Lecture 06
Sustainable mobility

CIVIL-239: Engineering a sustainable built environment

15 October 2024

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Scan to add to class Spotify paylist

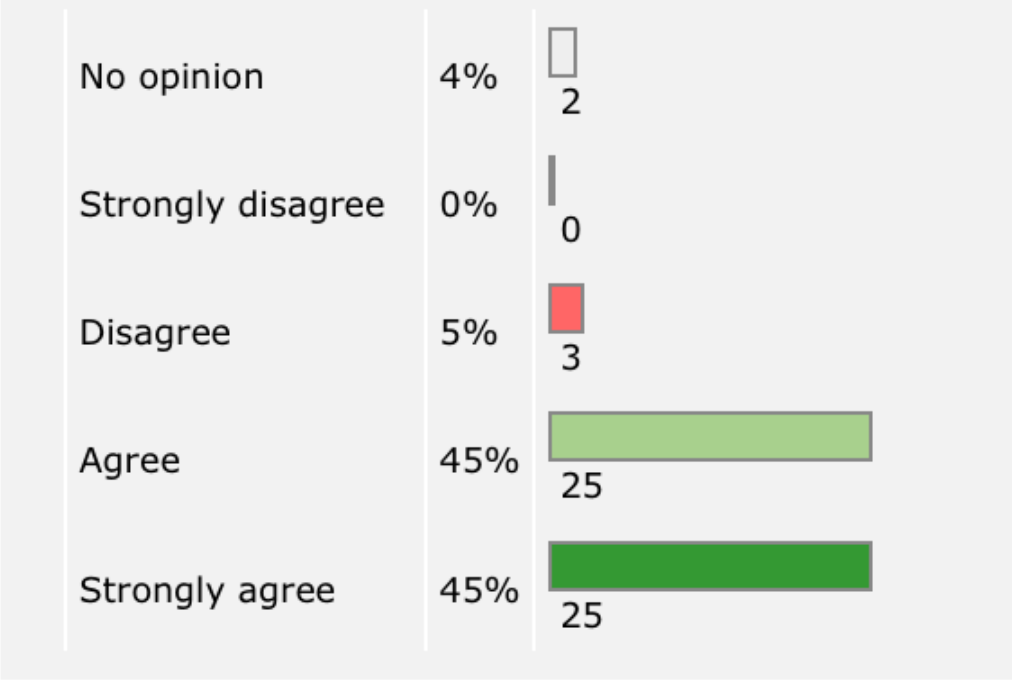
Midterm exam

- How to prepare:
  - Review slides and your notes
  - Review assignments
- Oct 29, 10:15-12:00
- Room CE 1 1
- Closed book and notes
- Bring a simple calculator
- Mix of multiple choice and open-ended questions
- Not intended to test memorization, but rather understanding of the material

Indicative feedback

- Slides and lectures
  - Interesting
  - Not clear what's useful for the exam
  - Plan: provide a summary at the end of today's class
- Assignments
  - Also interesting
  - Too much work
  - Would be good to get grades sooner
  - Plan: work on streamlining the exercises and grading to complement the lectures and learning

The running of the course enables my learning and an appropriate class climate



Outline

- Review systems thinking theory
- In-class exercise
- Sustainable and active mobility
- Walkability
- The 15-min city
- Systems thinking and social aspects of sustainability

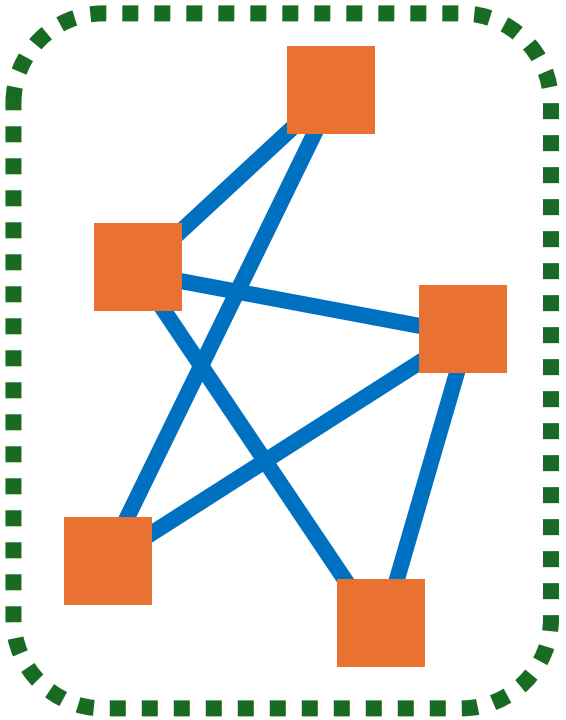
Transportation is a complex ***system***

