

# Nodes, Paths, and Edges: Using Mental Maps to Augment Crime Data Analysis in Urban Spaces

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EuroVis



An aerial, high-angle photograph of a city at night. The image is filled with the warm yellow and orange glow of streetlights and the cool blue and white light from building windows and signage. The streets are a complex network of lines, with some showing light trails from moving vehicles. The buildings vary in height and density, creating a textured urban landscape. The overall atmosphere is one of a vibrant, bustling metropolis.

Cities are made up of  
many people with ever-  
evolving needs

Citizens have different  
opinions on what is important  
about their city



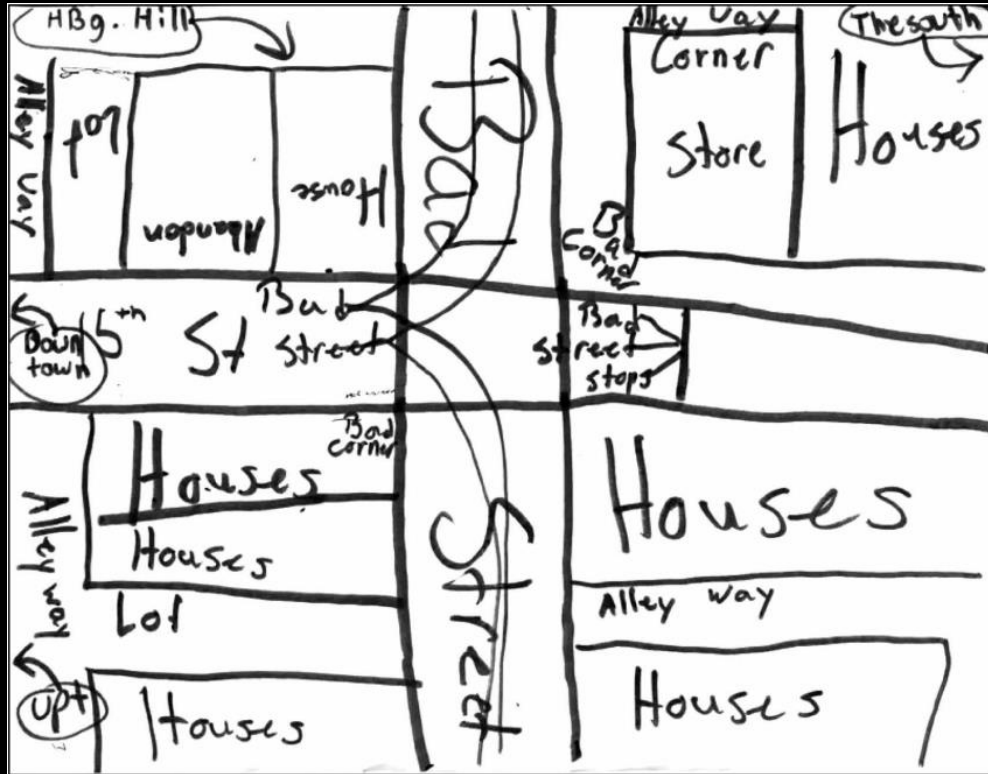
A photograph of a white police car at night, with its emergency lights on. The car is parked on a city street, and a traffic light is visible in the background. The car has "POLICE" written on the side and the number "3002" on the rear. There are two semi-transparent text boxes overlaid on the image. The background shows a city street at night with buildings and traffic lights.

Analysis of spatial data can help inform policy to fulfill those needs

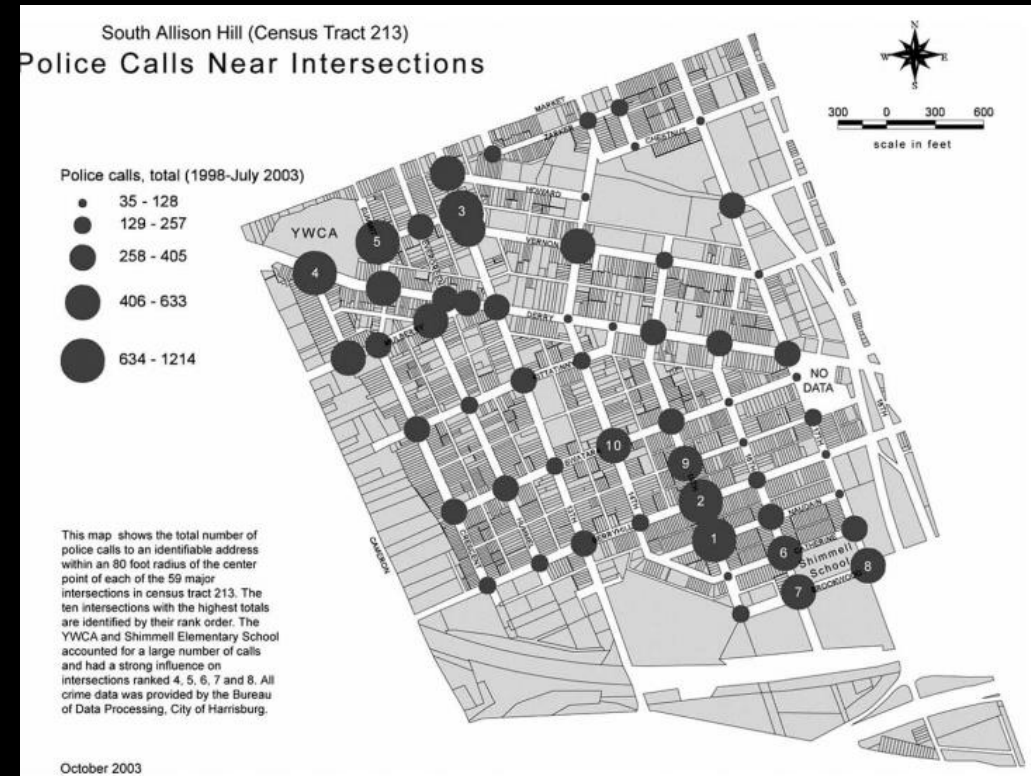
Community opinions and knowledge can diverge from authoritative data sources

Florence, C., Shepherd, J., Brennan, I., & Simon, T. (2011). Effectiveness of anonymised information sharing and use in health service, police, and local government partnership for preventing violence related injury: experimental study and time series analysis. *BMJ*, 342, d3313.

