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UPO UNIVERSITÀ DEL PIEMONTE ORIENTALE

UNIVERSITÀ DI TORINO

COMPLEX NETWORKS

A Complex Networks Approach to Evaluate the 15-Minute City Paradigm and Urban Segregation

Exploring Urban Accessibility, Connectivity, and Segregation Through Network Science

COMPLEX NETWORKS 2024

The 13th International Conference on Complex Networks and their Applications

10 - 12 December, 2024

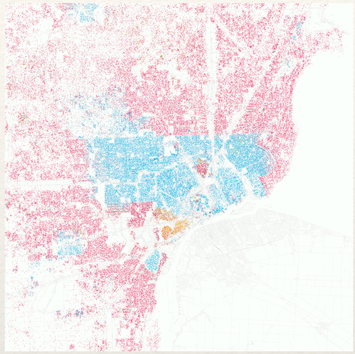
Istanbul, Turkey

Bright and dark sides of the "15 minute" city



- **Walkable** and **accessible** cities:
  everything you *really* need is **close**:
  - healthcare
  - education
  - public transportation
  - *water supply*
  - *electricity*
  - arts, museums, theaters
  - parks
  - shopping
  - (work)

- Self-sufficiency can accelerate urban **segregation**:
  - no cars: you are dependent on public transport for medium-long trips
  - smaller urban areas self-organize and are governed by homophily
  - but larger districts are more heterogeneous in terms of social class, education, income



Is the '15-minute city' idea a utopian ideal or dystopian nightmare?

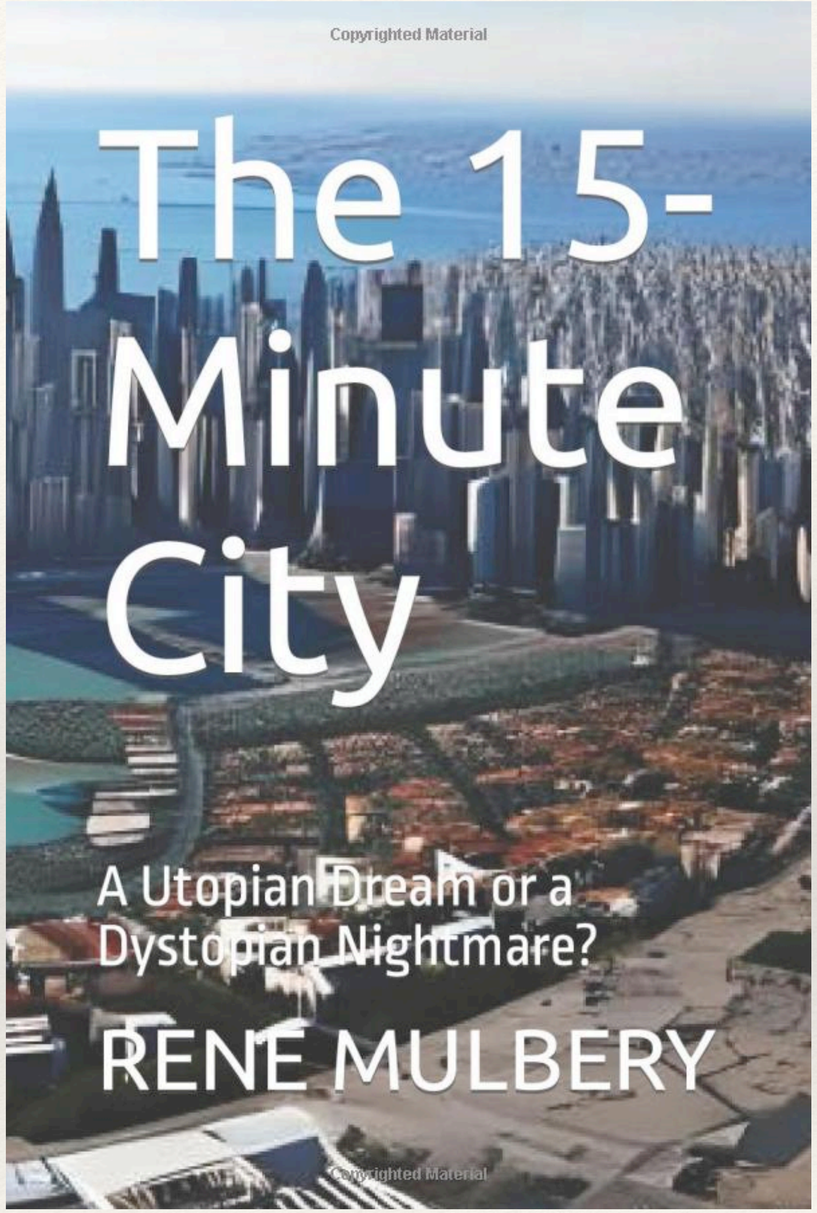
AP
By Philip Marcelo

3 Mar, 2023 03:46 AM 5 mins to read

15-minute cities: Path to dystopia or storm in a side street?

Urban planners and transportation professionals will need to address wild accusations about the motives behind 15-minute cities - and relevant criticisms too - if the concept is to scale to its potential

Air Quality & Weather Systems / June 5, 2023



Research questions

1. What patterns emerge when using complex network measures?
2. How does accessibility relate to urban connectivity and segregation?
3. Can I use accessibility and connectivity metrics for comparative purposes at different scales (i.e., cities, districts, census areas, residential addresses)?

Methods

- Data sources: OpenStreetMap, GTFS data, and Census data
  - Socio-demographic data when available
- Network construction (given a city c):
  - We map every **PoI** (including bus/metro/train stops) and every **residential address** to the closest intersection
  - **nodes**: intersections; **links**: streets segments
    weights: distance and transit time
  - **Pedestrian networks** for calculating accessibility to services and amenities
    $G_c^{\text{ped}} = (N_c, E_c)$
  - **Urban transport networks** for city scale connectivity
    $G_c^{\text{urb}} = (N_c, L_c)$

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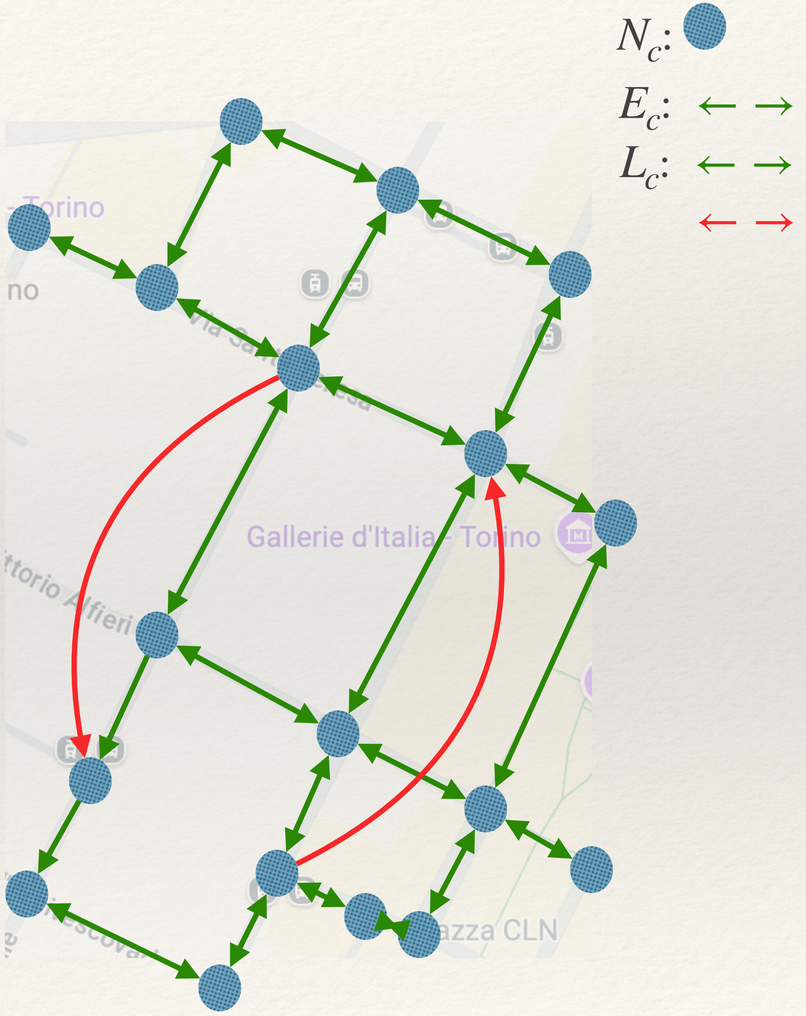

Accessibility Metrics

- Given $n \in N_c$
  - PoI-Proximity $\mathscr{P}(n) = t$
  - PoI-Density $\mathscr{D}(n, t)$
  - PoI-Entropy $\mathscr{E}(n, t)$
  - PoI-Accessibility $\mathscr{A}(n, t)$

PoI's categories:

Mobility

Active Living

Entertainment

Food Choices

Community

Education

Health and Well-being

PoI's categories as in: Nicoletti, L., et al. (2023). Disadvantaged communities have lower access to urban infrastructure. Environment and Planning B: Urban Analytics and City Science, 50(3), 831-849.

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$\mathscr{P}(n) = t$: at least one PoI for each category is within t minutes walk

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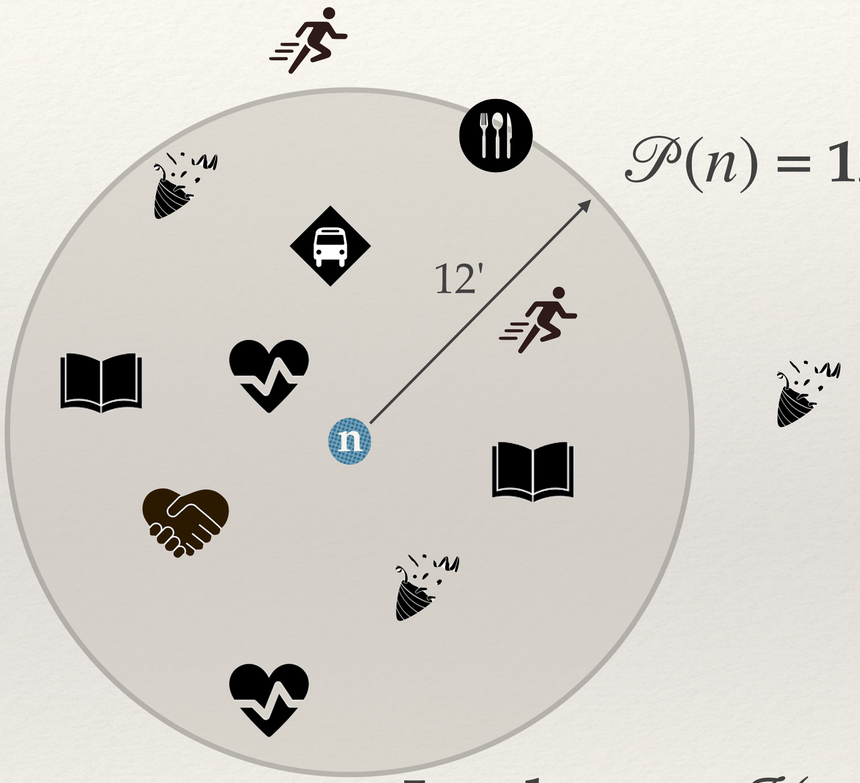

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$\mathscr{P}(n) = 12$: at least one PoI for each category is within *12* minutes walk

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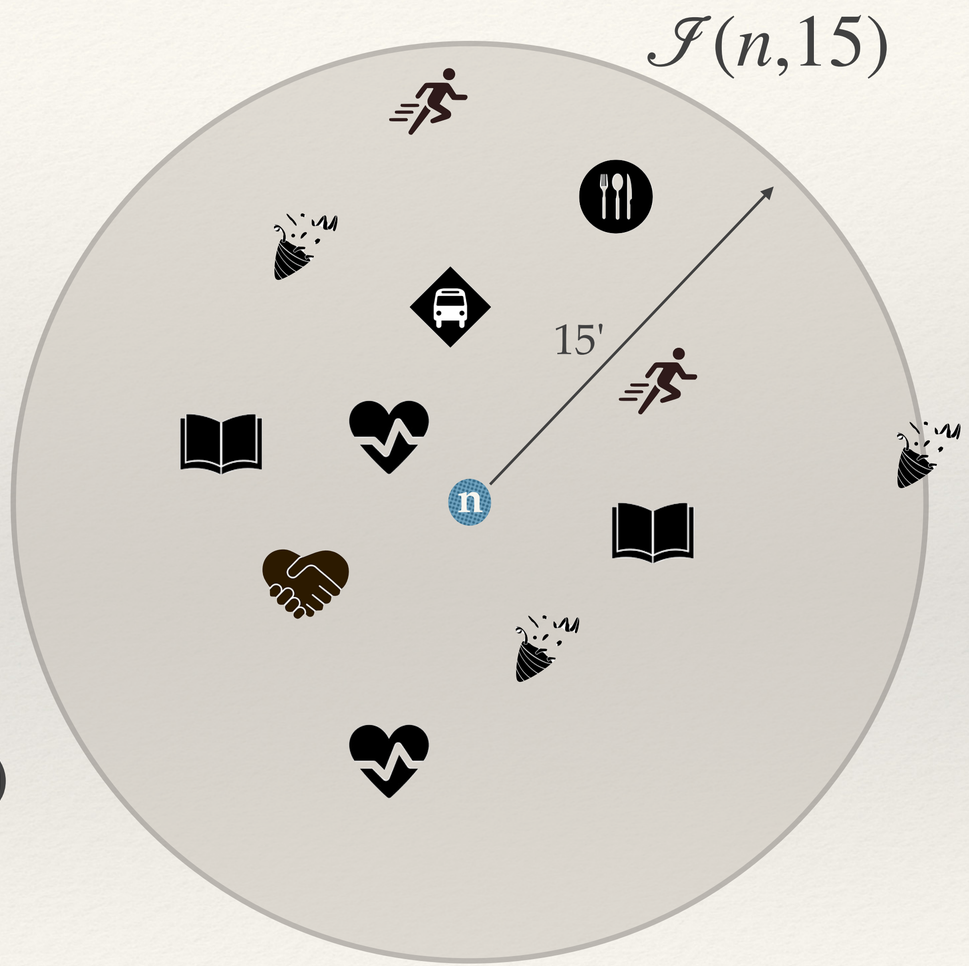

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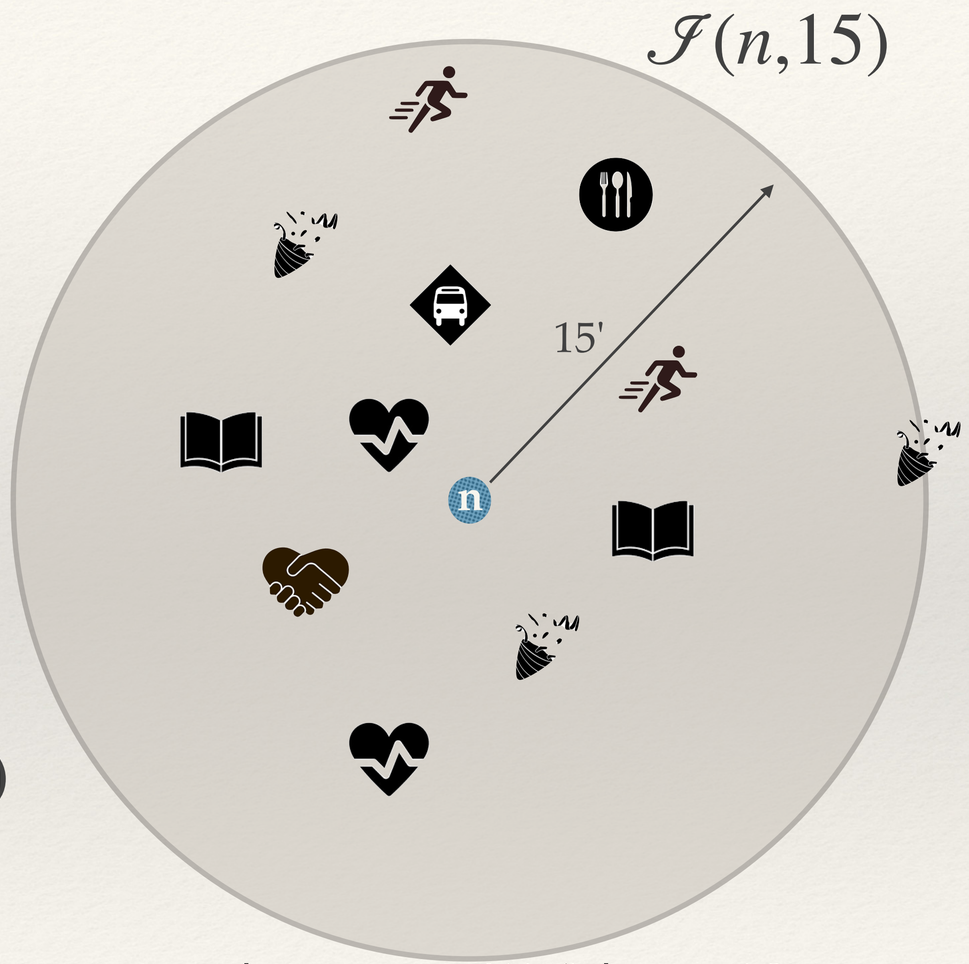

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$\mathscr{P}(n) = 12$

$$\mathscr{D}(n,15) = \frac{|\text{PoIs} \in \mathscr{I}(15)|}{\text{Area of} \mathscr{I}(n,15)} = \frac{12}{7\text{km}^2} = 1.71$$

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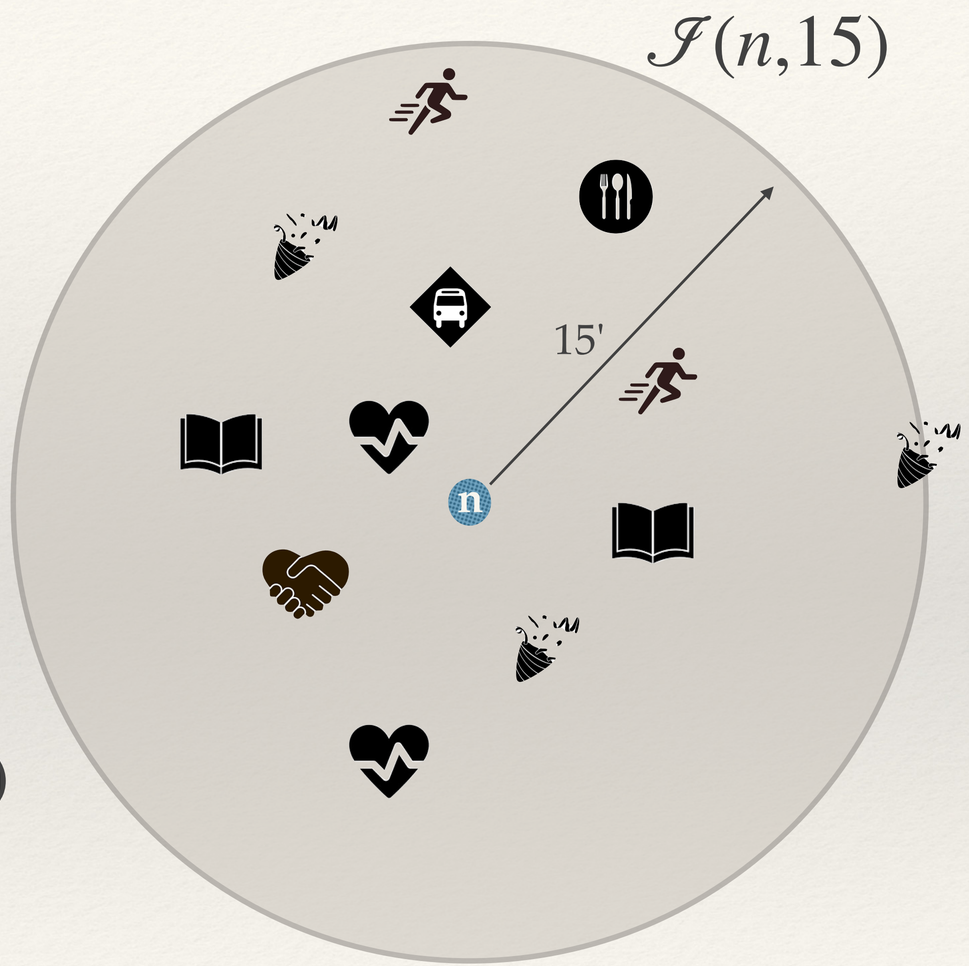

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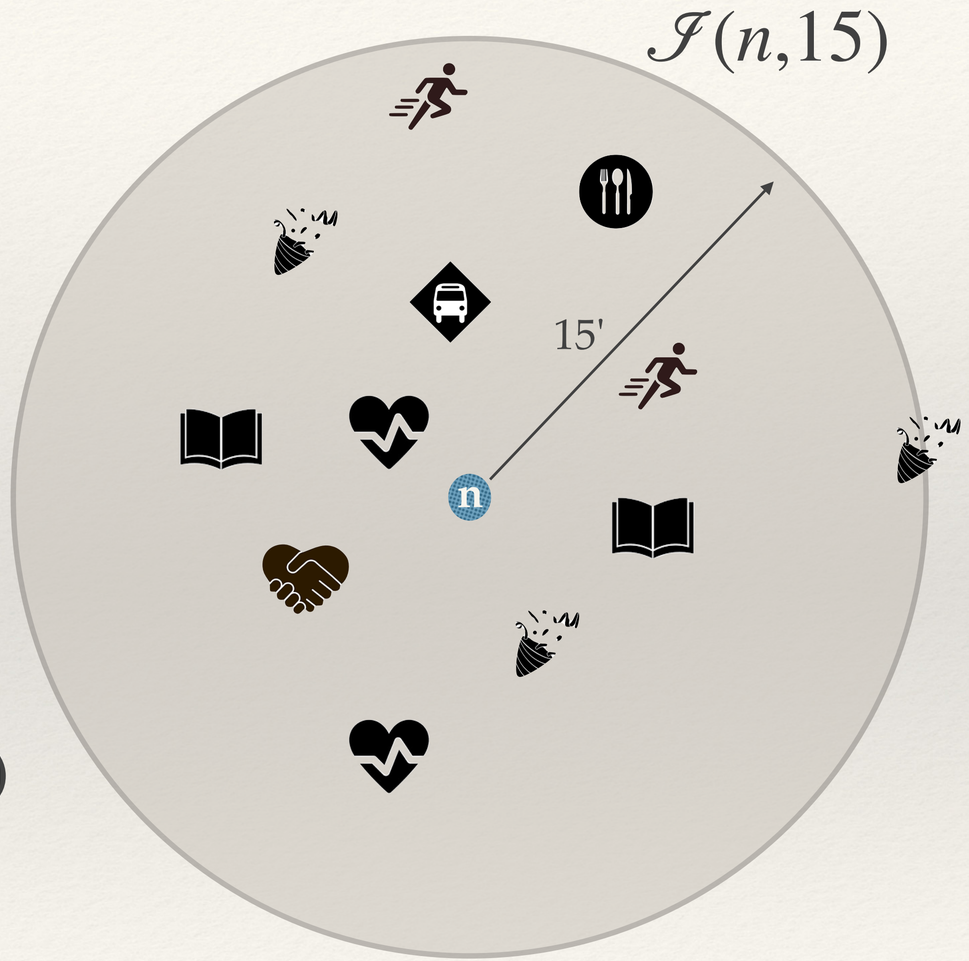

