ACCESS TO NON-WORK ACTIVITIES: WHAT IS THE IMPACT OF DAILY LABOR MOBILITY?

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Motivation

- Accessibility to opportunities is well-studied
- Progress from simpler placed-based Hansen-type trip-based measures to the more complex individual level activity-based measures
- Hansen-type approaches
  - Lack space-time constraints, single trip, static
  - Aggregate data from state sources
- Activity-based approaches
  - Space-time constraints, trip chaining and dynamic
  - For individuals, based on travel diary surveys, GPS travel data, or mobile phone tracking data

Motivation

- Comparison of place-based and person-based approaches

- **Place-based**
  - Capture aggregate and generalizable patterns
  - Location-based
    - Single unchained trip, typically commute
    - Single reference locations, typically home
  - Visualized by one reference location, typically home

- **Person-based**
  - Capture individual and unique activity patterns subject to constraints (capability, scheduling, authority)
  - Mobility-based
    - Multiple chained trips
    - Multiple reference locations
  - Visualized by one reference location, typically home

Motivation

- Issue 1 with people-based approach
  - Captures overall accessibility
  - Shows overall accessibility relative to home location
  - Hides contribution of accessibility realized relative to various other spatial anchor locations in people's daily activity patterns

- Do people gain or lose accessibility due to mobility?

Motivation

- Results show that mobility has positive and negative impacts on accessibility (Chen et al., 2018)
  - Mobility can enhance accessibility in activity-poor areas
  - Mobility can reduce accessibility in activity-rich areas
- Results spatially uneven and depend on time factor (activity duration)

Motivation

- Issue 2 with people-based approach
  - Based on massive mobile phone tracking data or travel diary/GPS data
  - Data is:
    - Expensive
    - Strictly regulated (privacy, access)
    - Not generalizable

- Can we use aggregate place-based data to understand impact of mobility on accessibility?

Motivation

- Mobility in place-based acessibility studies
  - Impact of work locations on
    - Social interaction (Farber et al., 2013)
    - Segregation (Farber et al., 2015)
    - Supermarket accessibility (Widener et al., 2013)
- Research gaps
  - Impact of work locations on other non-work activities
  - No accounting of local land use
  - Need systematic comparison of home-based and work-based accessibility

Research questions

- What are the impacts of mobility on place-based accessibility?
  - Impacts: share of workers, work-home accessibility ratio (WHR)
- How do the impacts vary by local land-use?
  - How many workers live and work in different types of local land-use?
- How do the impacts vary by income group?
  - How many workers of each income group improve or reduce their accessibility due to mobility?
- How does WHR vary by local land-use and income group?

Methods

- Cumulative opportunity place-based accessibility metric

$$A_i^H = \sum_k E_k \, f(c_{ik}) \qquad A_j^W = \sum_k E_k \, f(c_{jk})$$

$$f(c_{ij}) = \begin{cases} 1 & c_{ij} \leq T \\ 0 & c_{ij} > T \end{cases}$$

- Accessibility at home location *i*/work location *j* to opportunity *E* of type *k* within a travel cost threshold *T*, $N_{ik} = \{E_k | C_{ik} \leq T\}$/$N_{jk} = \{E_k | C_{jk} \leq T\}$ is the set of opportunities of type *k* within travel cost threshold *T* defined for home *i*/work *j*, and C_{ik}/C_{jk} is the travel cost from home *i*/work *j* to opportunity *k*.

Methods

- Local land use balance

$$LLUB = \frac{A_j^W}{A_i^H} = \frac{\sum_k E_k f(c_{jk})}{\sum_k E_k f(c_{ik})}$$

$$f(c_{ij}) = \begin{cases} 1 & c_{ij} \leq 3\ min \\ 0 & c_{ij} > 3\ min \end{cases}$$

- 3 minutes capture a small area, equivalent to 1 mile in Galster et al. (2001) based on an average travel speed of 20 mph

Methods

- Accessibility $A_i^H = \sum_k E_k f(c_{ik})$ $A_j^W = \sum_k E_k f(c_{jk})$ $f(c_{ij}) = \begin{cases} 1 & c_{ij} \leq TTB \\ 0 & c_{ij} > TTB \end{cases}$

