Do **Urban Form Characteristics** Perpetuate Disparities in **POI-based Mobility Changes** during COVID-19?

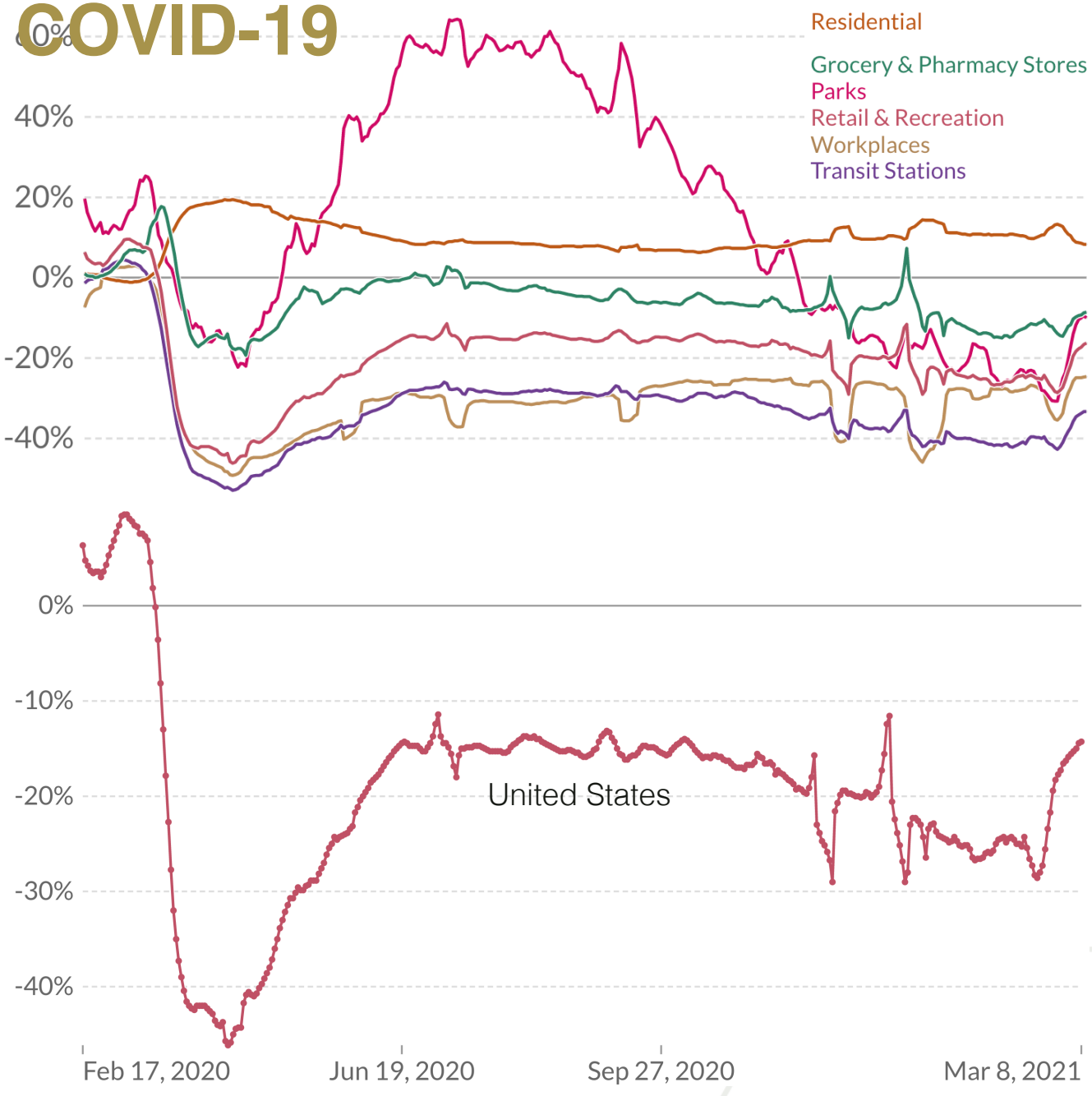
A Study of Fulton County, Georgia

Jun Wang and **Yilun Zha**
School of Architecture, Georgia Tech

Georgia Tech

Mobility Plummet in light of COVID-19

- A **20-30%** reduction of movement in the U.S. from early 2020 to 2021
  - First case in US: Jan 21, 2020
  - Georgia lockdown mandate: Mar 14, 2020
- **Varying** Impacts by purpose of trips
  - Most reduction in **Transit** and **Workplaces** trips
  - A “retaliatory” bounce-back on **Parks**