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$\mathscr{E}(n,15)$ = the entropy of the distribution of PoIs' categories within $\mathscr{I}(n,15) = 2.69$

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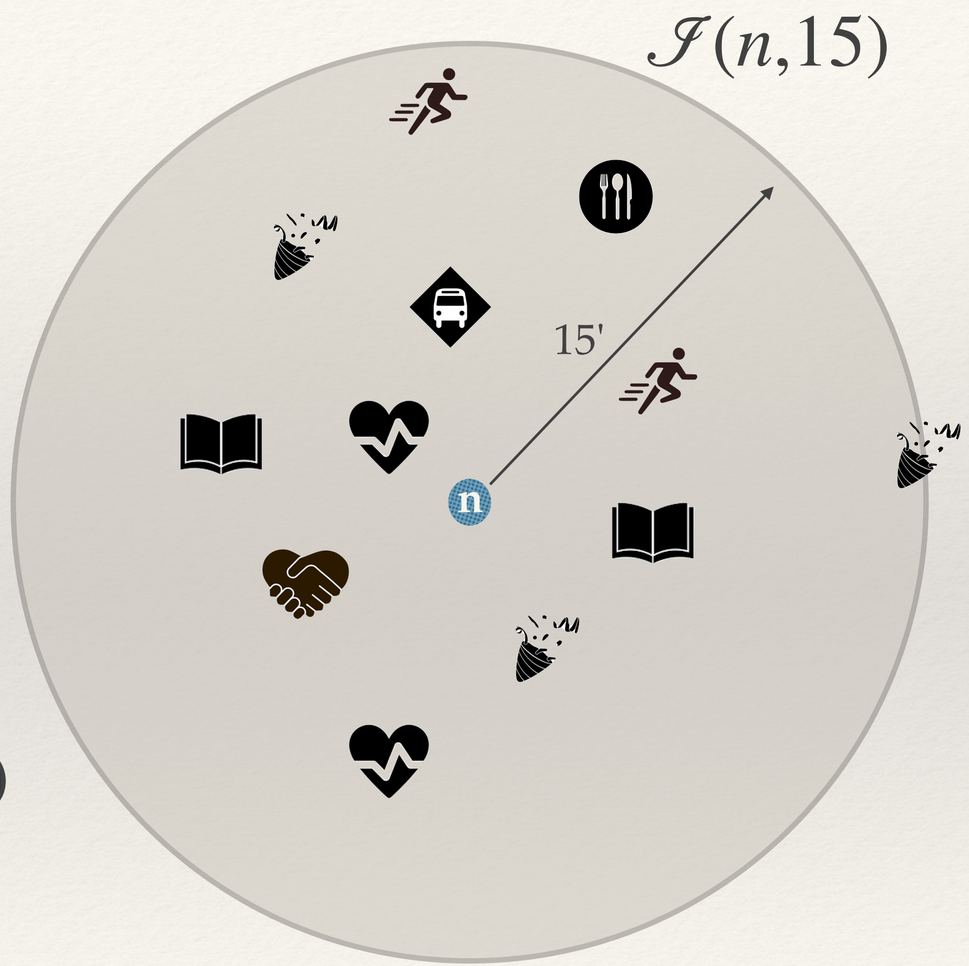

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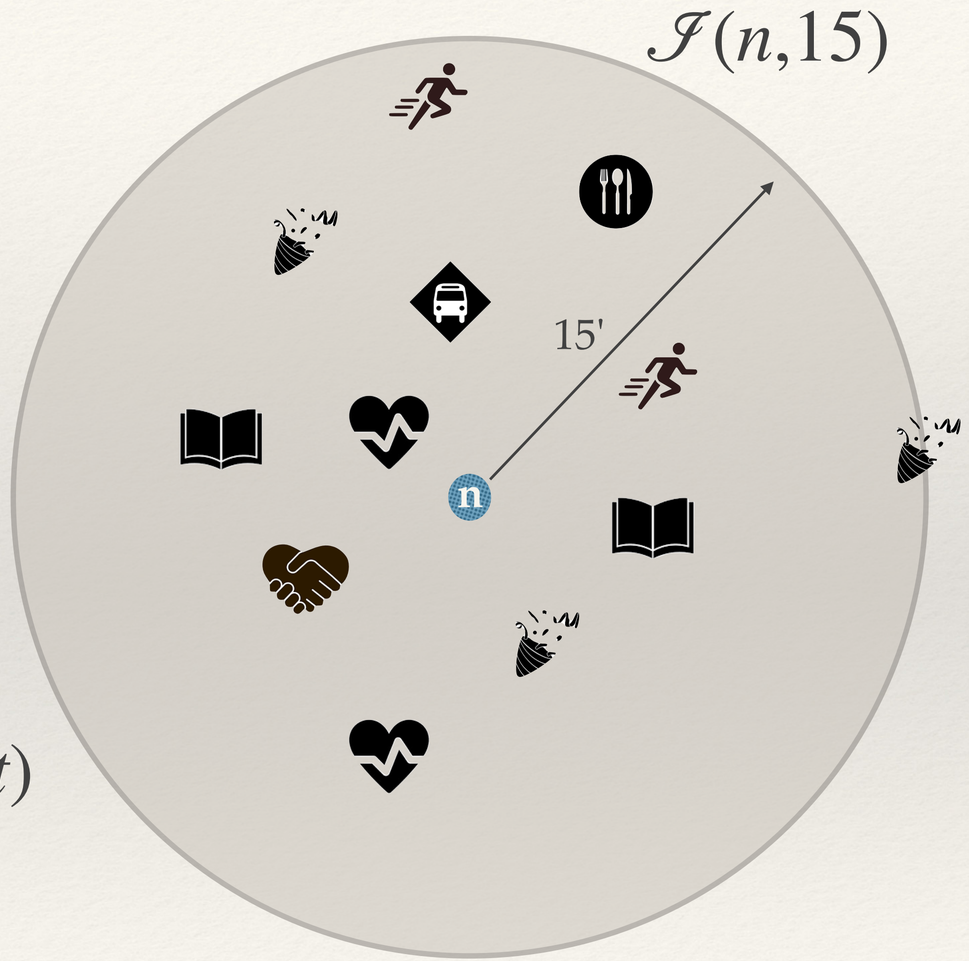

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$$\mathscr{A}(n,t) = w_1\mathscr{P}'(n) + w_2\mathscr{D}'(n,t) + w_3\mathscr{E}'(n,t)$$ e.g., $w_1 = w_2 = w_3 = 1/3$, and $t = 15$

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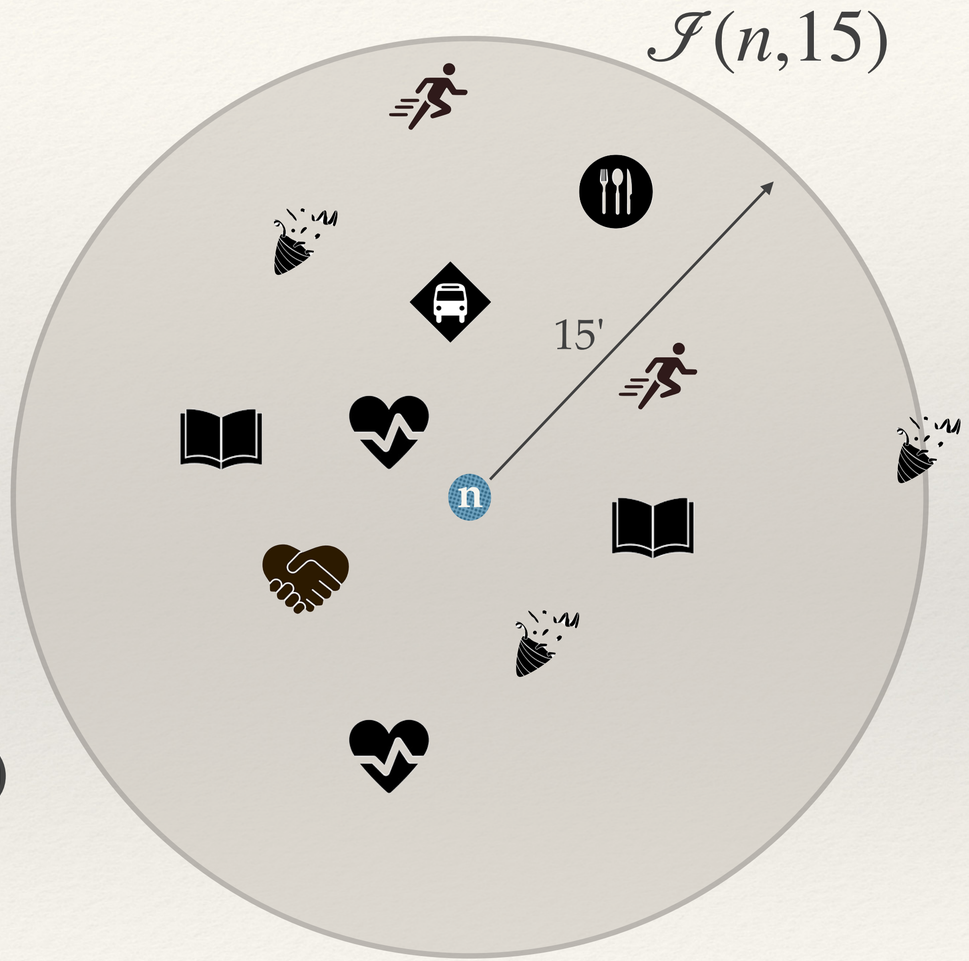

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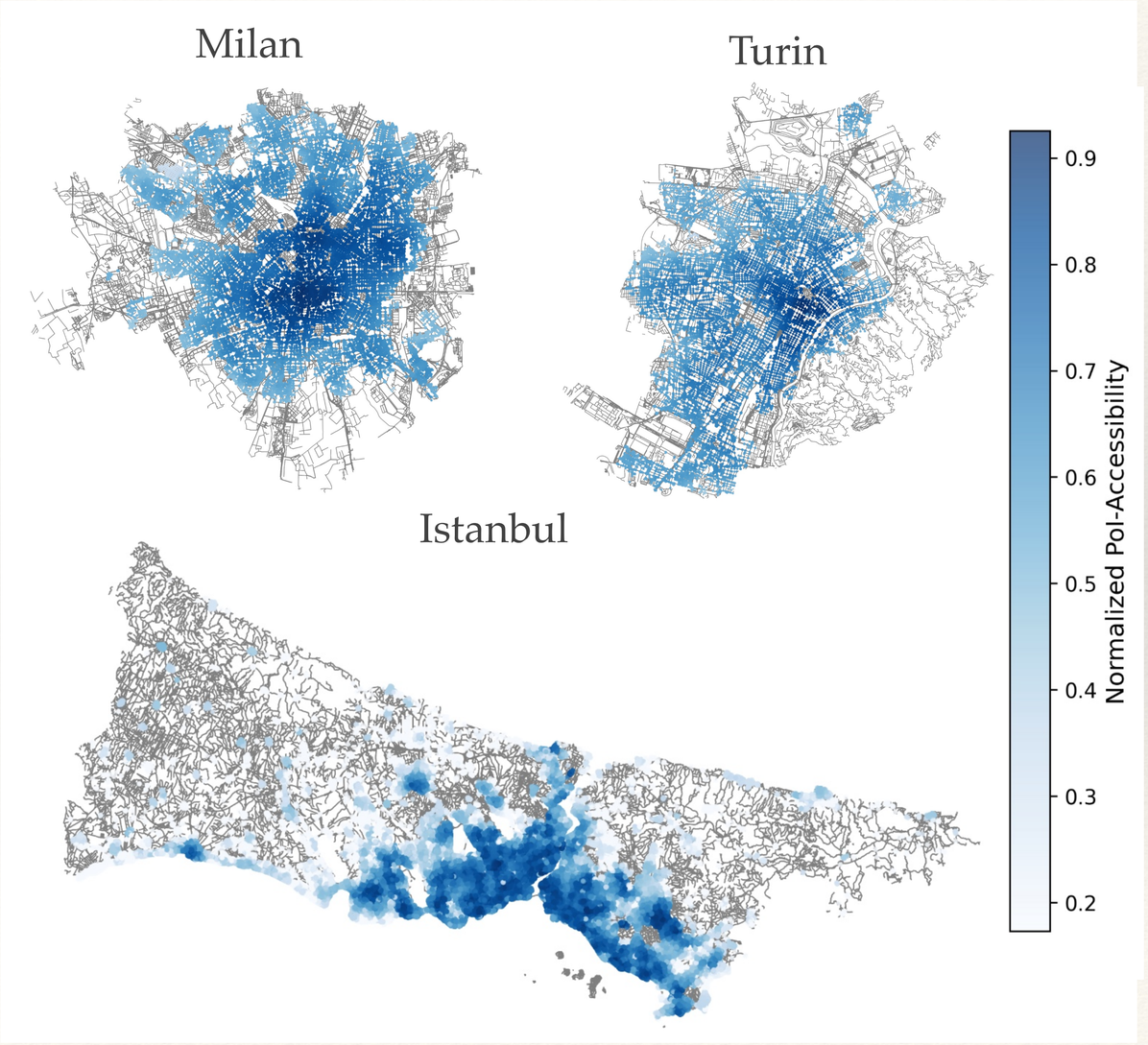
$\mathscr{A}(n,15) \in [0,1]$

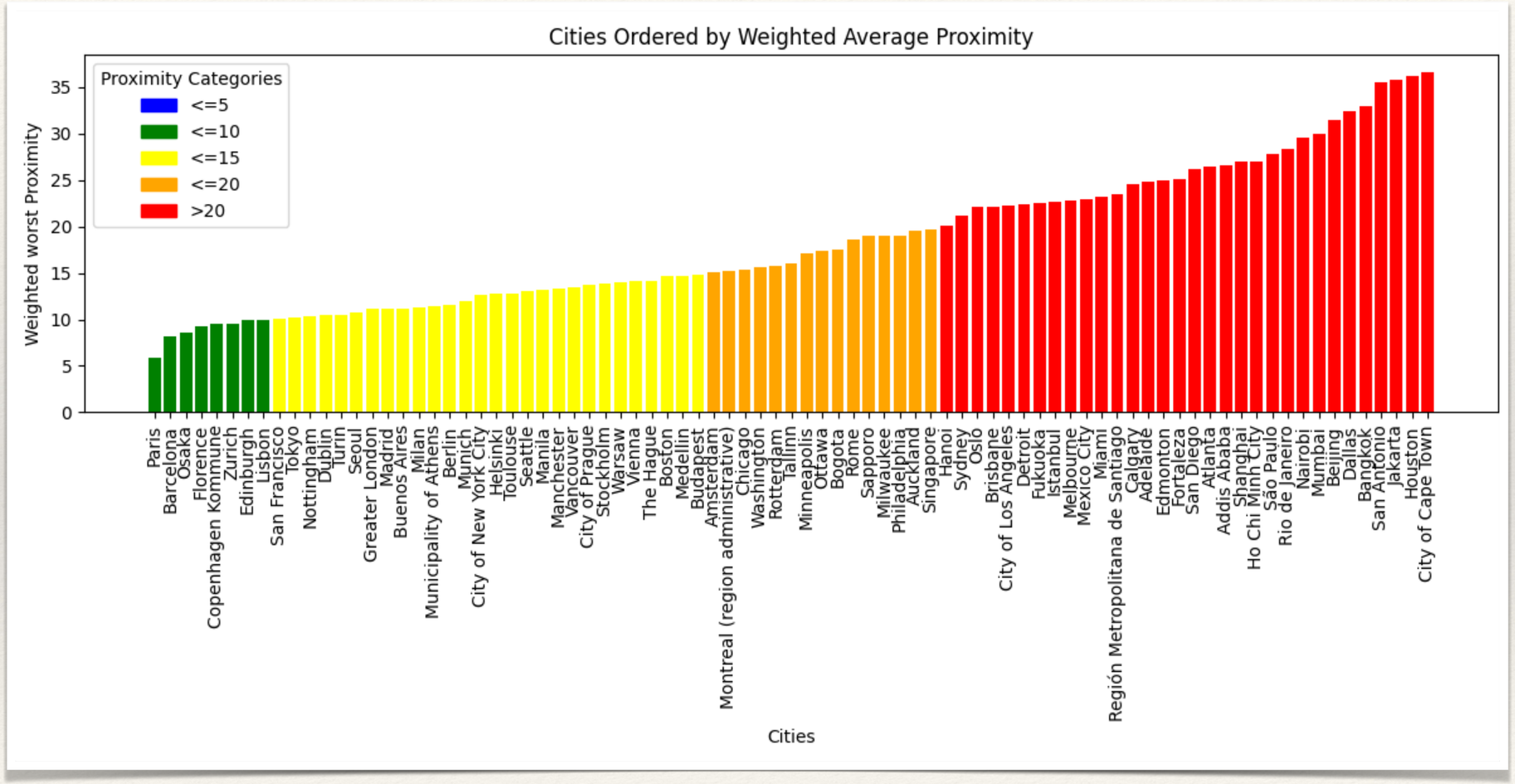
Accessibility metrics at different scales

- All the above metrics can be calculated for every node $n \in N_c$
- RQ1: we can calculate a range of metrics' statistics:
  - scales: census area, network clusters (e.g., by infomap), administrative districts, the city as whole
  - statistics: min, max, average, std, …
  - other:
    - how much people live in residential addresses with $\mathscr{P}(n) = t$?
    - Do income/education/immigration rate correlate with accessibility?
    - …



Comparing and ranking cities

- High correlation (Kendall's $\tau > 0.6$) with other rankings based on variants of this proximity measure [1, 2]



[1] Nicoletti, L., et al. (2023). Disadvantaged communities have lower access to urban infrastructure. Environment and Planning B: Urban Analytics and City Science, 50(3), 831-849.
[2] Bruno, M., et al. A universal framework for inclusive 15-minute cities. Nat Cities 1, 633–641 (2024).

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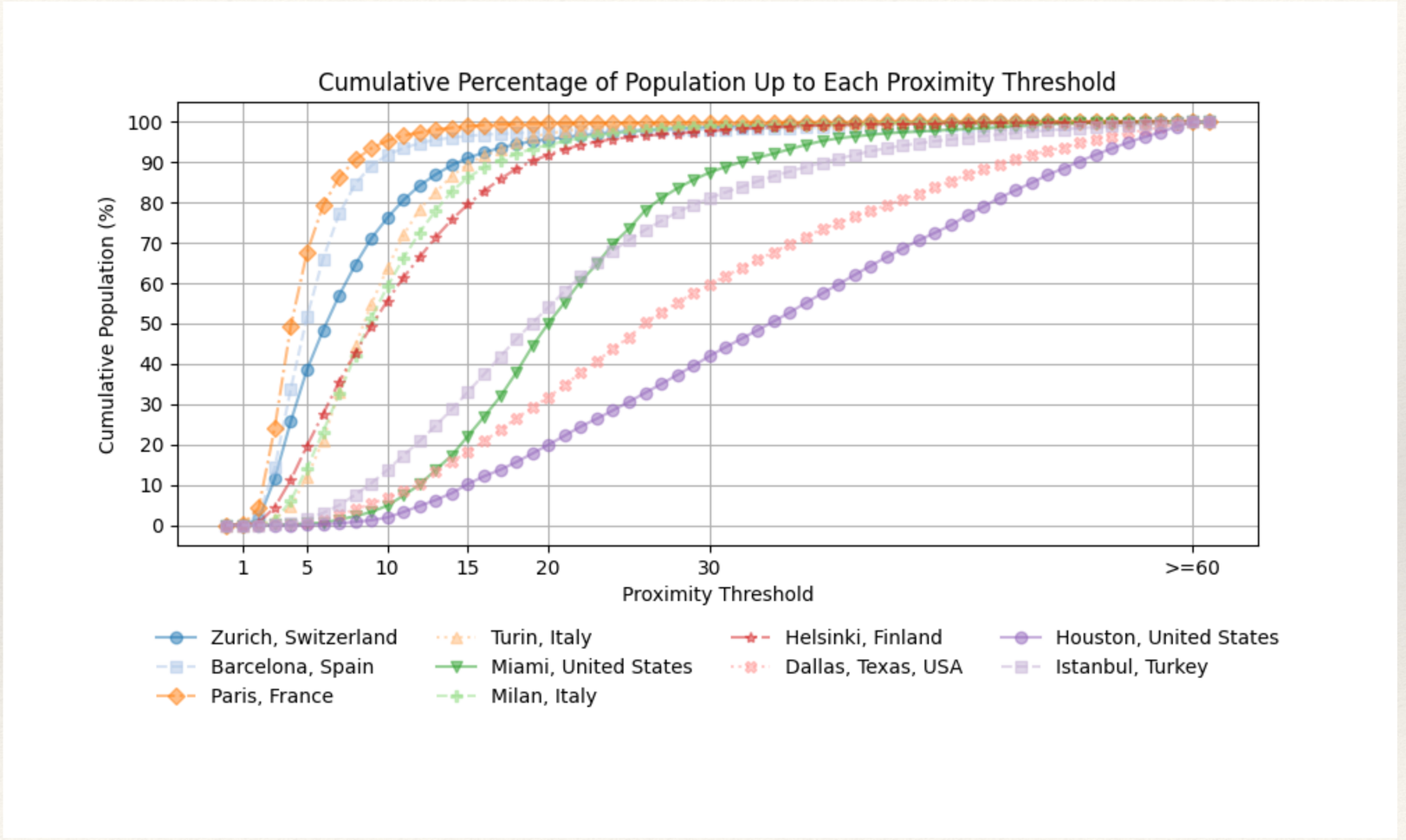
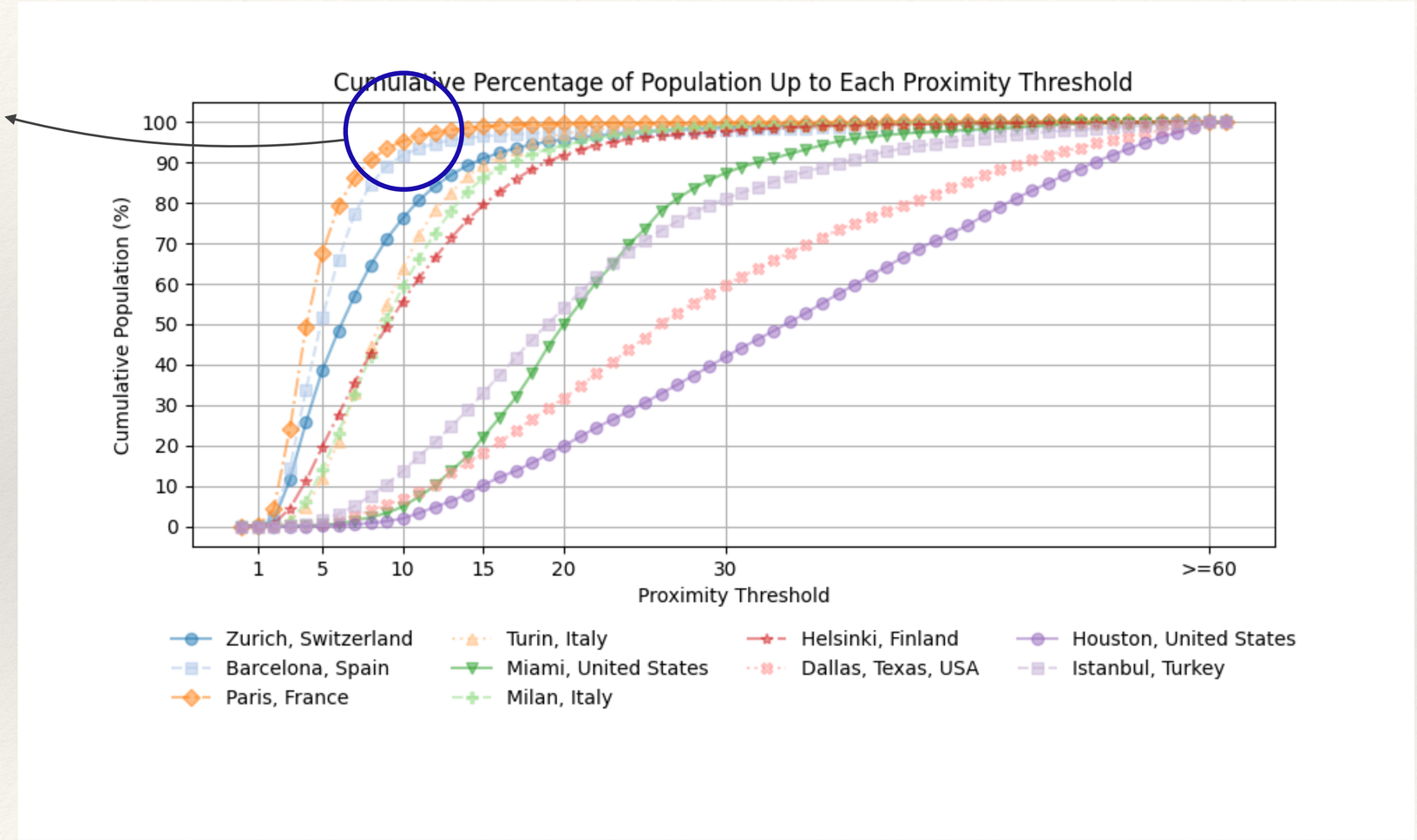


Comparing and ranking cities

$> 90\%$ of Paris citizens live in places with $\mathscr{P}(n) \leq 10$!