A system is…

a set of elements

interconnected coherently organized

in a way that achieves something

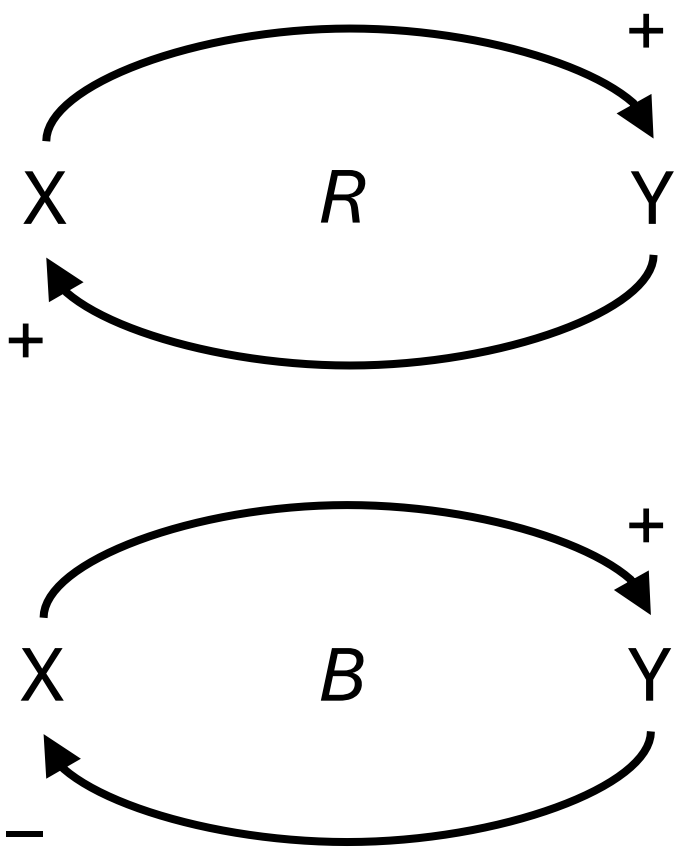


- Multiple parts without interdependencies are just collections
- The structure helps to drive the system toward its purpose

Systems definition: Meadows, 2008

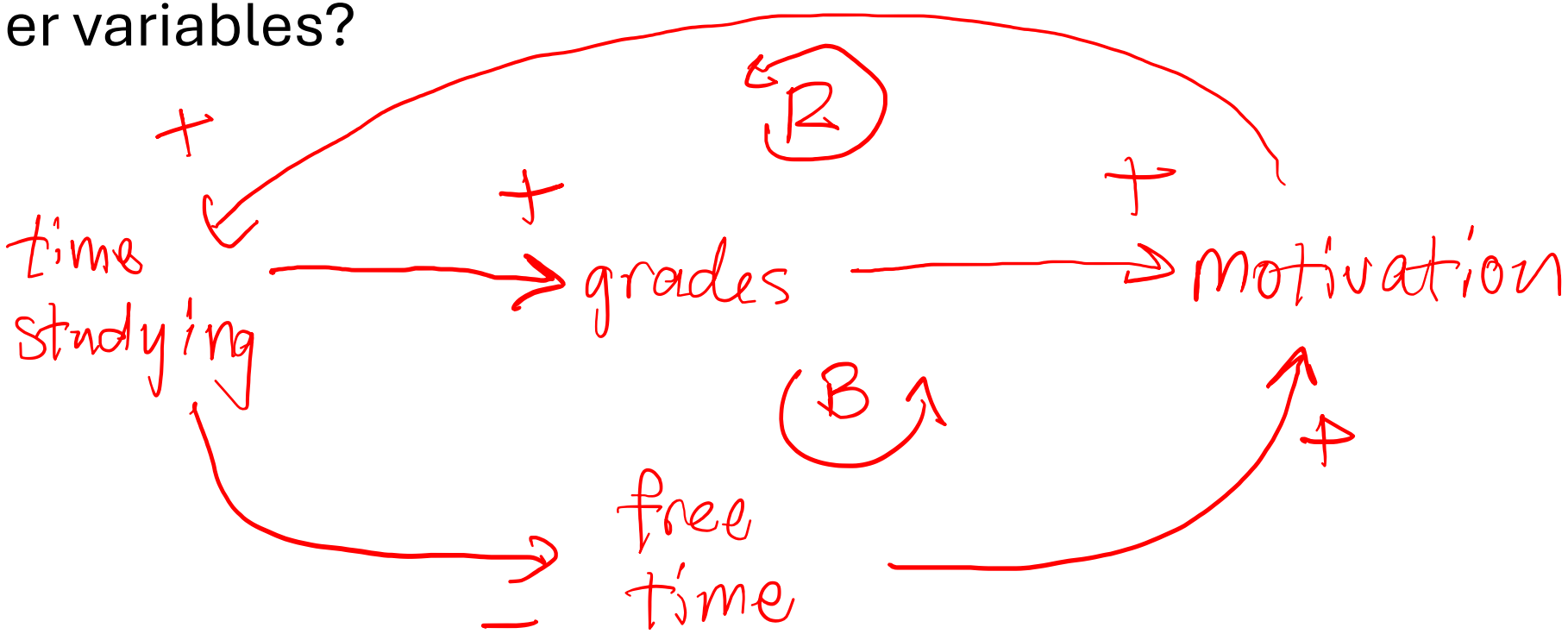
Visualizing systems with causal loop diagrams

