Towards the Generalization of Walkscape:

Multicity Validation of **Street View-Based Walkability Measurement**

Bon Woo Koo, Subhrajit Guhathakurta, Nisha Botchwey

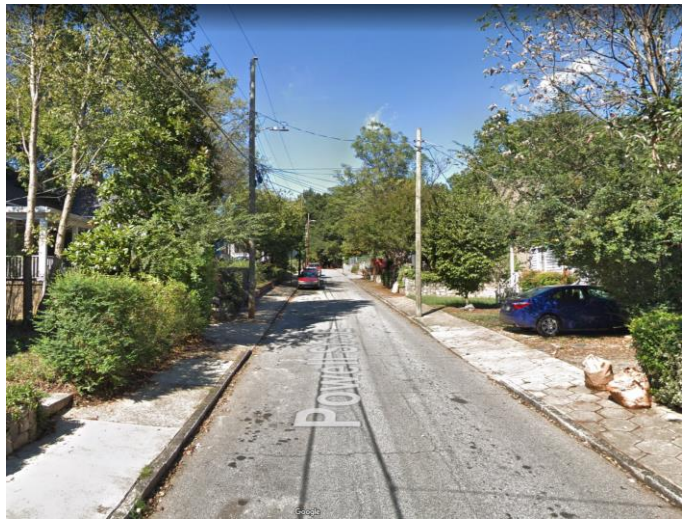
Georgia Institute of Technology

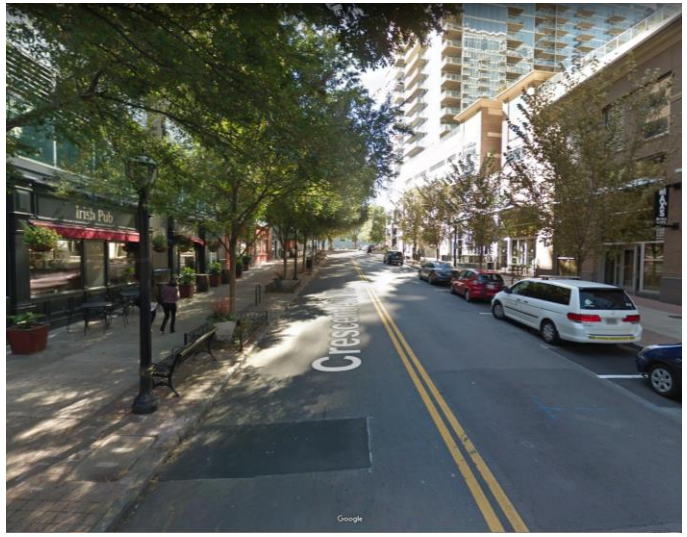
Updates to ACSP 2018

1. This is a follow-up study of the last year's presentation.
   - GSV + computer vision to measure walkable streetscape.
   - Significant improvements over Walk Score

2. This study expands to multiple cities with varying characteristics.

WHAT WE SEE vs **DATA**

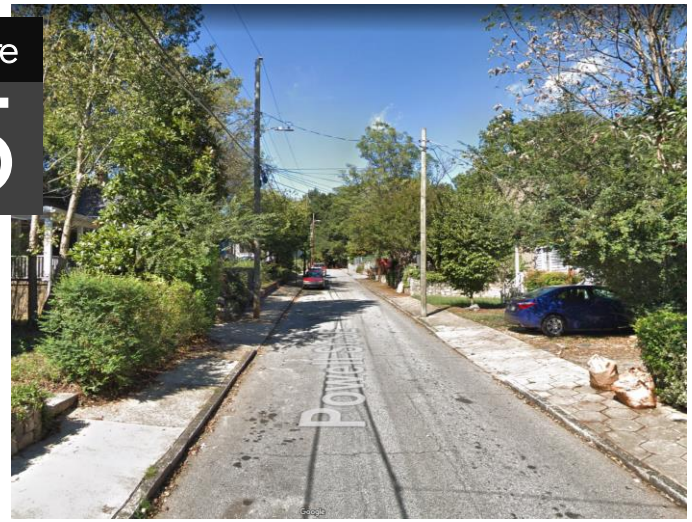




WHAT WE SEE vs DATA

WalkScore
88

WalkScore
85



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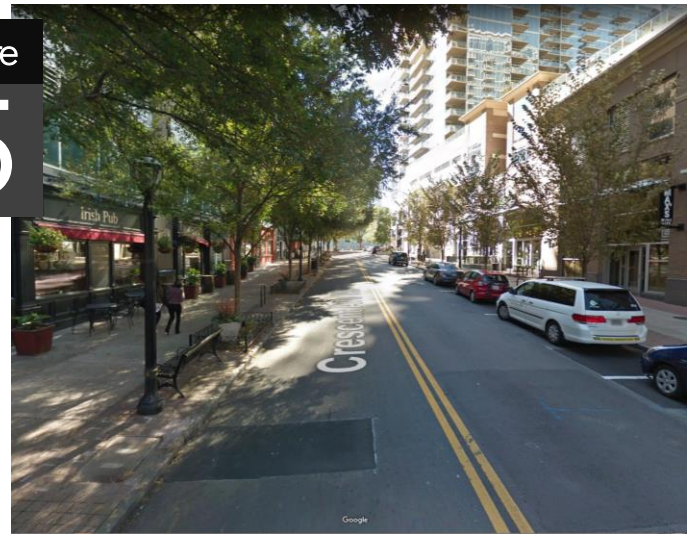


3 SCALES OF MEASUREMENT

Macroscale

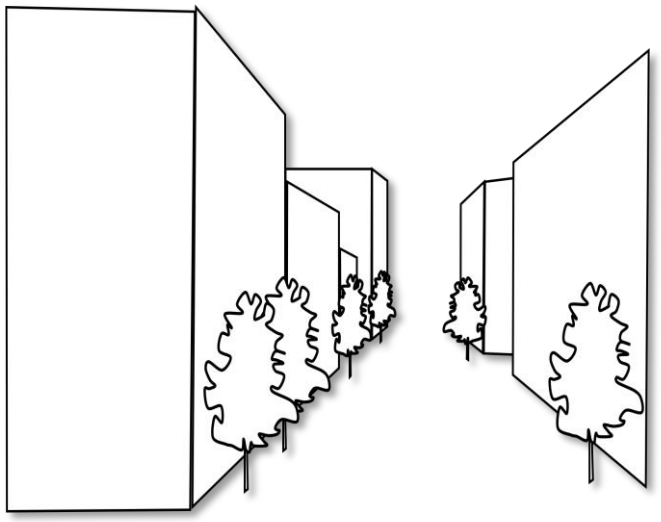
Large Urban Form Factors such as density, land use diversity, distance to destinations, and street connectivity

Sallis et al., 2011

Mesoscale

"… **three-dimensional space along a street** as bounded by buildings or other features (e.g., trees or walls)…"

Handy et al., 2002, p. 66



Microscale

Highly granular design details such as the style, color, and material of buildings, street furniture, and other fixtures on streets.

3 SCALES OF MEASUREMENT

USED IN MANY INDICES

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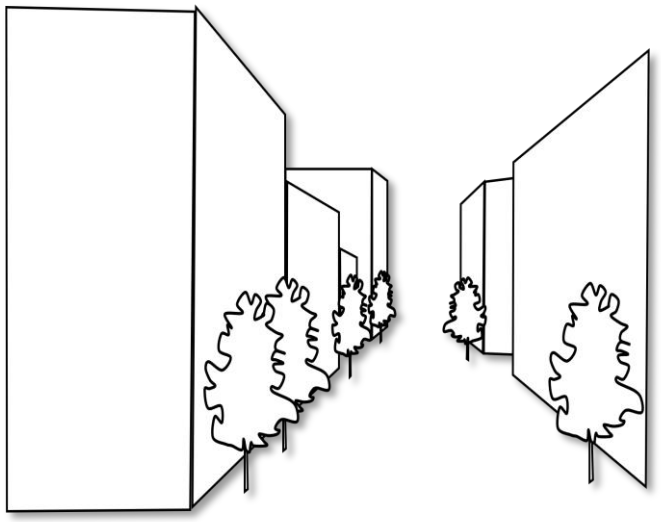

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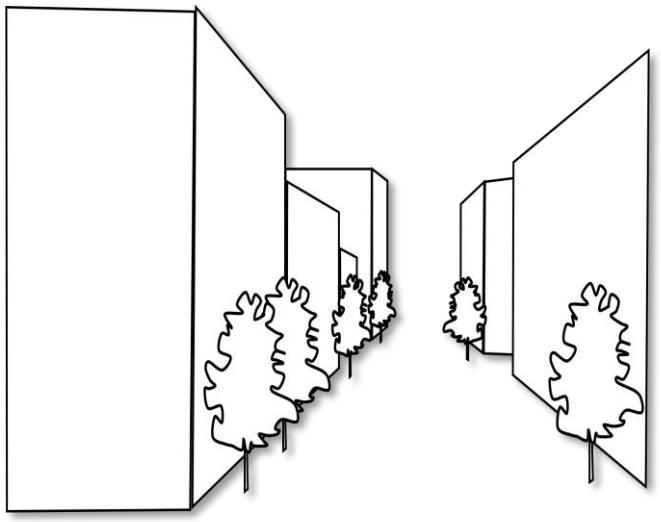

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3 SCALES OF MEASUREMENT +

5 HIERARCHY OF WALKING NEEDS HYPOTHESIS By Alfonzo, 2005

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2nd level

Connectivity

The fundamental needs.

Primary characteristics strongly affected by macroscale factors.

E.g., Distance/number of destinations, connectivity between uses Alfonzo, 2005

3rd level 4th level 5th level

Safety, Comfort, Pleasurability

Higher-order needs which are considered after connectivity.