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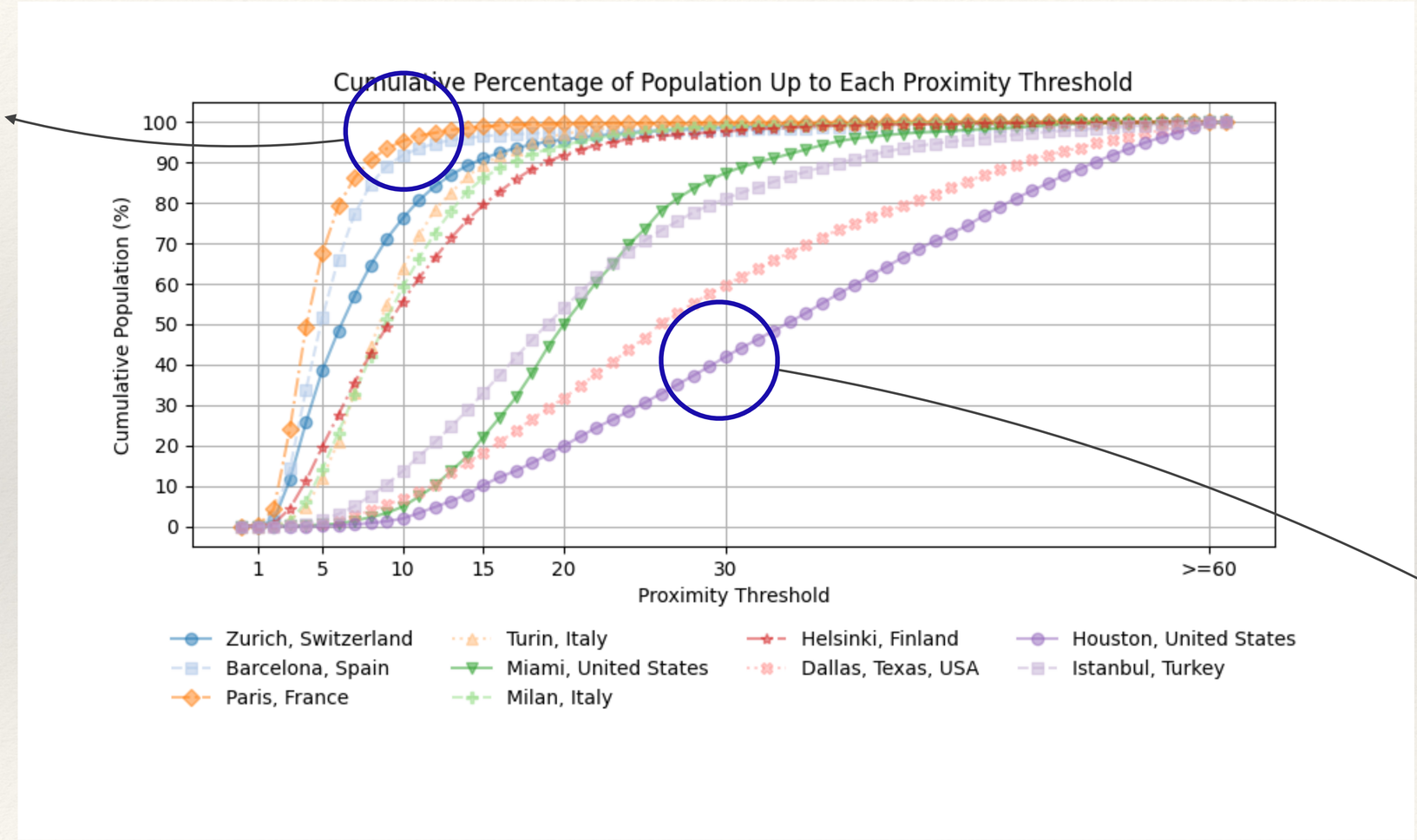
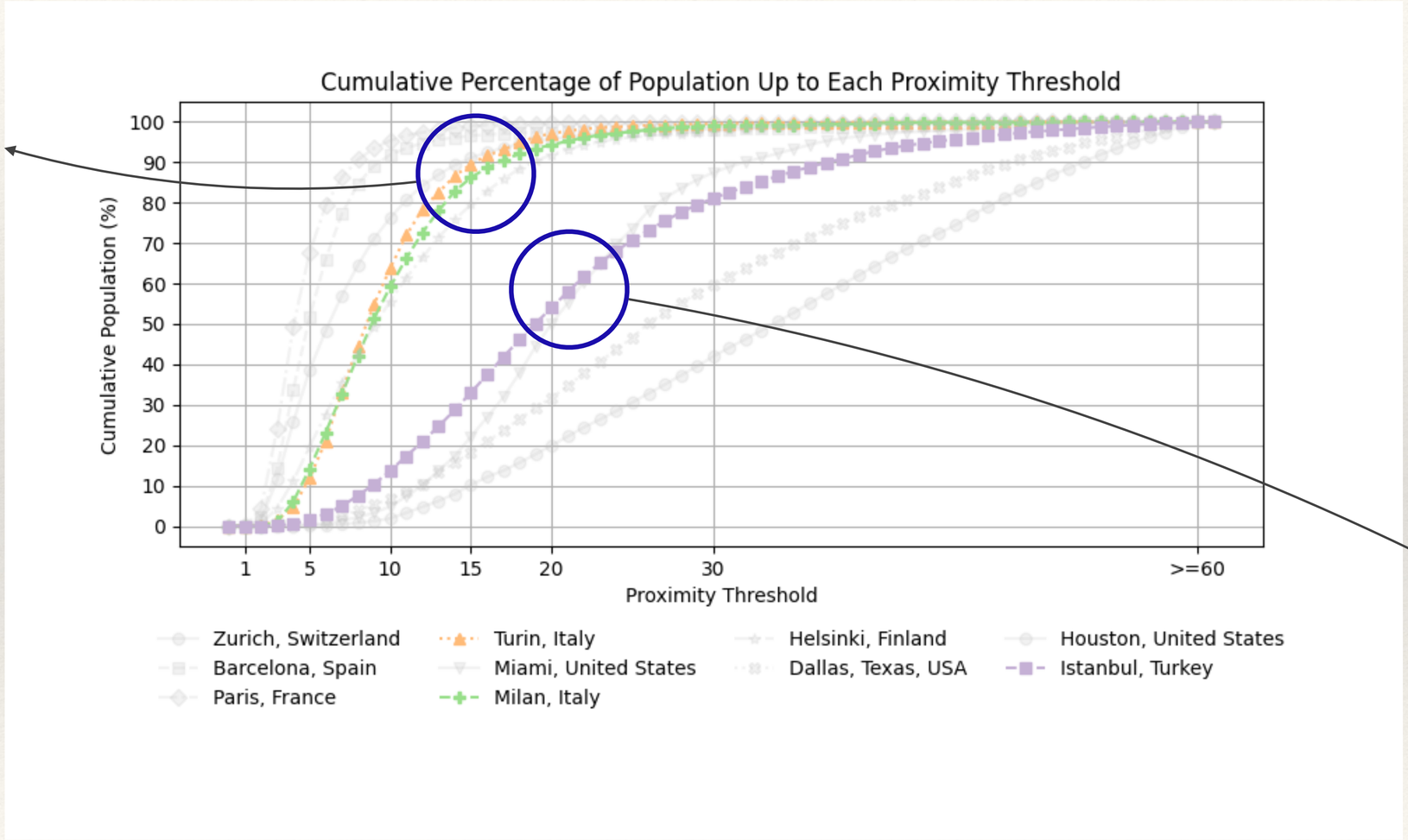


60% of Houston citizens live in places with $\mathscr{P}(n) \geq 30$!

Comparing and ranking cities

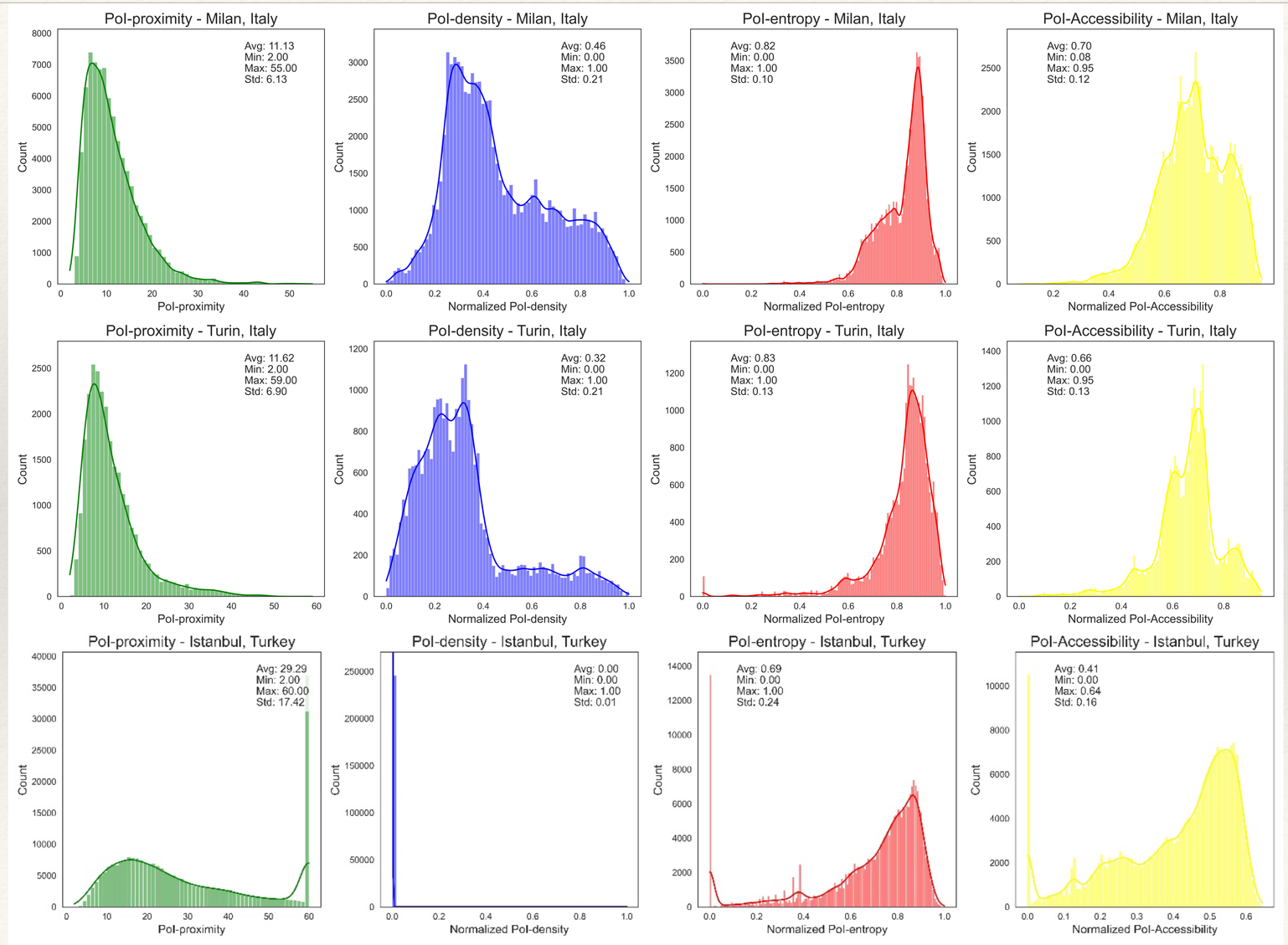
~ 90% of Milan and Turin citizens live in places with $\mathscr{P}(n) \leq 15$



~60% of Istanbul citizens live in places with $\mathscr{P}(n) \leq 20$!

Comparing and ranking cities

t = 15' for
PoI-{density, entropy, accessibility)

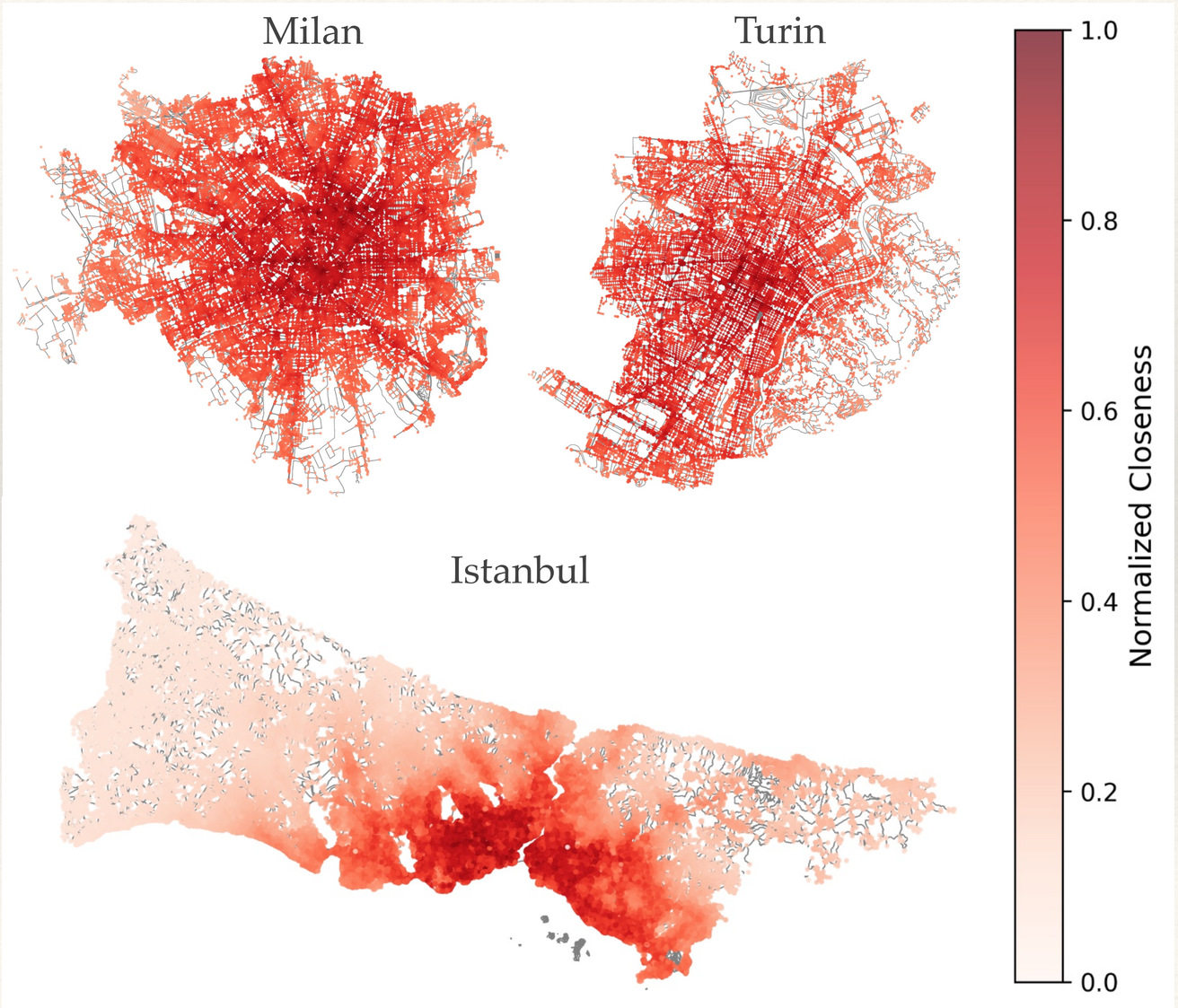


Connectivity metrics

- Given $n \in N_c$
  - (normalized) **Closeness**

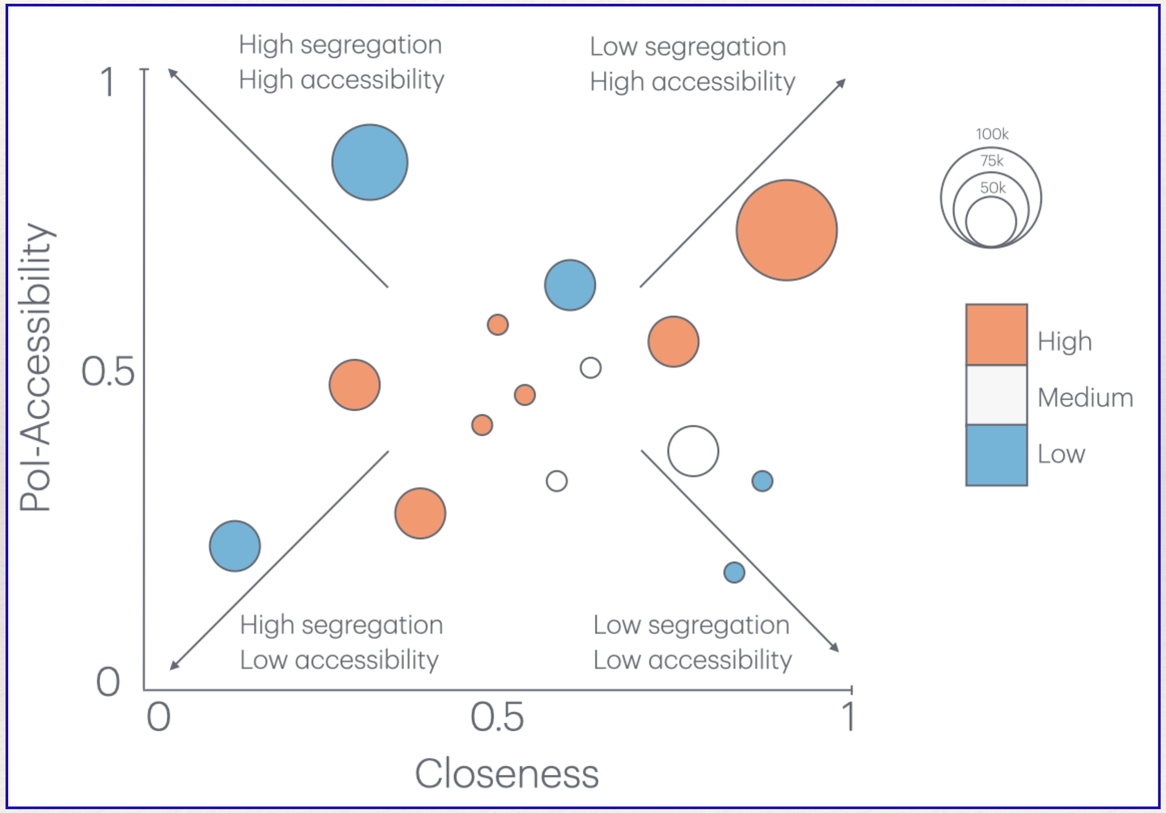
$$\mathscr{C}(n) = \frac{|N_c| - 1}{\sum_{m \neq n : m \in N_c} t(n, m)}$$

  - $t(n, m)$ is the shortest path length (i.e., temporal distance) that it takes to go from n to m in G_c^{urb}