- Causal loop diagrams (CLDs) are visual tools to represent how different variables are related and highlight feedback loops
- Components of a CLD:
  - Variables (components)
  - Arrows (connections)
  - Signs (indicate positive or negative relationships)



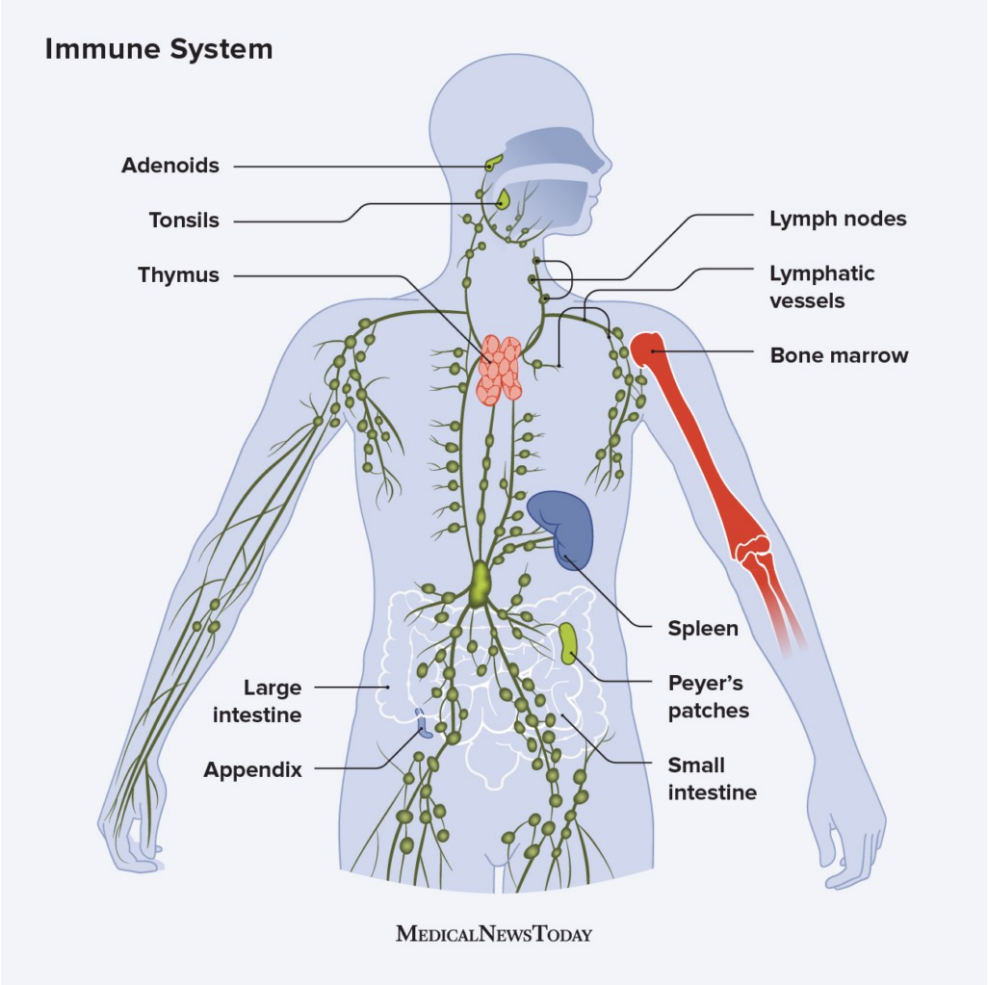
Simple CLD

- Variables: (1) time spent studying, (2) grades
- Other variables?



The importance of feedback loops

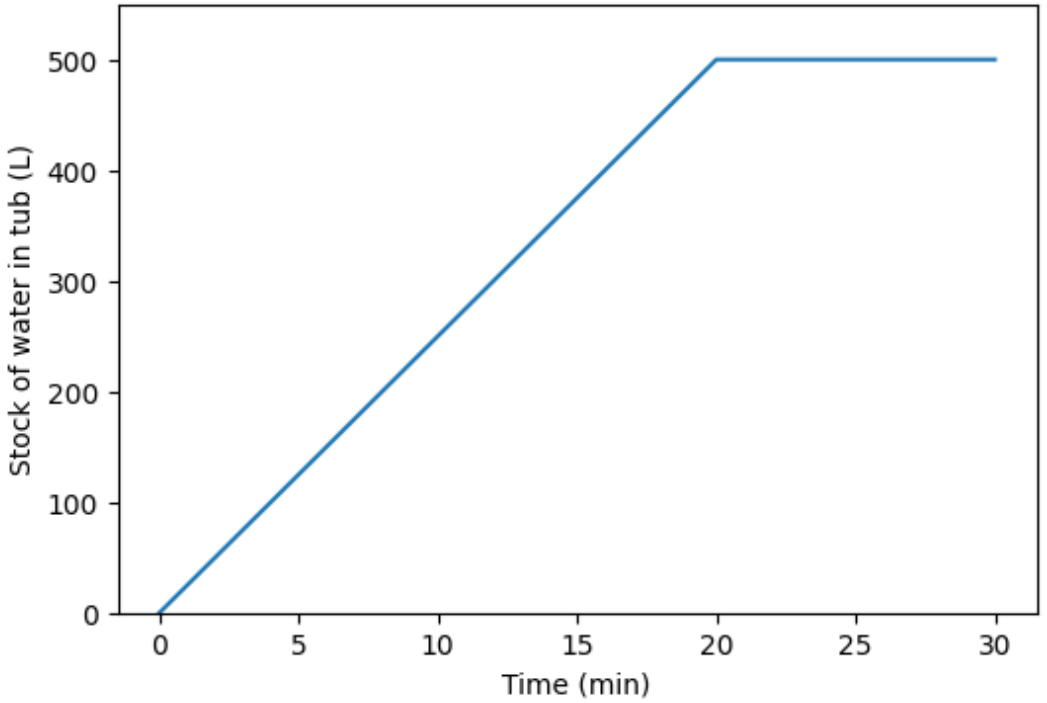
What happens when you get sick?