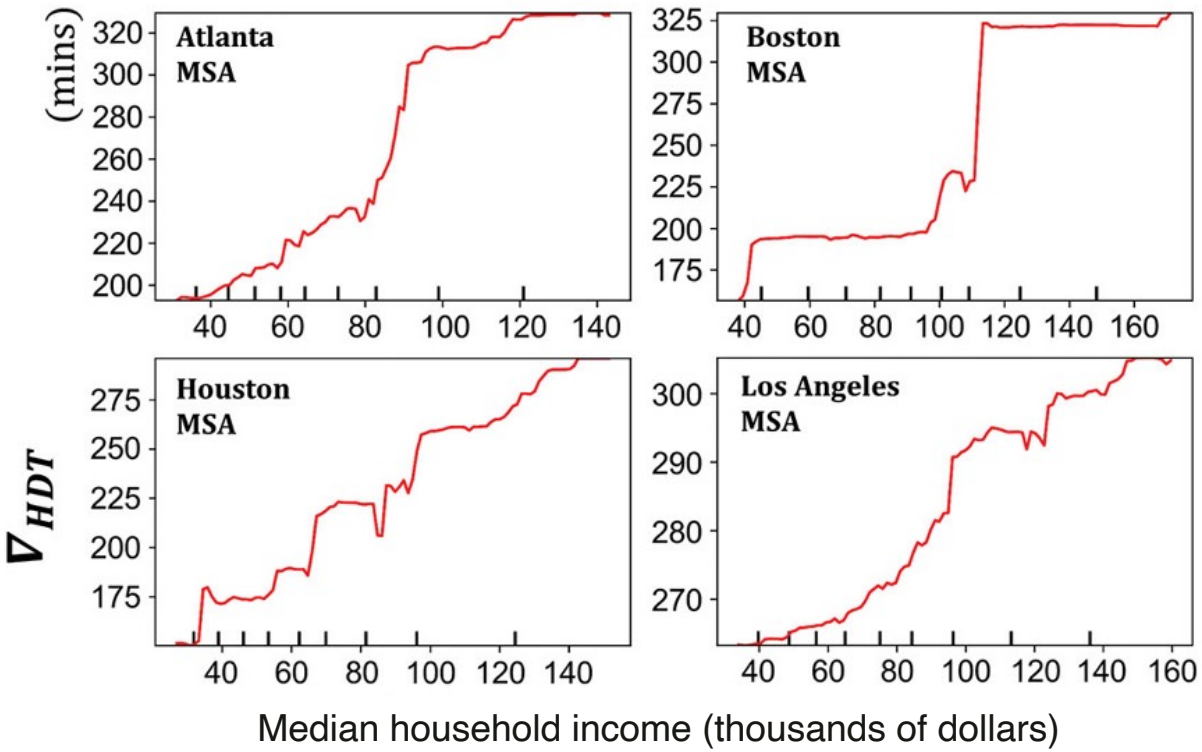


(Source: Google COVID-19 Community Mobility Report)

Mobility Changes: An uneven geography

- Regional and Metro/Urban-level research
  - Mobility Trend Tracking - GeoDS Lab@UW-Madison
  - Course-grained hotspot detection (Zhu et al., 2022)

- **Neighborhood-level study** is limited
  - Socioeconomic disparities - “Staying at home is a privilege” (Huang et al., 2021)
  - **Knowledge Gap**: fine-grained mobility changes by types and its spatial interpretation/association



(Source: Huang et al., 2021)

Research Question

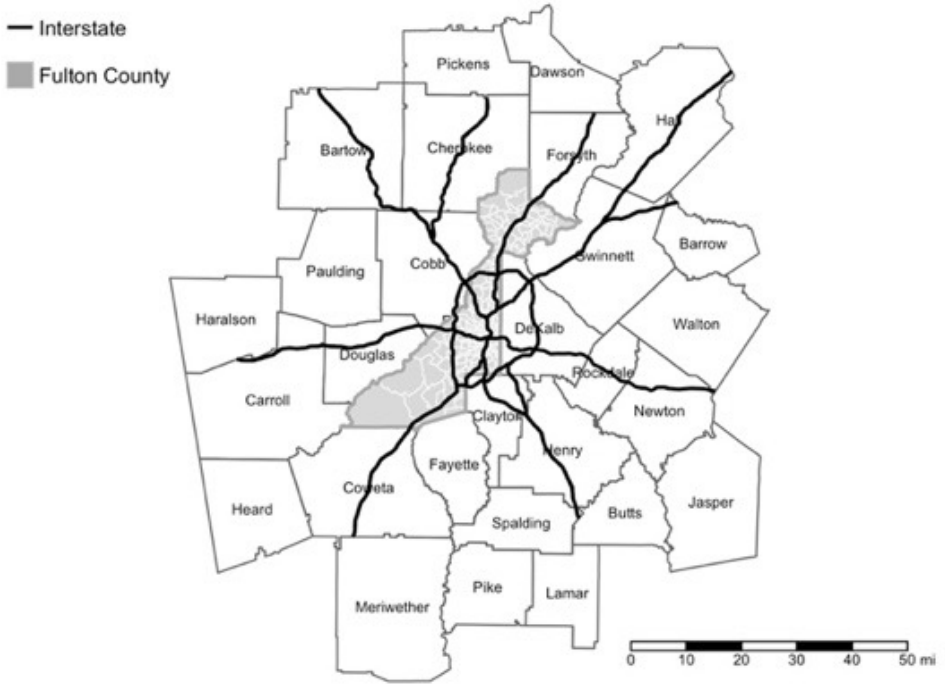
- On the neighborhood level, how does **the mobility for different types of movement** vary?
  - Key Hypothesis: The pattern of changes are different and may not merely follow the socioeconomic pattern.

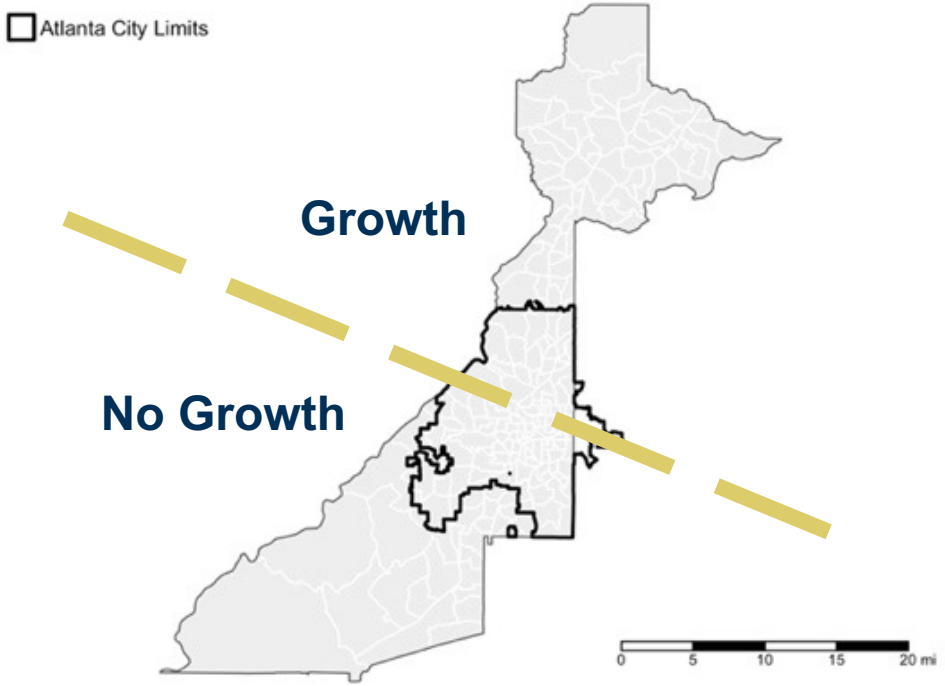
- To what extent is **the neighborhood-level built environment characteristics** associated with the disparity of mobility change, if existing, after controlling for SES factors?
  - Key Hypothesis: More Compact, denser neighborhoods may experience a lighter impact.