More closely affected by meso- or microscale factors.

Adkins et al, 2012; Alfonzo, 2005; Harvey et al., 2015; Harvey & Aultman-Hall, 2015

E.g., urban design factors linked with complexity and liveliness of scenes, street trees, 1st floor windows, architectural coherence & scale Alfonzo, 2005

3 SCALES OF MEASUREMENT +

5 HIERARCHY OF WALKING NEEDS HYPOTHESIS By Alfonzo, 2005

The omission means that

the commonly used indices may be insufficient in explaining

a more nuanced needs of pedestrians.

Mac

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to destinat

of

2nd level

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Primary characteristics strongly affected by macroscale factors.

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OUR APPROACH

MESOSCALE STREETSCAPE using Computer Vision + GSV Images

VALIDATION in Atlanta & San Francisco

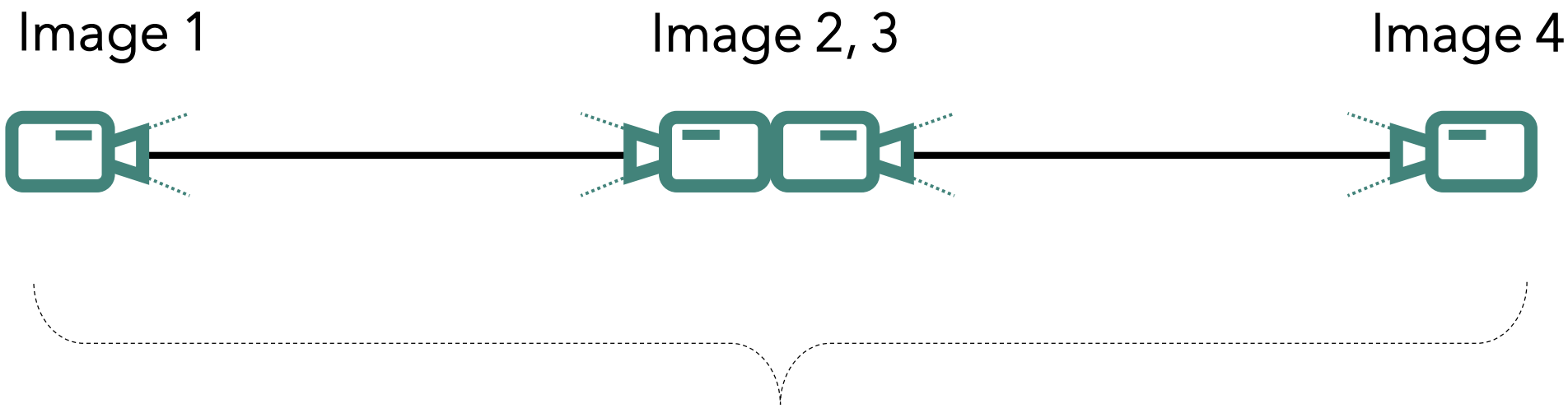
RESEARCH QUESTIONS

1. Is there a pattern to the **similarity/dissimilarity** between macro- and meso-scale factors?

2. To what extent does the **inclusion of meso-scale measures improve** the ability to explain people's decision to walk?

3. Do macro- and meso-scale measures contribute more to walking mode choice models **when they are used together than in isolation** (do they have synergy)?

DOWNLOADING GSV IMAGES

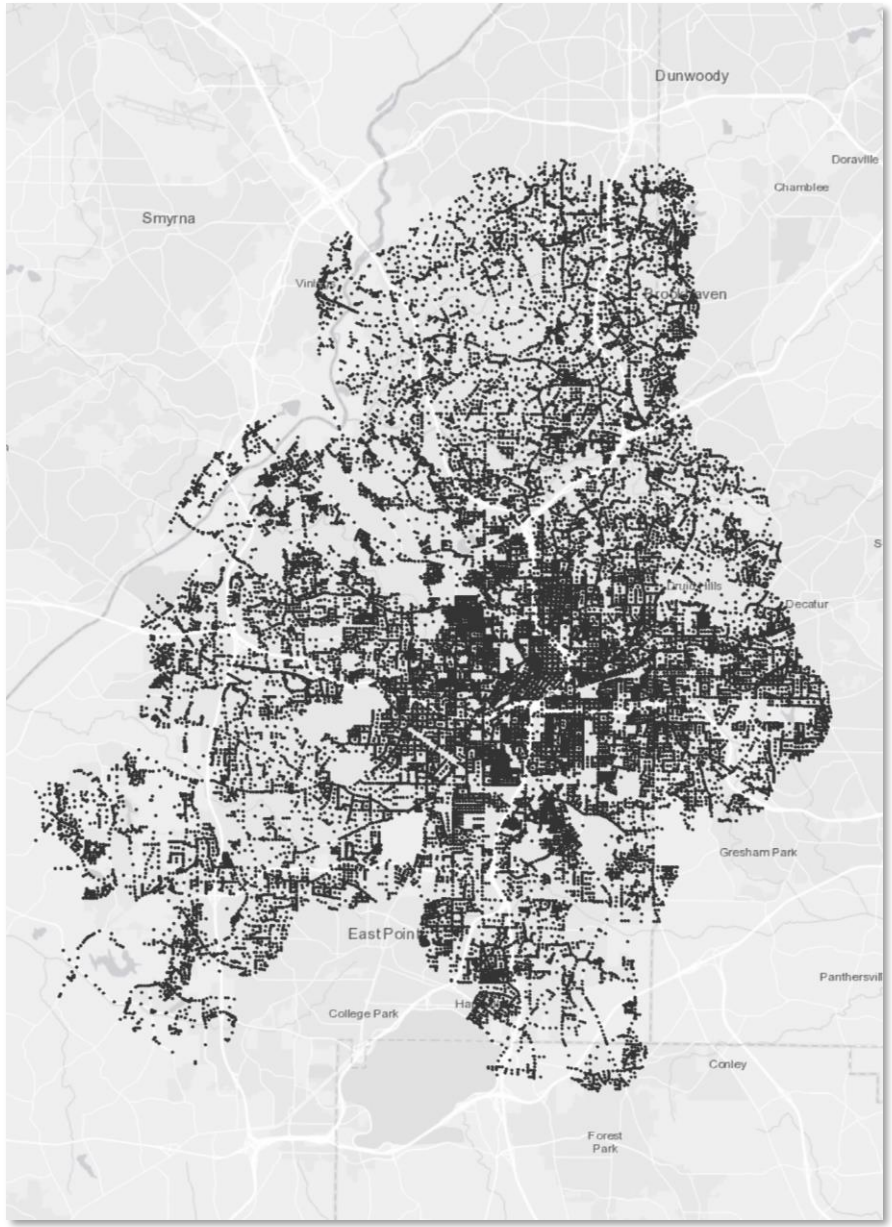


One street segment
(i.e. between two intersections)

4 images per street segment

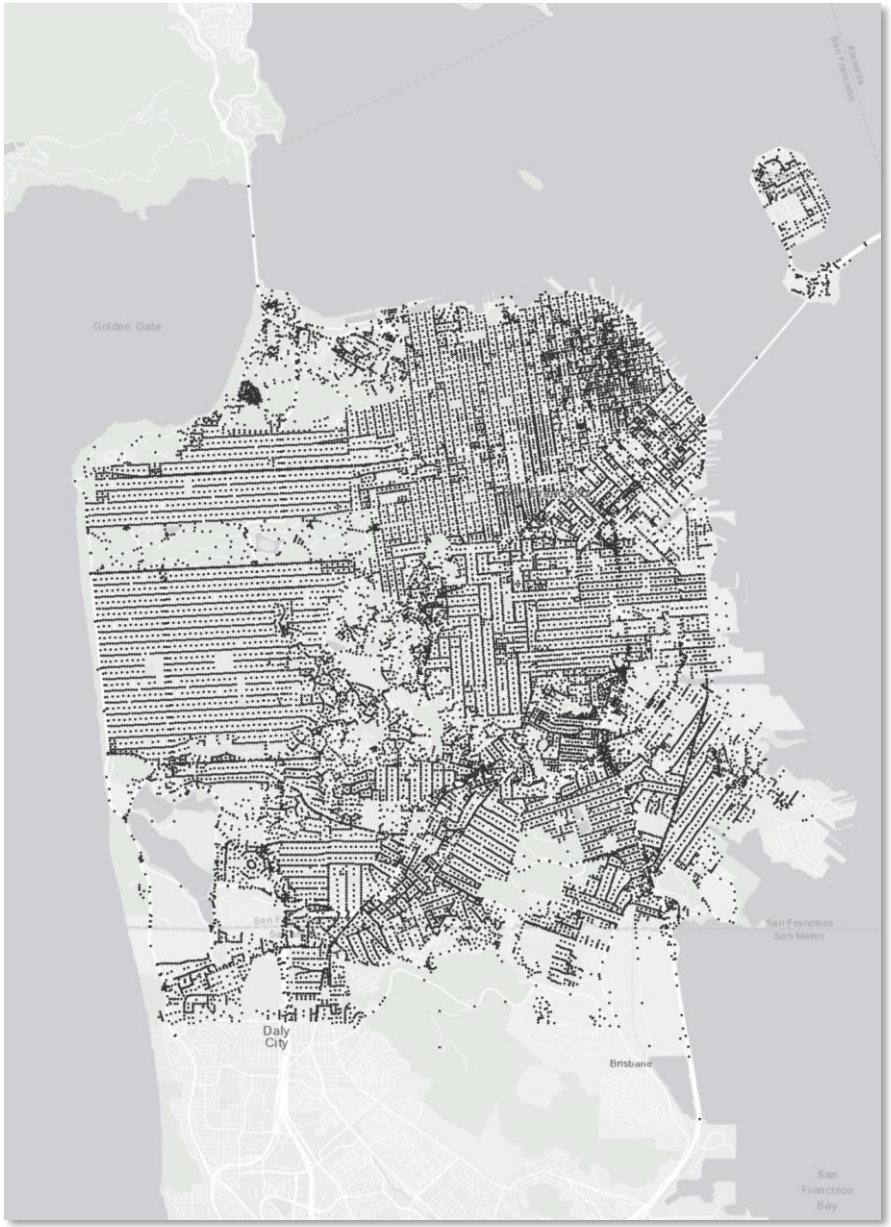
ATLANTA

70,105 GSV Images



SAN FRANCISCO

64,544 GSV Images



CONVERTING IMAGES TO DATA

Pyramid Scene Parsing Network – The winner of 2016 ImageNet Scene Parsing Challenge.