https://www.medicalnewstoday.com/articles/320101

Sime feedback example

Feedback: Water level affects outflow, which affects water level

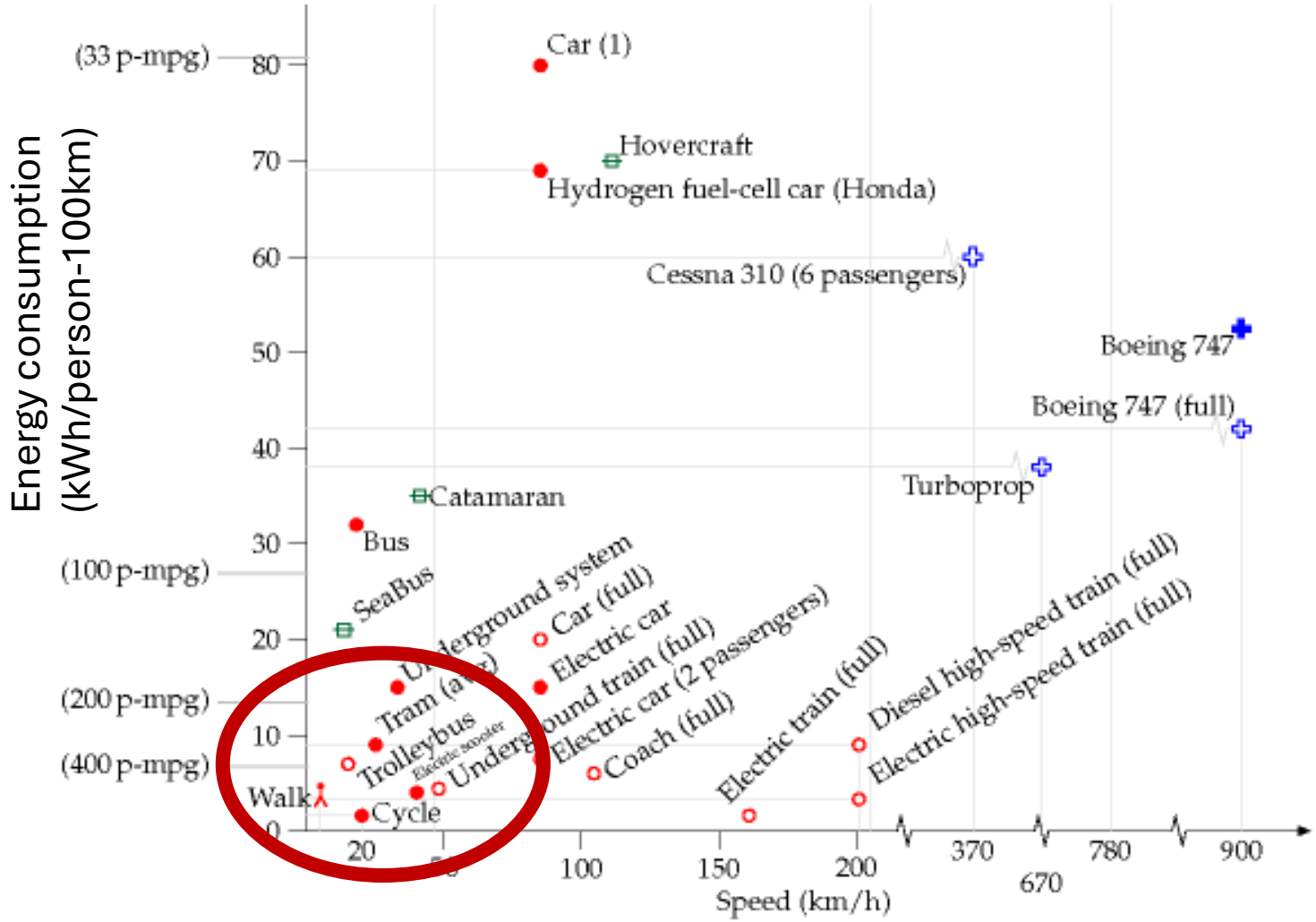


In-class exercise: Create a CLD

Lausanne is considering adding more bike lanes in particular places in the city. As a new systems thinking, you believe you can help in their decision-making by pointing out the relationships between (1) **number of cyclists**, (2) **real and perceived cycling safety**, (3) **car usage**, (4) **vehicle speed**, and (5) **cyclist injuries**. Identify 1 balancing feedback loop and 1 reinforcing feedback loop and draw them in a CLD to explain to the city.