Research Design – Study Area

- **Fulton County, Georgia**
  - Most populous county (1M+) in GA
  - House of the state capital: **Atlanta**
  - General Context: **The Growth Line**

- Unit of Analysis: **census-tract**
  - N=204
  - CBG-level data also available but unstable



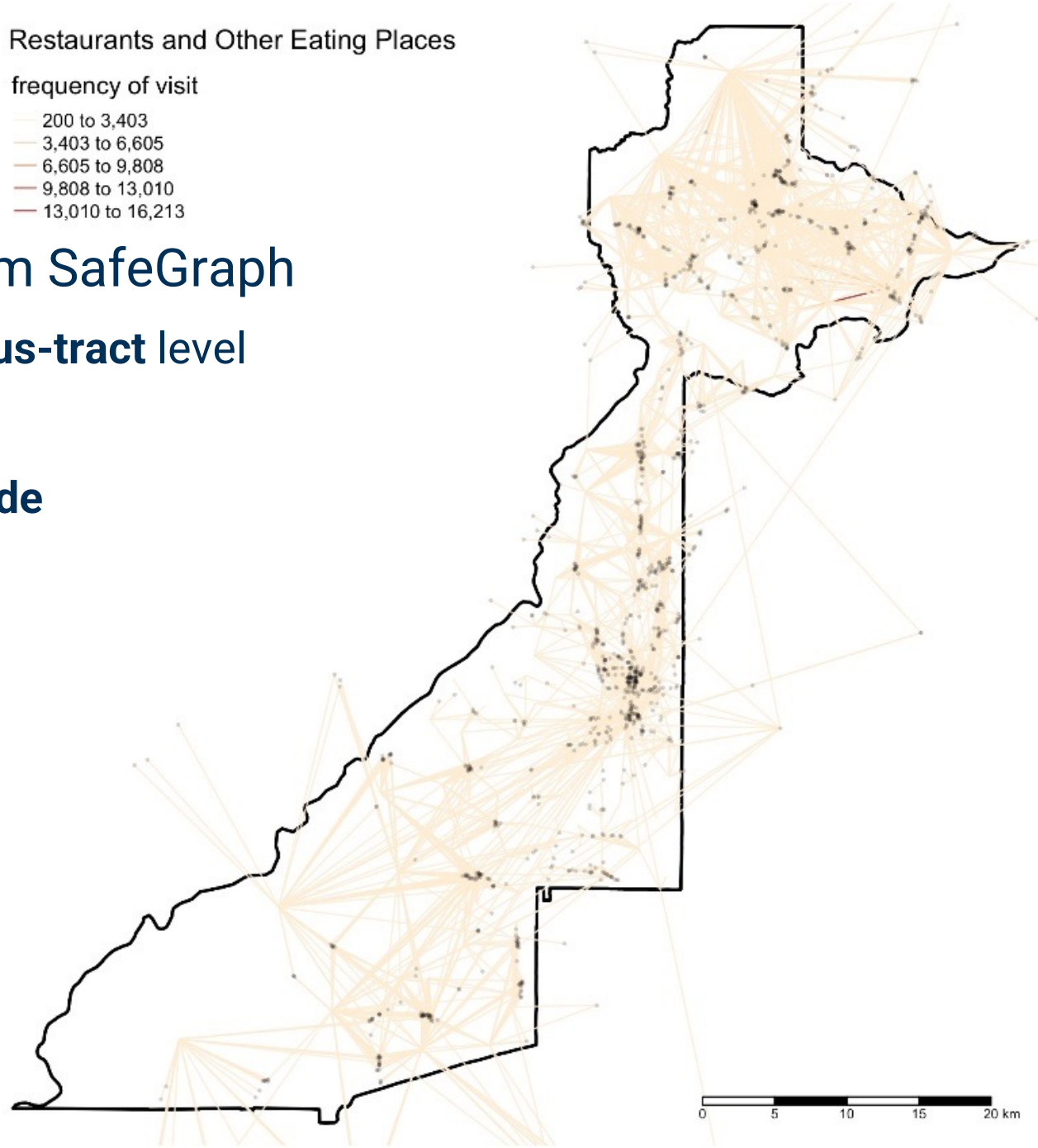


Research Design - Data

- POI-based Aggregated Cellular Data from SafeGraph
  - Aggregated at **census-block-group** or **census-tract** level
  - Sampled**: 5-10%** sampling rate
  - POIs categorized by 2022 **4-digit NAICS Code**

- Tech Specs:
  - Time frame: **March 2019 – March 2021**
  - Num. of POIs: **66,310**
  - OD pairs: **1M** (2019), **800k** (2020)

- Privacy Concerns



Research Design - Data

- Built Environment Characteristics
  - Selected by literature and experiences
  - Four Domains: **Density**, **Connectivity**, **Diversity**, and **Centrality**
- SES Variables
  - Income, race, education