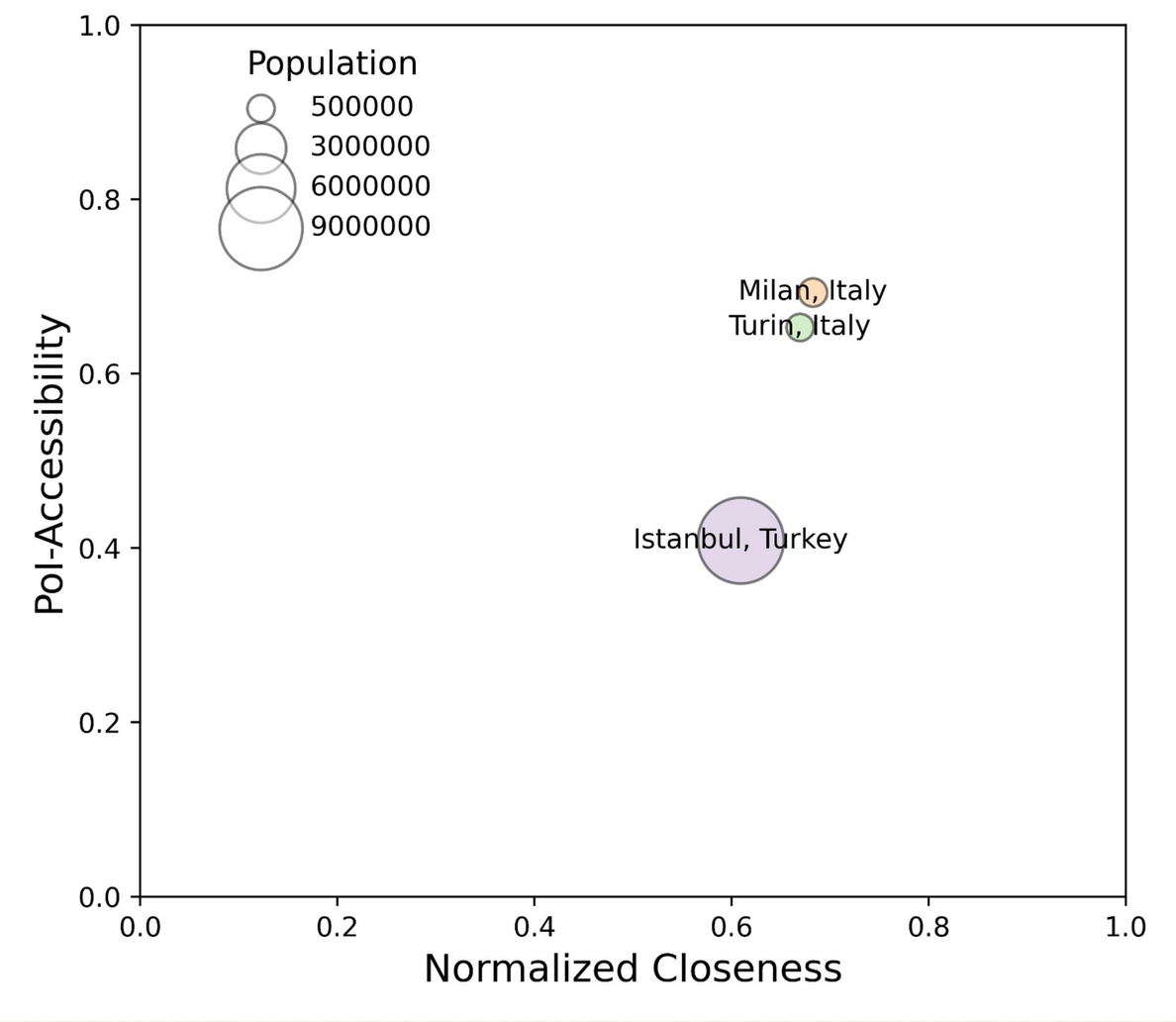
Closeness vs PoI-Accessibility

- Low closeness relates to high isolation/ segregation
- Low PoI-Accessibility relates to lack of services at walkable distance
- **Bubble charts** helps to understand how accessibility relates to urban connectivity and segregation



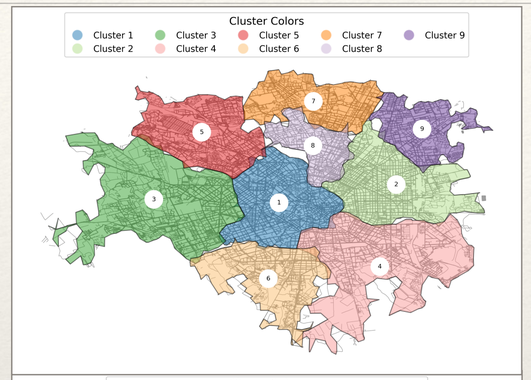
PoI-Accessibility vs Closeness(t=15′)

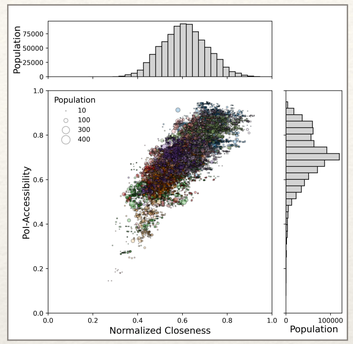
- RQ2: There are signals that accessibility relates to urban connectivity and segregation
- RQ3: For stronger signals, nodes in N_c can be aggregated in census areas, network clusters (e.g., by infomap), administrative districts, …

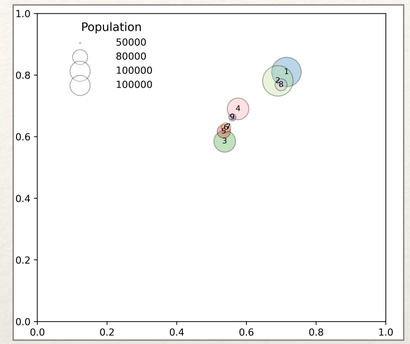


Accessibility, closeness, and population

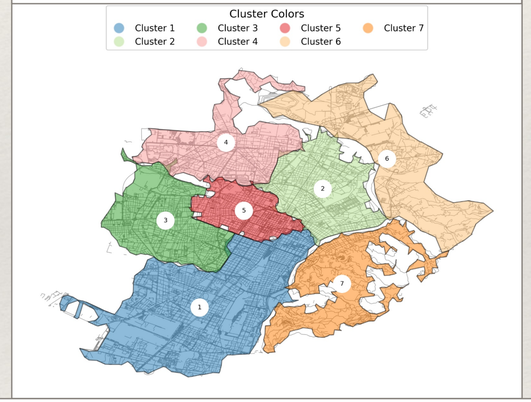
Milan

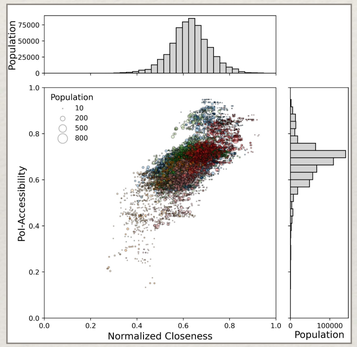


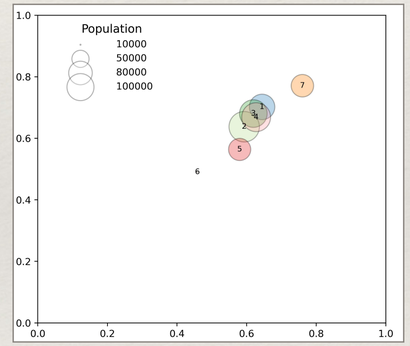




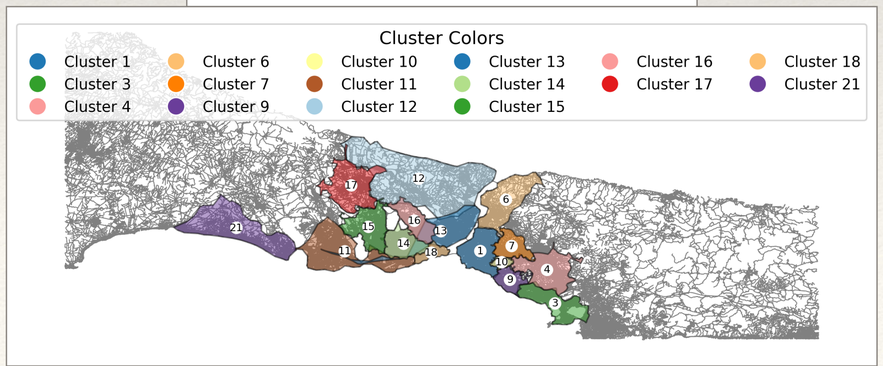
Turin

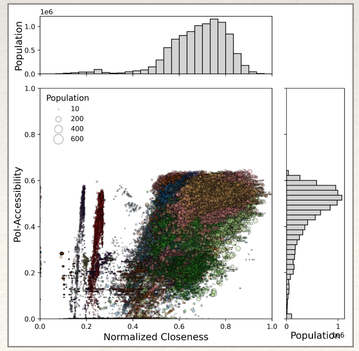


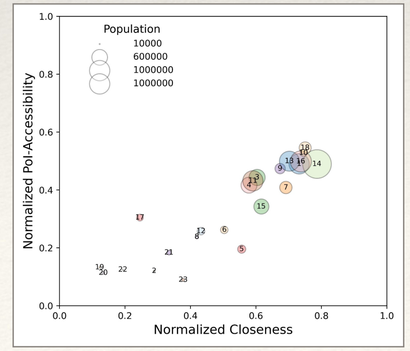




Istanbul







Accessibility, closeness and income

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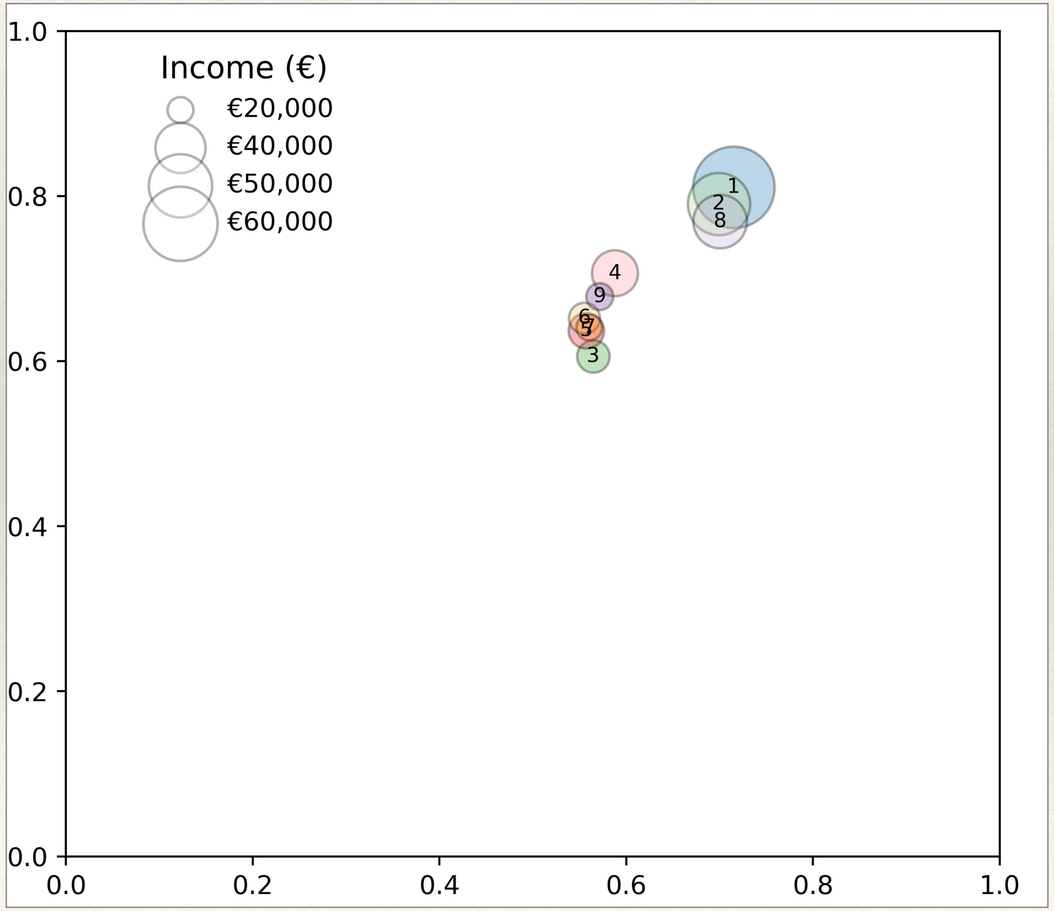
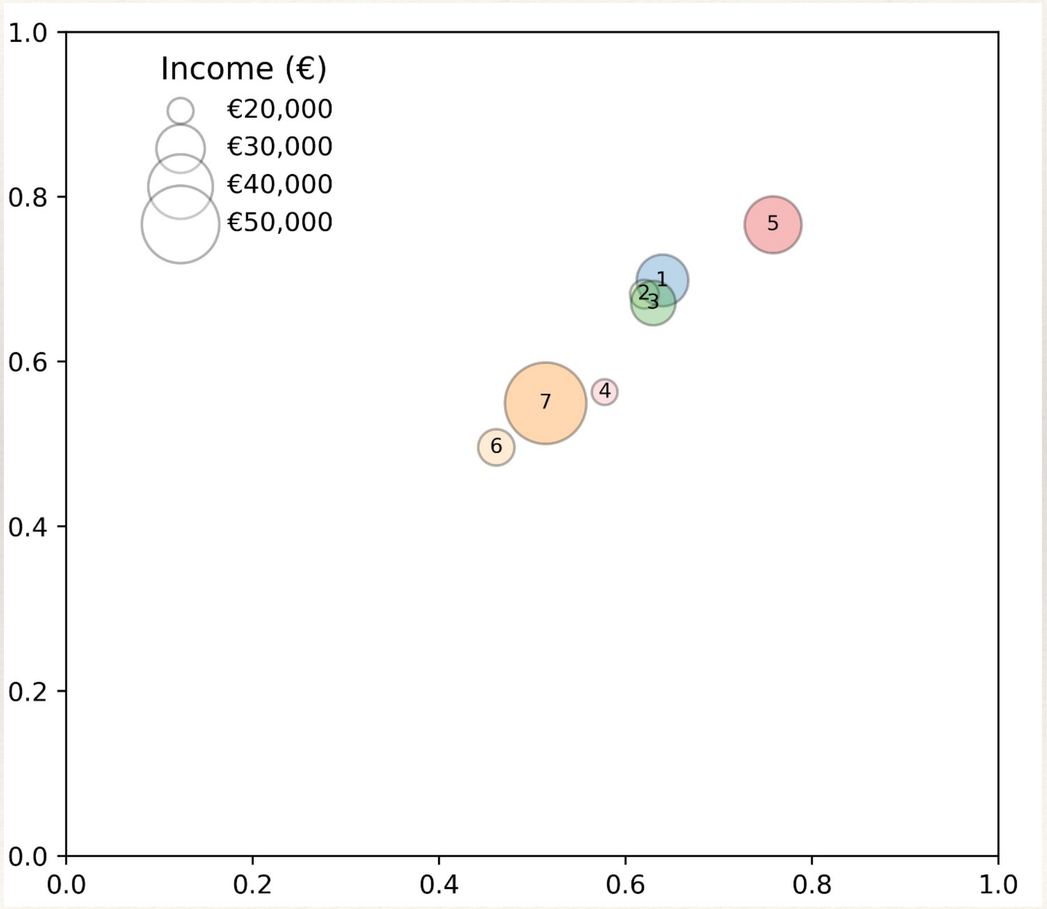
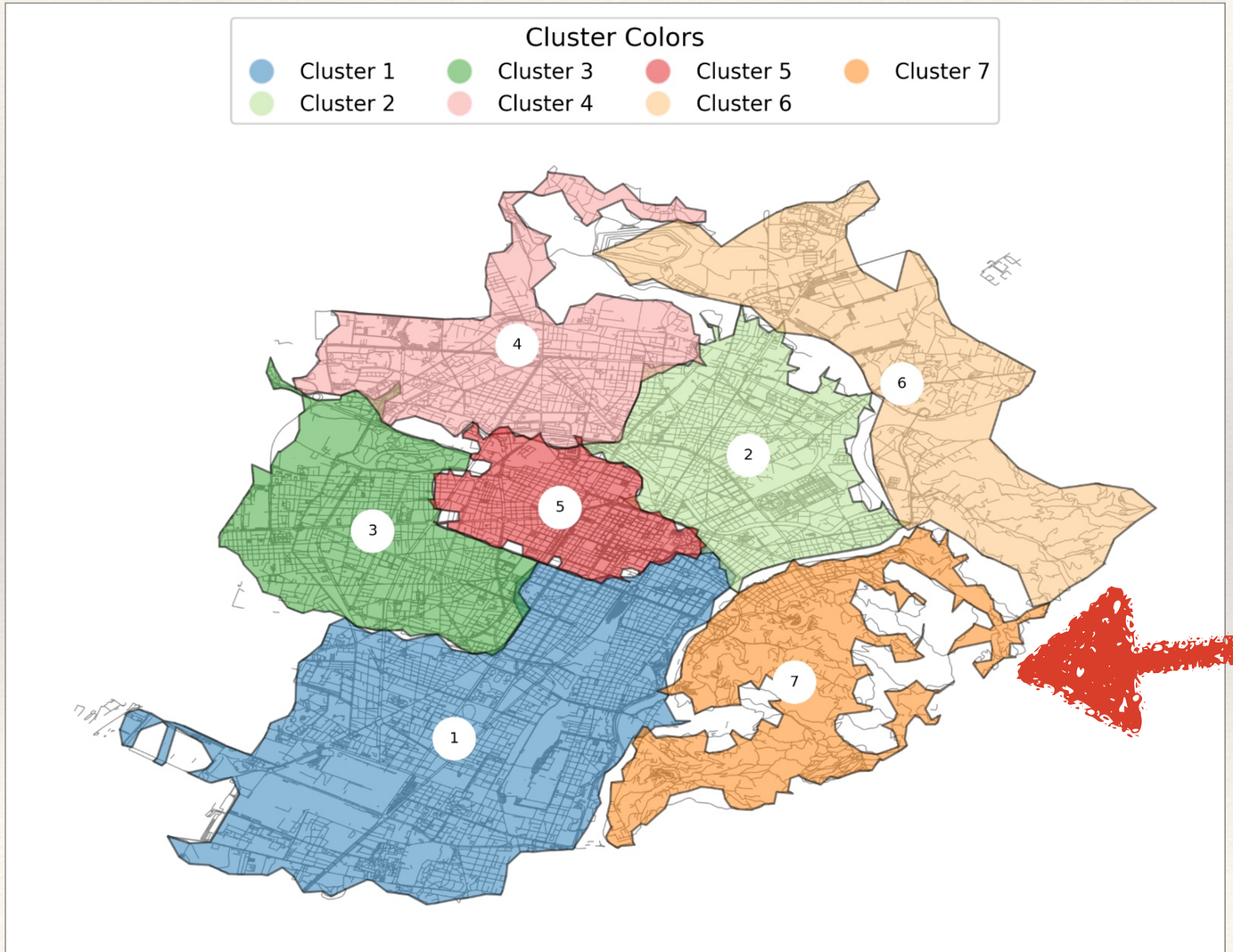


Turin



Accessibility, closeness and income



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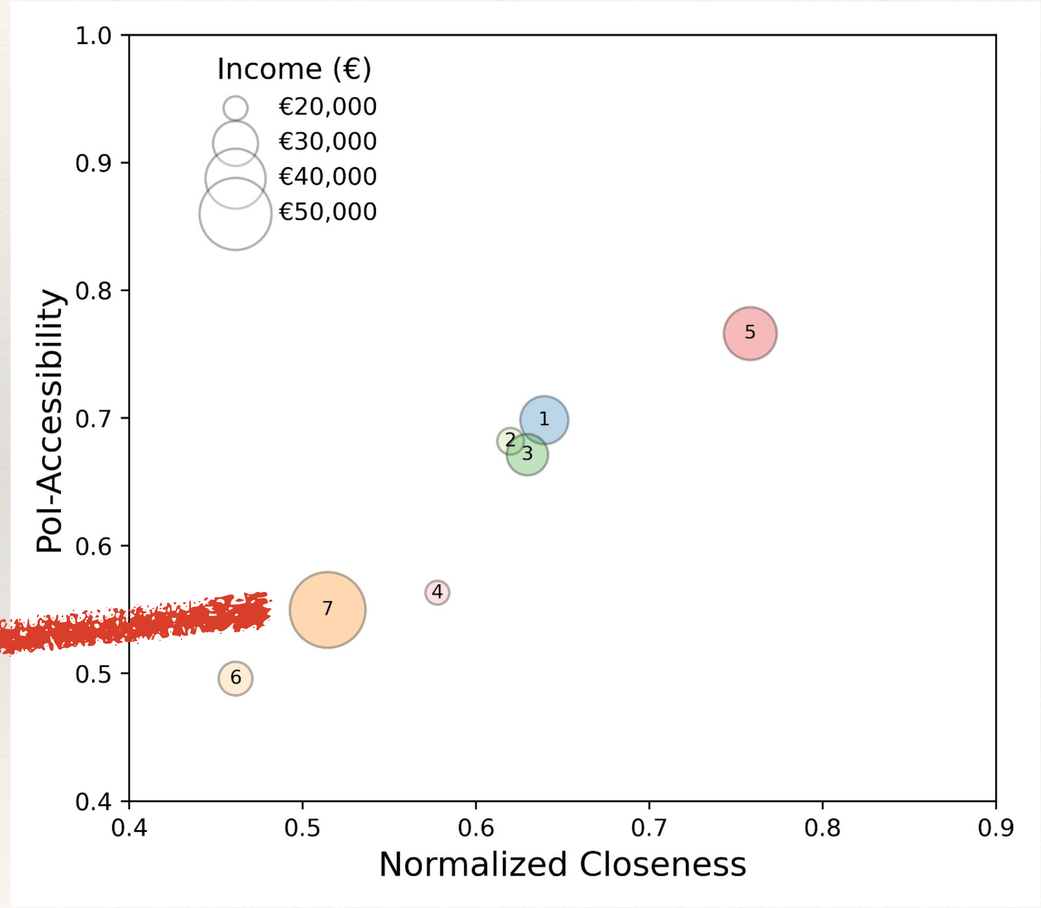
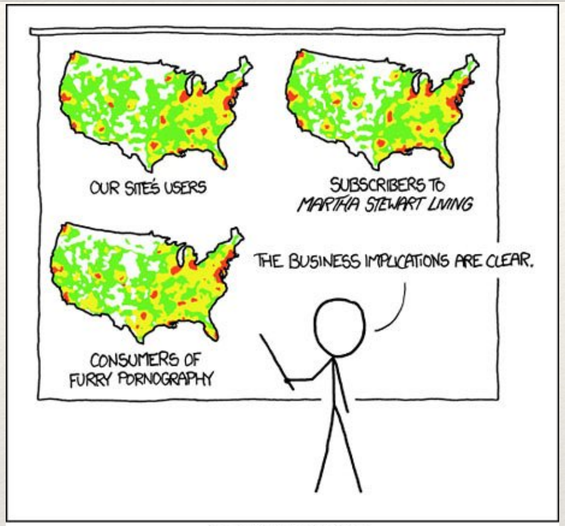
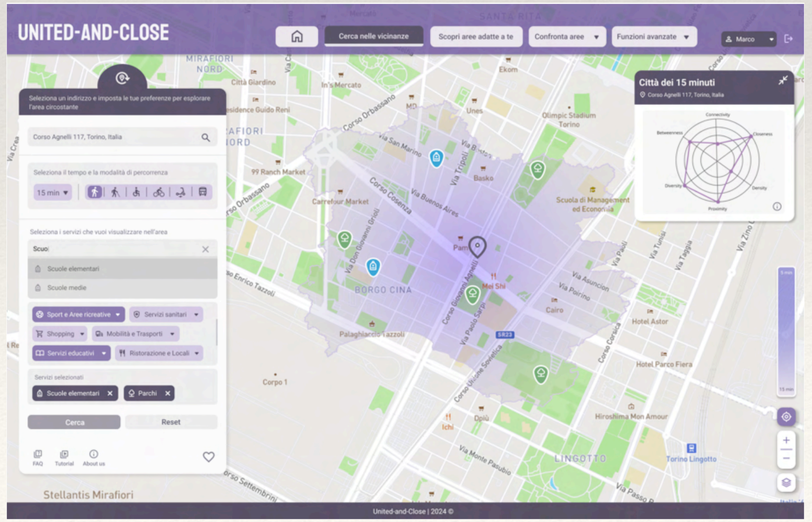


Conclusions: focus on citizens!