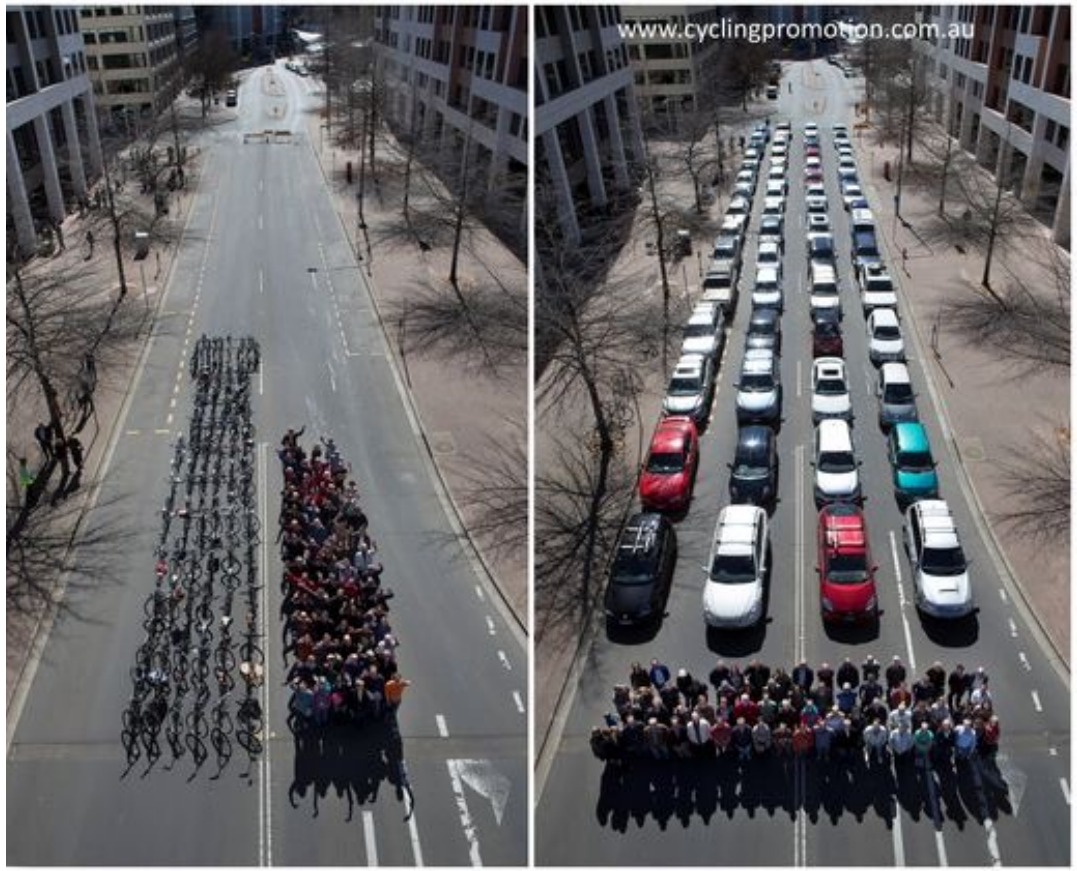
Sustainable mobility

- Focus on low-energy forms of transportation, specifically public transportation, walking and cycling



Active mobility (soft mobility)

- Human-powered mobility
- Clear energy benefits
- Benefits beyond energy
  - Health: reduced air pollution, physical health, mental health
  - Space: less space required vs personal vehicles
  - Economic: people pass by local shops
  - Other environmental benefits: noise pollution
  - Social?