Category	Variable	Label	Formula	Unit	Reference
Density	Built Area Density	bld_ratio	$BD_t = \sum_{i=1}^{i} A_{it}^B / A_t^T$	%	(Schirmer & Axhausen, 2016)
	Population Density	popden_sqmi	$PD_t = Pop_t / A_t^T$	#/sqmi	(Hamidi et al., 2015)
	Mean Setback	setback_avg_ft	$SB_t^\mu = \sum_{i=1}^{i} SB_{it} / i$	ft	(Clifton et al., 2008b)
	Average Block Size	blk_avg_sqft	$K_t^\mu = A_{mt}^K / m$	sqft	
Connectivity	Transit Stop Density	stopden	$TSDen_t = TS_t / A_t^T$	#/sqmi	(Clifton et al., 2008c)
	Street Density	stden	$SDen_t = L_t^e / A_t^T$	ft/sqmi	(Boeing, 2017)
	Intersection Density	interden	$ID_t = I_t / A_t^T$	#/sqmi	(Boeing, 2017)
Diversity	Standard Deviation of Building Size	bld_sd_sqft	$B_t^\theta = \sqrt{\sum_{i=1}^{i} (A_{it}^B - \mu_t^B)^2} / i$	-	(Schirmer & Axhausen, 2016)
	Entropy of Landuse Mix	tct_entro	$E_t = \sum_{u=1}^{u} \rho_{ut} \times \ln \rho_{ut}$	-	(Song, Merlin, et al., 2013)
	Mean Building Fractality	fract_avg	$F_t^\mu = \sum_{i=1}^{i} F_{it} / i$	-	(Basaraner & Cetinkaya, 2017)
Centrality	Betweenness Centrality	centrality	$g(v) = \sum_{o \neq v \neq d} \sigma_{od}(v) / \sigma_{od}$	-	(Song, Merlin, et al., 2013)
	Number of Incoming Trips per capita	trip_inwards	$TR_t = \sum D_{pt} / Pop_t$	#	

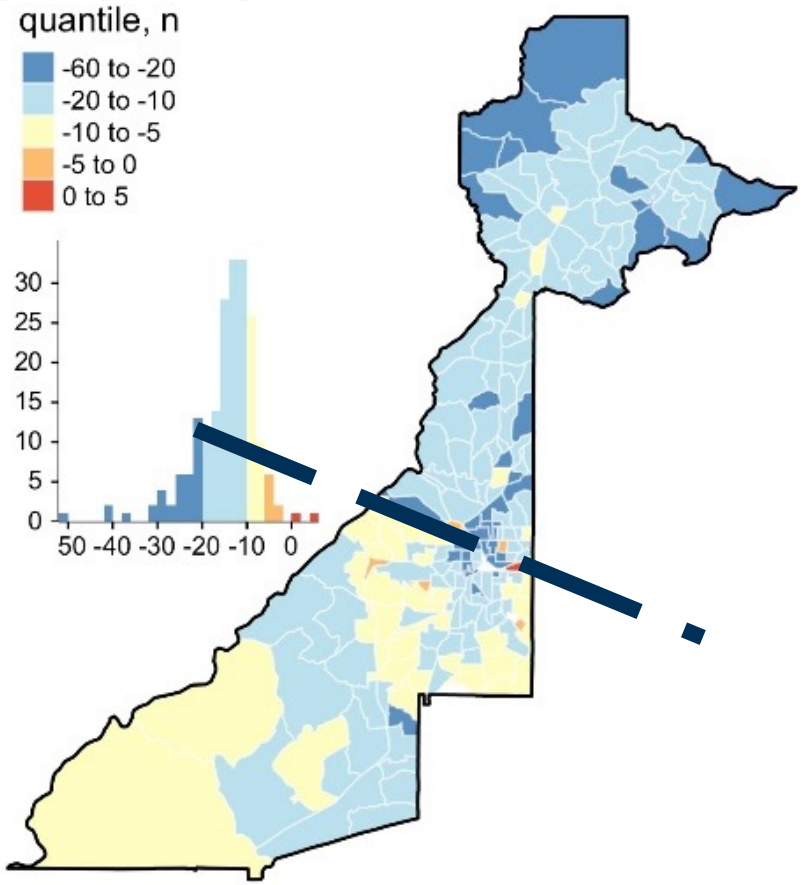
Georgia Tech

Research Design – Method

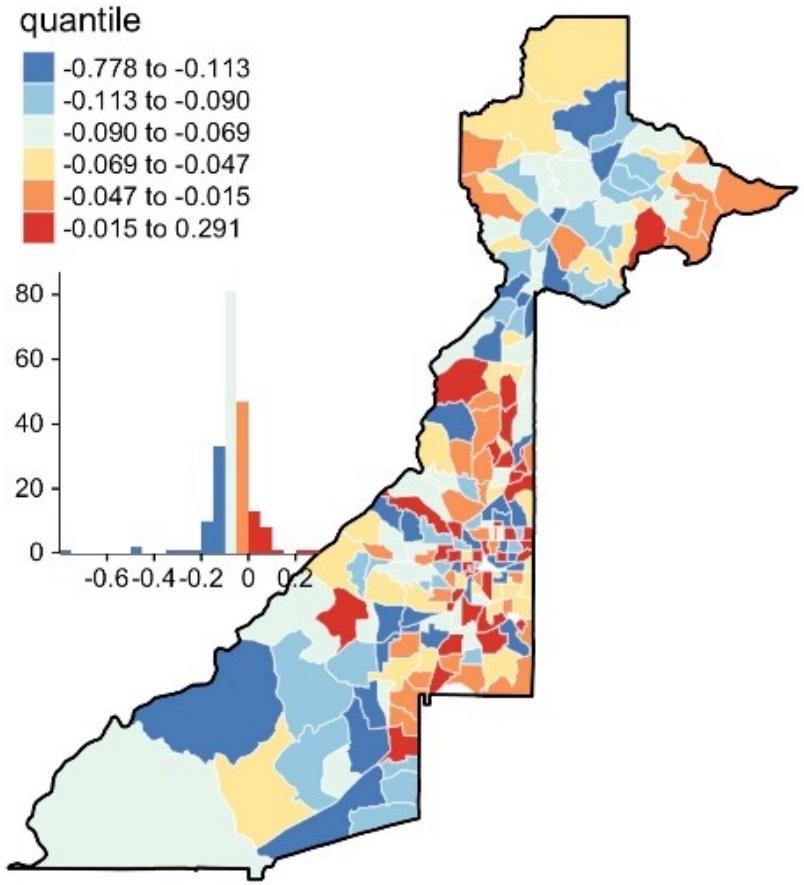
- Longitudinal Descriptive Analysis
  - Comparison: pre-COVID vs. COVID
  - Metrics: **1. frequency of trips per capita**
  - **2. weighted Shannon Entropy of trip types (diversity)**
  - **3. weighted average distance to destinations**
  - Trip Types: Restaurant, Park, Healthcare Facilities