- Accessibility work-home ratio:
  - where X_{ij} is the observed journey-to-work matrix

$$A_{ij}^{WHR} = \frac{A_j^W}{A_i^H} \forall\ i, j\ \in X_{ij}$$

- *TTB* = travel time budget
- 4 different scenarios assuming 60 minute time budget:
  - Activity duration: 50 minutes; one-way travel time: 5 minutes
  - Activity duration: 40 minutes; one-way travel time: 10 minutes
  - Activity duration: 30 minutes; one-way travel time: 15 minutes
  - Activity duration: 20 minutes; one-way travel time: 20 minutes

Study area and data

- Minneapolis – St. Paul metropolitan statistical area
  - Population: 3,348,859 (2010 U.S. Census)
  - 2,314 census block groups
- Employed residents and job totals from U.S. Census Longitudinal Employer-Household Dynamics (LEHD) database
  - 1,632,878 workers total
  - 372,868 are lower-income (-$1,250 per month)
  - 444,089 are medium-income ($1,251-$3,332 per month)
  - 815,921 are higher-income ($3,333+ per month)
- Non-work activities from Dun&Bradstreet business location database
  - 15 categories of non-work activities for our study area: banks, childcare facilities, convenience stores, dance and physical fitness, hospitals, libraries, medical clinics, religious organizations, restaurants, schools, automobile related services, personal grooming services, apparel shopping, appliances and other home shopping, and supermarkets
  - Aggregated to single category of total non-work activities

Results

Table 1. Share of **all workers** by Jobs-Housing Ratio (20 minute accessibility)

ALL WORKERS	WORK →	Housing Rich – Jobs Poor		Balanced		Jobs Rich – Housing Poor	
HOME		J <= 0.25H	0.25H > J <= 0.8H	0.8H > J <= 1.2H	1.2H >= J < 4H	J >= 4H	**Total**
Housing Rich – Jobs Poor	J <= 0.25H	9.10	6.61	2.06	11.14	23.67	**52.57**
	0.25H > J <= 0.8H	2.78	2.78	0.78	4.15	9.10	**19.59**
Balanced	0.8H > J <= 1.2H	0.73	0.68	0.26	1.14	2.58	**5.39**
	1.2H >= J < 4H	1.59	1.51	0.45	2.96	6.02	**12.52**
Jobs Rich – Housing Poor	J >= 4H	1.01	0.96	0.28	1.78	4.75	**8.79**
	Total	**15.21**	**12.54**	**3.83**	**21.17**	**46.12**	**98.86**

Table 2. Share of workers by Jobs-Housing Ratio (20 minute accessibility)

LOWER INCOME	WORK →	Housing Rich – Jobs Poor		Balanced		Jobs Rich – Housing Poor	
HOME		J <= 0.25H	0.25H > J <= 0.8H	0.8H > J <= 1.2H	1.2H >= J < 4H	J >= 4H	Total
Housing Rich – Jobs Poor	J <= 0.25H	13.06	8.42	2.47	10.18	16.37	50.50
	0.25H > J <= 0.8H	3.95	3.92	1.08	4.30	7.07	20.31
Balanced	0.8H > J <= 1.2H	1.01	0.94	0.40	1.15	2.07	5.57
	1.2H >= J < 4H	2.29	2.05	0.61	3.43	5.21	13.60
Jobs Rich – Housing Poor	J >= 4H	1.42	1.30	0.37	1.90	4.13	9.12
	Total	21.73	16.62	4.94	20.96	34.85	99.10

~30% ~38% ~71%

MEDIUM INCOME	WORK →	Housing Rich – Jobs Poor		Balanced		Jobs Rich – Housing Poor	
HOME		J <= 0.25H	0.25H > J <= 0.8H	0.8H > J <= 1.2H	1.2H >= J < 4H	J >= 4H	Total
Housing Rich – Jobs Poor	J <= 0.25H	10.04	7.20	2.22	10.28	18.90	48.64
	0.25H > J <= 0.8H	3.46	3.41	0.94	4.43	8.65	20.89
Balanced	0.8H > J <= 1.2H	0.92	0.85	0.31	1.22	2.49	5.80
	1.2H >= J < 4H	2.06	1.95	0.56	3.39	6.24	14.20
Jobs Rich – Housing Poor	J >= 4H	1.25	1.20	0.36	1.89	4.57	9.26
	Total	17.73	14.62	4.38	21.22	40.85	98.78