# Neighborhood Sketches



# Police Calls Near Intersections



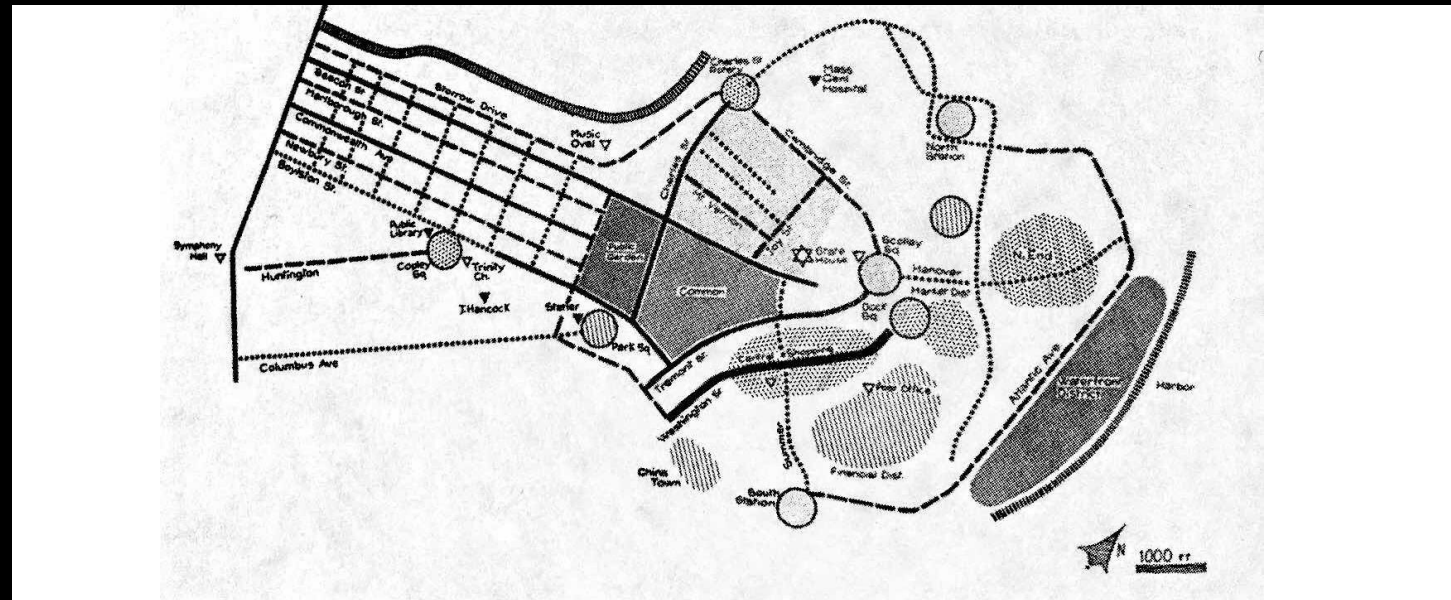
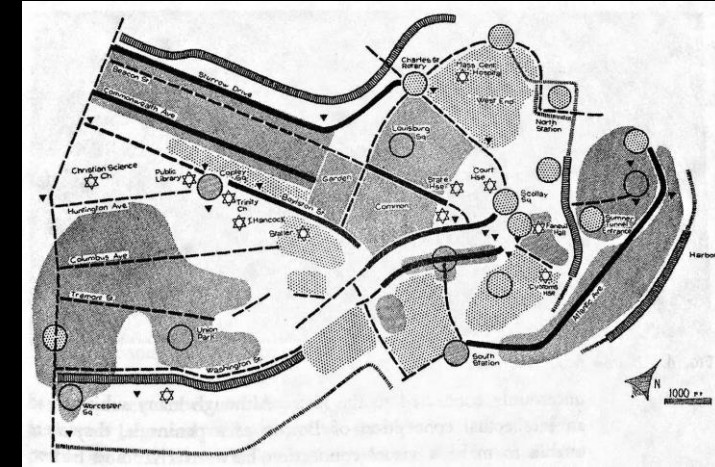
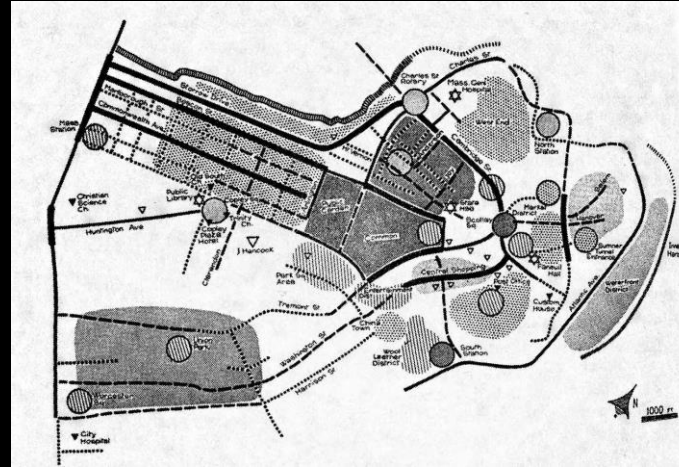
Dennis Jr, S. F. (2006). Prospects for qualitative GIS at the intersection of youth development and participatory urban planning. *Environment and Planning A*, 38(11), 2039-2054.



# Mental Maps of the City

## Forms of Boston

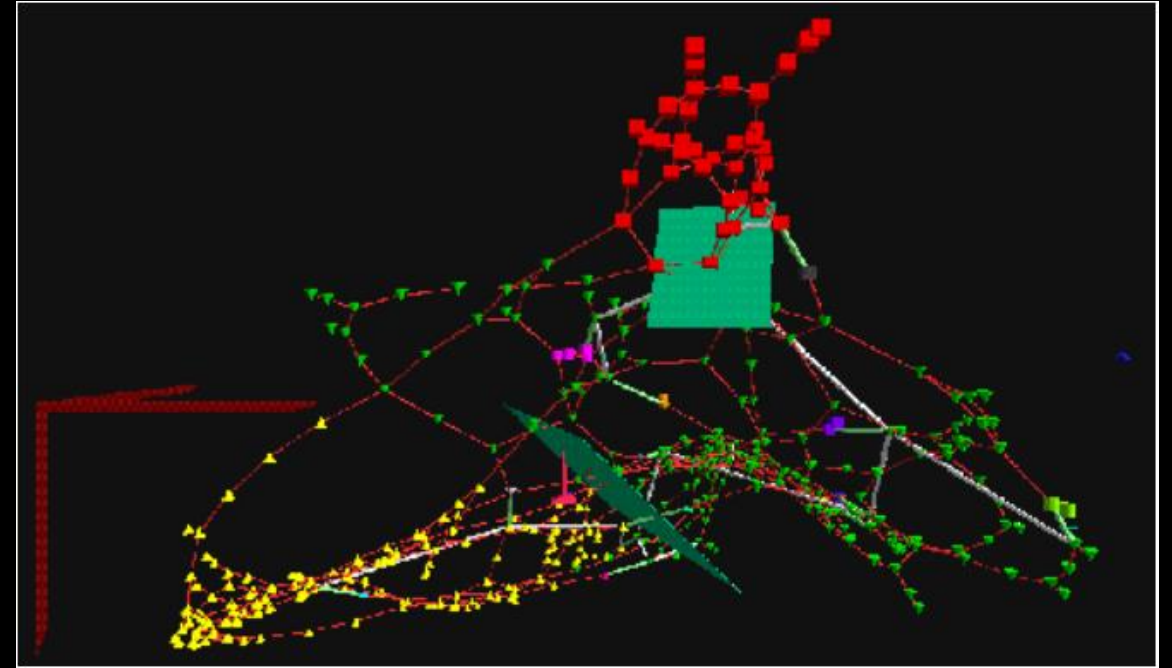
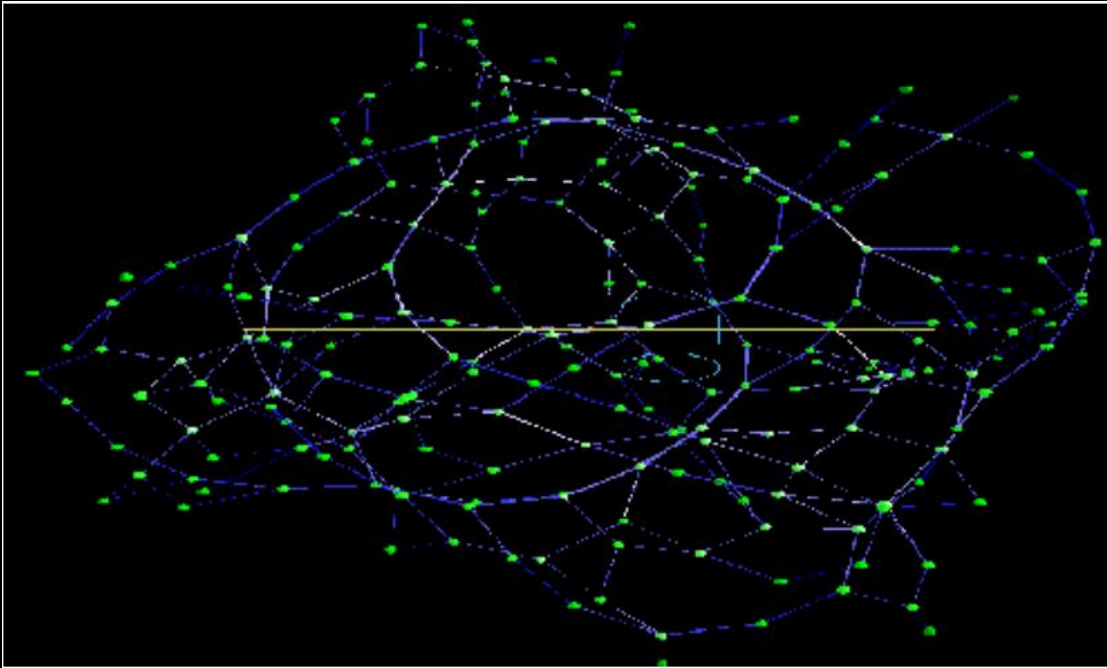
Images created from composite of elements discussed during verbal interviews about the city