- OLS and Spatial Lag Principal Component Regression

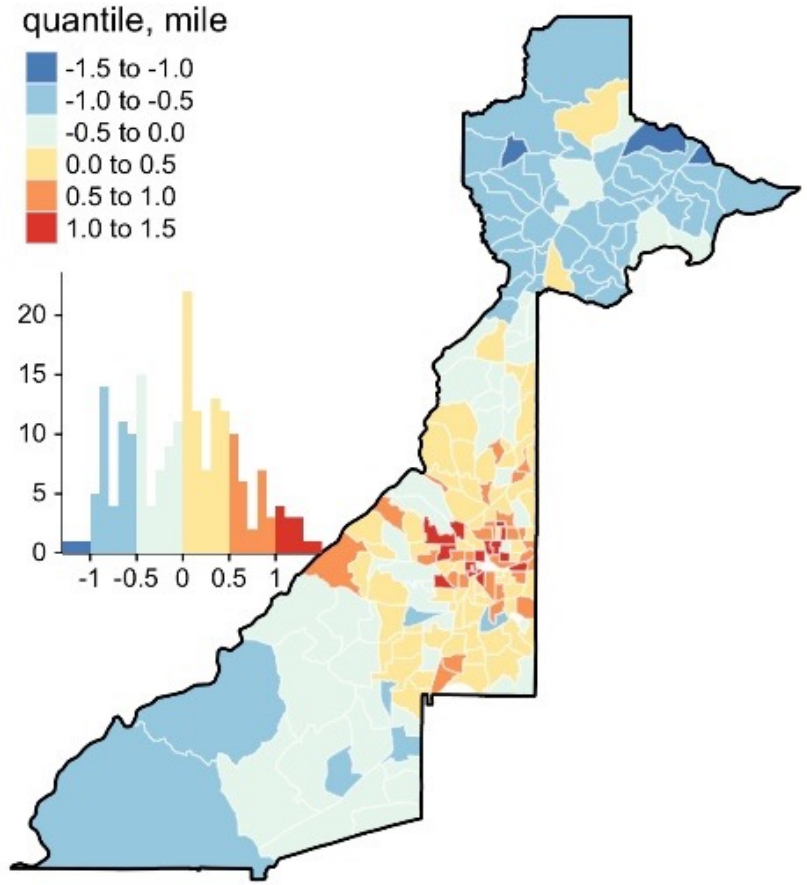
Results - Descriptive



Freq. of trips per capita



Weighted Shannon Entropy of trips



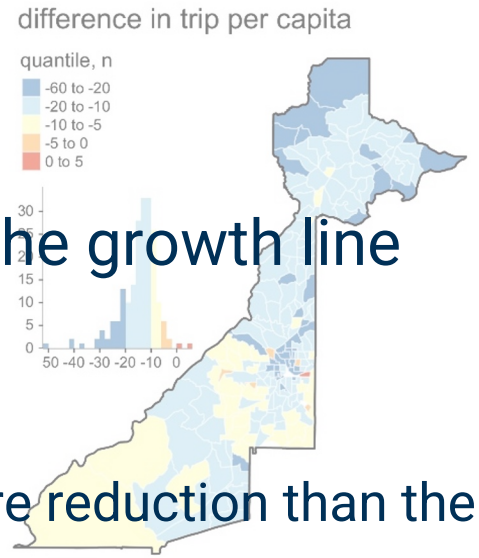
Weighted avg. distance to dest.

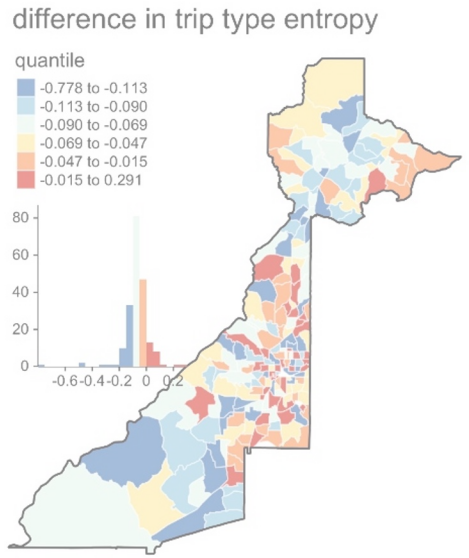
Diff = # of 2020 - # of 2019

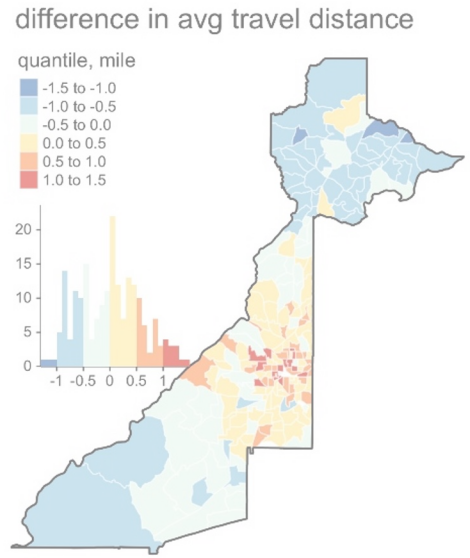
Georgia Tech

Results - Descriptive

- **Trip frequency reduction** follows the growth line pattern
  - **48%** overall decline
  - The “Growth” region show a **52%** more reduction than the “No-Growth”