- Network based measures:
  - not only accessibility but also general connectivity
- A signal that (good/poor) walkable accessibility correlates to (good/poor) urban transport connectivity
  - Poorly served citizens are not equally distributed world wide
  - Turin's interesting exception: not always "poorer" accessibility/connectivity is at interplay with "lower income"
- Need for open data and open platforms
- Ongoing:
  - Personalized filters for close by services
  - **Unite-and-Close**: a magnifying glass for the 15-minute city



PET PEEVE #208:
GEOGRAPHIC PROFILE MAPS WHICH ARE BASICALLY JUST POPULATION MAPS



Extra slides

Ideal vs real cities

Kudos to Vittorio Loreto!

Accessibility Metrics

- Given $n \in N_c$
  - PoI-Proximity $\mathscr{P}(n) = t$
  - PoI-Density $\mathscr{D}(n, t)$
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PoI's categories:

Mobility

Active Living

Entertainment

Food Choices

Community

Education

Health and Well-being

PoI's categories as in: Nicoletti, L., et al. (2023). Disadvantaged communities have lower access to urban infrastructure. Environment and Planning B: Urban Analytics and City Science, 50(3), 831-849.

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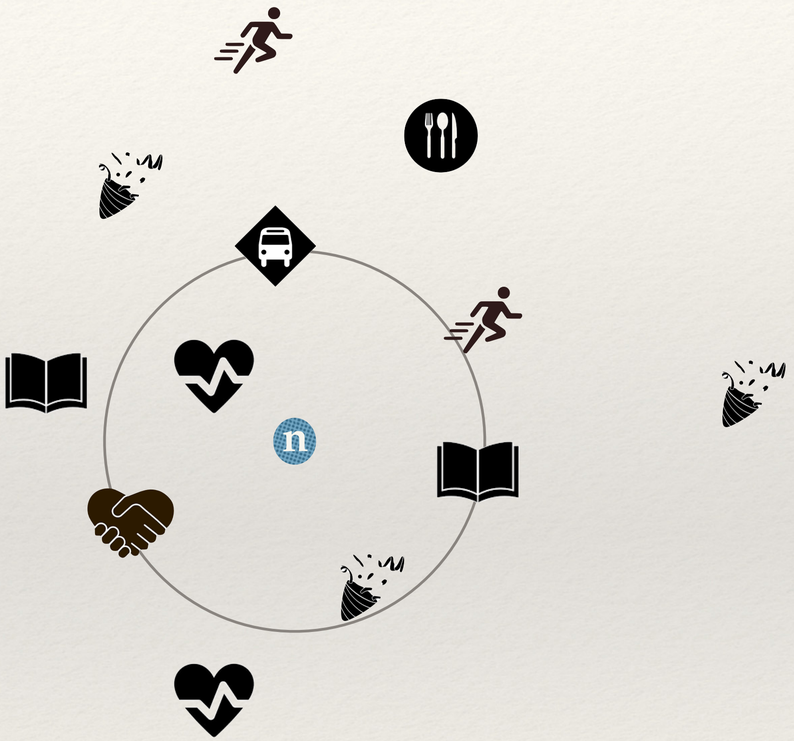

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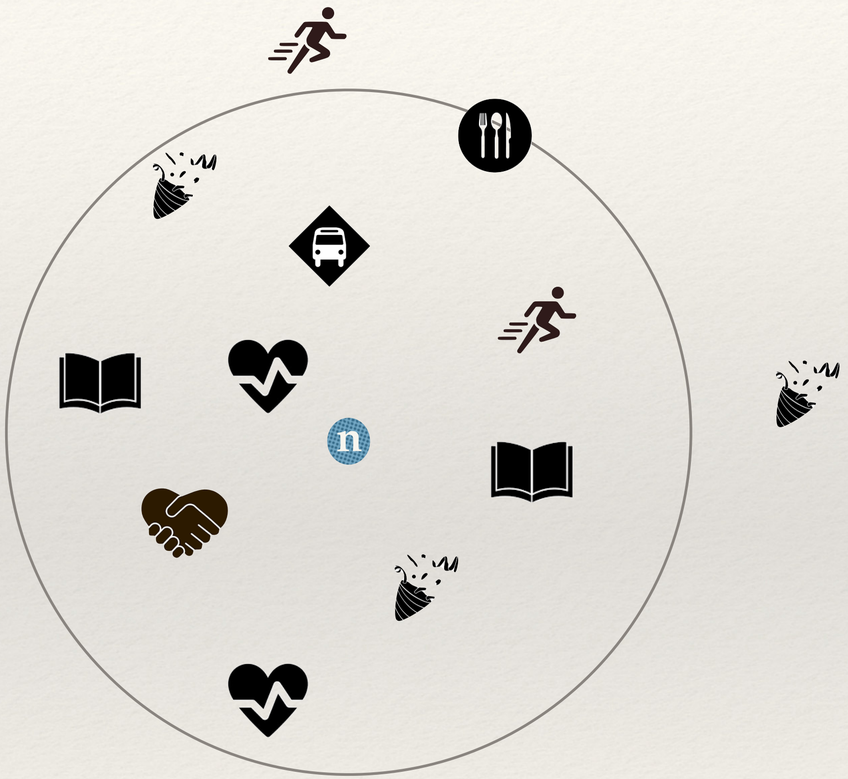

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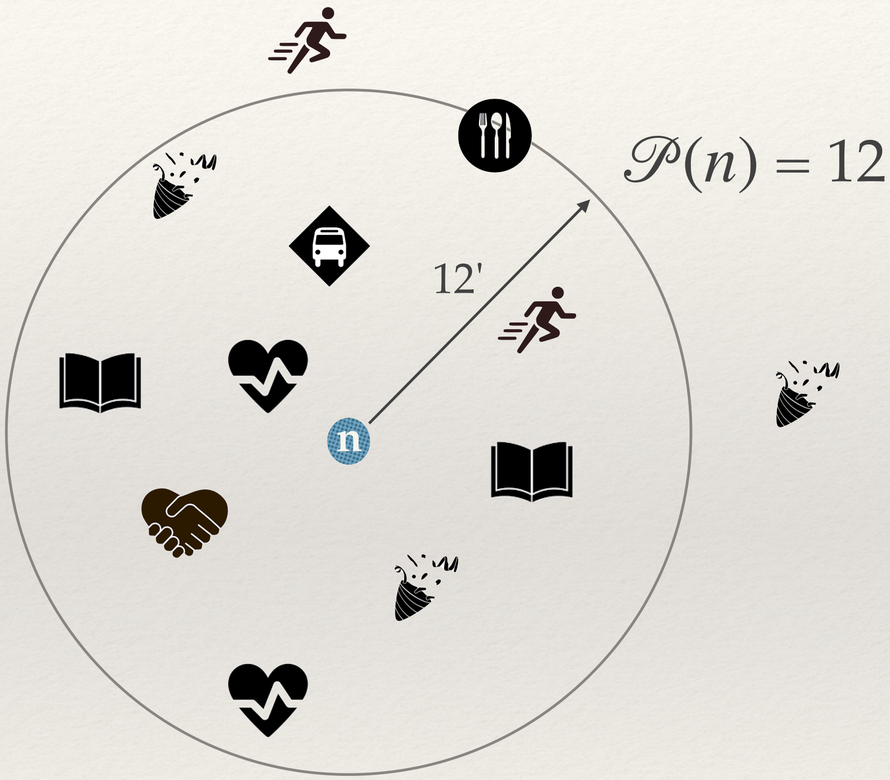

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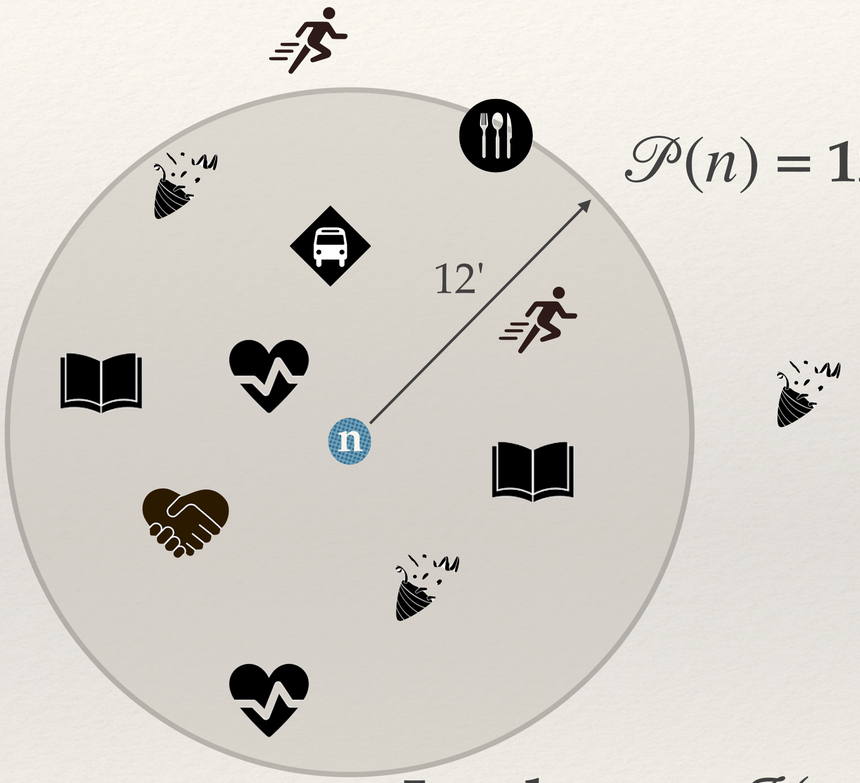

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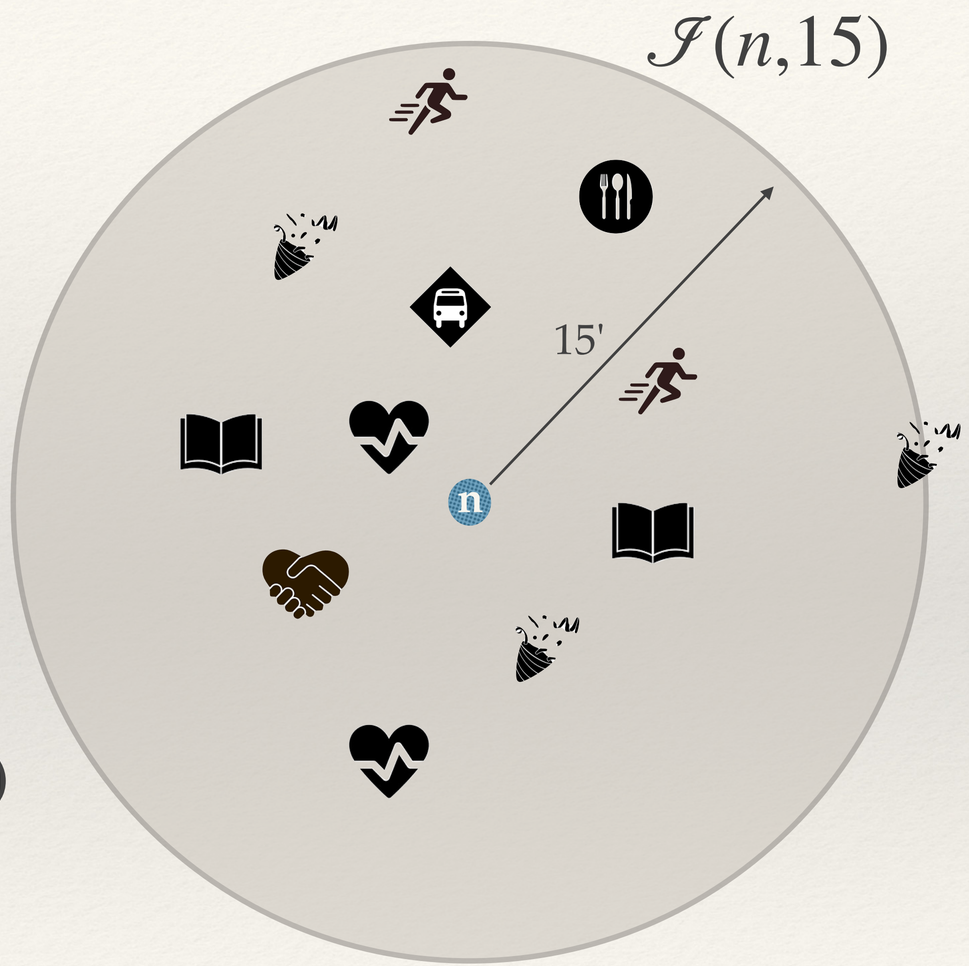

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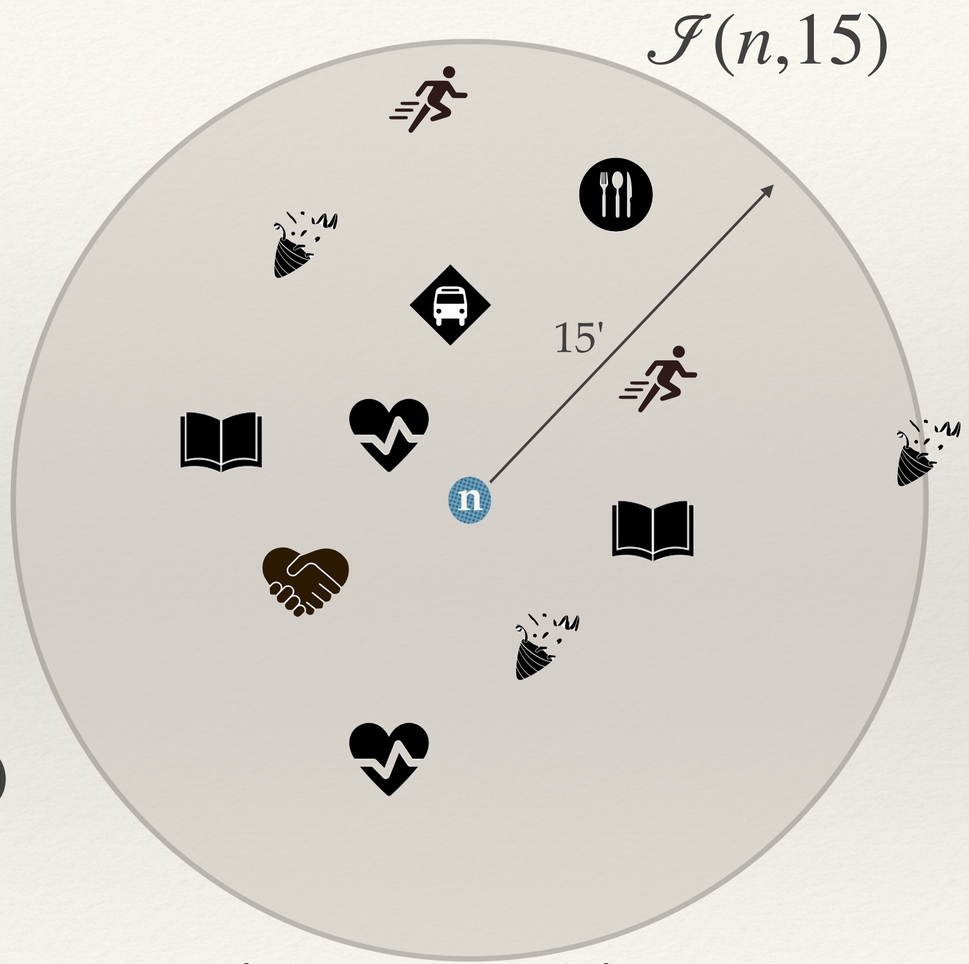

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- *Health and Well-being*

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$$\mathscr{D}(n,15) = \frac{|\text{PoIs} \in \mathscr{I}(15)|}{\text{Area of} \mathscr{I}(n,15)} = \frac{12}{7\text{km}^2} = 1.71$$

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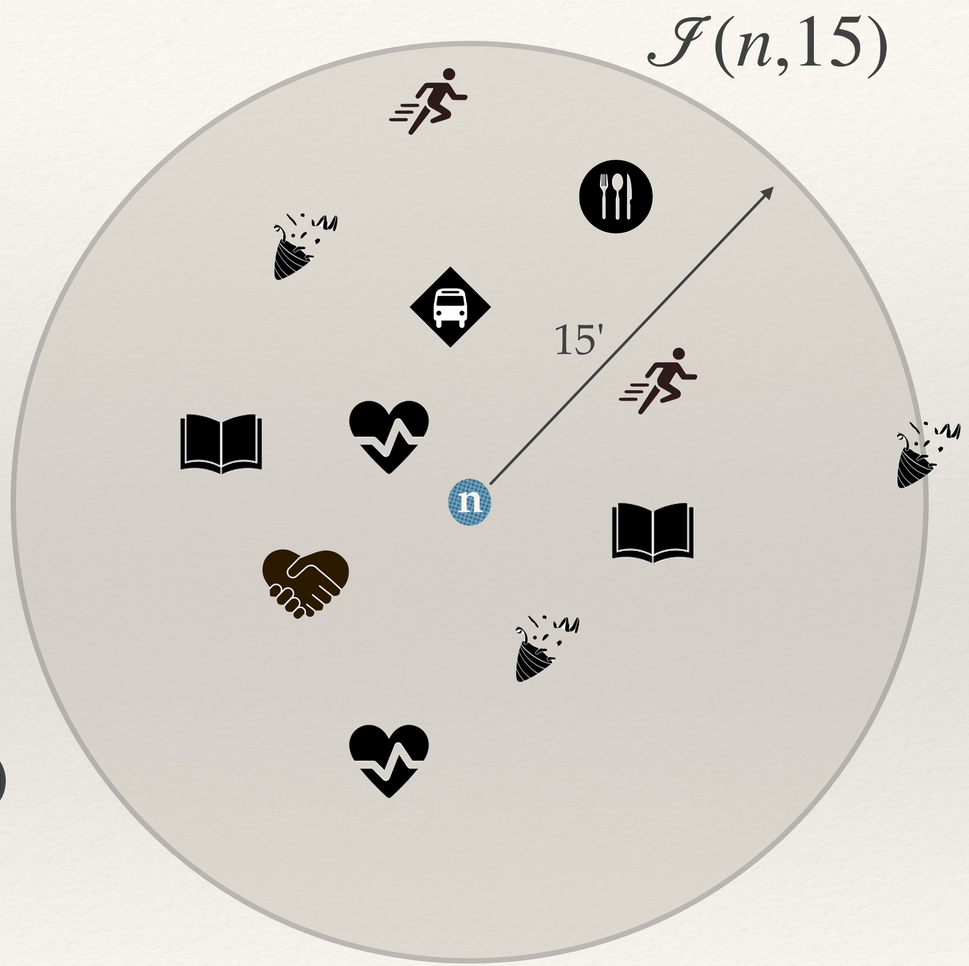

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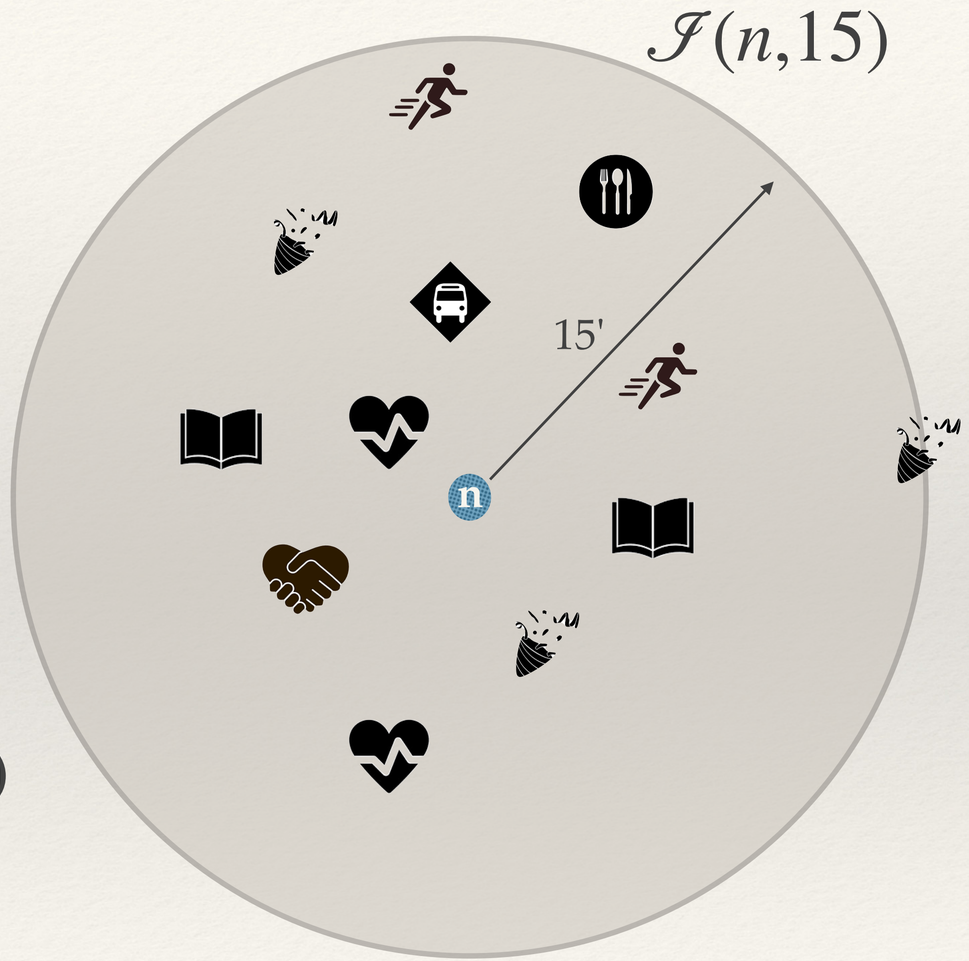