	PATH	EDGE	NODE	DISTRICT	LANDMARK
major element					
minor element					

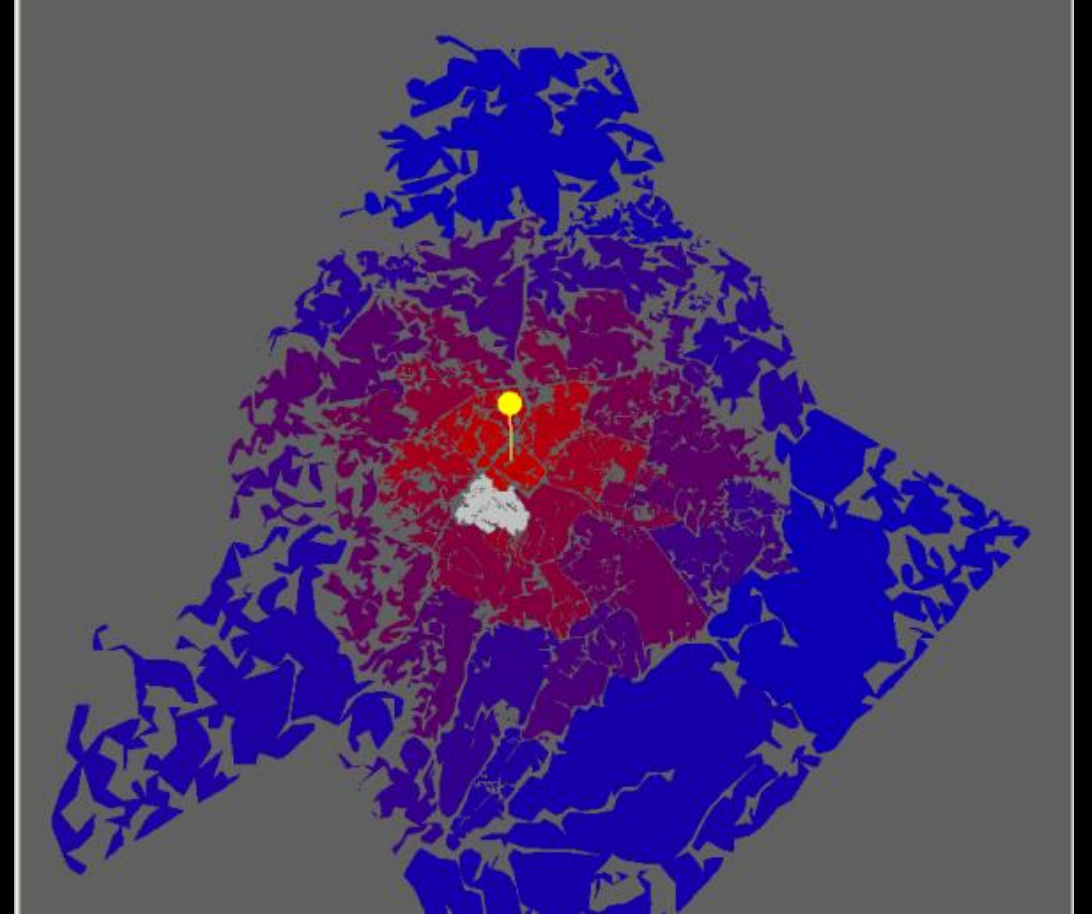
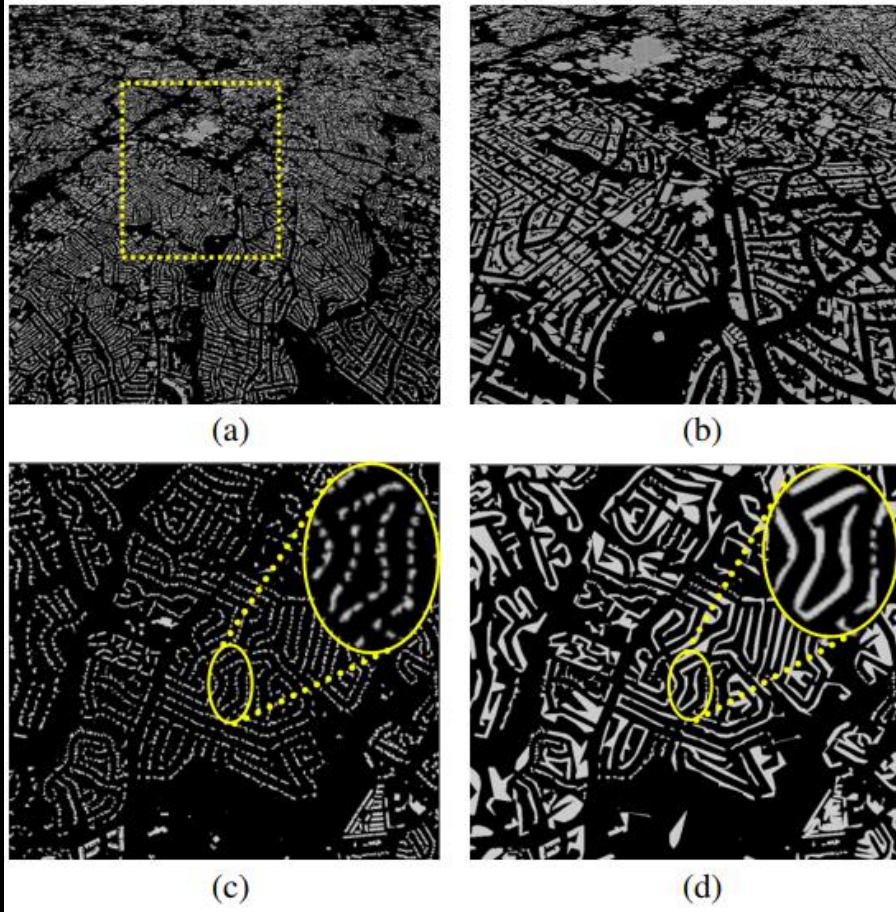
Kevin Lynch, The Image of the City, 1960

# Legibility Enhancement for InfoVis



Ingram, R., & Benford, S. (1995, October). Legibility enhancement for information visualisation. In Proceedings of the 6th conference on Visualization'95 (p. 209). IEEE Computer Society.

# Urban Simplification

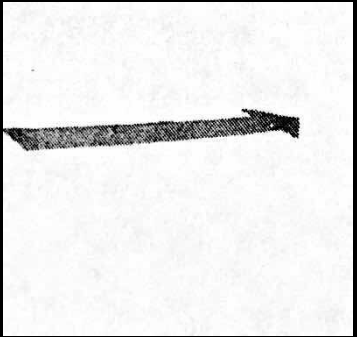


Chang, R., Wessel, G., Kosara, R., Sauda, E., & Ribarsky, W. (2007). Legible cities: Focus-dependent multi-resolution visualization of urban relationships. *IEEE transactions on visualization and computer graphics*, 13(6), 1169-1175.

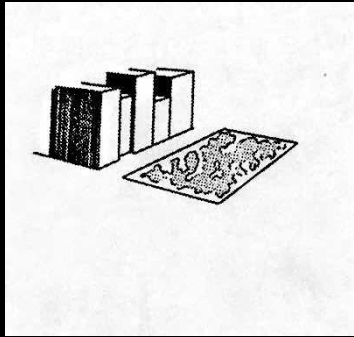


# Mental Maps of the City

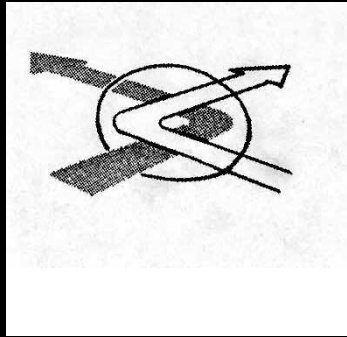
Kevin Lynch, *The Image of the City*, 1960



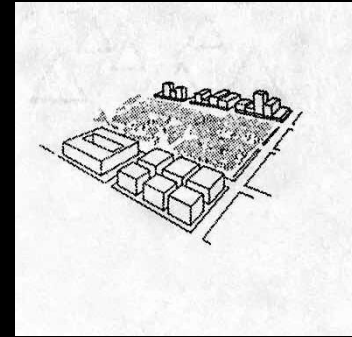
Paths



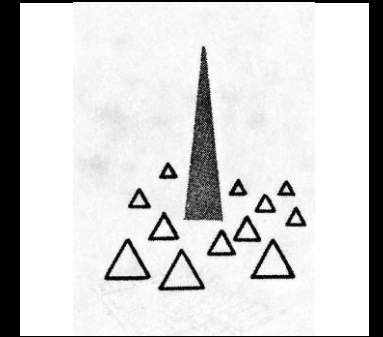
Edges



Nodes



Districts



Landmarks

Brantingham, P. L., & Brantingham, P. J. (1993). Nodes, paths and edges: Considerations on the complexity of crime and the physical environment. *Journal of Environmental Psychology*, 13(1), 3-28.



An aerial photograph of a coastal landscape. At the top, blue waves with white foam break onto a wide, light-brown sandy beach. Below the beach is a horizontal road with several cars. The bottom half of the image is a dense green forest. A semi-transparent text box is overlaid on the top left, and another semi-transparent box with the word 'Paths' is in the bottom right, next to a small white box containing a black arrow.