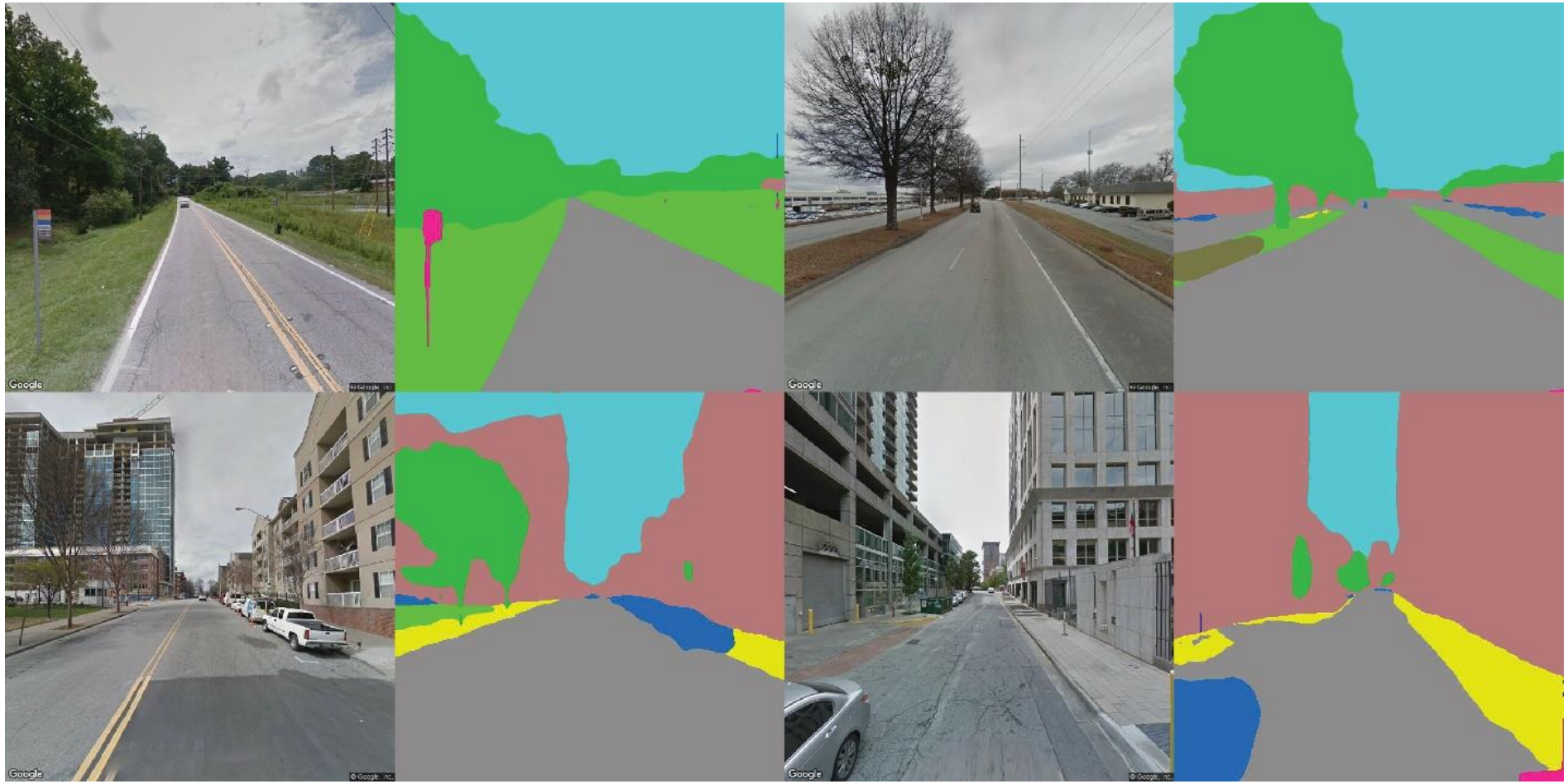
The goal is to assign each pixel in the image a label.

Pre-trained model on ADE20K dataset → Pixel-wise accuracy over 80%.

http://groups.csail.mit.edu/vision/datasets/ADE20K/
https://github.com/Vladkryvoruchko/PSPNet-Keras-tensorflow

Method	Mean IoU(%)	Pixel Acc.(%)
PSPNet(50)	41.68	80.04
PSPNet(101)	41.96	80.64
PSPNet(152)	42.62	80.80
PSPNet(269)	**43.81**	**80.88**
PSPNet(50)+MS	42.78	80.76
PSPNet(101)+MS	43.29	81.39
PSPNet(152)+MS	43.51	81.38
PSPNet(269)+MS	**44.94**	**81.69**

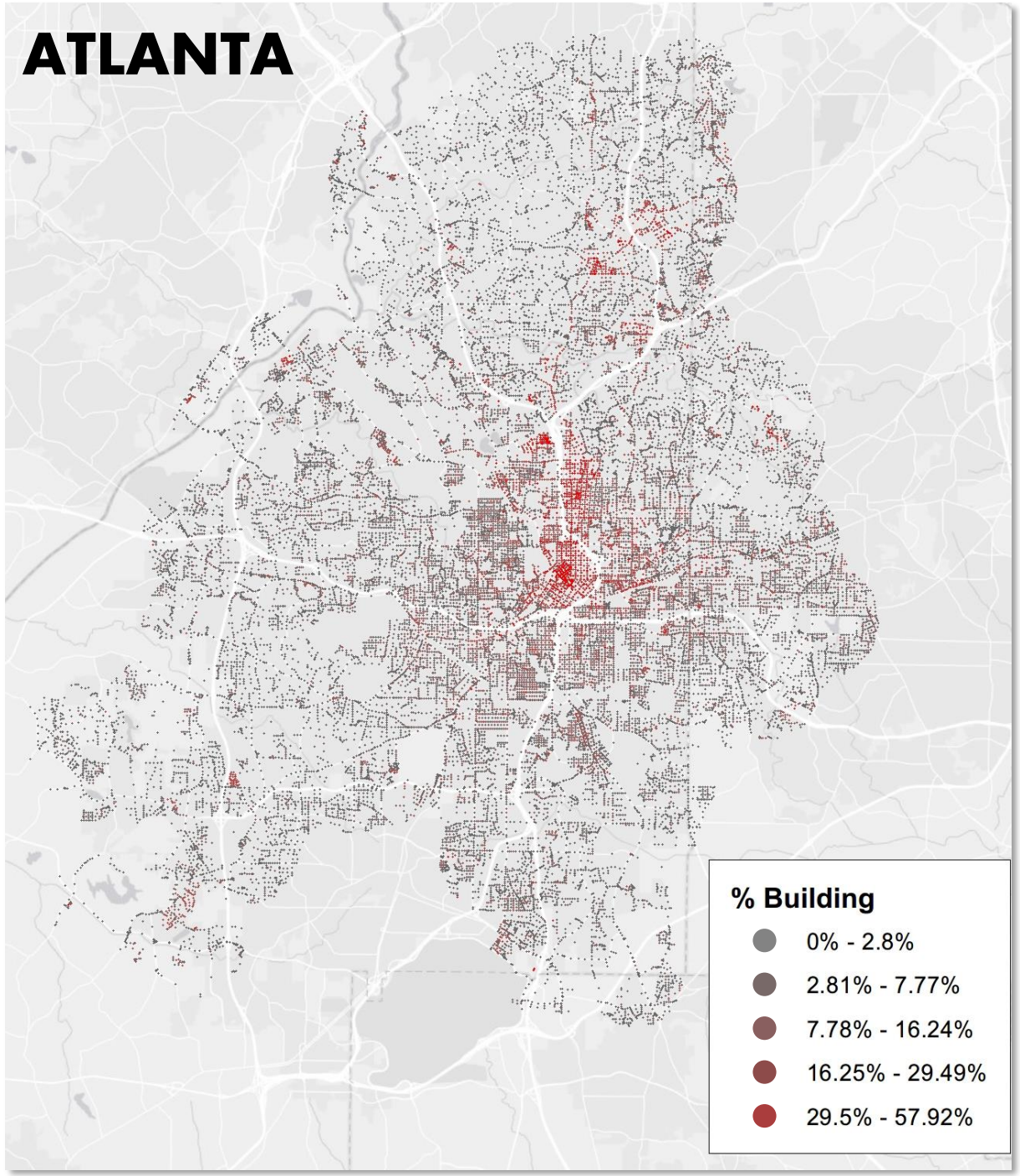
Zhao, H., Shi, J., Qi, X., Wang, X., & Jia, J. (2017, July). Pyramid scene parsing network. In IEEE Conf. on Computer Vision and Pattern Recognition (CVPR) (pp. 2881-2890).