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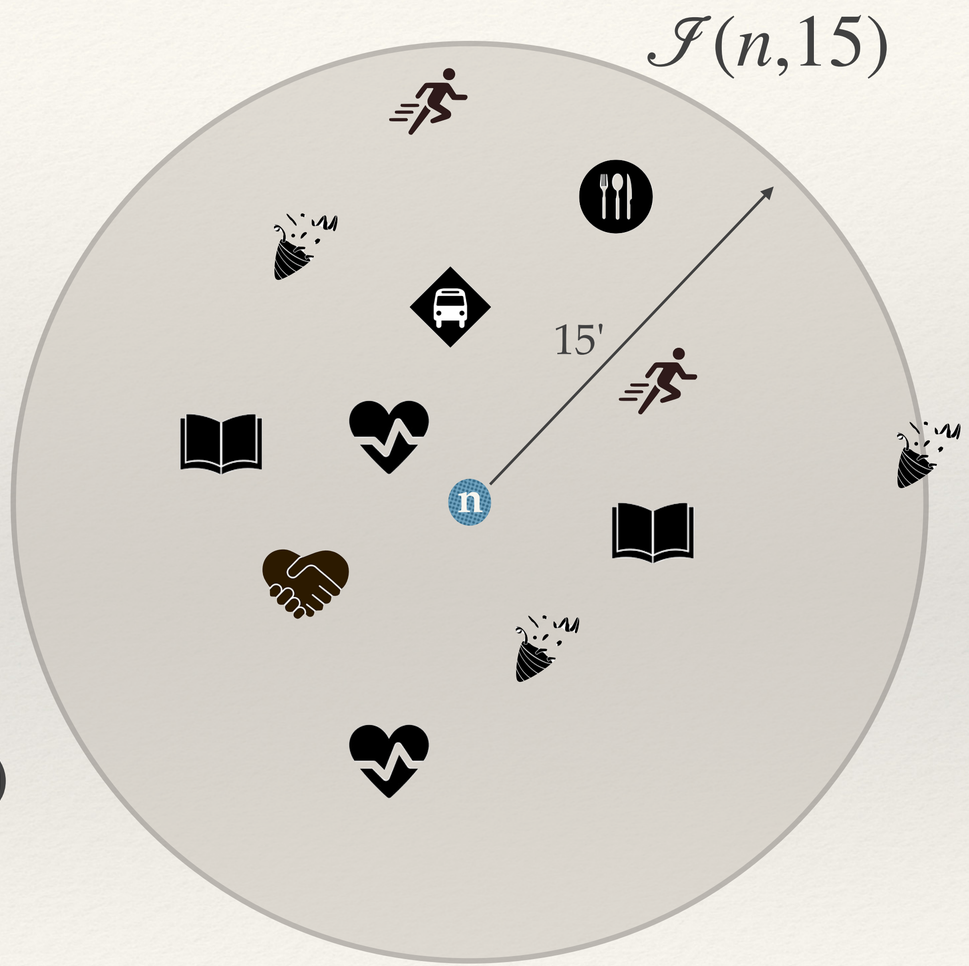

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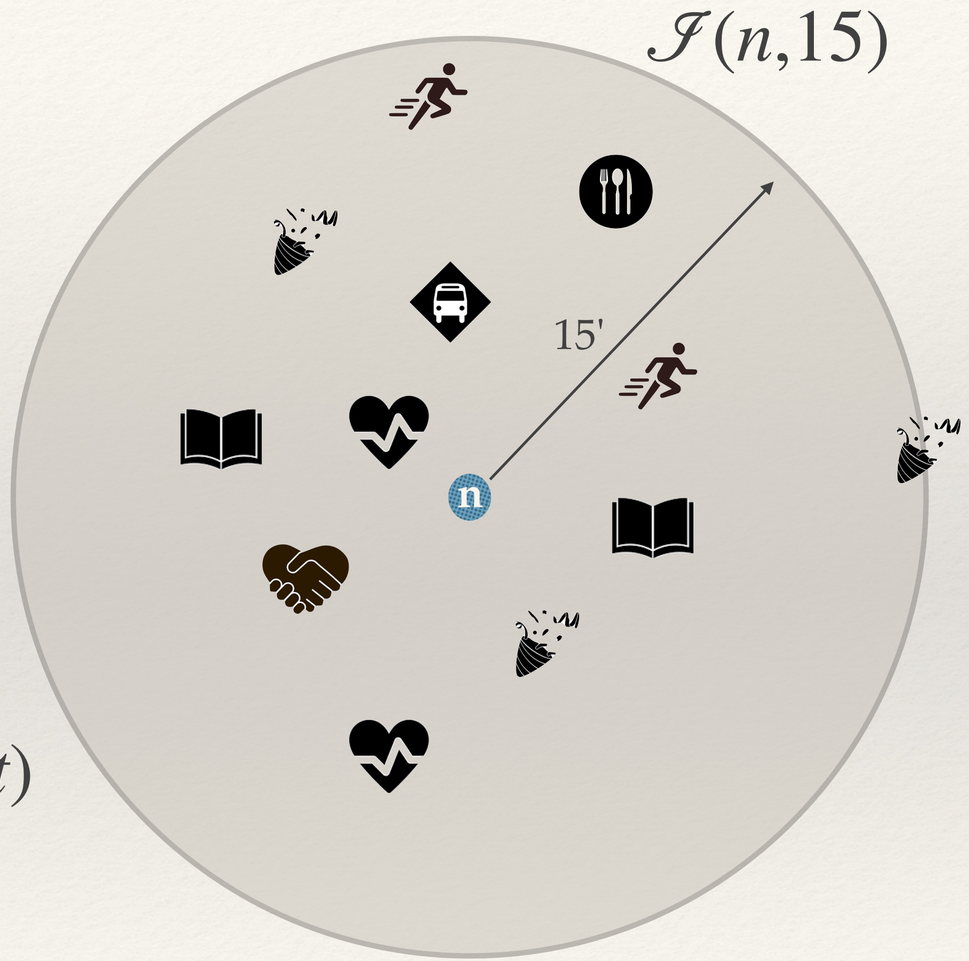

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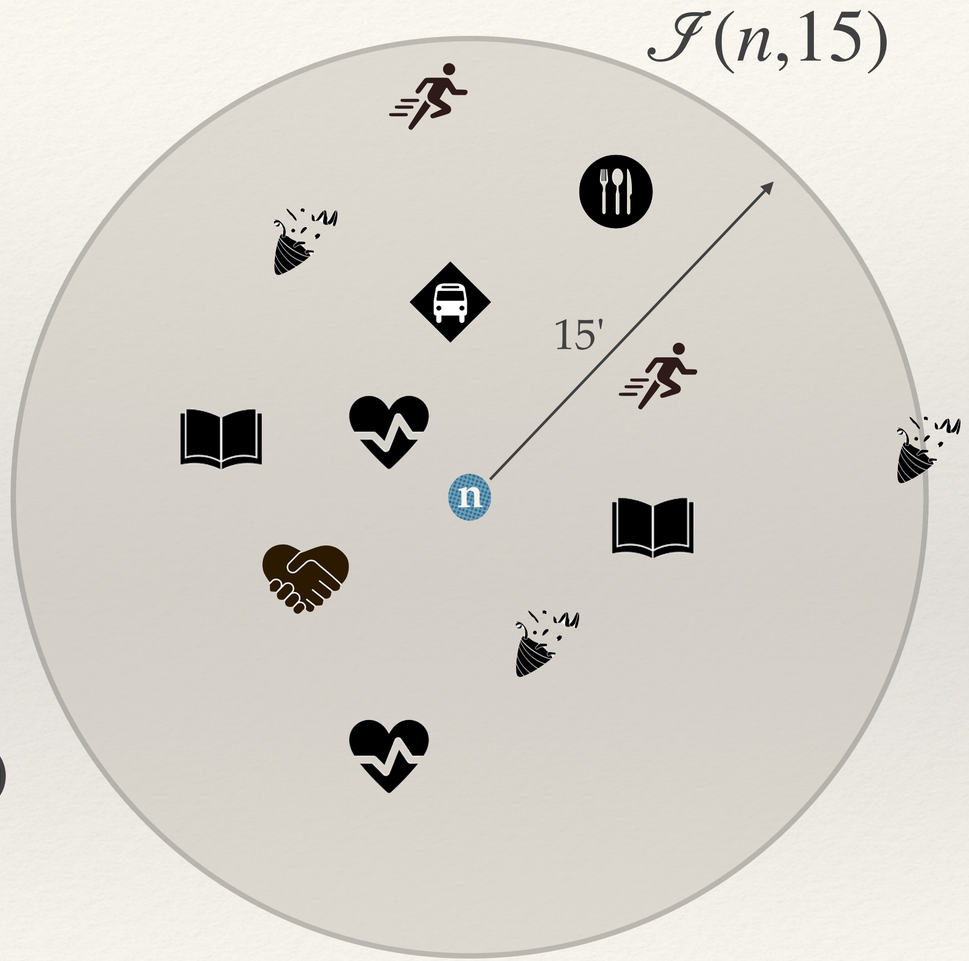

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$\mathscr{A}(n,15) \in [0,1]$

Alternatives for density and entropy

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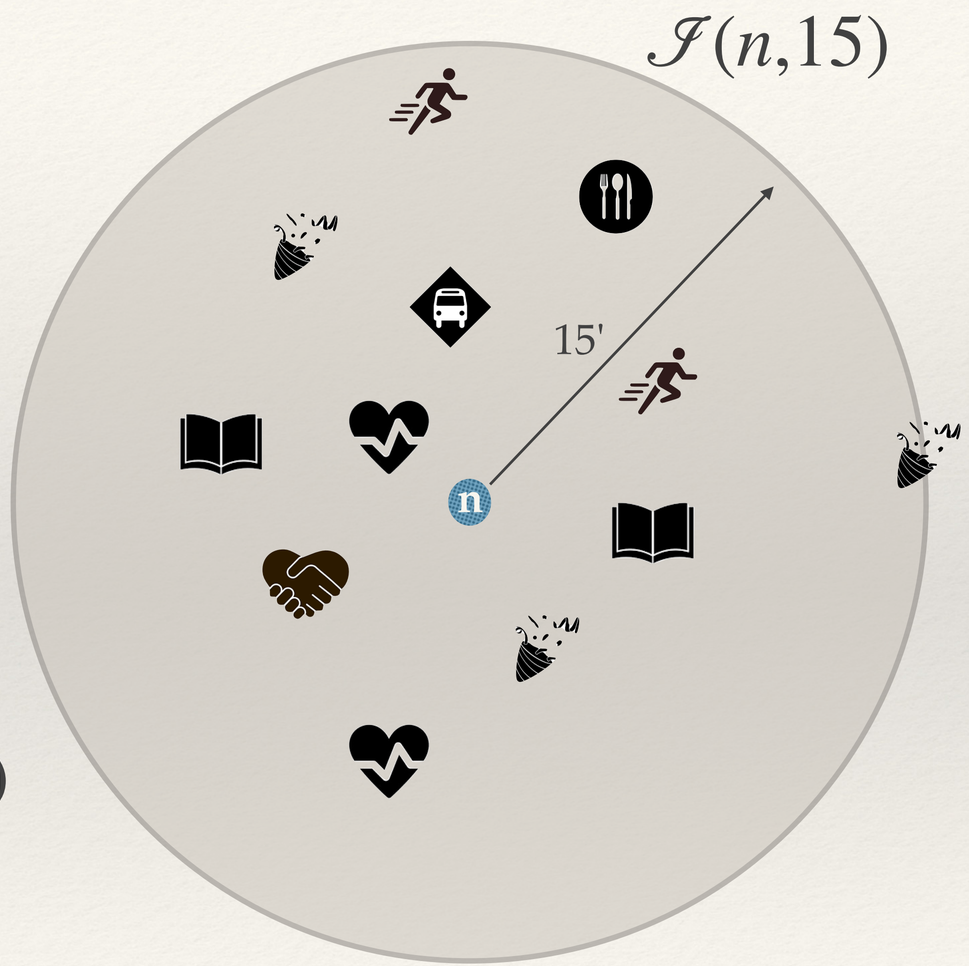

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  - PoI-Entropy $\mathscr{E}(n, t)$
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$$\mathscr{D}(n,15) = \frac{12}{7\ \text{km}^2} = 1.71$$

$$\mathscr{D}(m,15) = \frac{8}{7\ \text{km}^2} = 1.14$$

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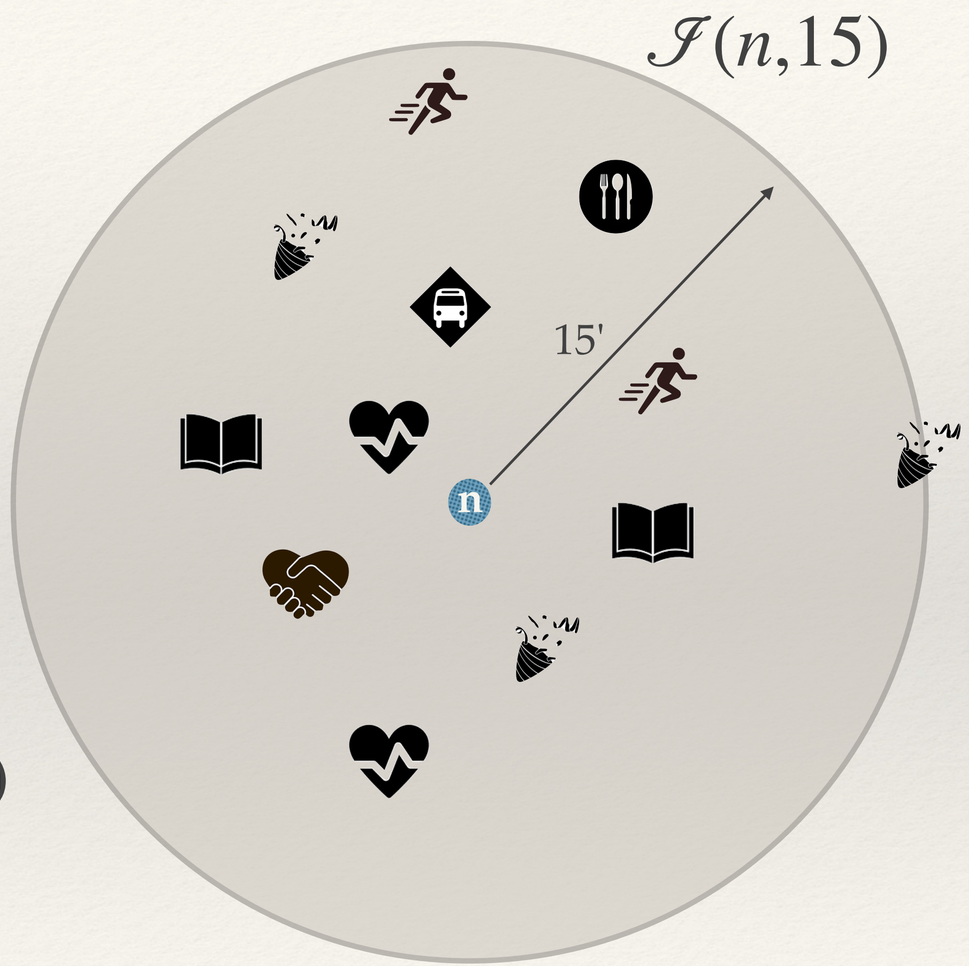

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$\mathscr{E}(n,15) = 2.69$ $\mathscr{E}(m,15) = 0.76$

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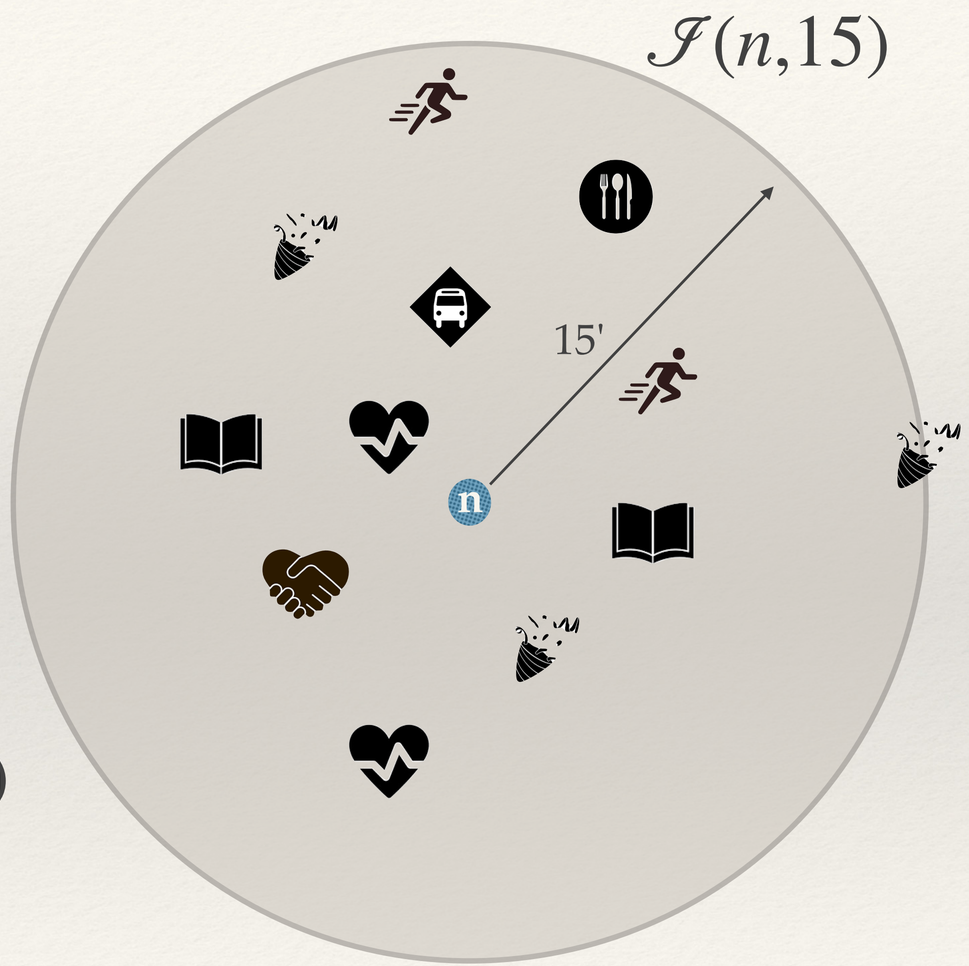

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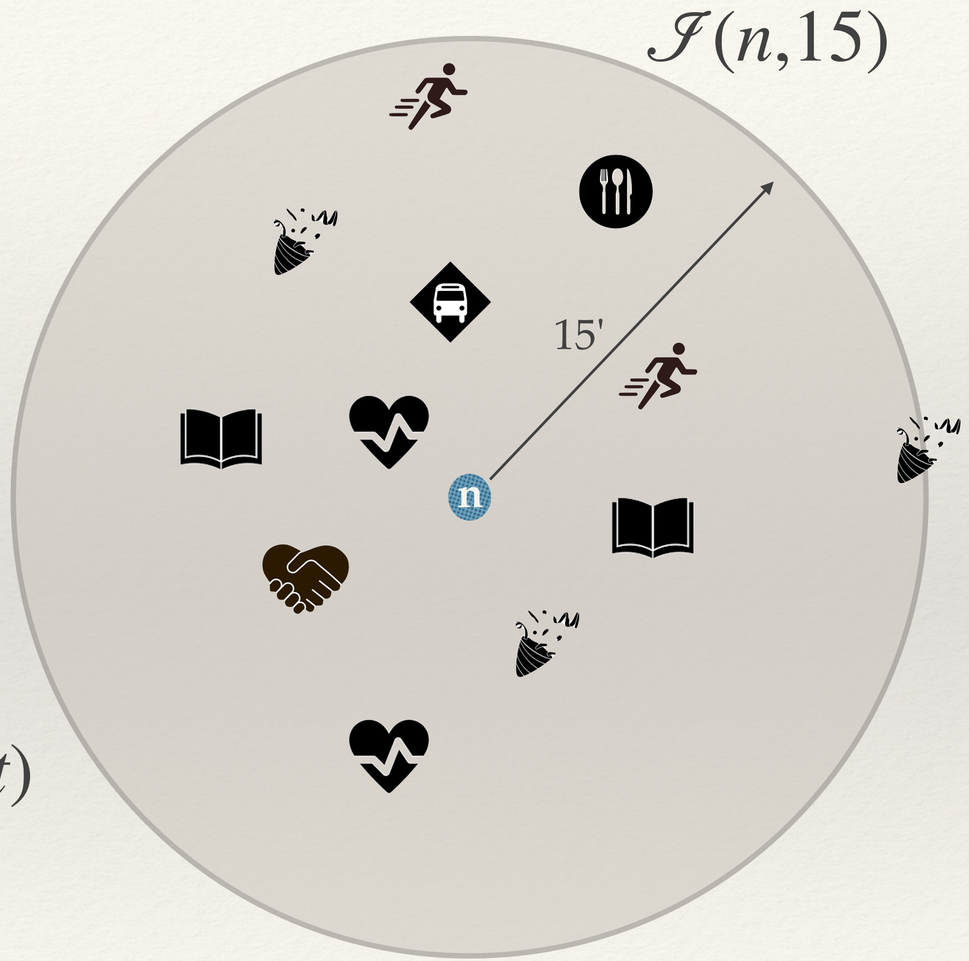