- **Urban tracts** travel to more distant destinations compared to **suburban tracts**
  - An average of **1.2-mile INCREASE** within the city limit of Atlanta, compared to a **1-mile DECREASE** for others

Growth-No Growth

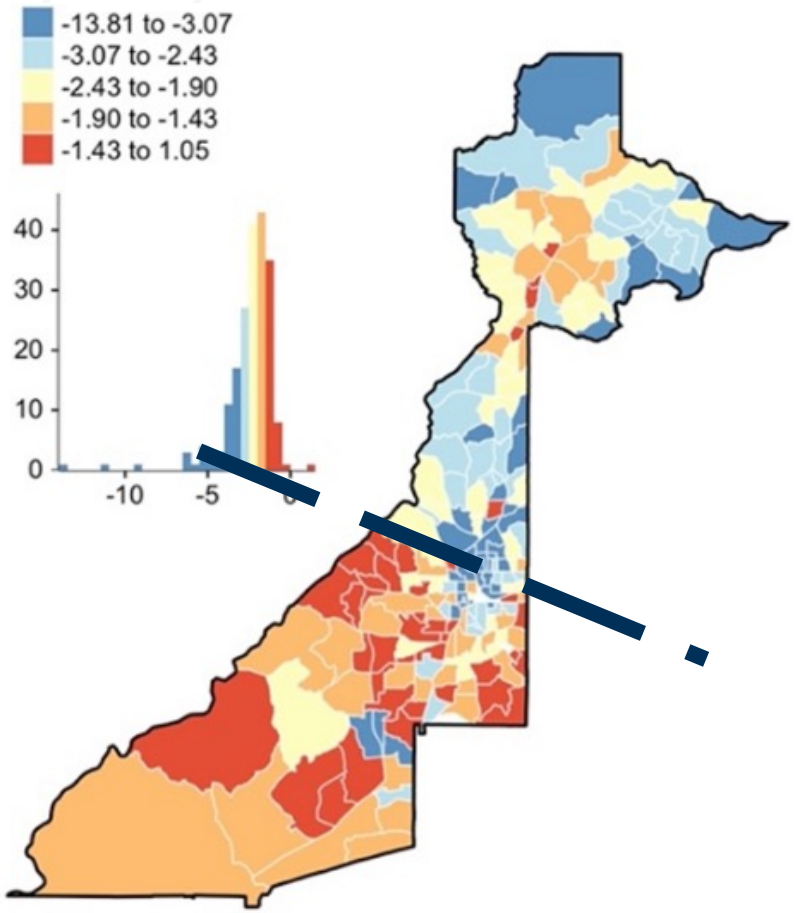
Urban - Suburban

Random

- No visible pattern found on Entropy

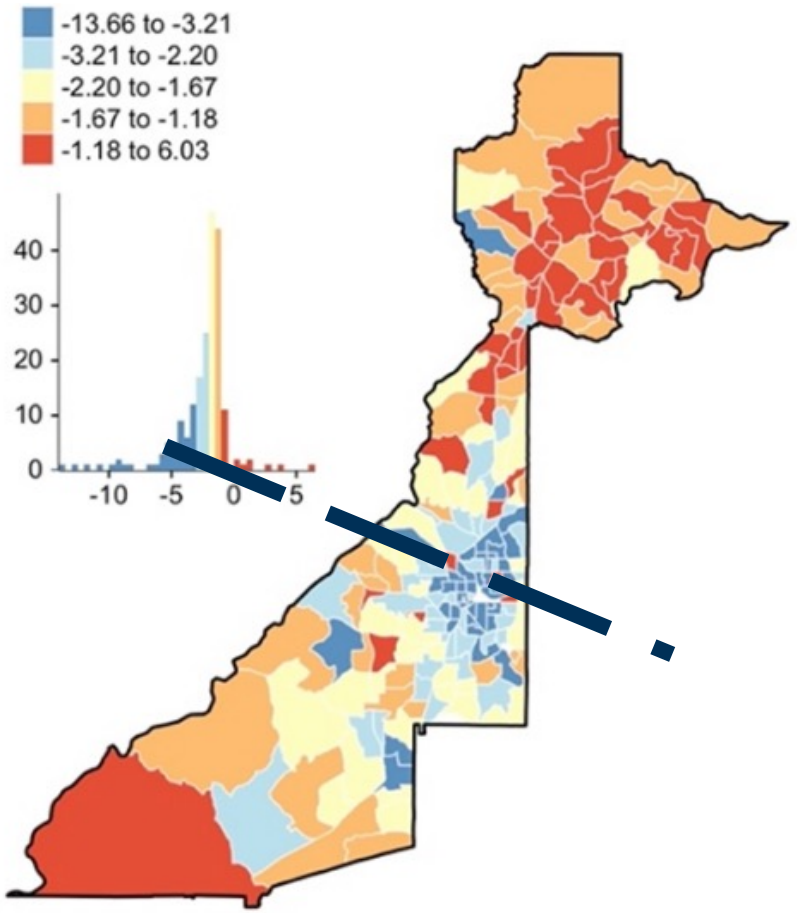
Georgia Tech

Results - Descriptive

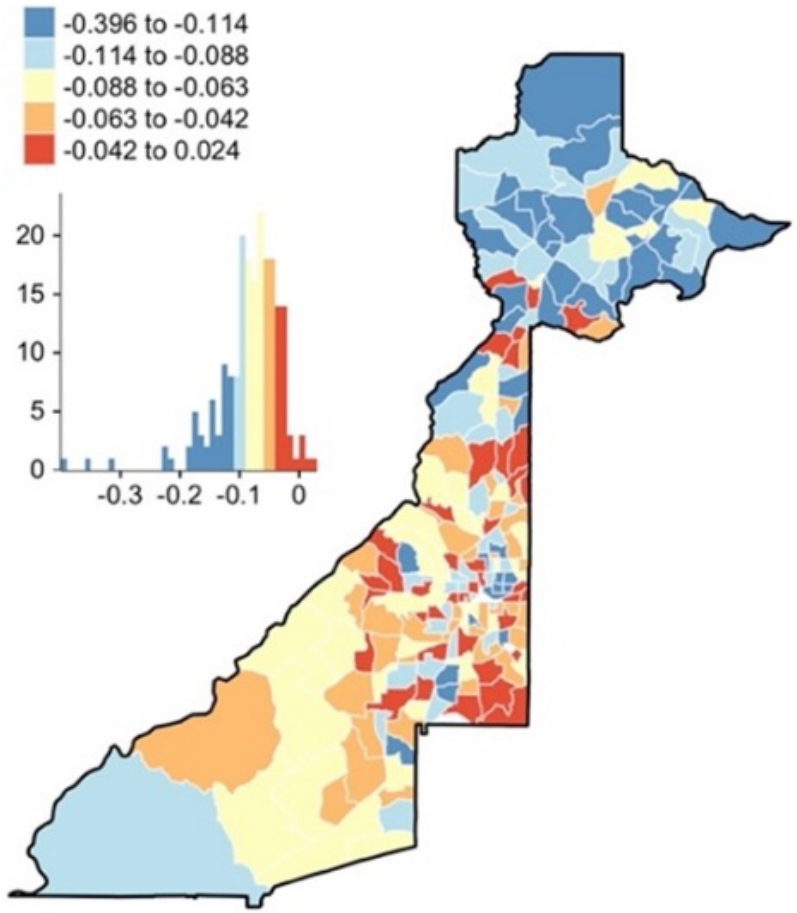


Restaurants

* Digitalization of the urban food system