Channels along which a  
person moves

Roads, sidewalks, canals,  
transit

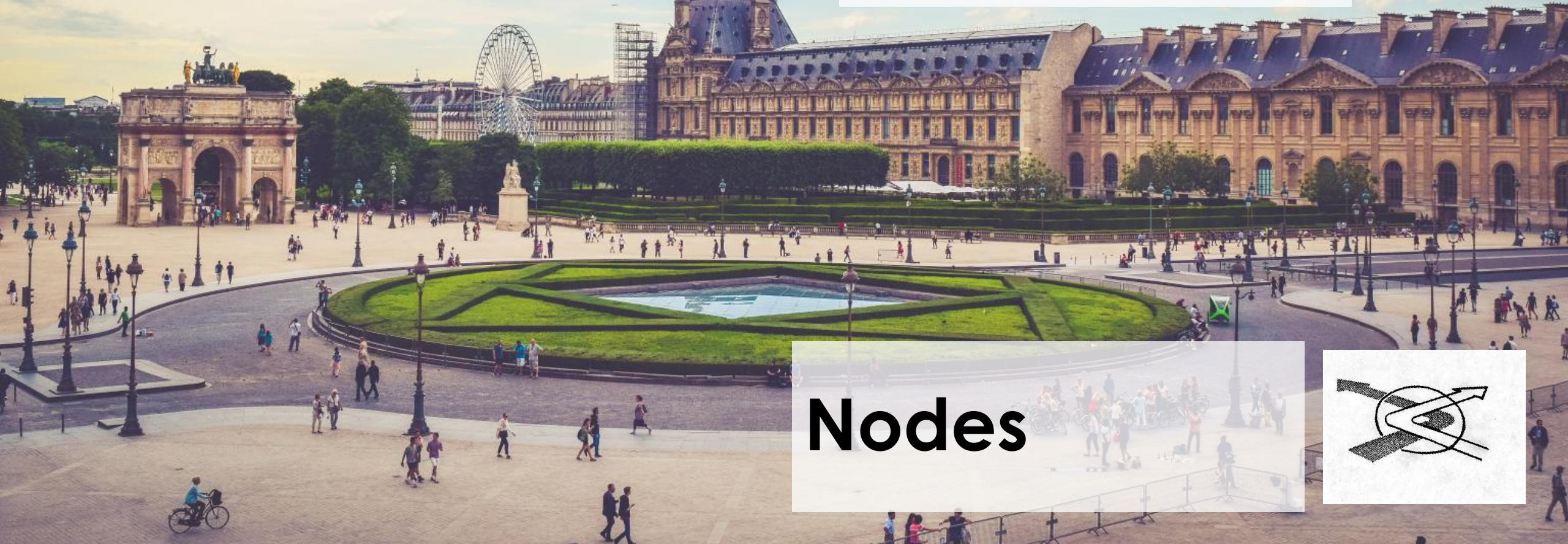
**Paths**



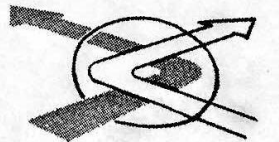


Strategic spots of intense  
community focus

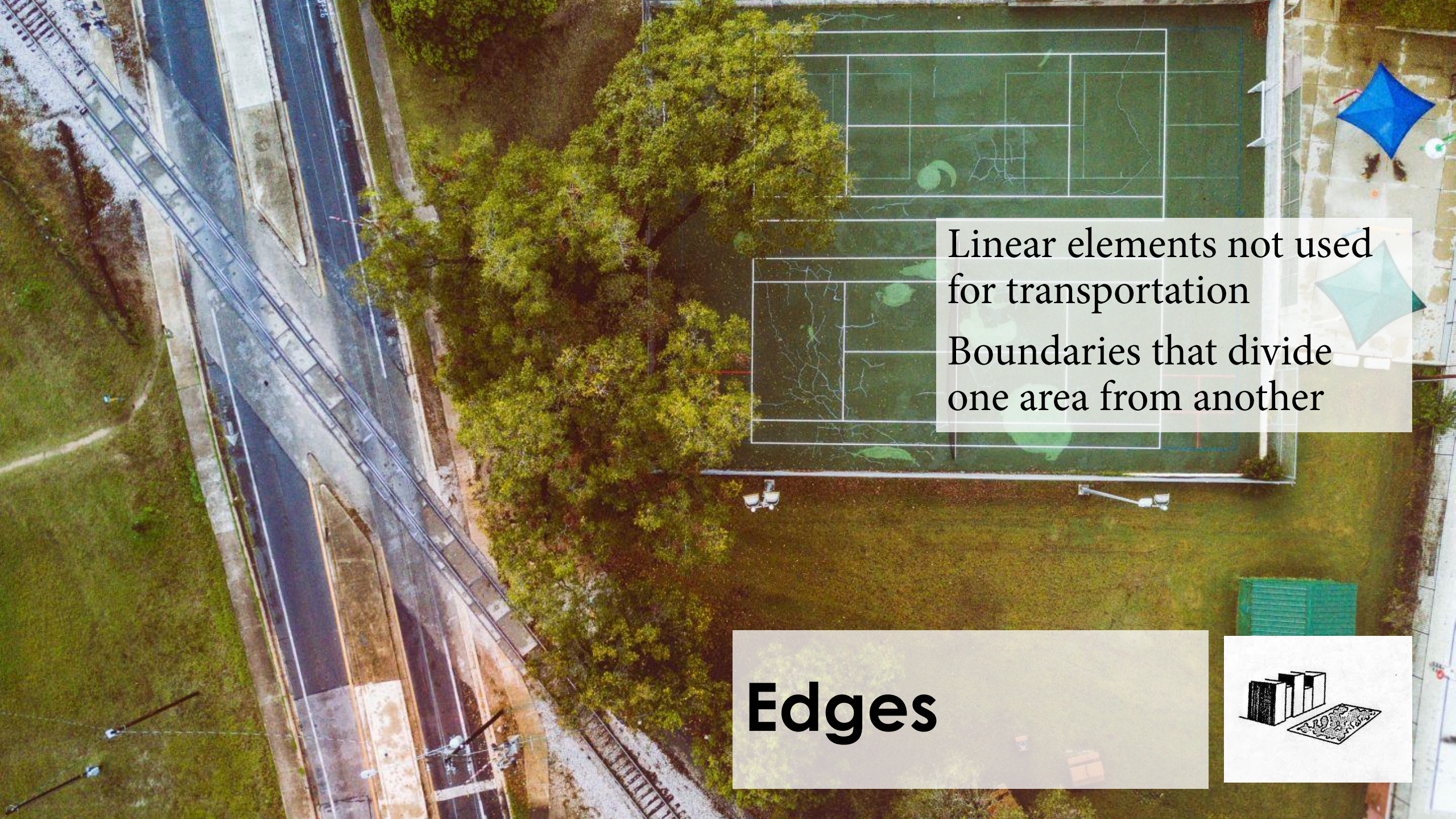
Junction of paths or  
concentration of features