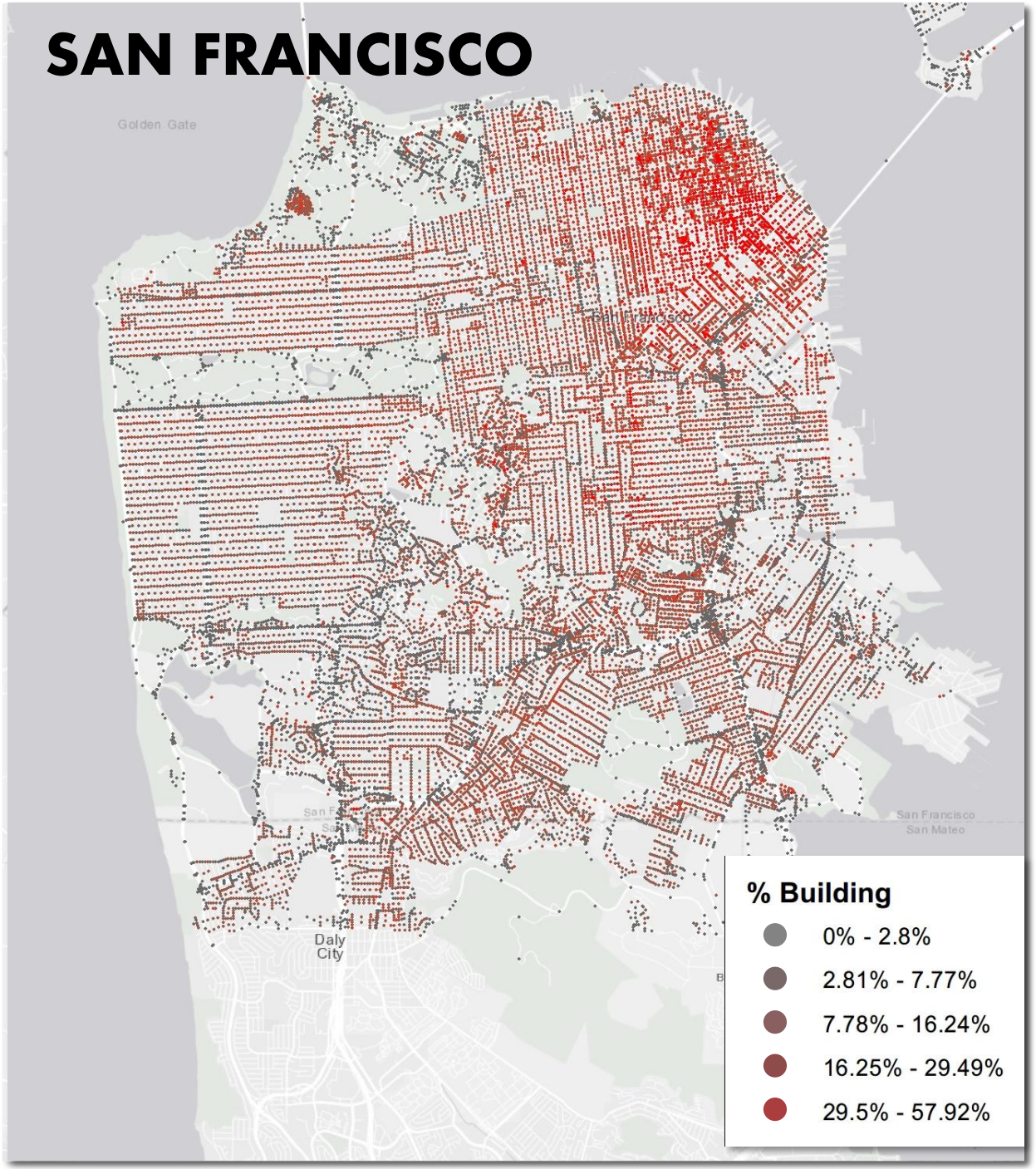
Calculated the proportion of pixels of

Building, Sky, Road, Sidewalk, Grass, Tree, Plant, and Path
for each image

ATLANTA



SAN FRANCISCO



DEPENDENT VAR: NHTS 2017 ADD-ON

Dependent Var.

Trip Mode (walking / non-walking)

Person-level Control Var.

Age, Gender, Race, Working Status,
Education, Driver Status,
Count of Walking Trips in Last 7 Days

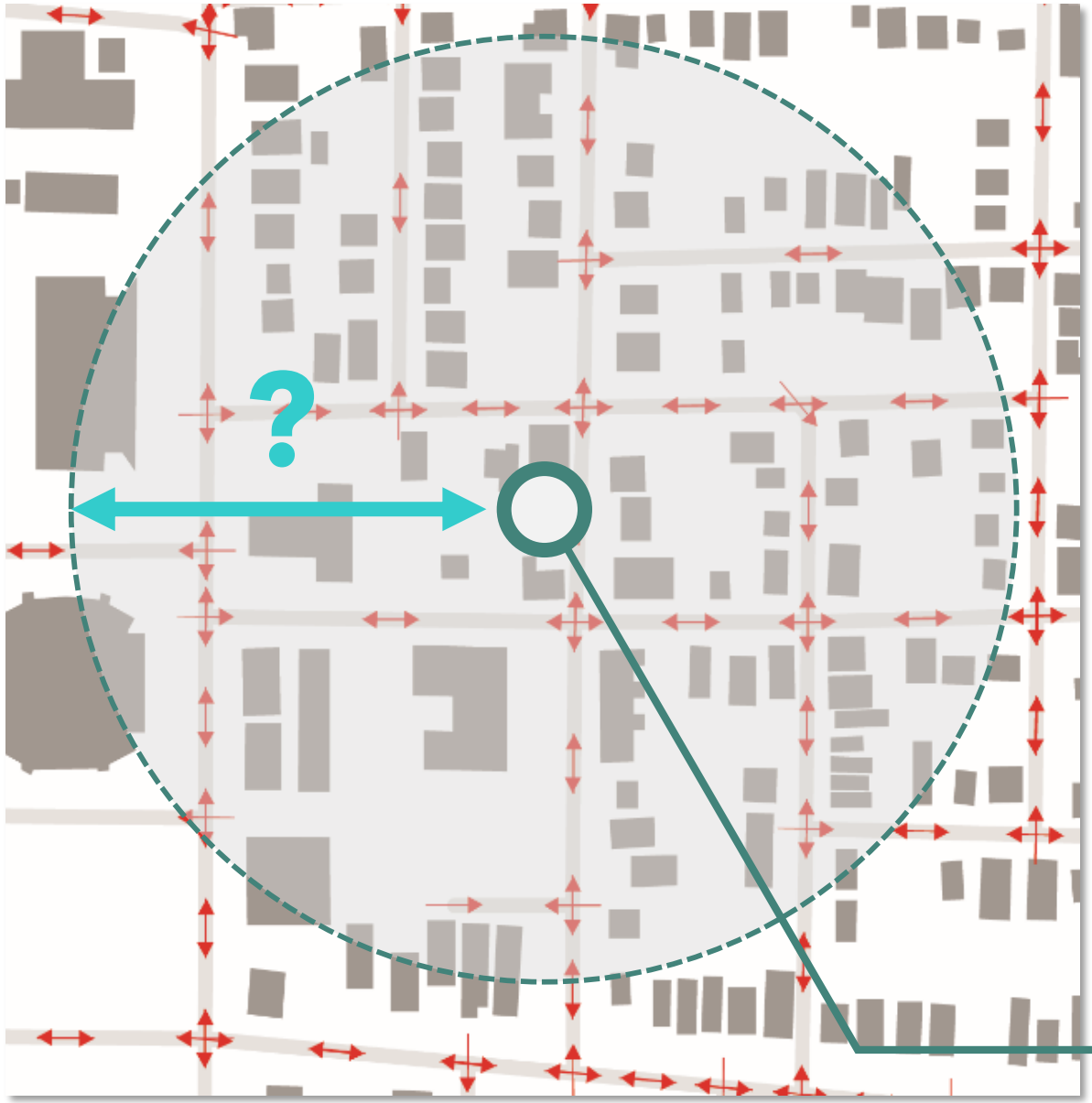
Household-level Control Var.

Vehicle per HH, HH income

ATL	San Fran
509 trips	1,156 trips

- Travel Distance ≤ 1 mile
- Only Origins
- Two separate analyses due to confidentiality

MERGING STREETSCAPE & TRAVEL DATA



IF buffer is too small

- Streetscape measure may be overly sensitive to street-by-street variations.
- Add unintended noise to the measure.

