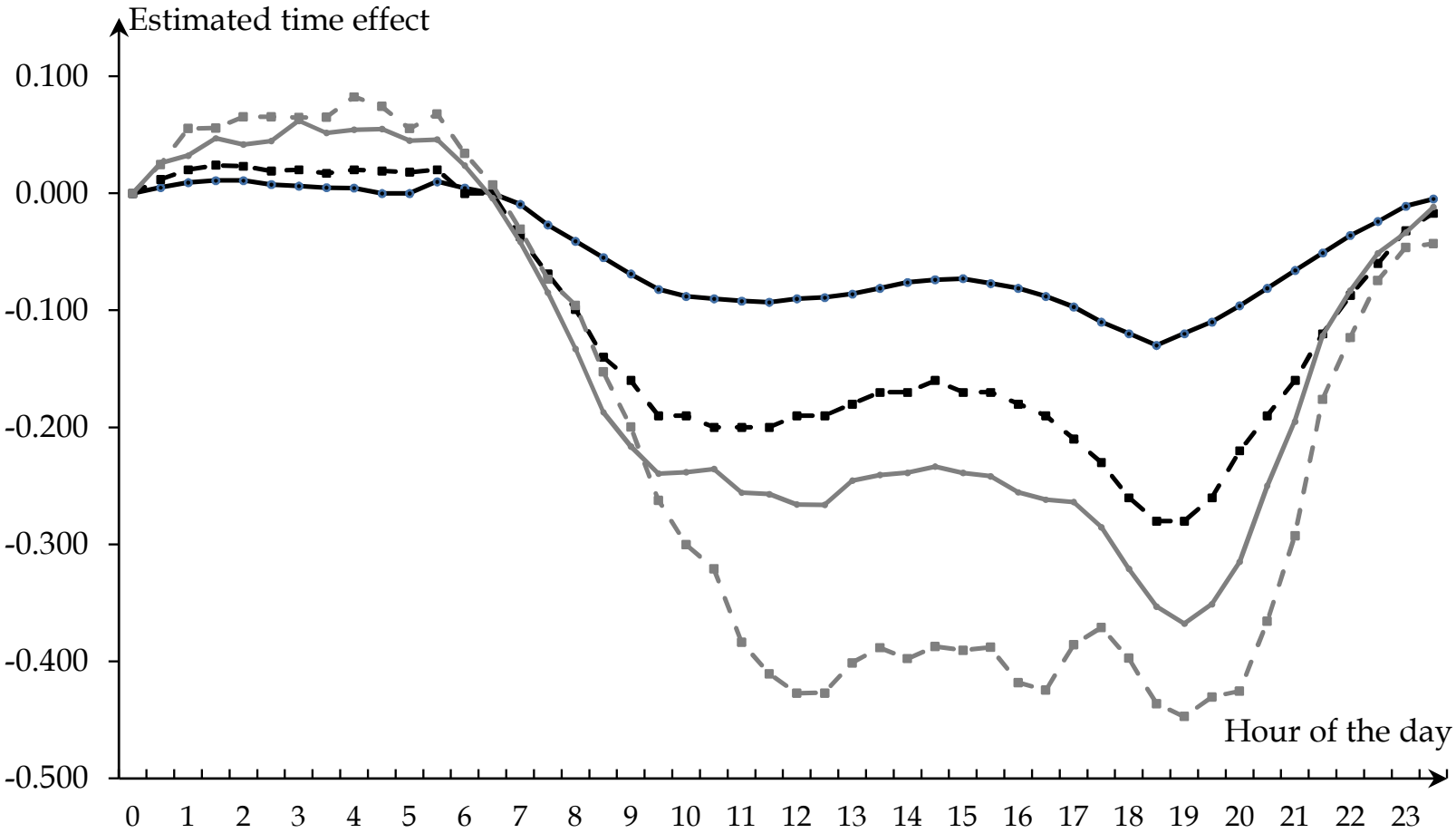
Who's slow?

Rank	City	State	Index
1	Kolkata	West Bengal	-0.33
2	Bangalore	Karnataka	-0.25
3	Hyderabad	Andhra Pradesh	-0.25
4	Mumbai	Maharashtra	-0.24
5	Varanasi (Benares)	Uttar Pradesh	-0.24
6	Patna	Bihar	-0.23
7	Bhagalpur	Bihar	-0.22
8	Delhi	Delhi	-0.22
9	Bihar Sharif	Bihar	-0.19
10	Chennai	Tamil Nadu	-0.18
11	Muzaffarpur	Bihar	-0.16
12	Aligarh	Uttar Pradesh	-0.15
13	English Bazar (Malda)	West Bengal	-0.15
14	Darbhanga	Bihar	-0.15
15	Gaya	Bihar	-0.14
16	Allahabad	Uttar Pradesh	-0.13
17	Ranchi	Jharkhand	-0.13
18	Dhanbad	Jharkhand	-0.12
19	Akola	Maharashtra	-0.12
20	Pune	Maharashtra	-0.12

Who's fast?