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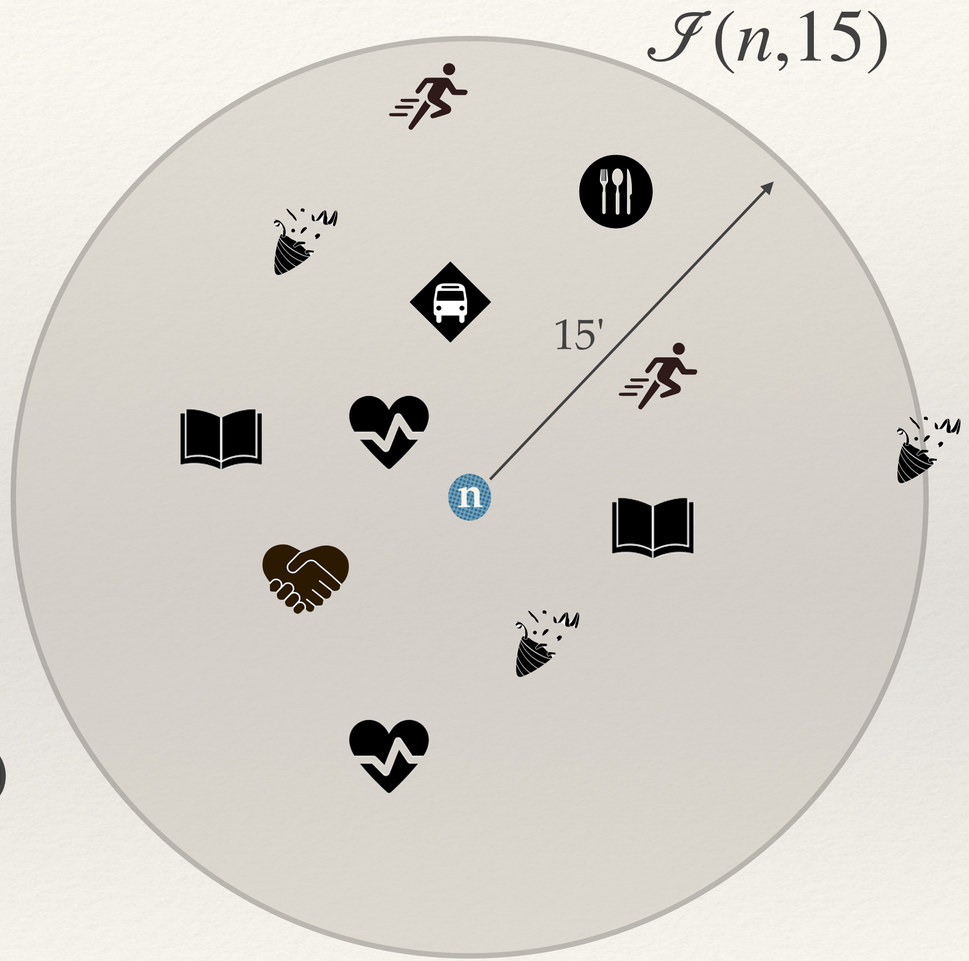

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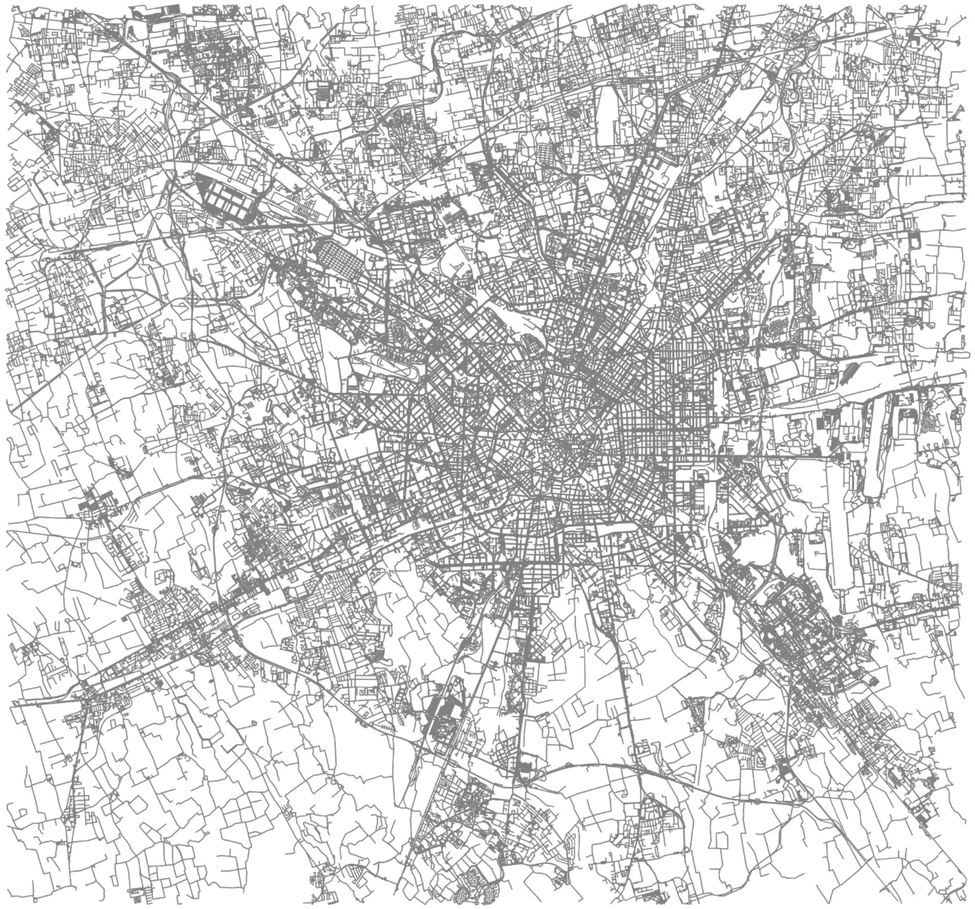
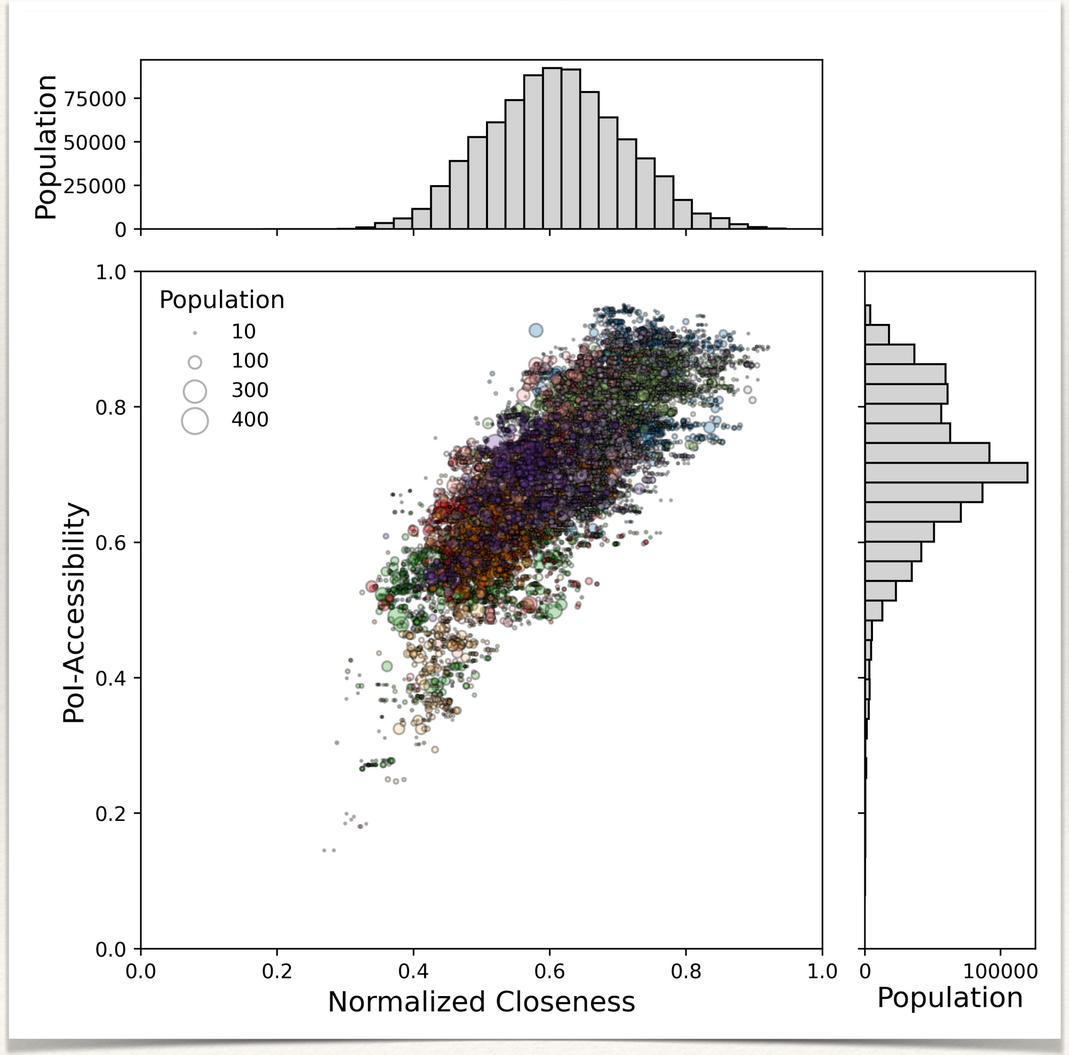
closeness vs poi-accessibility

Closeness vs PoI-Accessibility (t=15′)

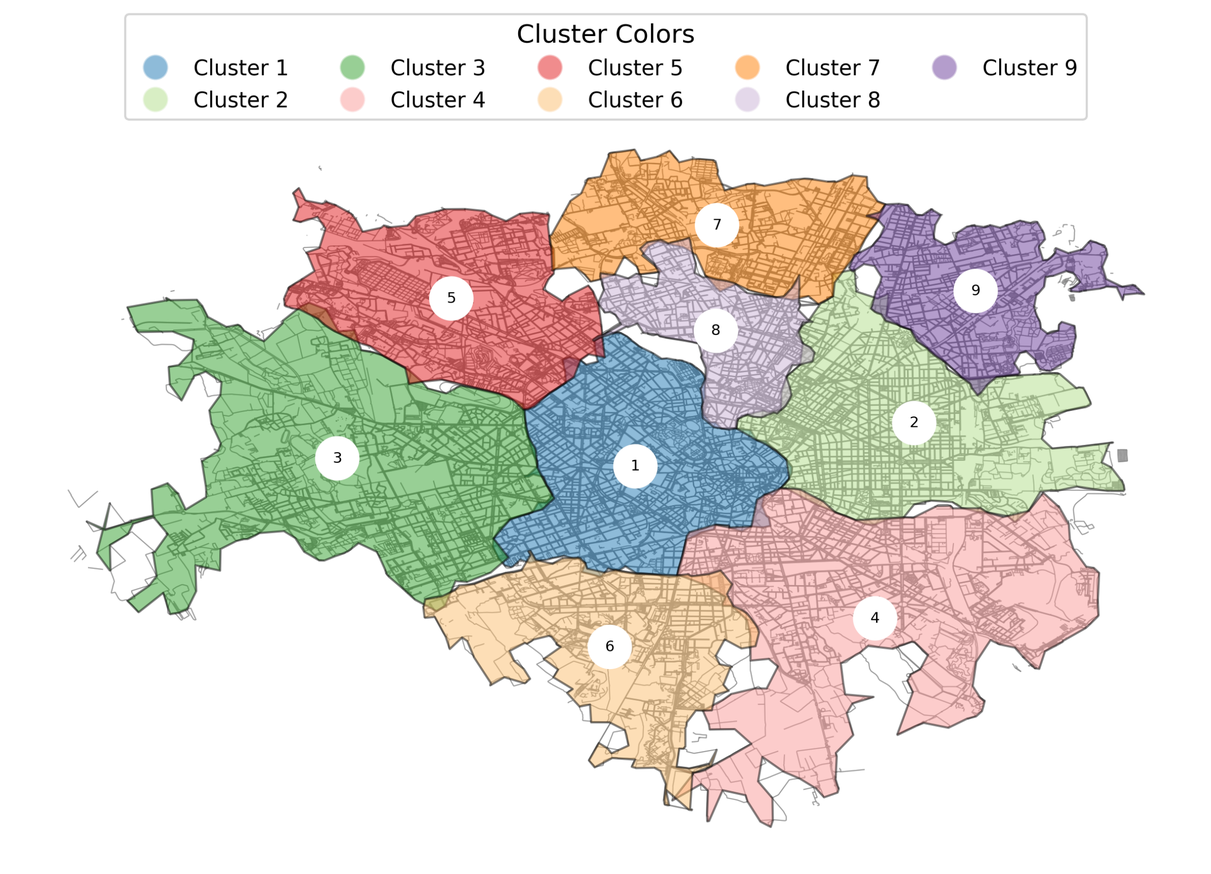
Milan, census areas

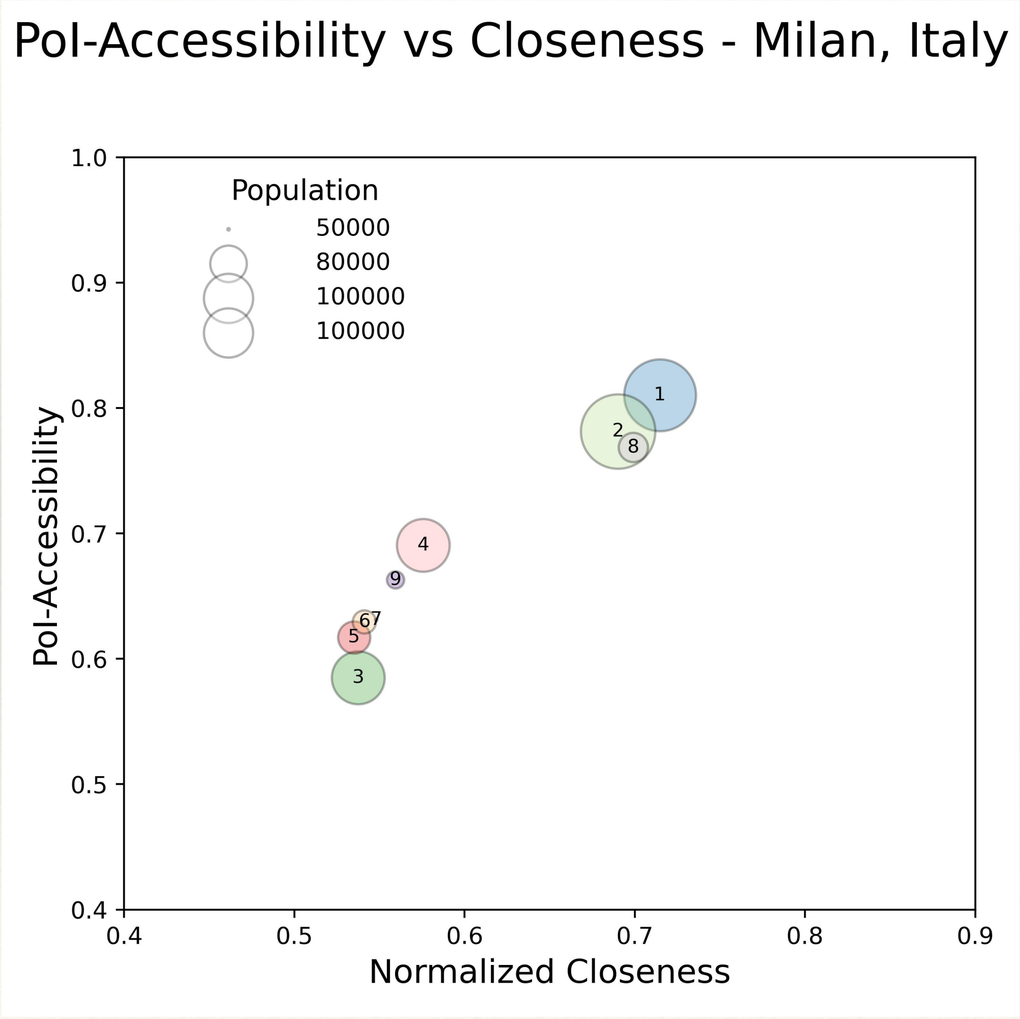




Closeness vs PoI-Accessibility (t=15′)

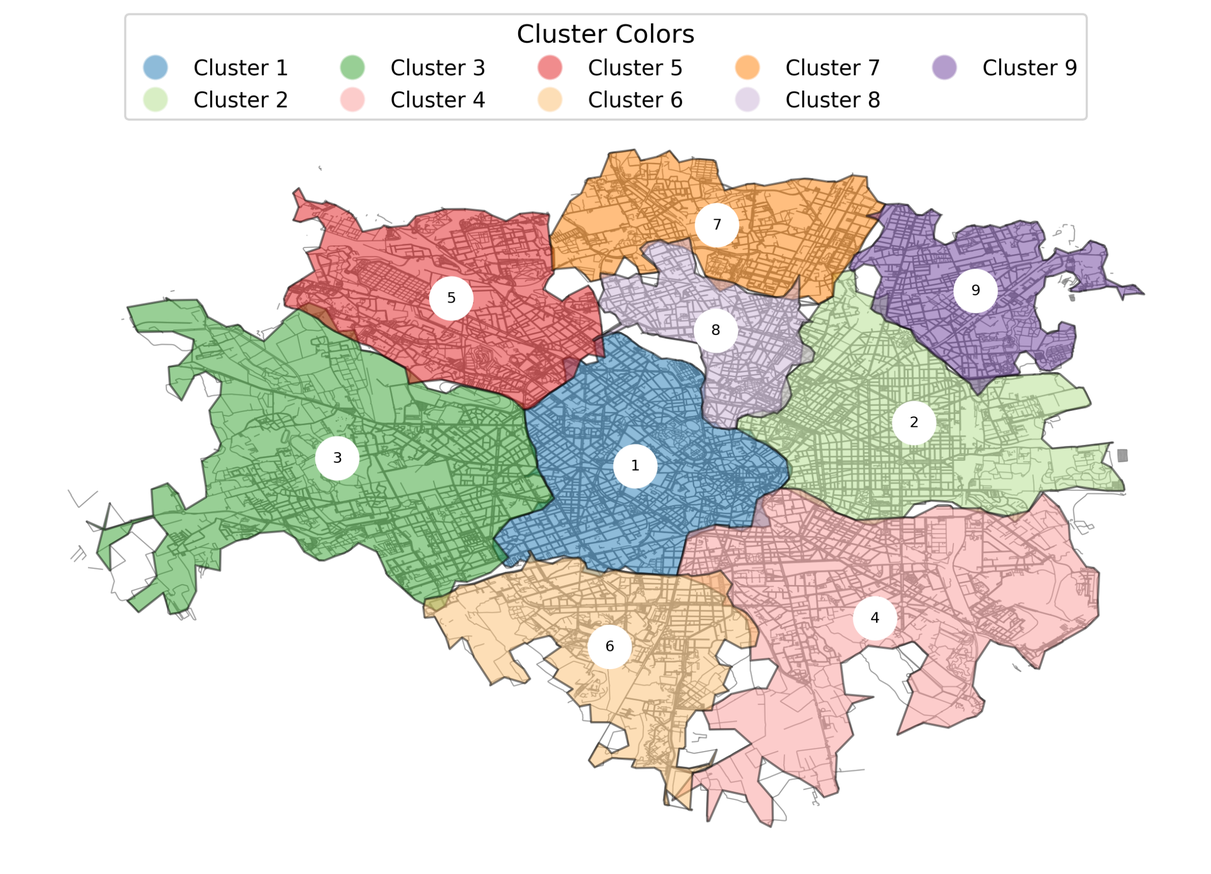
Milan, infomap clusters

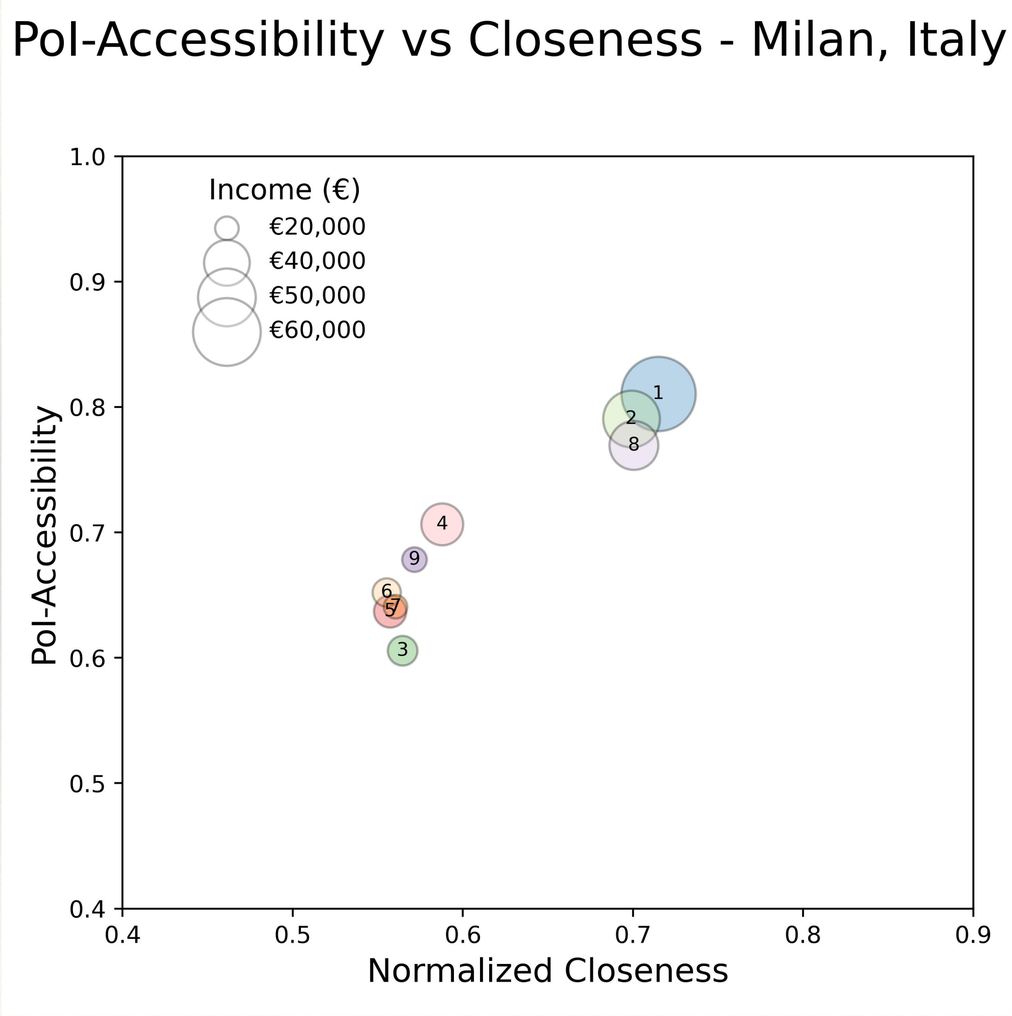




Closeness vs PoI-Accessibility (t=15′)