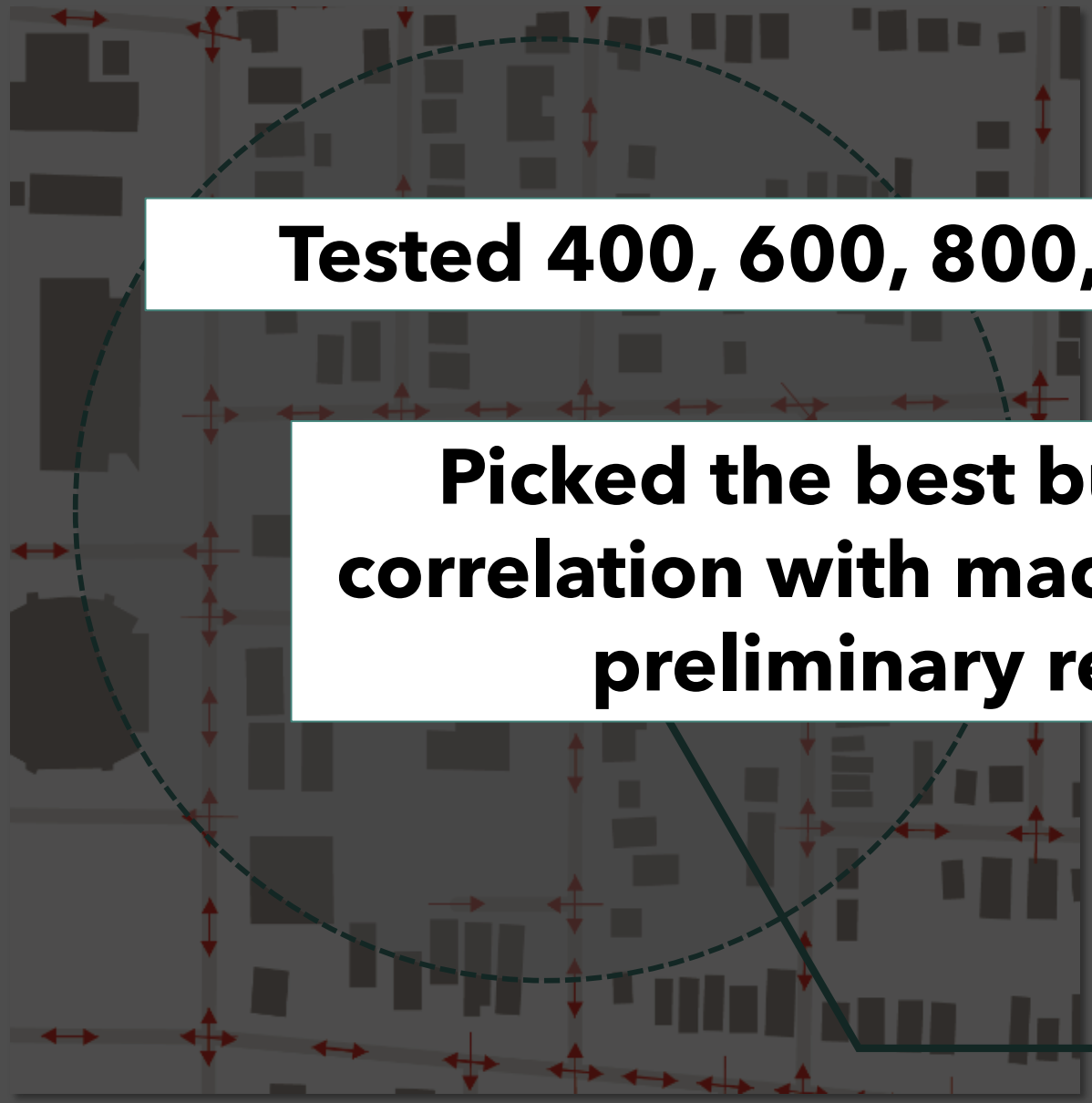
IF buffer is too large

- Streetscape may smooth-out too much and loose sensitivity to localized variations.
- Less efficient due to the concern of multicollinearity (% building ~ population density).

GSV Images

Trip Origin Location

MERGING STREETSCAPE & TRAVEL DATA



IF buffer is too small

Too sensitive to street-by-street variation

asure.

Tested 400, 600, 800, 1000-meter buffer

Picked the best buffer based on correlation with macroscale factors & preliminary regressions

correlated with

Concern of multicollinearity.

GSV Images

Trip Origin Location

TURNING PERCENTAGES INTO WALKABILITY

3 Streetscape Components

1. **Building-to-street ratio** =

$$\frac{\%\text{Building}}{\%\text{Sidewalk} + \%\text{Road} + \%\text{Path}}$$

2. **Greenness** =

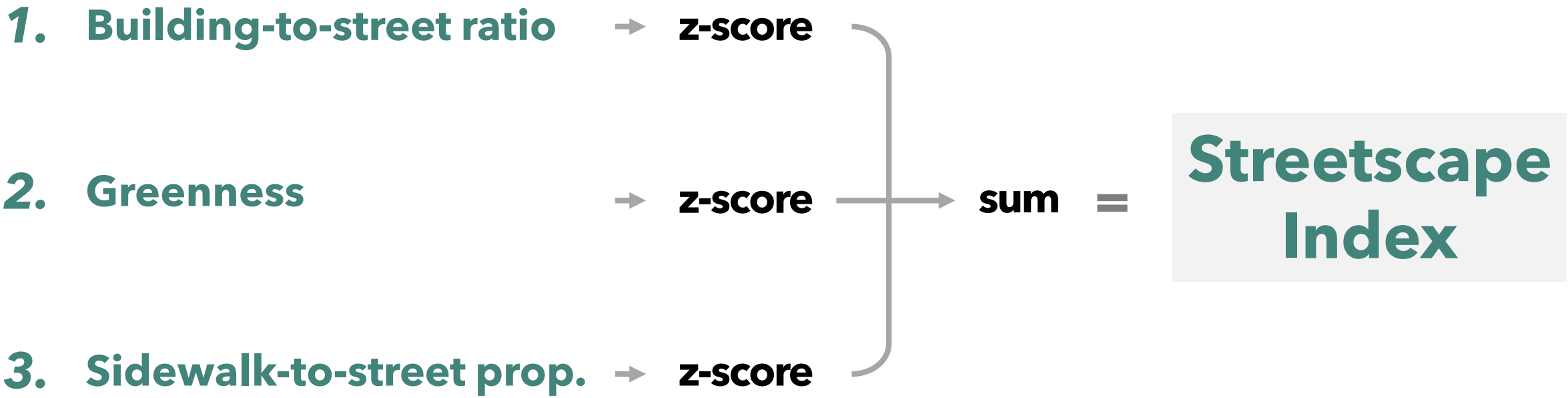
$$\%\text{Tree} + \%\text{Plant} + \%\text{Grass}$$