Walkability (and bikeability)

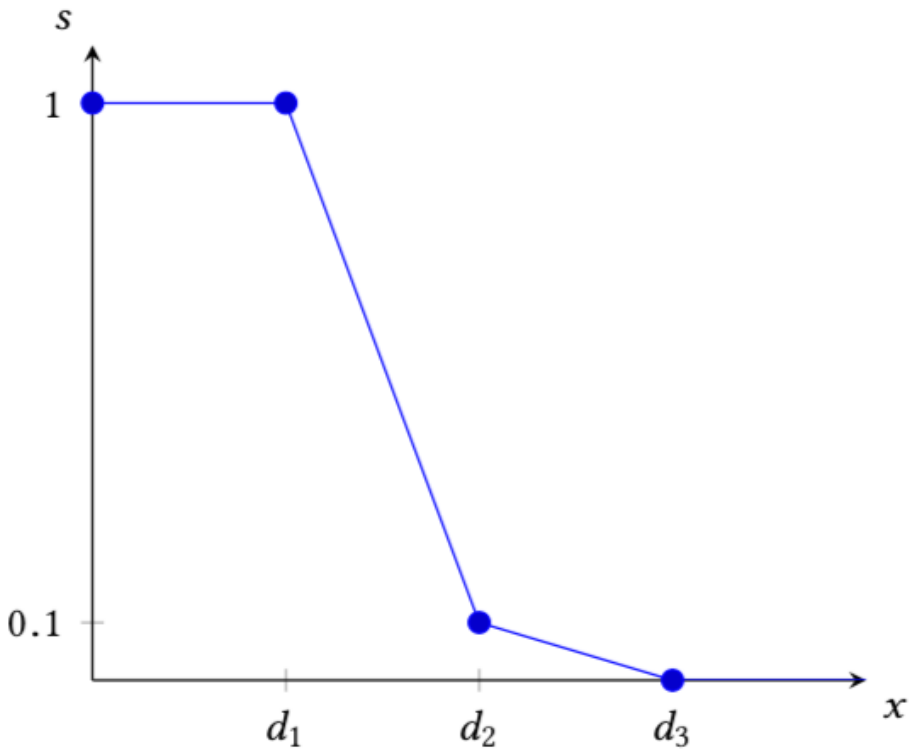
- Walkability is the accessibility of amenities in an urban area of foot (bicycle)
  - Amenities: destinations in an urban environment like stores, restaurants, schools, offices, healthcare facilities, …
- Influenced by many factors
  - Density: things need to be close enough for walking (cycling) to be feasible
  - Land use: need a diversity of amenities nearby
  - Quality of the paths for walking
  - Safety
  - …