Rank	City	Index	
1	Ranipet	Tamil Nadu	0.35
2	Bokaro Steel City	Jharkhand	0.28
3	Srinagar	Jammu and Kashmir	0.26
4	Kayamkulam	Kerala	0.23
5	Jammu	Jammu and Kashmir	0.23
6	Thrissur	Kerala	0.19
7	Palakkad	Kerala	0.16
8	Chandigarh	Chandigarh	0.16
9	Alwar	Rajasthan	0.15
10	Thoothukkudi	Tamil Nadu	0.15

Time of day effects



Decomposing mobility

We can decompose mobility into uncongested mobility and congestion

- Uncongested mobility explains explains 70% of the variance of mobility
- Congestion explains 15% (and this is broader than just too many vehicles travelling)
- Congestion has more explanatory power during peak hours, in large cities, and in central locations
- Cities that have better uncongested mobility are also more congested
- **Poor mobility in India driven mostly by low speeds at all times rather than overcrowded roads at peak hours**

Who's least accessible?

Rank	City	State	Index
1	Kolkata	West Bengal	-0.56
2	Mumbai	Maharashtra	-0.45
3	Delhi	Delhi	-0.45
4	Bokaro Steel City	Jharkhand	-0.42
5	Asansol	West Bengal	-0.41
6	Hyderabad	Andhra Pradesh	-0.40
7	Dehradun	Uttaranchal	-0.39
8	Mathura	Uttar Pradesh	-0.36
9	Dhanbad	Jharkhand	-0.36
10	Guntur	Andhra Pradesh	-0.36
11	Chandrapur	Maharashtra	-0.35
12	Vijayawada	Andhra Pradesh	-0.35
13	Bangalore	Karnataka	-0.33
14	Aligarh	Uttar Pradesh	-0.32
15	Begusarai	Bihar	-0.32
16	Chennai	Tamil Nadu	-0.31
17	Bhagalpur	Bihar	-0.30
18	Allahabad	Uttar Pradesh	-0.29
19	Jalandhar	Punjab	-0.27
20	Gulbarga	Karnataka	-0.26

Who's most accessible?

Rank	City	State	Index
1	Anantapur	Andhra Pradesh	0.40
2	Anand	Gujarat	0.39
3	Kannur	Kerala	0.39
4	Latur	Maharashtra	0.39
5	Hubli-Dharwad	Karnataka	0.37
6	Brahmapur	Orissa	0.37
7	Nizamabad	Andhra Pradesh	0.36
8	Davangere	Karnataka	0.35
9	Palakkad	Kerala	0.35
10	Bhilwara	Rajasthan	0.34

Decomposing accessibility

We decompose accessibility into proximity and mobility:

- Proximity and mobility explain most of accessibility
- Mobility alone explains 21% of the variance of accessibility
- Proximity alone explains 81%
- Proximity and mobility in India are essentially uncorrelated (unlike in the US).

Explaining accessibility, mobility, uncongested mobility, and congestion

Next we try to explain accessibility, proximity, mobility, uncongested mobility, and congestion using a range of city level characteristics

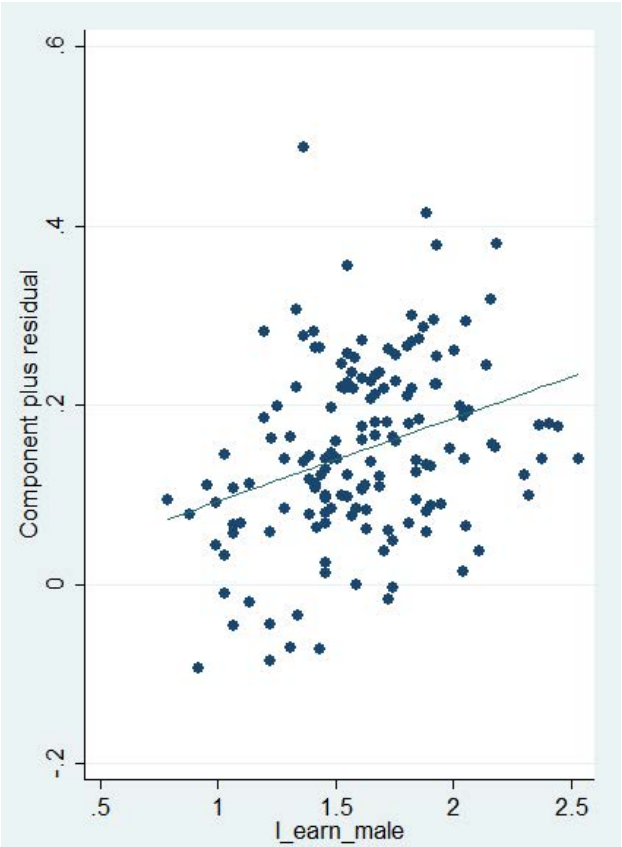
Determinants of accessibility and proximity