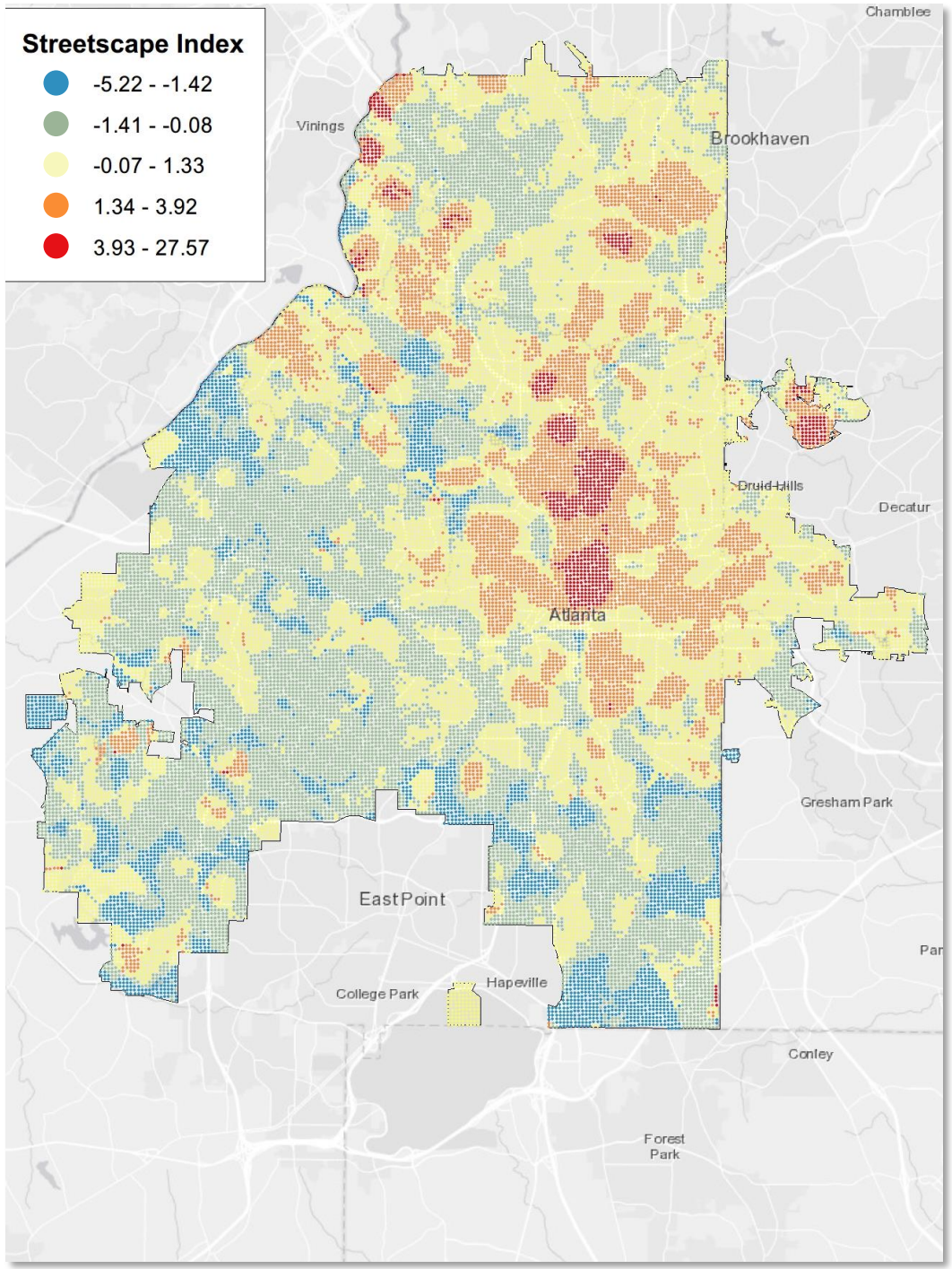
3. **Sidewalk-to-street prop.** =

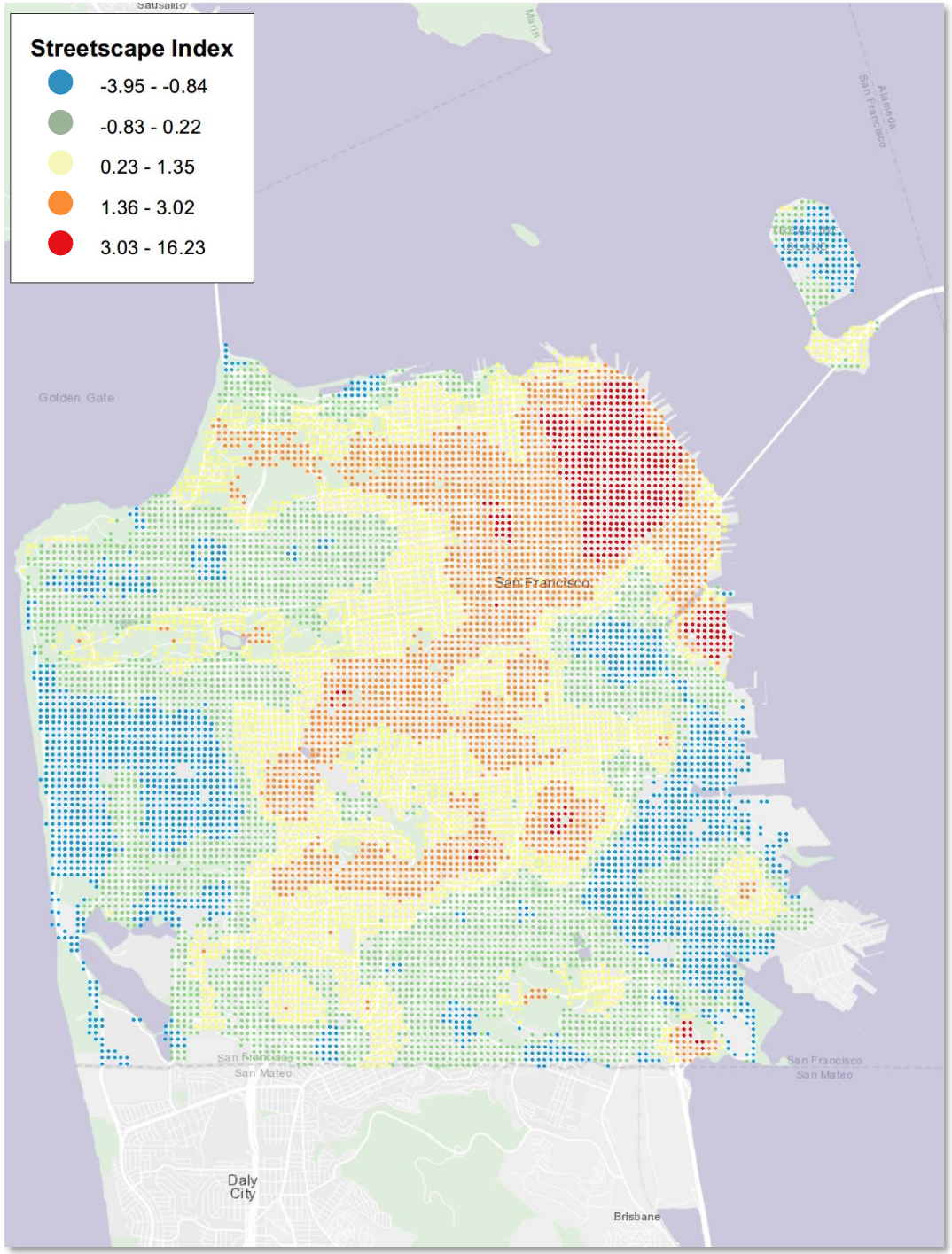
$$\frac{\%\text{Sidewalk}}{\%\text{Sidewalk} + \%\text{Road} + \%\text{Path}}$$

PERCENTAGES INTO WALKABILITY

1 Streetscape Index (tentative)




Streetscape Index
-5.22 - -1.42
-1.41 - -0.08
-0.07 - 1.33
1.34 - 3.92
3.93 - 27.57
Chamblee
Vinings
Brookhaven
Druid Hills
Decatur
Atlanta
Gresham Park
East Point
College Park
Hapeville
Conley
Forest Park


Streetscape Index
-3.95 - -0.84
-0.83 - 0.22
0.23 - 1.35
1.36 - 3.02
3.03 - 16.23
Golden Gate
San Francisco
Daly City
Brisbane

OTHER BUILT ENVIRONMENT MEASUREMENTS

5Ds

Ewing & Cervero, 2010

Density	Job Count / Area
Diversity	Entropy (residential, commercial, office, institutional)
Design	Intersection Count / Area
Destination Accessibility	Walk Score (API query for trip origin)
Distance to Transit	Network Distance to Major Transit

Measured for 400-meter buffer of trip origin

RESEARCH DESIGN

		Dep. Var		FEASIBILITY	MACROSCALE	MESOSCALE
Macro-scale only	Model 1	Walk / Non-Walk	=	Personal/HH Control	Walk Score	
	Model 2	Walk / Non-Walk	=	Personal/HH Control	All 5Ds	
Meso-scale only	Model 3	Walk / Non-Walk	=	Personal/HH Control	-	3 Streetscape Comp.
	Model 4	Walk / Non-Walk	=	Personal/HH Control	-	1 Streetscape Index
Macro- and Meso-scale	Model 5	Walk / Non-Walk	=	Personal/HH Control	All 5Ds	3 Streetscape Comp.
	Model 6	Walk / Non-Walk	=	Personal/HH Control	All 5Ds	1 Streetscape Index

RESULT:

CORRELATION between Streetscape Index ~ 5D Measures

ATLANTA

	(log) Employment Density	Land Use Mix	Intersection Density	(log) Distance to Transit	Walk Score
400 m	**0.670*** **	0.000	**0.540*** **	**-0.600*** **	**0.550*** **
600 m	**0.730*** **	0.020	**0.590*** **	**-0.680*** **	**0.630*** **
800 m	**0.750*** **	0.070	**0.590*** **	**-0.690*** **	**0.670*** **
1000 m	**0.780*** **	0.070	**0.610*** **	**-0.700*** **	**0.670*** **
Change	**+0.11**	**+0.07**	**+0.07**	**+0.10**	**+0.12**

SAN FRANCISCO

	(log) Employment Density	Land Use Mix	Intersection Density	(log) Distance to Transit	Walk Score
400 m	**0.500*** **	-0.290***	**0.540*** **	-0.150***	0.300***
600 m	**0.520*** **	-0.310***	**0.530*** **	-0.150***	0.330***
800 m	**0.540*** **	-0.340***	**0.530*** **	-0.180***	0.380***
1000 m	**0.550*** **	-0.380***	**0.510*** **	-0.190***	**0.420*** **
Change	**+0.05**	**+0.09**	**-0.03**	**+0.04**	**+0.12**

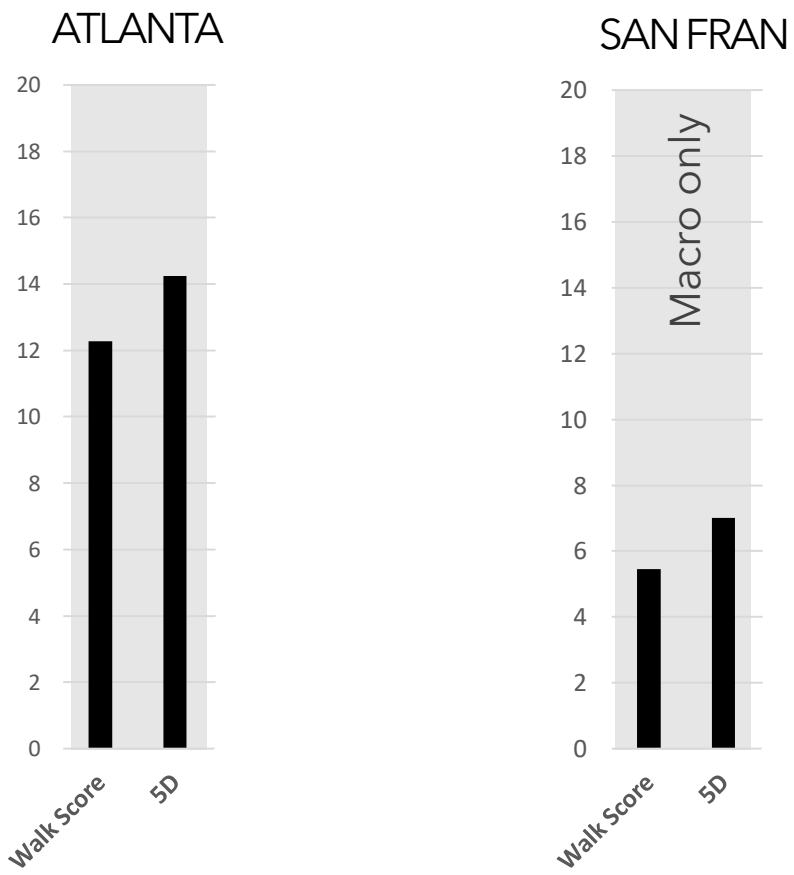
CORRELATION ANALYSIS

- 400 meter minimizes the correlation.
- Correlation tends to increase as the buffer distance increases.
- Correlations are stronger in Atlanta (0.65) than in San Fran (0.37) on average.

RESULT:

MODEL FIT (all models contain control var.)