**Nodes**



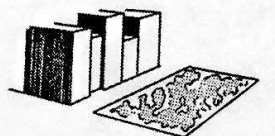




Linear elements not used  
for transportation

Boundaries that divide  
one area from another

**Edges**





# Nodes, Paths, and Edges

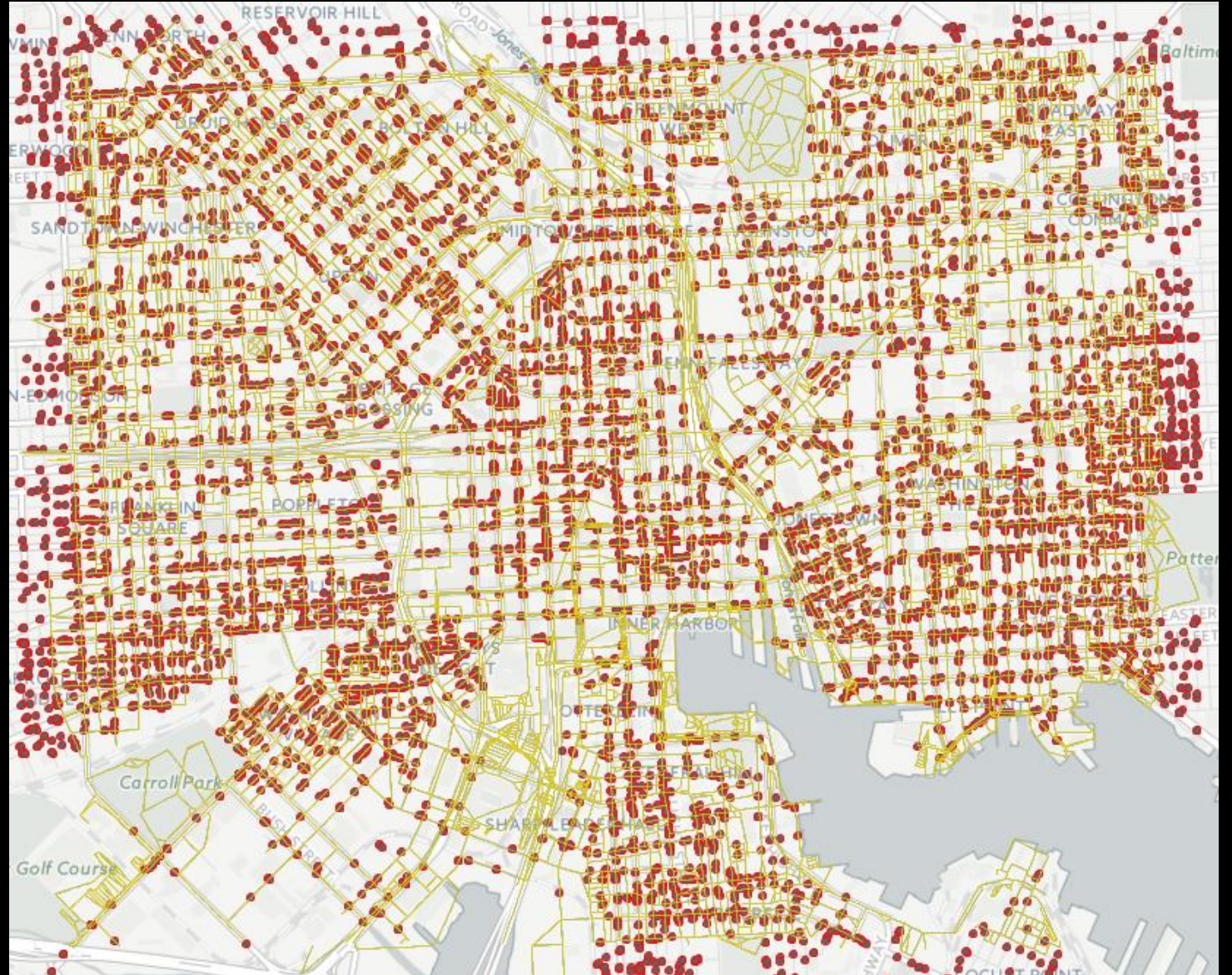
A map of a city street network, likely in New York City, showing a dense grid of streets. The map is overlaid with a network visualization where nodes (intersections) and edges (street segments) are highlighted in red and yellow. The network is more concentrated in the central and right portions of the map, with some blue lines indicating specific paths or boundaries. The background is a light gray map with street names and landmarks visible.

How do we use mental maps to analyze spatial data?



# UCR Crime Data 2015

- Major Violent and Non-Violent Crimes
- Collected for Atlanta, Baltimore, and Chicago





# Lixels

An aerial photograph of a coastal landscape. At the top, there are blue waves breaking onto a sandy beach. Below the beach is a strip of green vegetation. A horizontal road runs across the middle of the image. The road is highlighted with a thick yellow line. On either side of the road, there are red circles of varying sizes, connected to the road by thin red vertical lines. The circles are distributed across the entire width of the image, with some appearing above the road and some below. The background consists of dense green trees and vegetation.

Xie, Z., & Yan, J. (2008). Kernel density estimation of traffic accidents in a network space. *Computers, Environment and Urban Systems*, 32(5), 396-406.