Dep. var.	(1) Access.	(2) Access.	(3) Access.	(4) Prox.	(5) Prox.	(6) Prox.
Dest.	All	City Hall	Other	All	City Hall	Other
log population	-0.054	-0.058	-0.059^{a}	0.11^{b}	0.087	0.11^{a}
	(0.036)	(0.16)	(0.019)	(0.054)	(0.23)	(0.026)
log area	-0.090^{c}	-0.14	-0.065^{b}	-0.26^{a}	-0.30	-0.24^{a}
	(0.049)	(0.21)	(0.025)	(0.072)	(0.30)	(0.038)
log roads	0.17^{a}	0.46^{b}	0.086^{a}	0.17^{a}	0.60^{b}	0.045^{c}
	(0.046)	(0.19)	(0.020)	(0.062)	(0.26)	(0.026)
share car	0.31	0.52	0.28^{c}	0.14	0.44	0.089
	(0.29)	(1.26)	(0.16)	(0.41)	(1.75)	(0.21)
share motorcycle	0.46^{a}	0.66	0.36^{a}	0.42^{b}	0.75	0.29^{a}
	(0.14)	(0.63)	(0.086)	(0.19)	(0.87)	(0.10)
tortuosity	-0.41^{b}	-0.98	-0.34^{b}	-0.67^{b}	-1.29	-0.61^{a}
	(0.20)	(0.70)	(0.13)	(0.27)	(0.96)	(0.20)
log pop. growth	0.14^{b}	0.55^{b}	0.028	0.10	0.65	-0.041
	(0.071)	(0.28)	(0.035)	(0.099)	(0.40)	(0.046)
Observations	153	148	153	153	148	153
R-squared	0.39	0.11	0.68	0.34	0.08	0.70

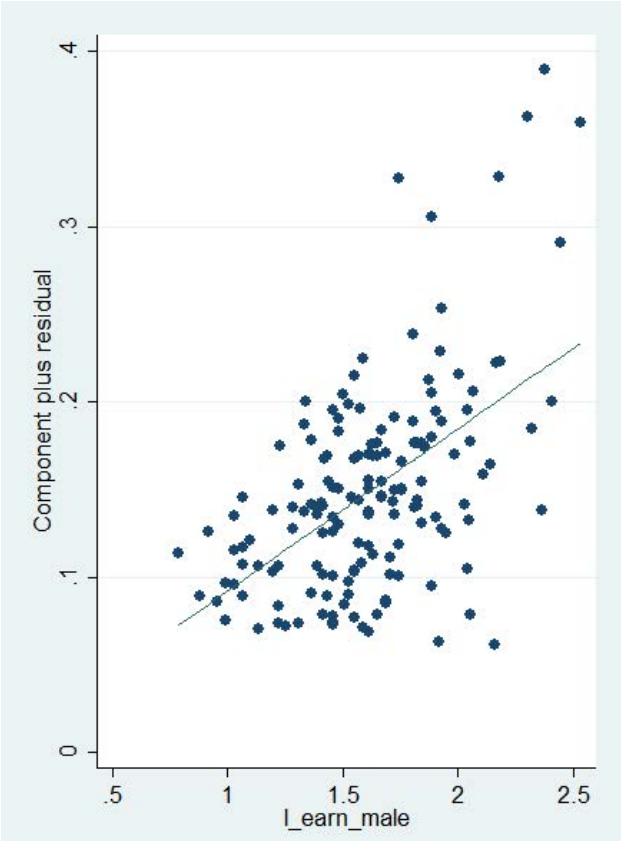
Determinants of accessibility

- **Population**: worsens uncongested mobility and congestion and improves proximity. Small effect on accessibility.
  - In the US Couture (2016) finds reverse: NYC worse mobility but best accessibility.
- **Income**: bell-shaped impact (next slide)
- **Primary roads**: improve uncongested mobility, do little on congestion, improve proximity. Positive impact on accessibility.
- **Share drivers**: positively associated with uncongested mobility, negatively with congestion, and positively associated with proximity. Positive impact on accessibility.

The effect of income on uncongested mobility and congestion



Uncongested mobility



Congestion factor

Some conclusions about transportation in Indian cities

- Tremendous heterogeneity in mobility and accessibility across India
- Congestion matters but maybe not as much as we think
- There is general mobility problem in Indian cities
- More roadway allows people to go places but it has only a small effect on mobility
- Larger cities are slower and more congested but equally accessible
- Mobility improves and then declines with city income

On-going work

- We downloaded data about establishments
- Estimate accessibility indices with economic/welfare meaning
- Walking and transit
- Measures of the road network (including its "gridiness")
- Move beyond India
- Use framework to understand impact of transportation efficiency on spatial dispersion of economic activity (agglomeration)