Adj. McFadden R^2



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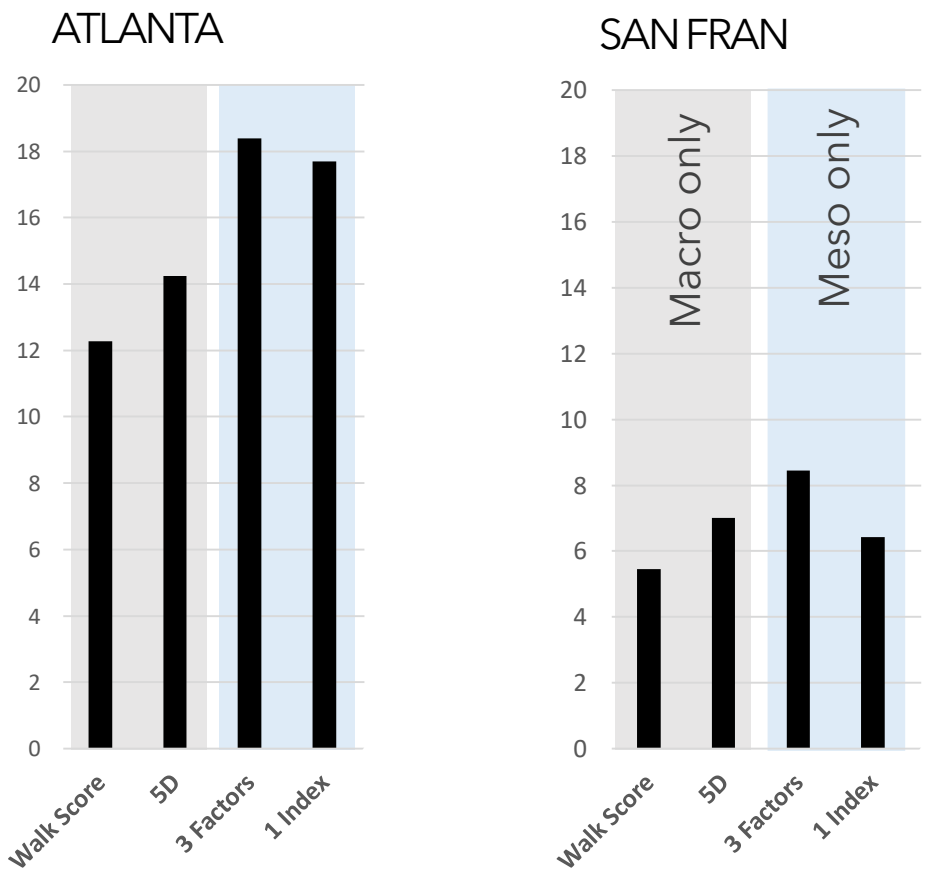

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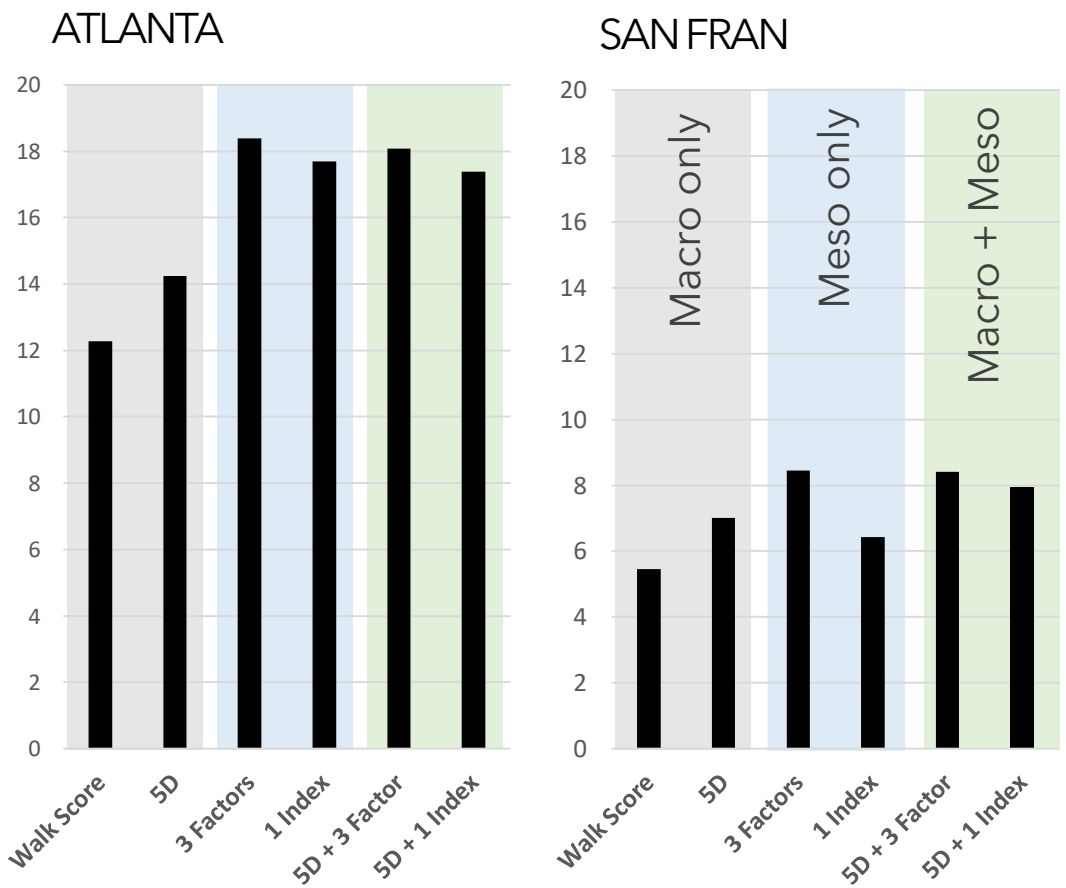

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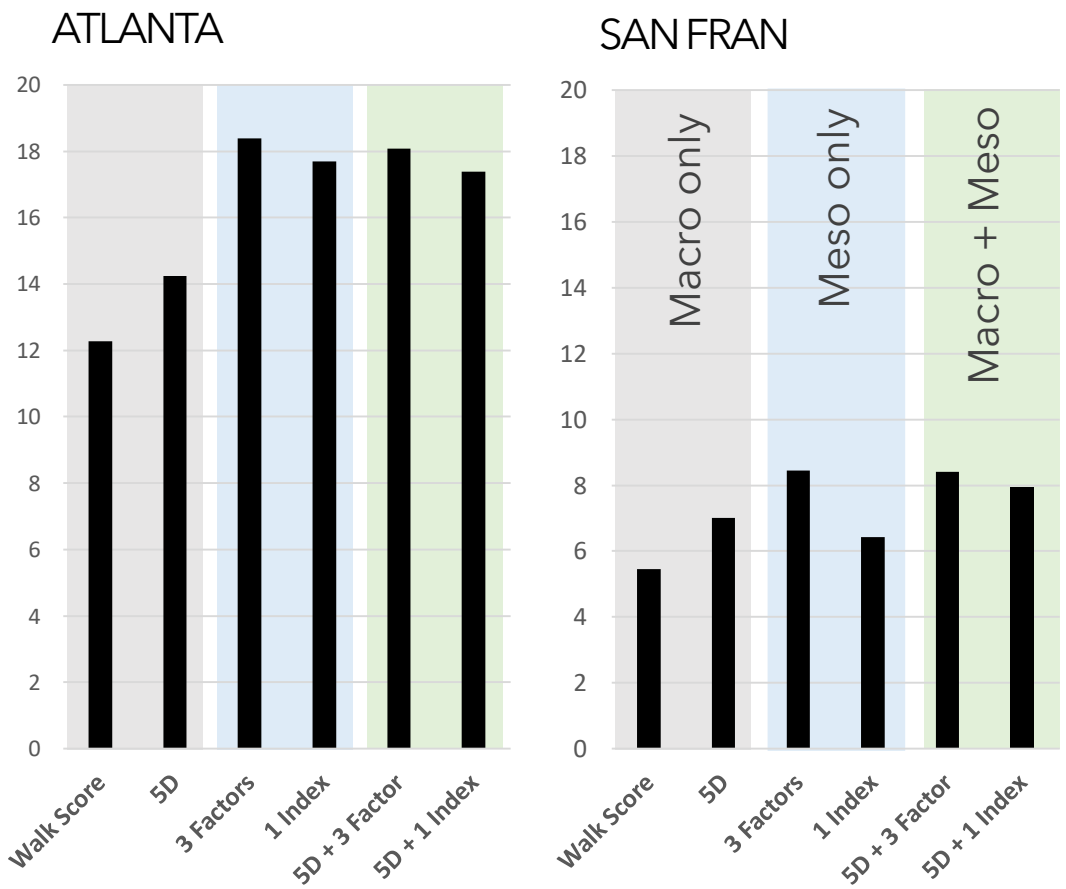


To what extent does adding streetscape measures improve the model?

- Streetscape components or Index improved the model fit in **both Atlanta and San Fran.**
- 3 components are better than 1 Index.

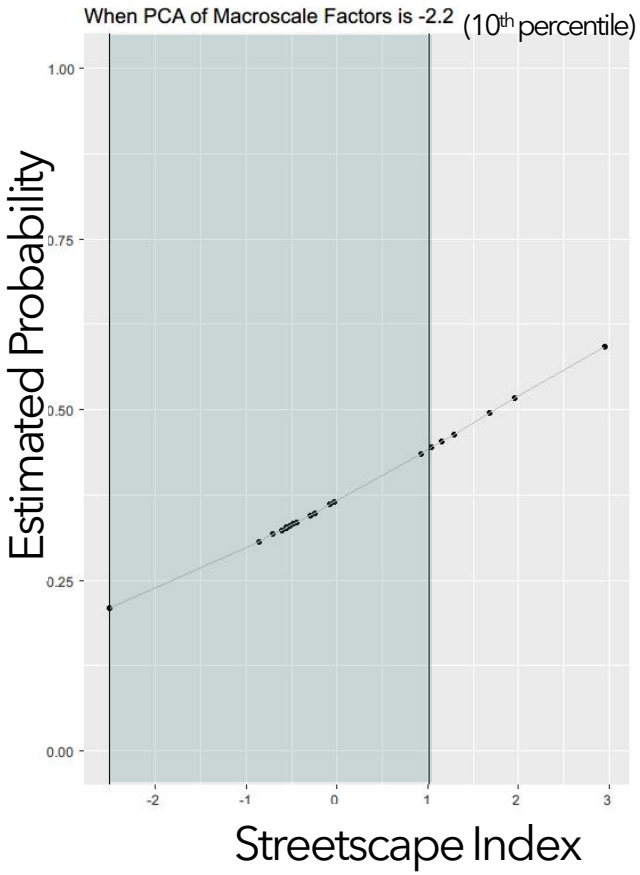
Do macro- and streetscape measures have unique contributions when used together?