HIGHER INCOME	WORK →	Housing Rich – Jobs Poor		Balanced		Jobs Rich – Housing Poor	
HOME		J <= 0.25H	0.25H > J <= 0.8H	0.8H > J <= 1.2H	1.2H >= J < 4H	J >= 4H	Total
Housing Rich – Jobs Poor	J <= 0.25H	6.81	5.48	1.78	12.04	29.51	55.62
	0.25H > J <= 0.8H	1.89	1.93	0.57	3.92	10.26	18.57
Balanced	0.8H > J <= 1.2H	0.50	0.47	0.18	1.09	2.85	5.09
	1.2H >= J < 4H	1.03	1.03	0.31	2.51	6.26	11.14
Jobs Rich – Housing Poor	J >= 4H	0.70	0.68	0.20	1.68	5.14	8.39
	Total	10.93	9.59	3.03	21.24	54.01	98.80

~16% ~21% ~56% ~74%

Table 3. Share of workers by work-home accessibility ratio and activity duration.

	50 min. activity duration (5 min. one-way)				40 min. activity duration (10 min. one-way)				30 min. activity duration (15 min. one-way)				20 min. activity duration (20 min. one-way)			
	ALL	LOW	MED	HIGH	ALL	LOW	MED	HIGH	ALL	LOW	MED	HIGH	ALL	LOW	MED	HIGH
W > 16H	9.77	**8.06**	7.81	**11.59**	3.72	2.81	2.89	4.59	2.40	1.72	1.88	2.99	1.37	**1.01**	1.10	**1.67**
W > 8H	5.37	**4.23**	4.19	**6.52**	4.07	2.94	3.16	5.06	3.48	2.45	2.73	4.34	2.36	**1.64**	1.89	**2.94**
W > 4H	10.06	**8.37**	8.57	**11.63**	8.80	6.49	6.84	10.90	8.03	5.70	6.15	10.08	6.35	**4.50**	4.91	**7.96**
W > 2H	17.28	**16.09**	16.25	**18.36**	18.31	15.12	16.18	20.90	17.26	13.52	14.51	20.42	16.42	**12.68**	13.37	**19.75**
W > 1.2H	15.39	**16.41**	16.14	**14.52**	21.76	21.92	21.91	21.61	24.44	24.30	24.64	24.40	25.13	**23.84**	24.81	**25.87**
W = H	11.94	**14.39**	13.26	**10.14**	17.86	21.75	19.77	15.08	22.14	26.74	24.45	18.83	29.05	**34.15**	31.91	**25.23**
H > 1.2W	11.06	**12.09**	12.27	**9.94**	13.02	14.96	14.86	11.16	13.40	15.56	15.41	11.34	13.02	**15.31**	15.00	**10.93**
H > 2W	8.14	**8.74**	9.19	**7.30**	6.78	7.65	7.95	5.75	5.62	6.58	6.57	4.67	4.30	**4.80**	4.79	**3.82**
H > 4W	3.73	**4.09**	4.37	**3.23**	2.59	3.03	3.08	2.13	1.86	2.03	2.11	1.65	1.24	**1.34**	1.36	**1.14**
H > 8W	1.63	**1.92**	1.96	**1.32**	1.02	1.28	1.11	0.85	0.66	0.72	0.72	0.61	0.30	**0.28**	0.31	**0.31**
H > 16W	5.49	**5.45**	5.84	**5.32**	1.20	1.24	1.26	1.15	0.32	0.31	0.34	0.31	0.23	**0.20**	0.29	**0.21**

Results

Table 4. Work-Home accessibility ratio for all workers by local jobs-housing ratio (20 minutes)