# Network Kernel Density Estimation (KDE)





# Network KDE



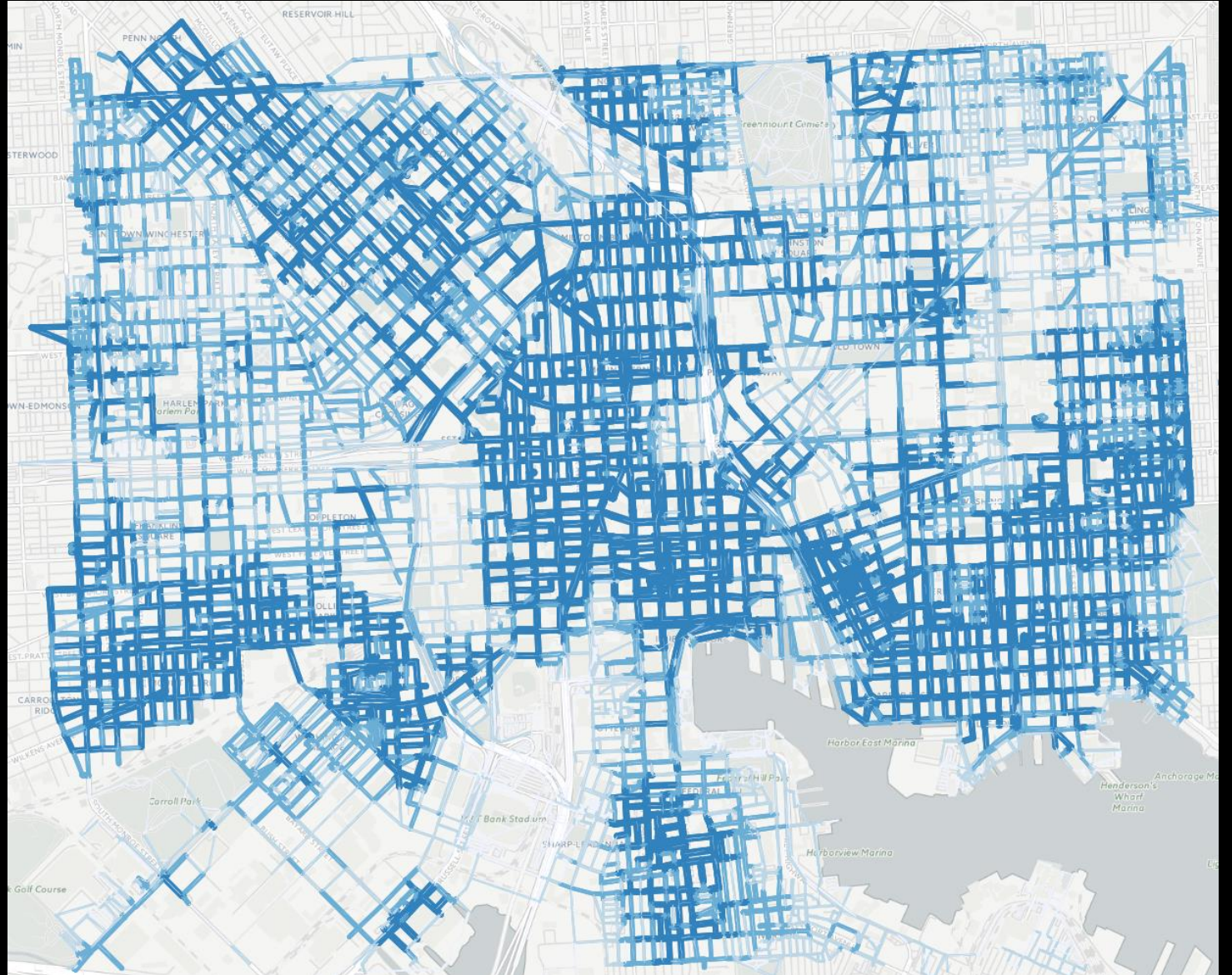


# Network KDE

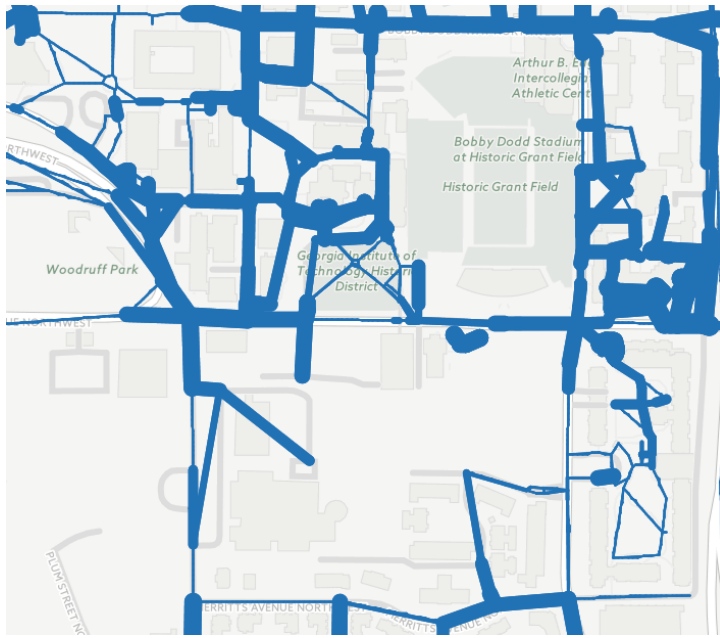




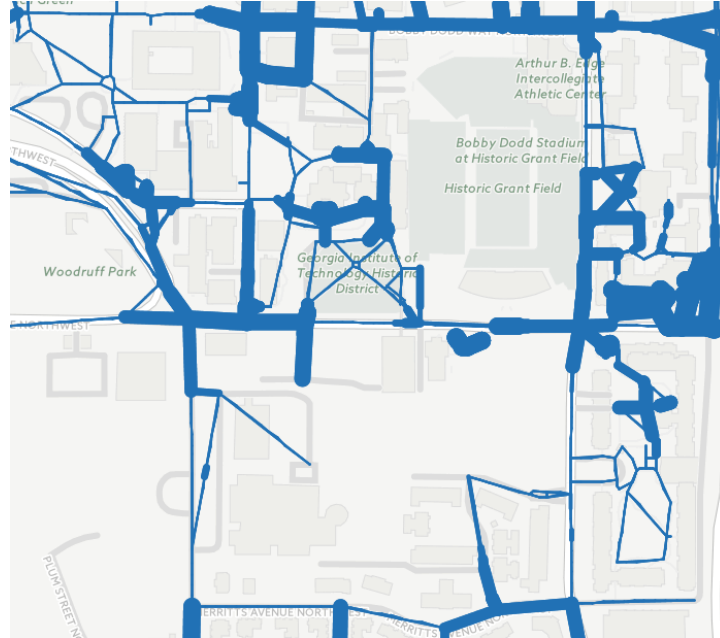
# Baltimore KDE



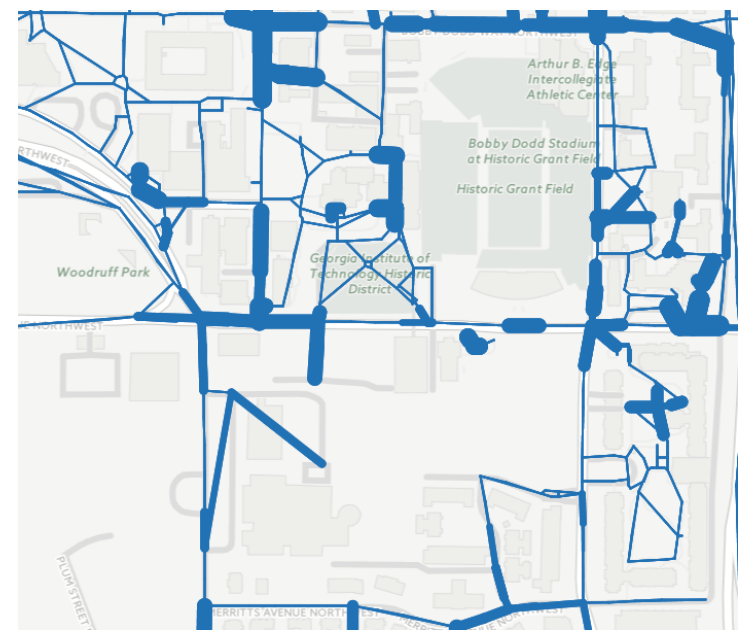




5m



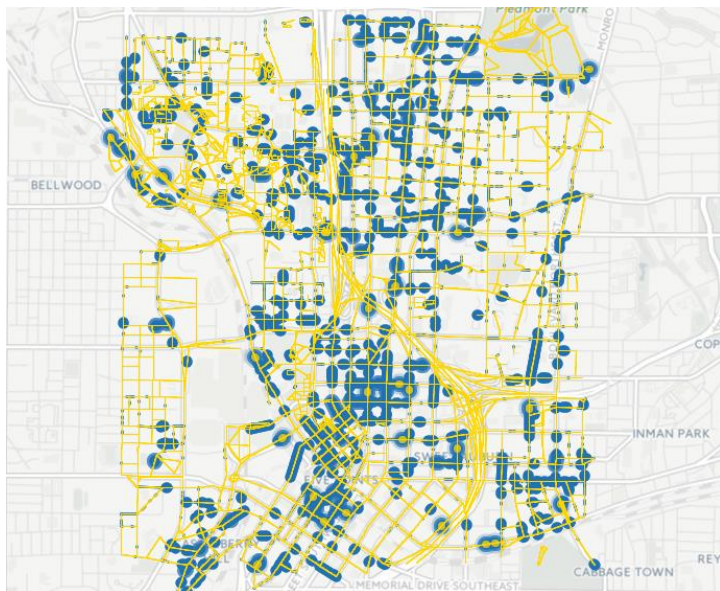
10m



25m

# Lixel Size





10m



100m



1000m

# Bandwidth



# Mental Map Features

## Nodes

Churches

Schools

## Edges

Railroads

Major Highways

Water Features



# Feature Effects for KDE

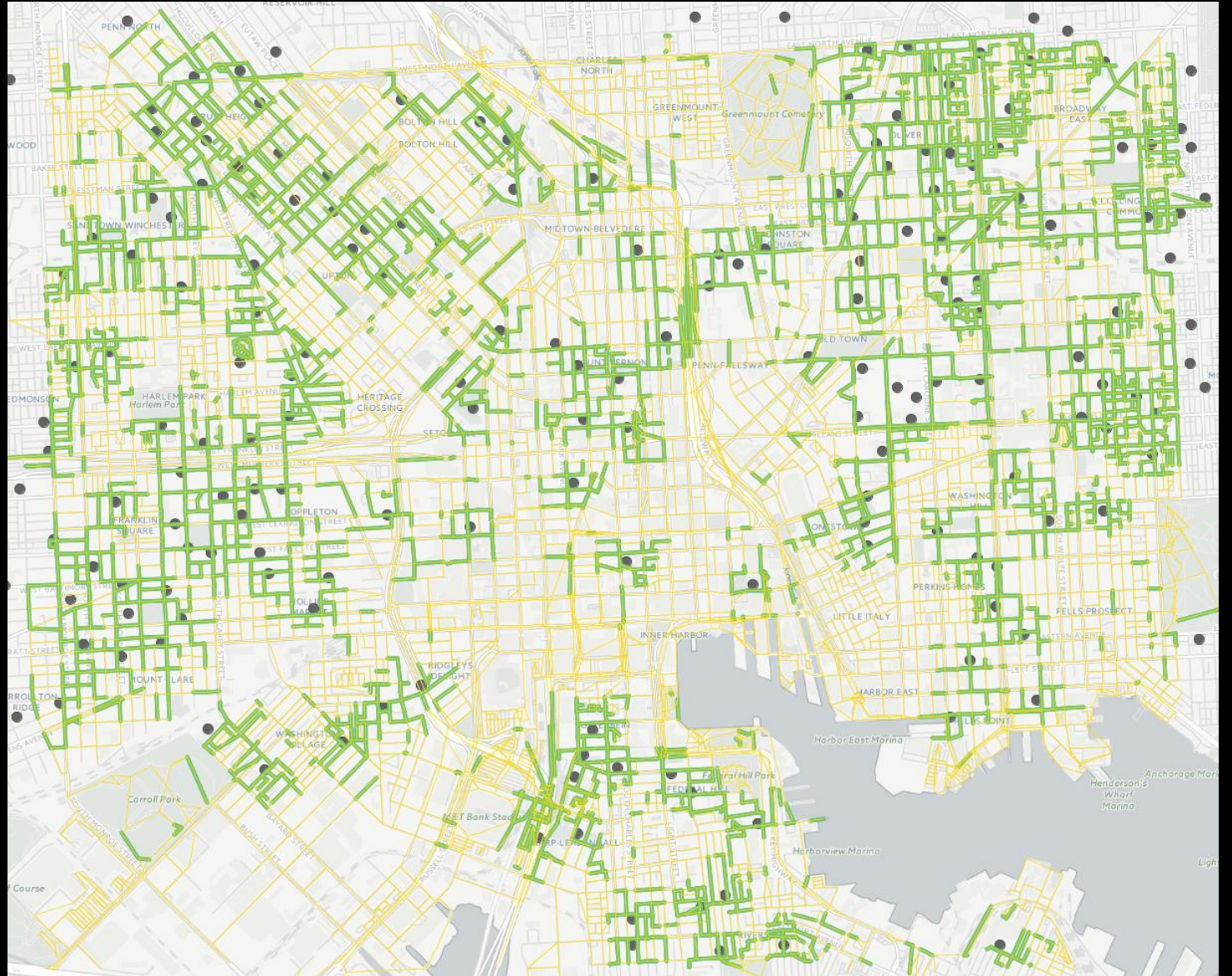
## Nodes

Amplify nearby lixels, increasing  
bandwidth





# Baltimore Nodes

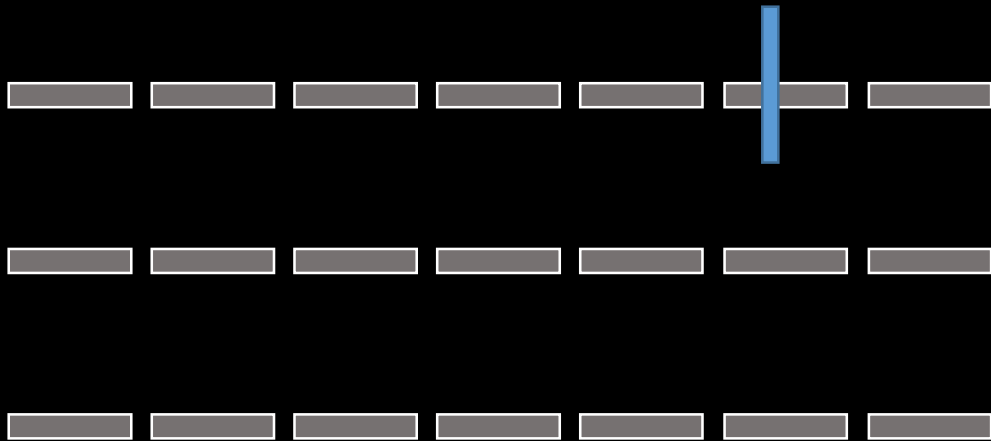




# Feature Effects for KDE

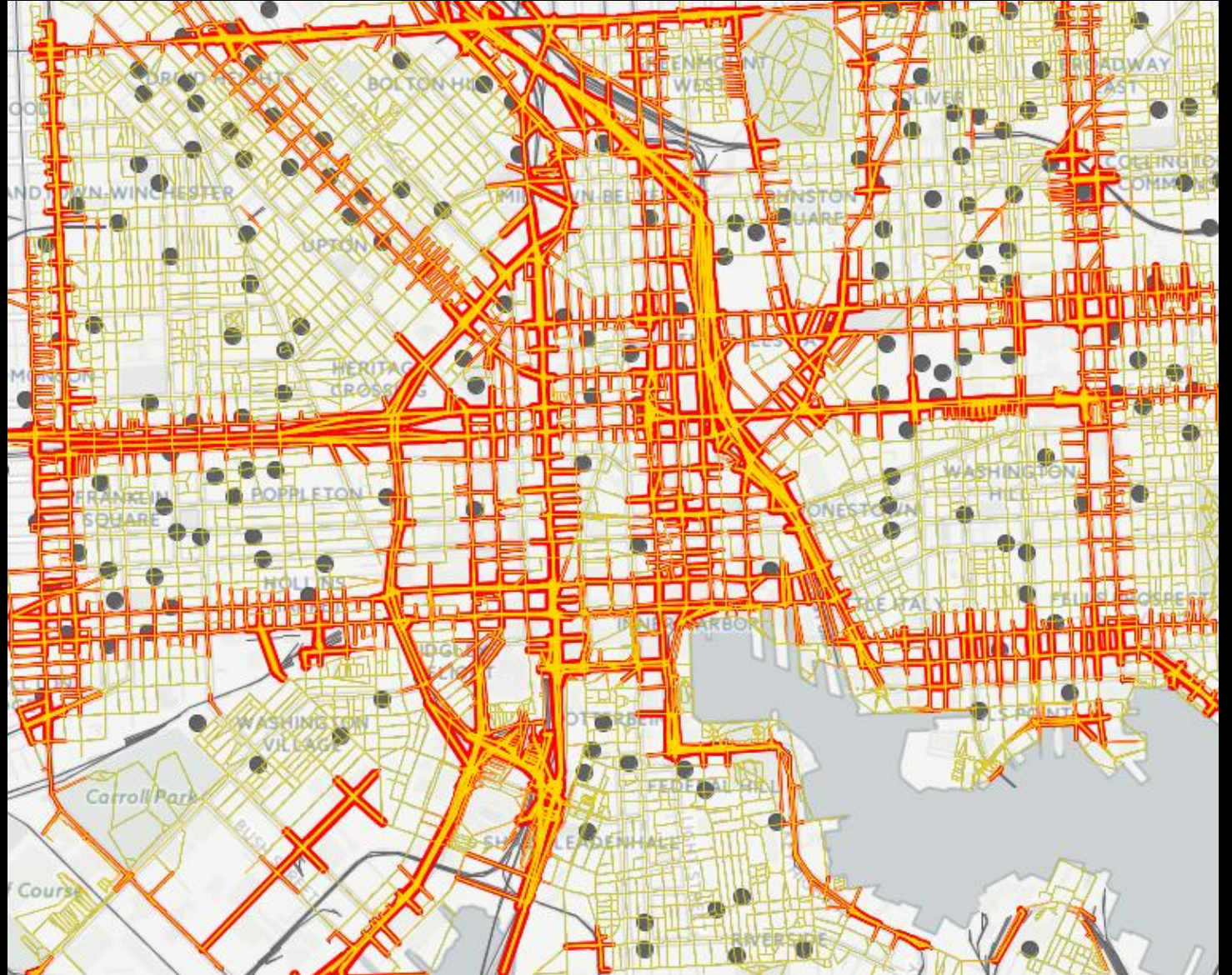