- Using **only meso-scale measures (3 components) is slightly better** than using both meso- and macro-scale in both Atlanta and San Fran.

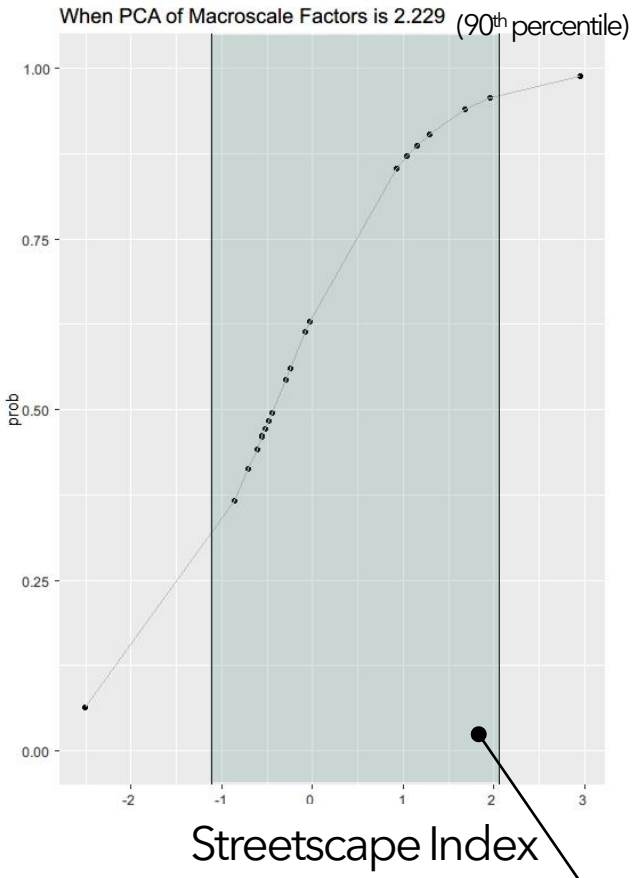
RESULT:

INTERACTION - ATLANTA

When macroscale is unfavorable to walking



When macroscale is supportive of walking



In-Sample Region

- **PCA of 5Ds** to form one measure of macro-scale.
- The interaction is significant **only in Atlanta.**
- Streetscape Index positively linked with *P*(walk).
- **The effect is much stronger when macro-scale measures are supportive of walking.**

RESULT:

COEFFICIENTS

ATLANTA

		5Ds		5Ds + 3 Factors		5Ds + 1 Index	
		Estimate	Z-value	Estimate	Z-value	Estimate	Z-value
5Ds	**LN Dist. To Transit**	0.482	2.619 **	-0.160	-0.677	0.121	0.604
	Intersection Density	0.019	0.155	0.147	1.009	0.153	1.171
	LN Employment Density	0.190	1.170	-0.053	-0.302	0.018	0.106
	Land Use Diversity	-0.237	-1.217	-0.169	-0.811	-0.198	-0.975
	Walk Score	-0.040	-0.233	0.043	0.242	-0.015	-0.088
Streetscape	**Building to Street**			**1.562**	**4.643 *****		
	Greenness			**0.839**	**3.342 *****		
	Sidewalk to Street			**0.352**	**2.132 ***		
	Streetscape Index					**0.843**	**4.514 *****
	Adj. McFadden R2	**0.142**		**0.181**		**0.174**	

Max VIF: 5.370 Obs: 509

SAN FRAN

		5Ds		5Ds + 3 Factors		5Ds + 1 Index	
		Estimate	Z-value	Estimate	Z-value	Estimate	Z-value
5Ds	**LN Dist. To Transit**	-0.008	-0.095	0.034	0.393	0.011	0.122
	Intersection Density	-0.146	-1.355	-0.364	-3.033 **	-0.297	-2.518 *
	LN Employment Density	0.608	4.379 ***	0.134	0.638	0.538	3.713 ***
	Land Use Diversity	0.049	0.428	0.061	0.502	0.094	0.799
	Walk Score	0.036	0.378	0.072	0.099	0.078	0.800
Streetscape	**Building to Street**			**0.958**	**3.595 *****		
	Greenness			**0.207**	**1.865 †**		
	Sidewalk to Street			**-0.109**	**-0.707**		
	Streetscape Index					**0.356**	**3.349 *****
	Adj. McFadden R2	**0.070**		**0.084**		**0.094**	

Max VIF: 6.402 Obs: 1,156

All models contain the control variables.
They are omitted for brevity.

†p<0.1 level; *p<0.05 level; ** p<0.01 level; ***p<0.001 level

WHY DOES MESO WORK BETTER THAN MACRO?

1. IT CAN BETTER REPRESENT ACTUAL PEDESTRIAN VIEW

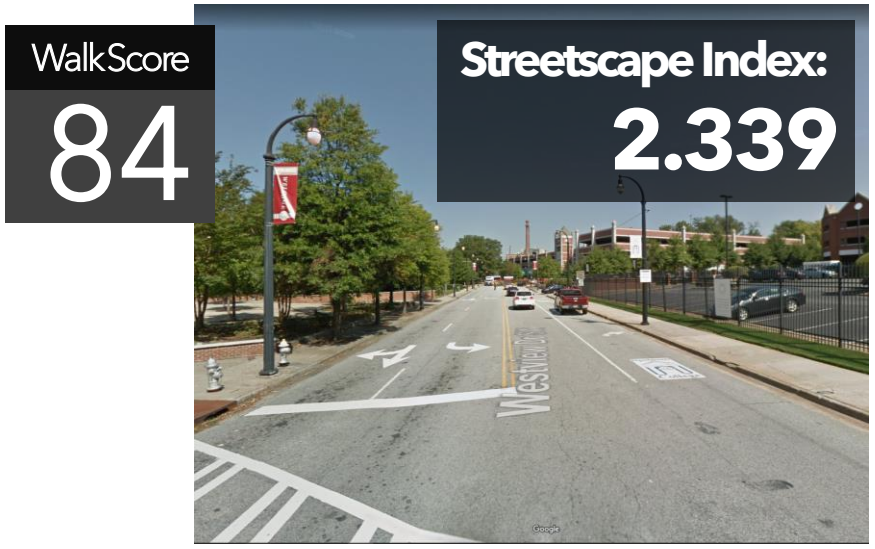
- E.g., visual dominance of street trees = **complex interactions** of tree height, canopy size, distance from buildings, slope of the street, etc.
- The literature reports the **effectiveness of eye-level measures** compared to overhead measures.

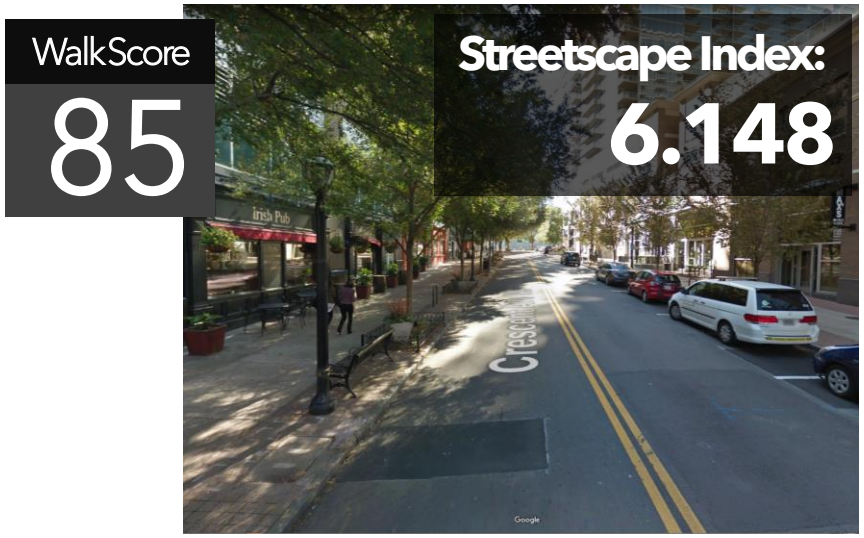
Jiang et al. (2017); Lu et al. (2019)

2. IT CAN DOUBLE AS A PROXY OF MACRO-SCALE MEASURES

- Average *r* between **0.37 (SF)** and **0.65 (ATL).**
- Meso-scale measures **may account for part of the macro-scale measures** while providing benefits of eye-level measures (speculative).
- More so when pedestrians are new to the area. Some macro-scale measures (e.g., access to destination) are not directly perceivable while streetscape is.

WHAT WE SEE vs DATA





WHAT'S NEXT

Micro-scale measures = Macro + Meso + Micro

Refinement of computer vision model = A plan for CV on the quality of sidewalk

A better way to create an index

Connecting the results with practice = What planning tools should we use to improve macro, meso, or micro?

OTHER RELATED RESOURCES

Koo, B. W., Boyd, N., Guhathakurta, S., & Botchwey, N. (2019). Environmental Equity and Spatiotemporal Patterns of Urban Tree Canopy in Atlanta. *Journal of Planning Education and Research*, 0739456X19864149.

(Under review) Koo, B. W., Guhathakurta, S., & Botchwey, N. Impacts of neighborhood and street-level walkability on walking behaviors: A big data approach using street view images

Thank you

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Nisha Botchwey nisha.botchwey @gatech.edu