ALL WORKERS	WORK →	Housing Rich – Jobs Poor		Balanced		Jobs Rich – Housing Poor	
HOME		J <= 0.25H	0.25H > J <= 0.8H	0.8H > J <= 1.2H	1.2H >= J < 4H	J >= 4H	**Total**
Housing Rich – Jobs Poor	J <= 0.25H	10.32	15.96	17.32	17.69	23.52	16.96
	0.25H > J <= 0.8H	1.62	1.82	2.08	2.33	2.49	2.07
Balanced	0.8H > J <= 1.2H	1.02	1.23	1.24	1.41	1.54	1.29
	1.2H >= J < 4H	0.94	1.14	1.12	1.28	1.40	1.18
Jobs Rich – Housing Poor	J >= 4H	0.88	1.09	1.03	1.20	1.32	1.10
	Total	**2.96**	**4.25**	**4.56**	**4.78**	**6.05**	**4.52**

LOWER INCOME	WORK →	Housing Rich – Jobs Poor		Balanced		Jobs Rich – Housing Poor	
HOME		J <= 0.25H	0.25H > J <= 0.8H	0.8H > J <= 1.2H	1.2H >= J < 4H	J >= 4H	Average
Housing Rich – Jobs Poor	J <= 0.25H	7.28	15.25	18.86	15.08	16.58	**14.61**
	0.25H > J <= 0.8H	1.53	1.59	1.92	1.95	2.37	**1.87**
Balanced	0.8H > J <= 1.2H	1.04	1.20	1.23	1.34	1.53	**1.27**
	1.2H >= J < 4H	0.94	1.10	1.12	1.21	1.39	**1.15**
Jobs Rich – Housing Poor	J >= 4H	0.95	1.13	0.97	1.19	1.29	**1.11**
	Average	**2.35**	**4.05**	**4.82**	**4.16**	**4.63**	**4.00**

MEDIUM INCOME	WORK →	Housing Rich – Jobs Poor		Balanced		Jobs Rich – Housing Poor	
HOME		J <= 0.25H	0.25H > J <= 0.8H	0.8H > J <= 1.2H	1.2H >= J < 4H	J >= 4H	Average
Housing Rich – Jobs Poor	J <= 0.25H	9.30	14.29	14.11	14.16	15.96	**13.56**
	0.25H > J <= 0.8H	1.60	1.74	1.71	2.14	2.41	**1.92**
Balanced	0.8H > J <= 1.2H	1.00	1.19	1.17	1.33	1.49	**1.24**
	1.2H >= J < 4H	0.96	1.13	1.10	1.25	1.36	**1.16**
Jobs Rich – Housing Poor	J >= 4H	0.92	1.07	0.99	1.18	1.34	**1.10**
	Average	**2.76**	**3.88**	**3.82**	**4.01**	**4.51**	**3.80**

HIGHER INCOME	WORK →	Housing Rich – Jobs Poor		Balanced		Jobs Rich – Housing Poor	
HOME		J <= 0.25H	0.25H > J <= 0.8H	0.8H > J <= 1.2H	1.2H >= J < 4H	J >= 4H	Average
Housing Rich – Jobs Poor	J <= 0.25H	11.76	16.18	16.38	18.61	25.79	**17.74**
	0.25H > J <= 0.8H	1.68	1.98	2.21	2.50	2.60	**2.20**
Balanced	0.8H > J <= 1.2H	1.01	1.24	1.21	1.49	1.60	**1.31**
	1.2H >= J < 4H	0.93	1.17	1.12	1.33	1.43	**1.20**
Jobs Rich – Housing Poor	J >= 4H	0.79	1.06	1.05	1.22	1.31	**1.09**
	Average	**3.24**	**4.33**	**4.39**	**5.03**	**6.55**	**4.71**

Table 5. Share of workers by Jobs-Housing Ratio (20 minute accessibility)

Conclusions

- Mobility impacts different groups differently
  - 20%-37% of lower-income gain more than 2x accessibility at work than home
  - 32%-48% of higher-income gain more than 2x accessibility at work than home
- Impacts of mobility decrease with increase travel time to non-work activities
- Impacts greater than 2x only at very extreme jobs-housing imbalance (4x more housing than jobs)
- About 50% of each income group live in housing rich areas
- 54% of higher income work in jobs rich areas, but only 35% of lower income
- Accessibility work-home ratio is useful metric of location choices/behavior and urban form

Future research

- Extend research to other urban and geographical contexts
  - Other U.S. cities, cities in other countries
- Develop theoretical framework for this metric as indicator for urban form and location/travel behawior
  - Test in different urban contexts in terms of urban size, shape, density gradient etc.

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