## Edges

Dampen nearby lixels, increasing length for path calculations





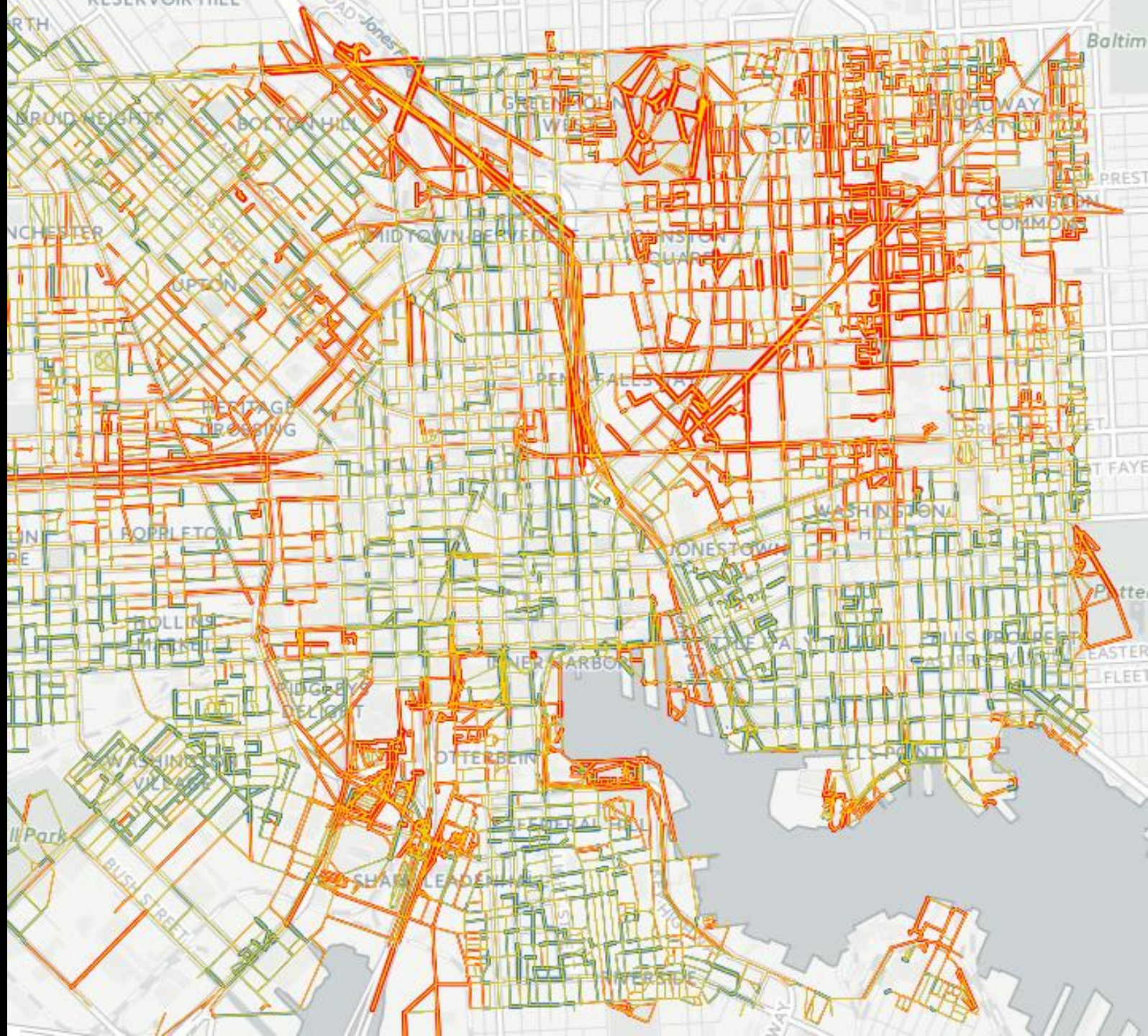
# Baltimore Edges





# Baltimore Comparison

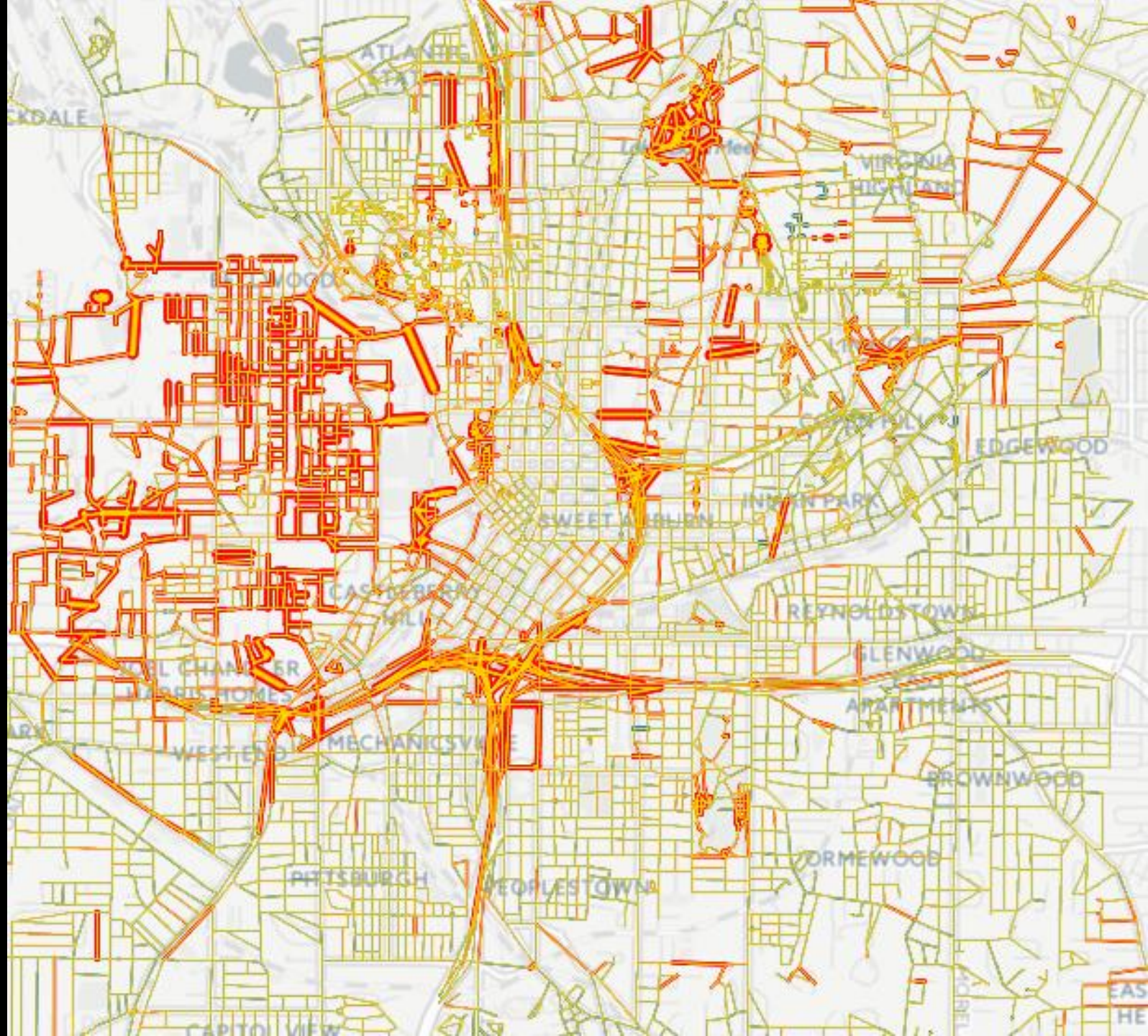
Largest disparity occurs with high mental map distributions in East Baltimore in the neighborhoods of Oliver, Dunbar-Broadway, and Middle East





# Atlanta Comparison

Greatest disparity between the mental map and the raw data occurs around West Midtown and the intersection between the major highways in the center of the map near downtown

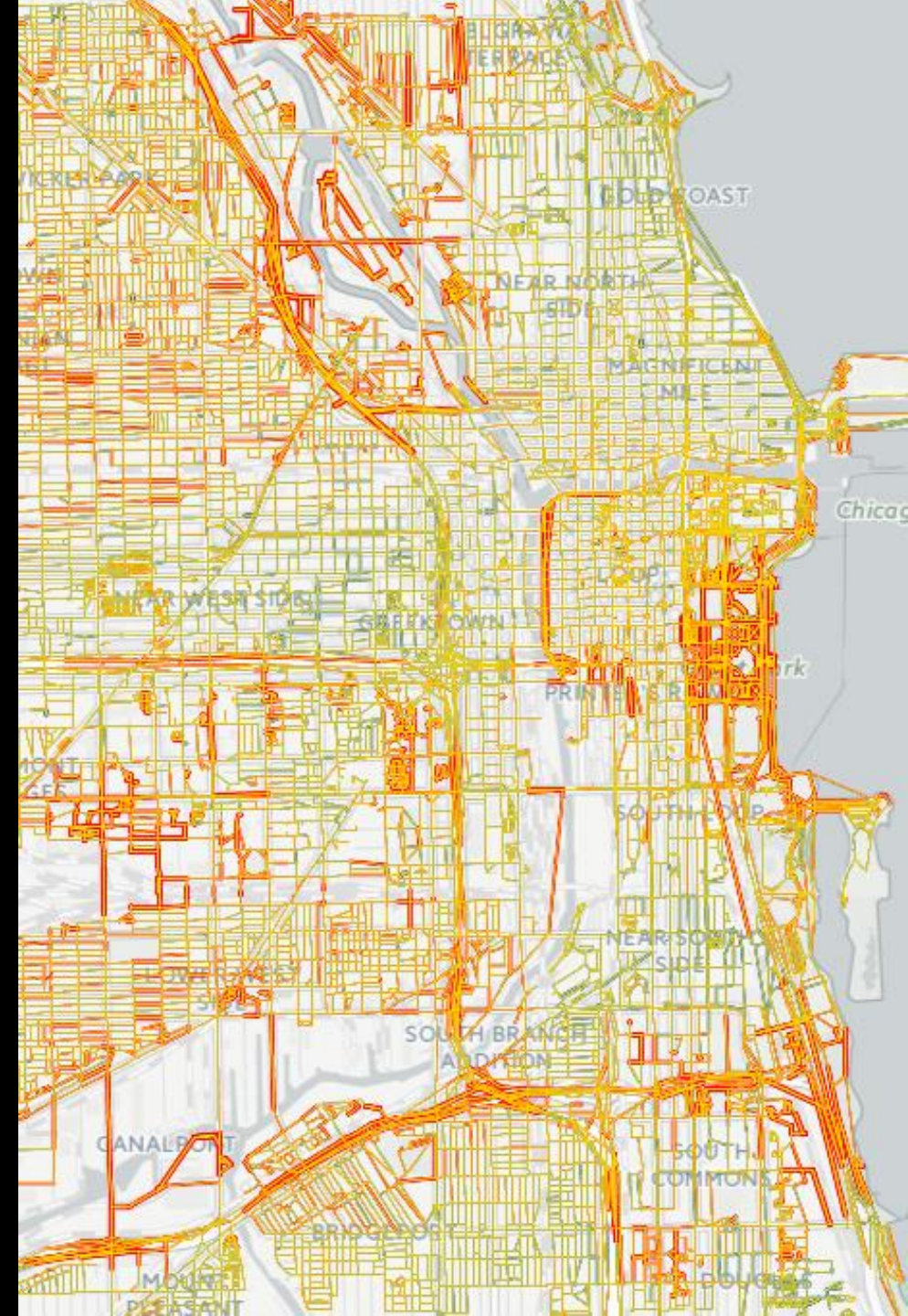




# Chicago Comparison

Disparities exist on the edge between the Loop and South Loop neighborhood

To the south, neighborhoods along the lake and to the southwest along the highway also have an increase, as well as the northern neighborhoods around Goose Island





# Conclusions

- We proposed a novel technique for applying mental maps based on nodes, paths, and edges to spatial data
- We provided preliminary findings from the application of our technique to property crime data in three US cities



# Future Work

- Collect first-hand sketches and mental map data from citizens in Atlanta
- Work with local neighborhood leadership to analyze spatial data in the context of mental maps
- Following the Cardiff Model: Work with health services, police, and local government in Atlanta to prevent violence



# Questions?



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