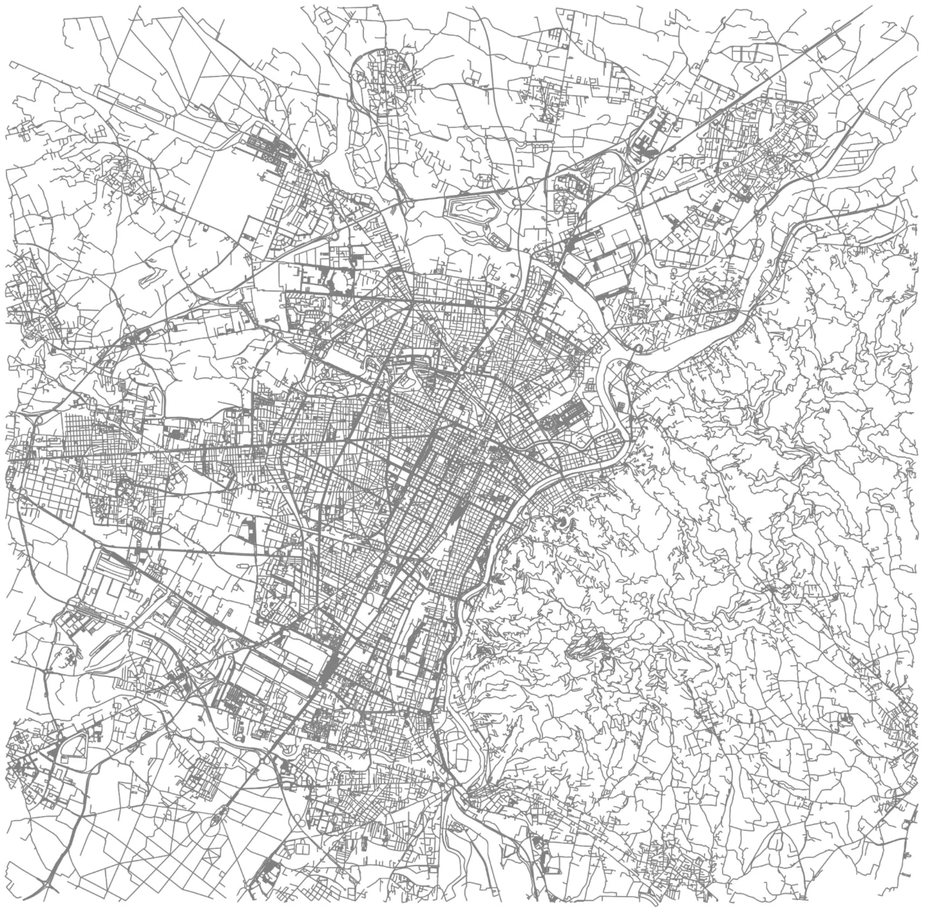
Milan, infomap clusters

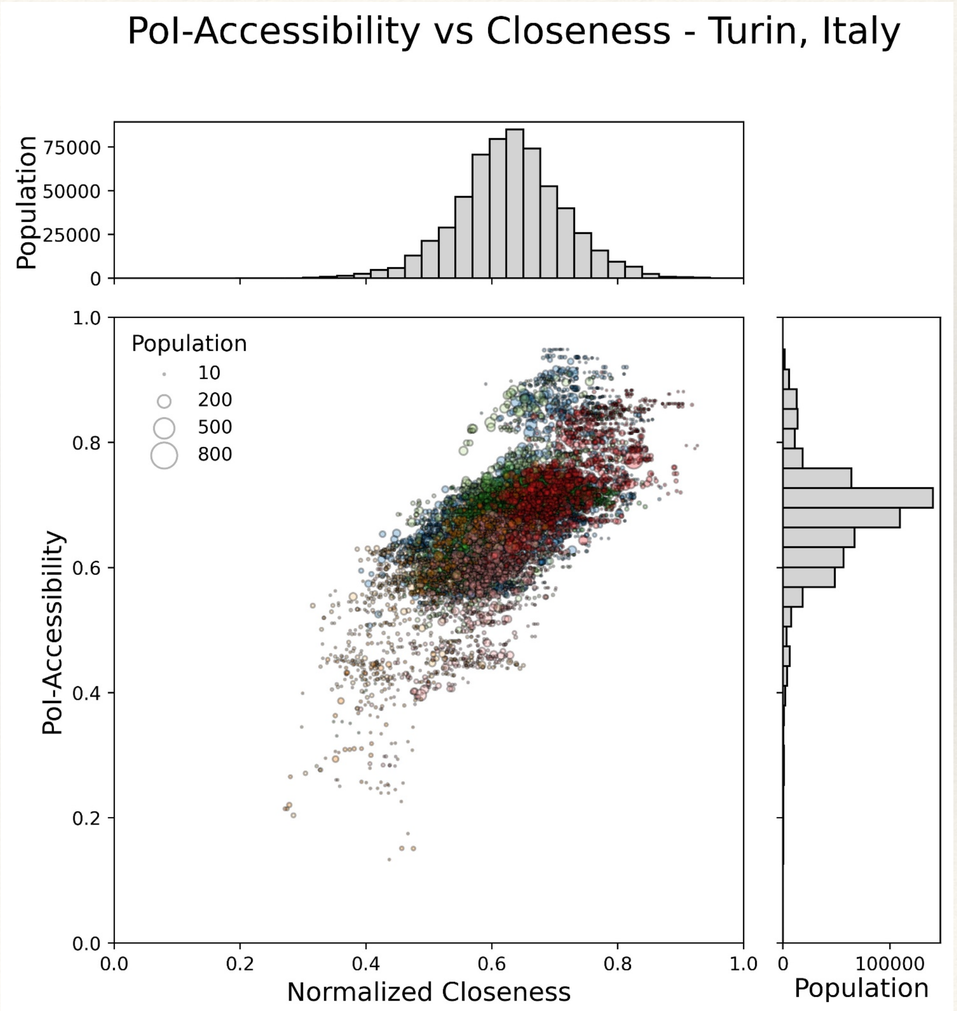




Closeness vs PoI-Accessibility (t=15′)

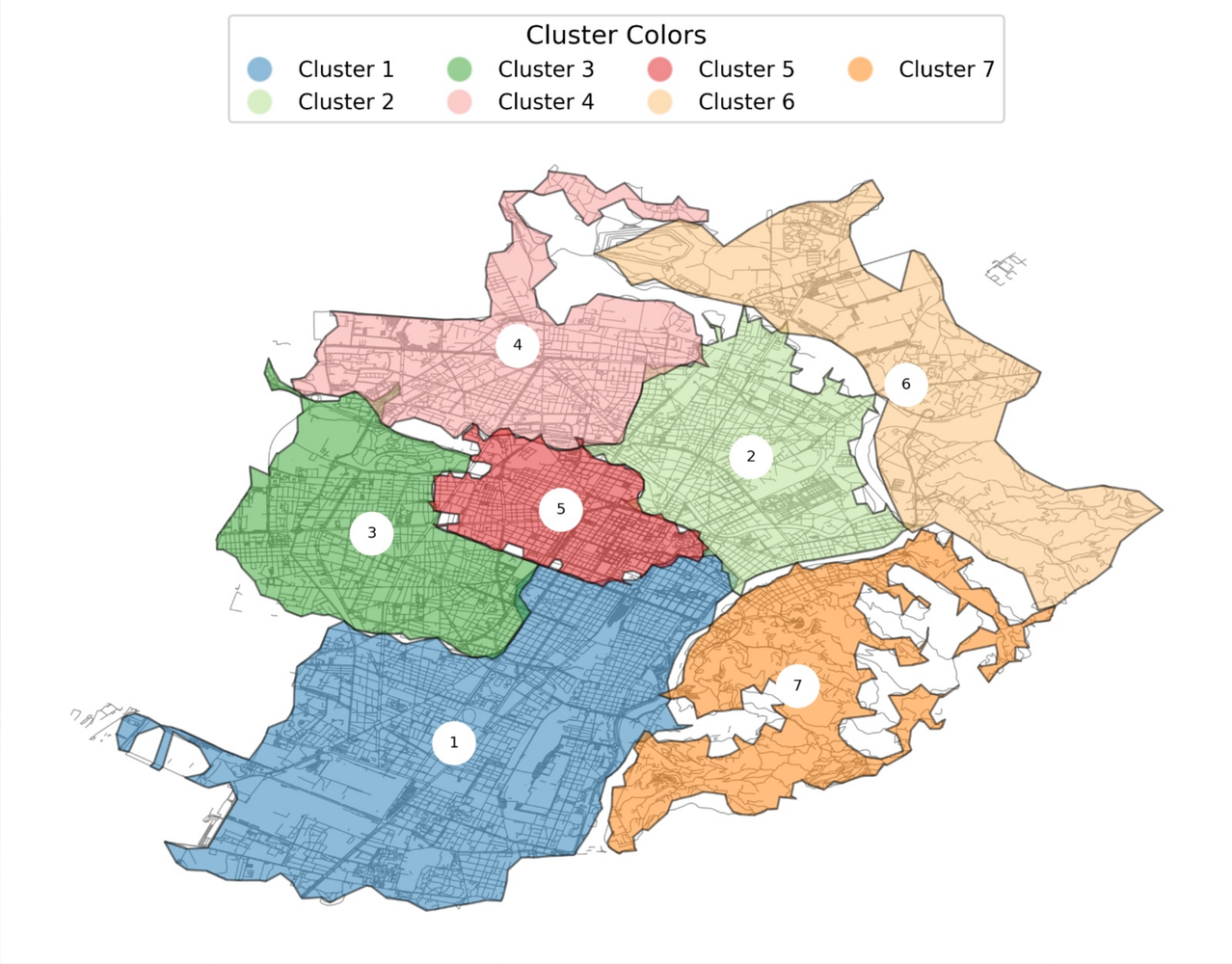
Turin, census areas

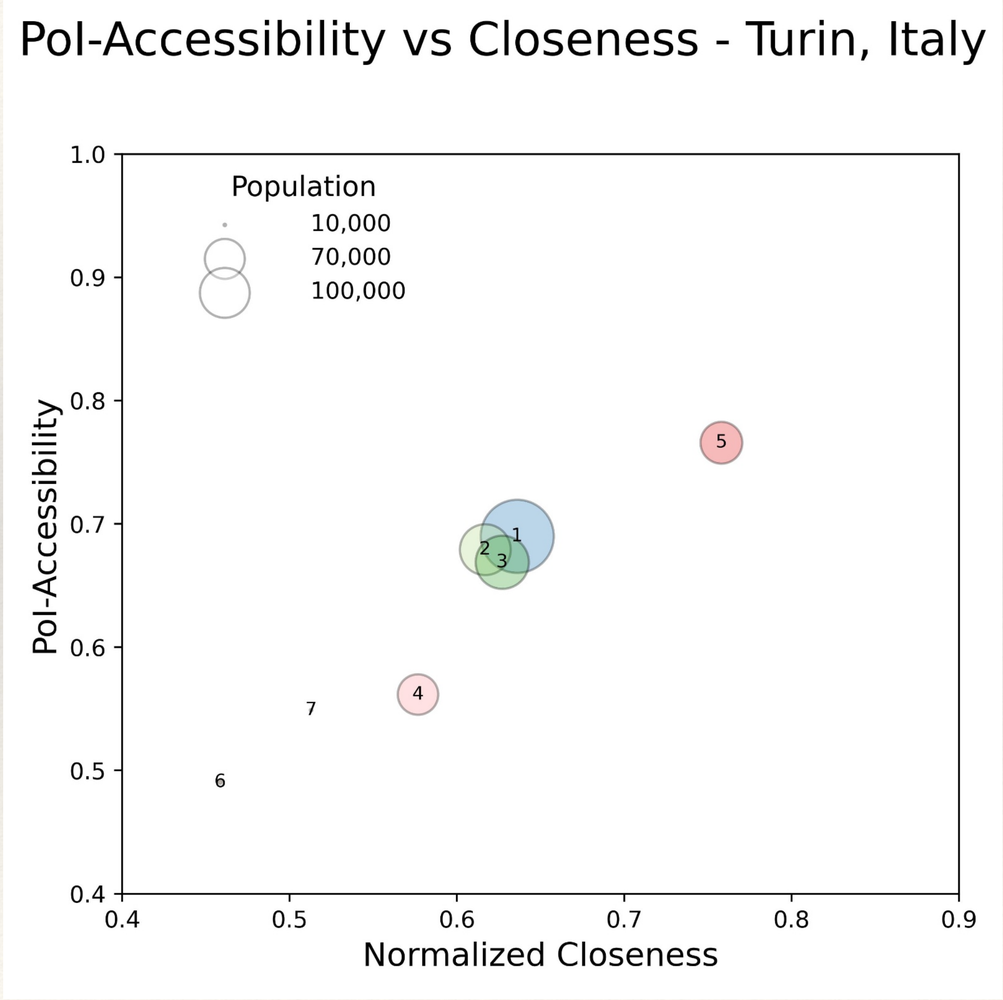




Closeness vs PoI-Accessibility (t=15′)

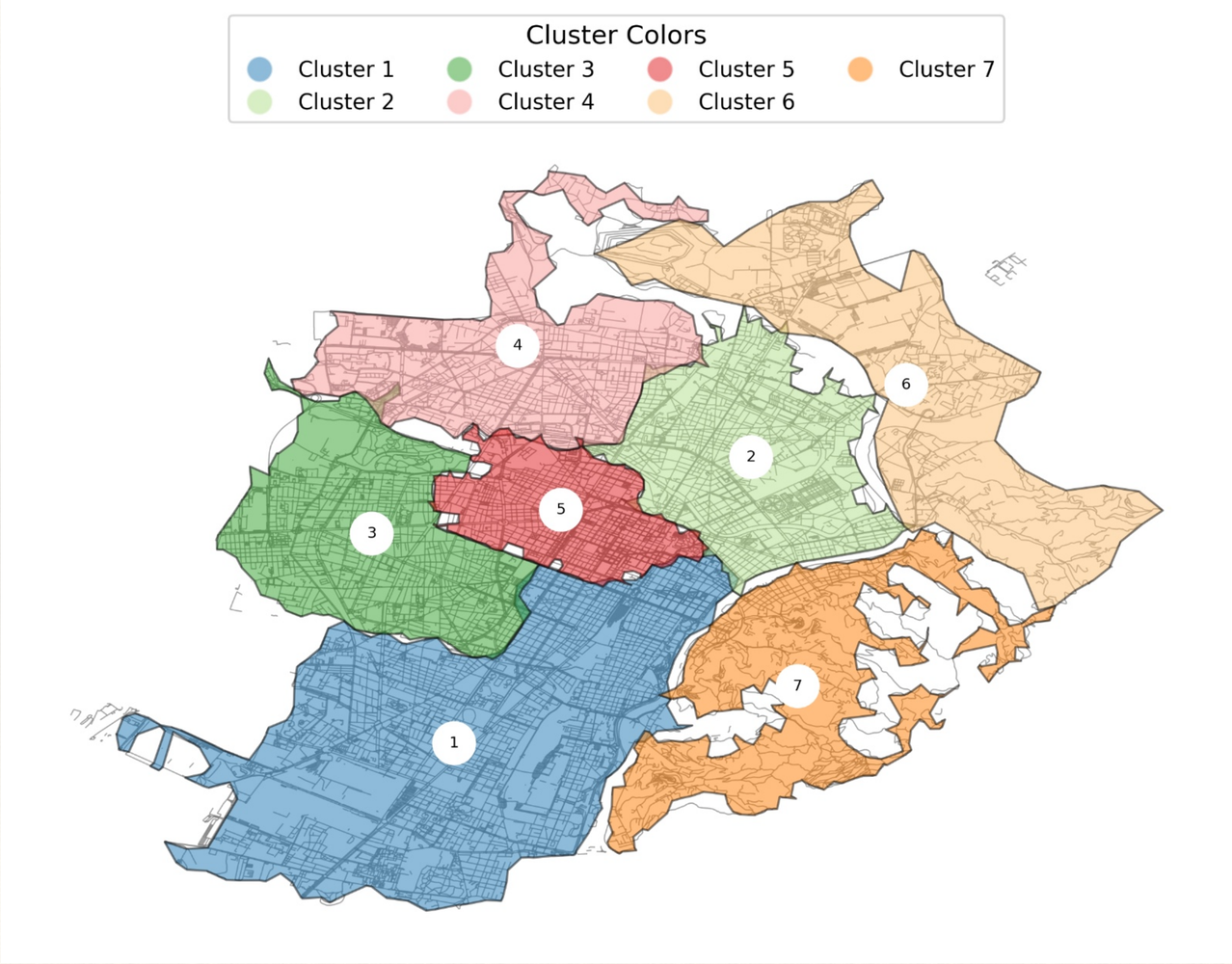
Turin, infomap clusters

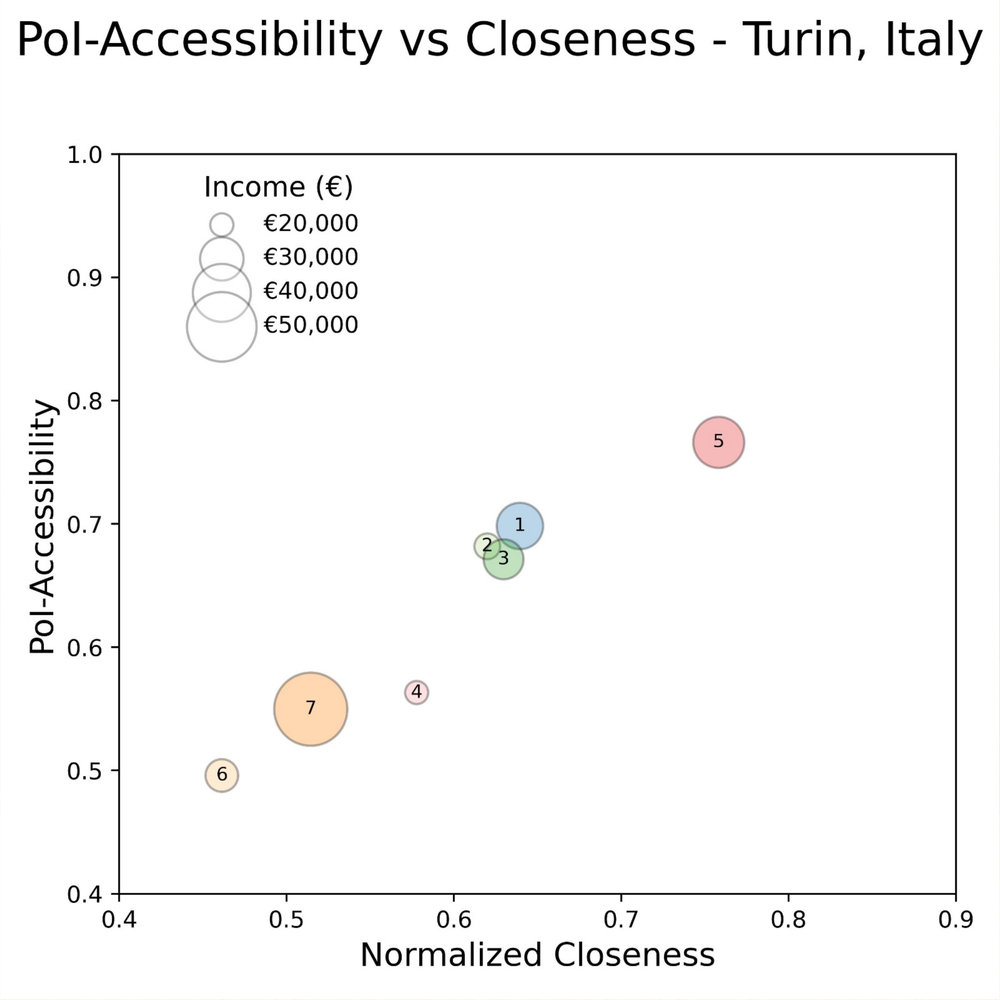




Closeness vs PoI-Accessibility (t=15′)

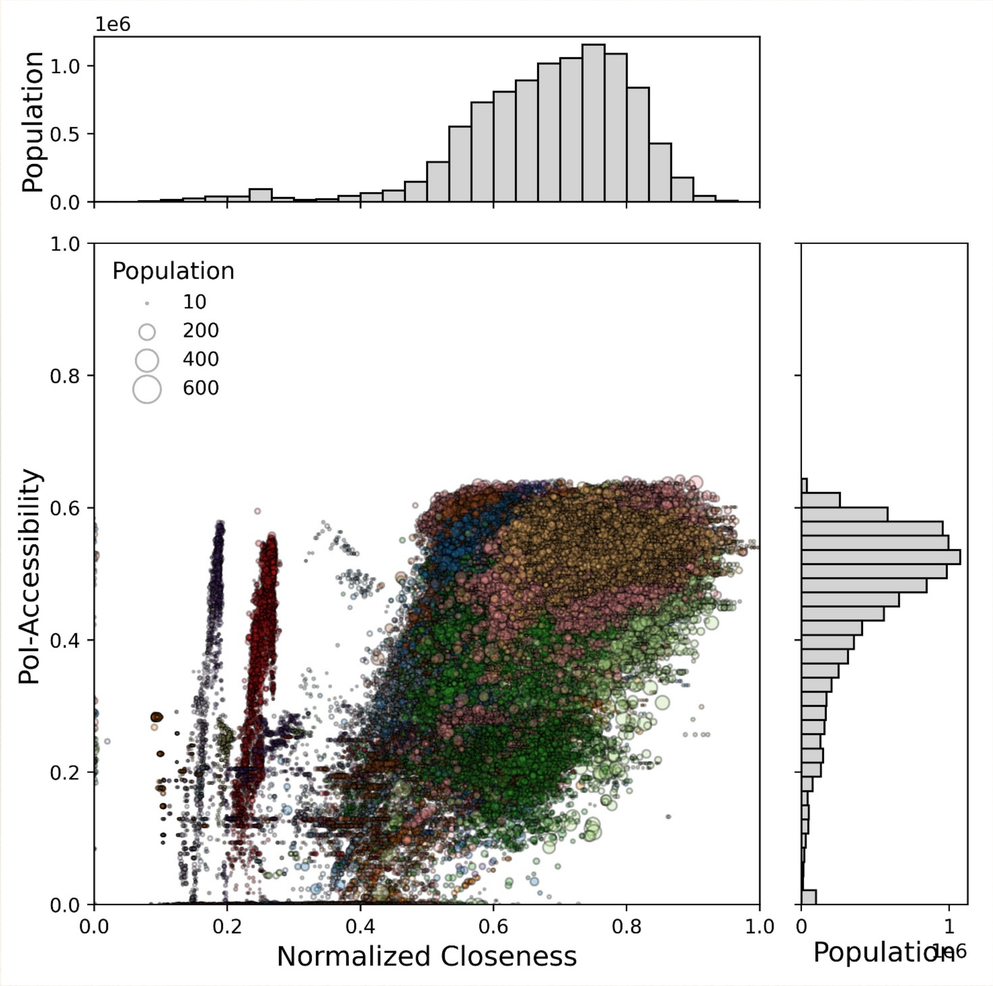
Turin, infomap clusters





Closeness vs PoI-Accessibility (t=15′)

Istanbul, census areas



Closeness vs PoI-Accessibility (t=15′)

Istanbul, infomap clusters