Parks



Healthcare Facilities

Freq. of Trips per capita

Georgia Tech

Results – PCA/FA

- Good cumulative variance explained: **75.1%**
- Great match with pre-conceived conceptual structure: **4 Factors**
  - **FC1 - Density + Connectivity**
  - **FC2 - Diversity**
  - **FC3 - Density**
  - **FC4 - Centrality**
- Strong association between **connectivity** and **density**

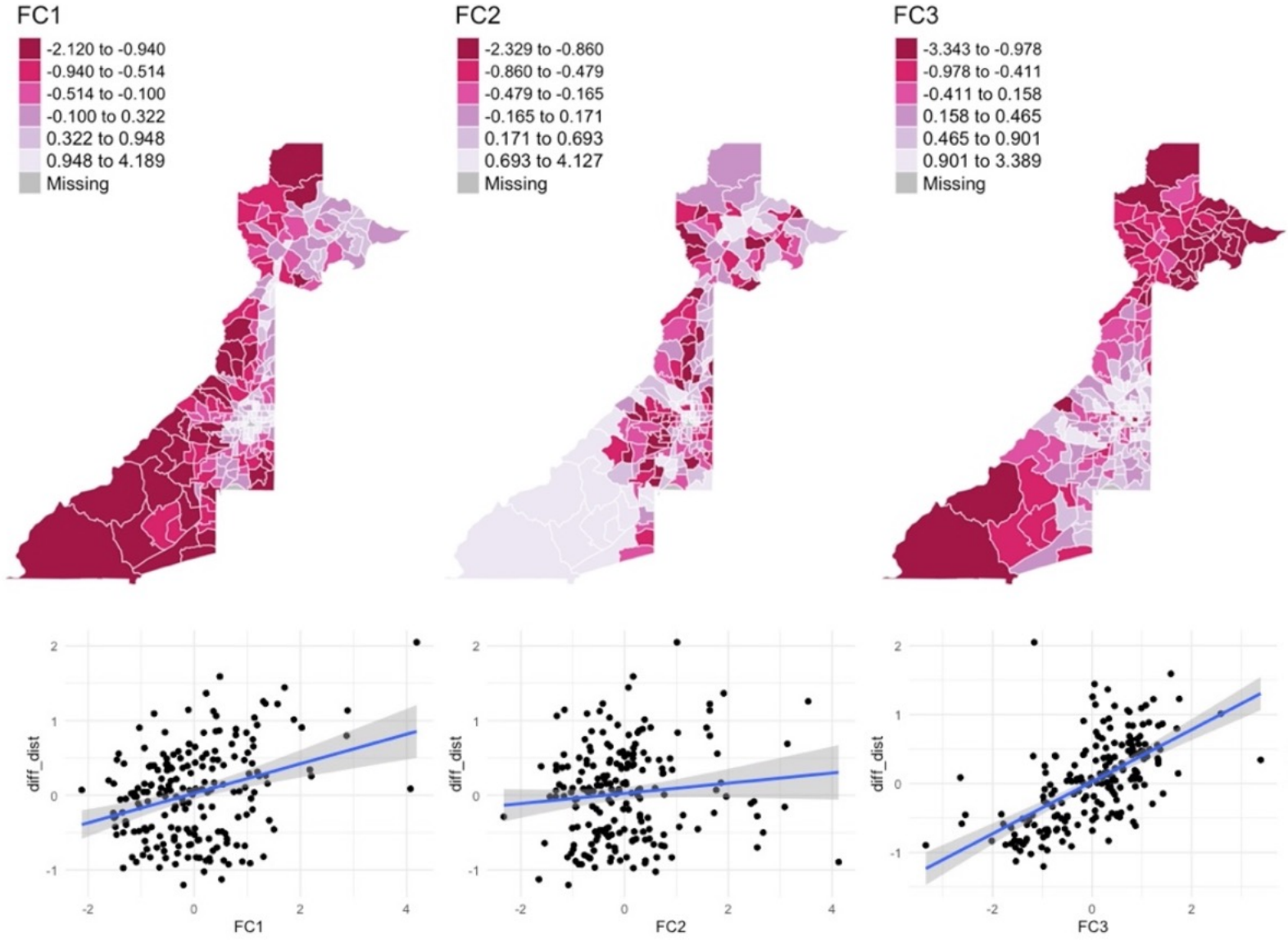
Table 4: Rotated Factor Structure of built environment variables

Variables	Factor 1	Factor 2	Factor 3	Factor 4
Density				
bld_ratio	**0.619**	0.228	**0.590**	0.172
popden_sqmi	**0.639**		**0.445**	
setback_avg_ft	**-0.787**	0.284	**-0.219**	
blk_avg_sqft	**-0.359**	0.343	**-0.671**	
Connectivity				
interden	**0.933**			
stden	**0.900**		0.226	
stopden	**0.569**	0.101		
Diversity				
tct_entro	-0.280	**0.715**		
bld_sd_sqft		**0.785**		
fract_avg	-0.228	**-0.850**	-0.173	
Centrality				-0.156
betweeness_centrality		0.422	**0.723**	
trip_inwards		0.103		**0.981**
Factor 1 (Density + Connectivity)	1			
Factor 2 (Diversity)		1		
Factor 3 (Density + Centrality)			1	
Factor 4 (Centrality)				1
Eigenvalue	4.71	2.52	0.94	0.82
Proportion Var. explained	30.7%	19.2%	16.4%	8.7%
Cumulative Var. explained	30.7%	49.9%	66.4%	75.1%

Results – PCA/FA

- **Inner-ring suburban tracts** have lower connectivity than most outer suburban tracts

- Bivariate correlation: First three factors have moderate to strong associations with **the change in trip distance**



Results – Regression

	OLS								Spatial Lag			
	Dependent Variables											
	trip counts per capita		trip type entropy		average trip distance		Restaurant trip counts per capita		Restaurant trip counts per capita		average trip distance	
	estimate	p-value	estimate	p-value	estimate	p-value	estimate	p-value	estimate	p-value	estimate	p-value
Urban Form Factors												
FC1 (Density + Connectivity)	-2.701	6.35e-07 ***	0.011	0.148	0.240	1.21e-10 ***	-0.764	1.12e-11 ***	-0.610	< 2e-16 ***	0.149	< 2e-16 ***
FC2 (Diversity)	-1.270	0.006 **	3.802e-04	0.956	0.072	0.021 *	-0.305	0.001 **	-0.253	0.005 **	0.074	0.008 **
FC3 (Density + Centrality)	-1.437	0.006 **	0.014	0.061 .	0.349	< 2e-16 ***	-0.345	0.001 **	-0.254	0.014 *	0.234	< 2e-16 ***
FC4 (Centrality)	-1.322	0.006 **	0.003	0.718	0.001	0.963	-0.312	0.001 **	-0.262	0.004 **	0.002	0.938
SES Variables												
medhhinc	-8.325e-05	0.001 ***	6.083e-07	0.063 .	4.22e-07	0.772	-1.214e-05	0.006 **	-9.542e-06	0.023 *	2.612e-07	0.844
pc_white	7.474	0.028 *	-0.004	0.936	-0.255	0.262	1.538	0.025 *	1.425	0.029 *	-0.027	0.893
pc_bachelors	-3.521	0.485	-0.118	0.121	0.007	0.982	-2.047	0.045 *	-1.934	0.049 *	-0.160	0.605
COVID												
vac_per_capita	3.967	0.655	0.061	0.648	-1.857	0.002 **	1.508	0.401	1.446	0.406	-0.926	0.102
Spatial Lag												
rho									0.224	0.017 *	0.387	< 2e-16 ***
(Intercept)	-10.084	1.13e-15 ***	-0.058	0.001 ***	0.166	0.032 *	-1.274	1.35e-07 ***	-0.916	0.001 ***	0.114	0.111
Observation	201		201		201		201		201		201	
R2	0.263		0.032		0.547		0.395		0.415		0.606	
Adjusted R2	0.232		0.008		0.528		0.370		0.409		0.602	
Spatial Dependence												
Lagrange Multiplier (lag)	3.977	*	0.186	0.656	23.1662	***	4.357	*				
Robust LM (lag)	17.036	***	0.537	0.463	31.383	***	10.118	**				
Jarque-Bera	147.084	***	3527.48	***	2.532	0.281	2140.561	***				

Note: Significance codes: p <0.001'***' p<0.01 '**' p< 0.05 '*' p< 0.1 '.'

Georgia Tech

Results – Regression

- All factors are significantly associated with trip frequencies and trip distance
  - Density, connectivity, and diversity increase the chance of having **FEWER** reduction on trip frequencies
  - Surprisingly, those “good” traits **INCREASE** the average travel distance during COVID-19

- Highest goodness-of-fit from the spatial model on trip distance (R2 = 0.602)
  - no association found on entropy (diversity)

Discussion and Conclusion

- **Built environment characteristics** show a strong association with overall mobility as well as mobility to public spaces

- The mix of **economic adversity** and **poor-quality built environment** can lead to serious impact on disadvantaged population during public health crisis
  - A combination of the urban-suburban and growth-no-Growth

- Some trips cannot be replaced by the digitalization of food/work. **Urban design in the post-pandemic era** should prioritize those experiences.

Georgia Tech

Thank you!

Jun Wang
jwang3095@gatech.edu

Yilun Zha
yilunzha@gatech.edu

Georgia Tech