First walkability metrics: WalkScore

- Goal: calculate score for walkability for an individual residential unit

$$Score = \frac{1}{A}\left(\sum_{a=1}^{A} \mathbf{w}_a \mathbf{s}_a\right) 100$$

- a: amenity type
- $\mathbf{w}_a$: vector of weights for amenity type
- $\mathbf{s}_a$: vector of distance scores for amenity type
- Note: each amenity type can have different vector lengths (e.g. 2 grocery stores vs. 20 restaurants)
  - Requiring more of an amenity type implies the importance of multiple of that type

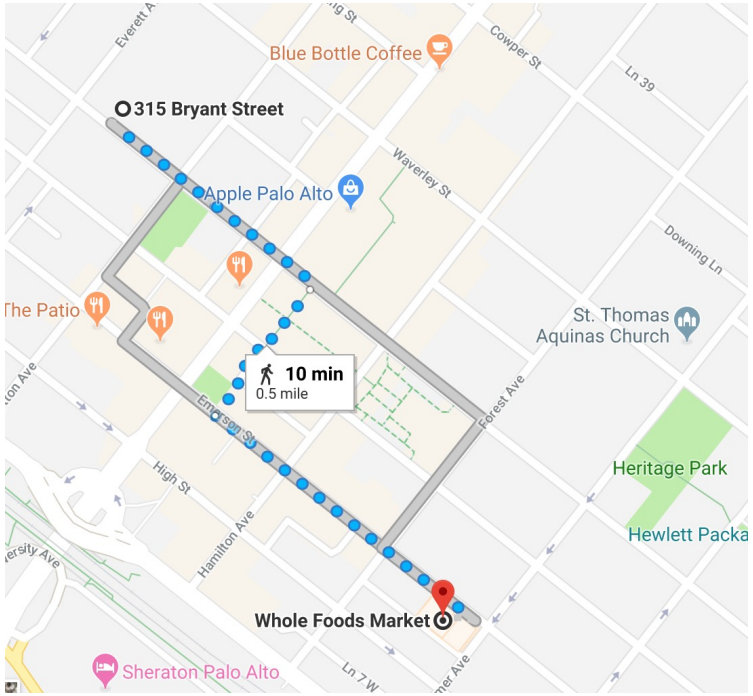


Calculating WalkScore

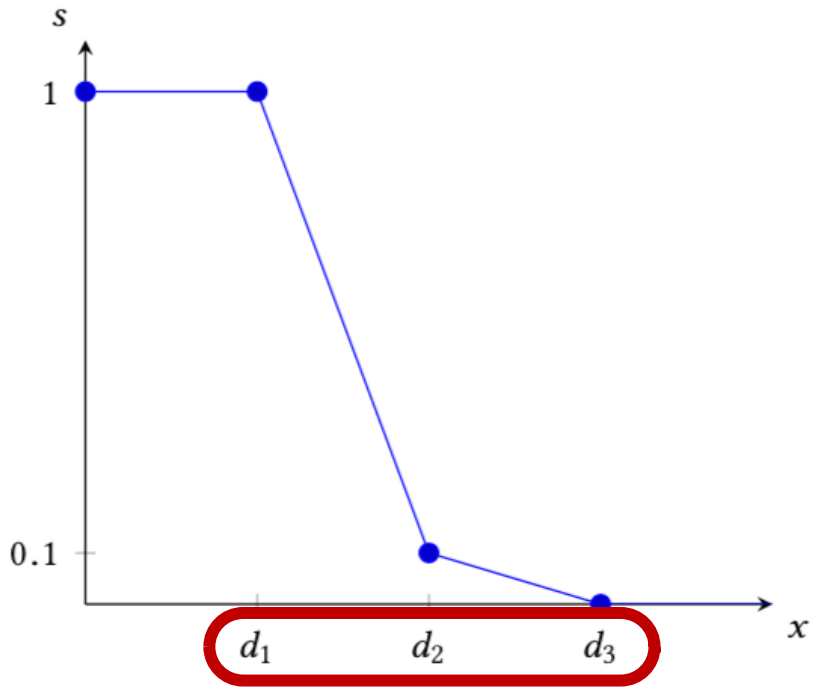
Define amenities

Amenity	Weight
Grocery	[3]
Restaurants	[.75, .45, .25, .25, .225, .225, .225, .225, .2, .2]
Shopping	[.5, .45, .4, .35, .3]
Coffee	[1.25, .75]
Banks	[1]
Parks	[1]
Schools	[1]
Books	[1]
Entertainment	[1]

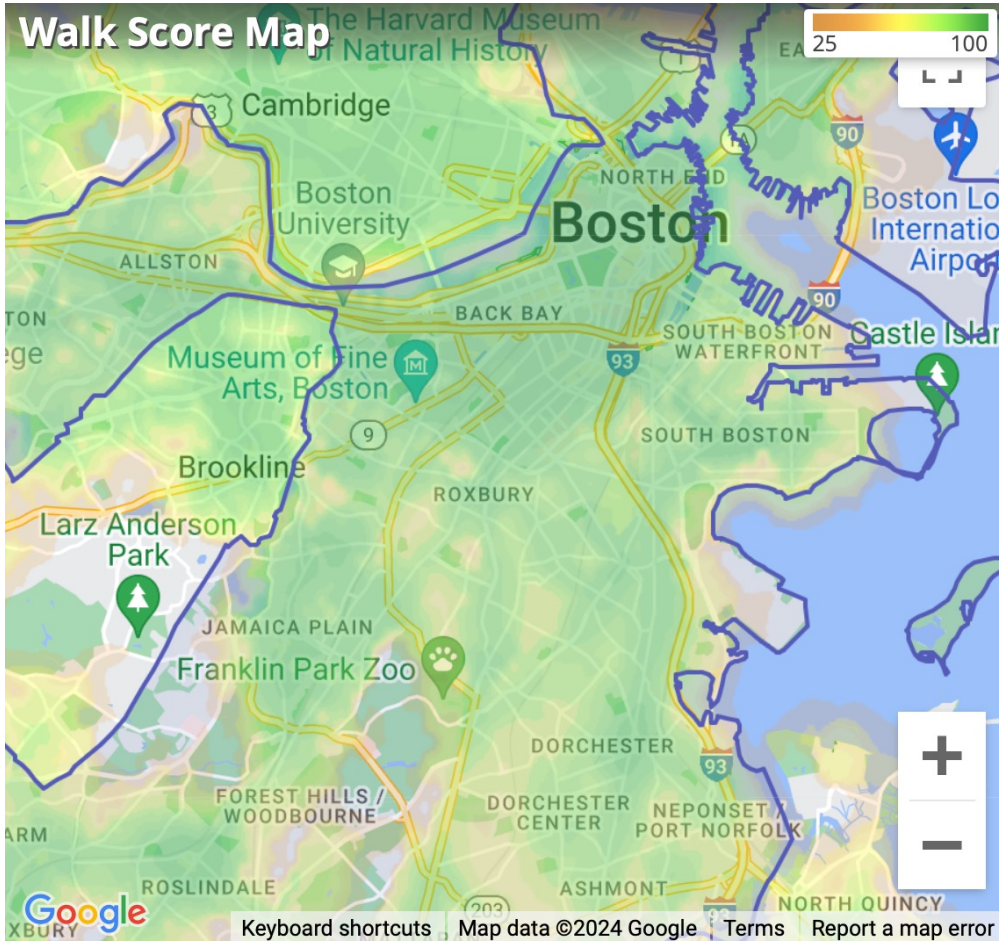
Measure distances

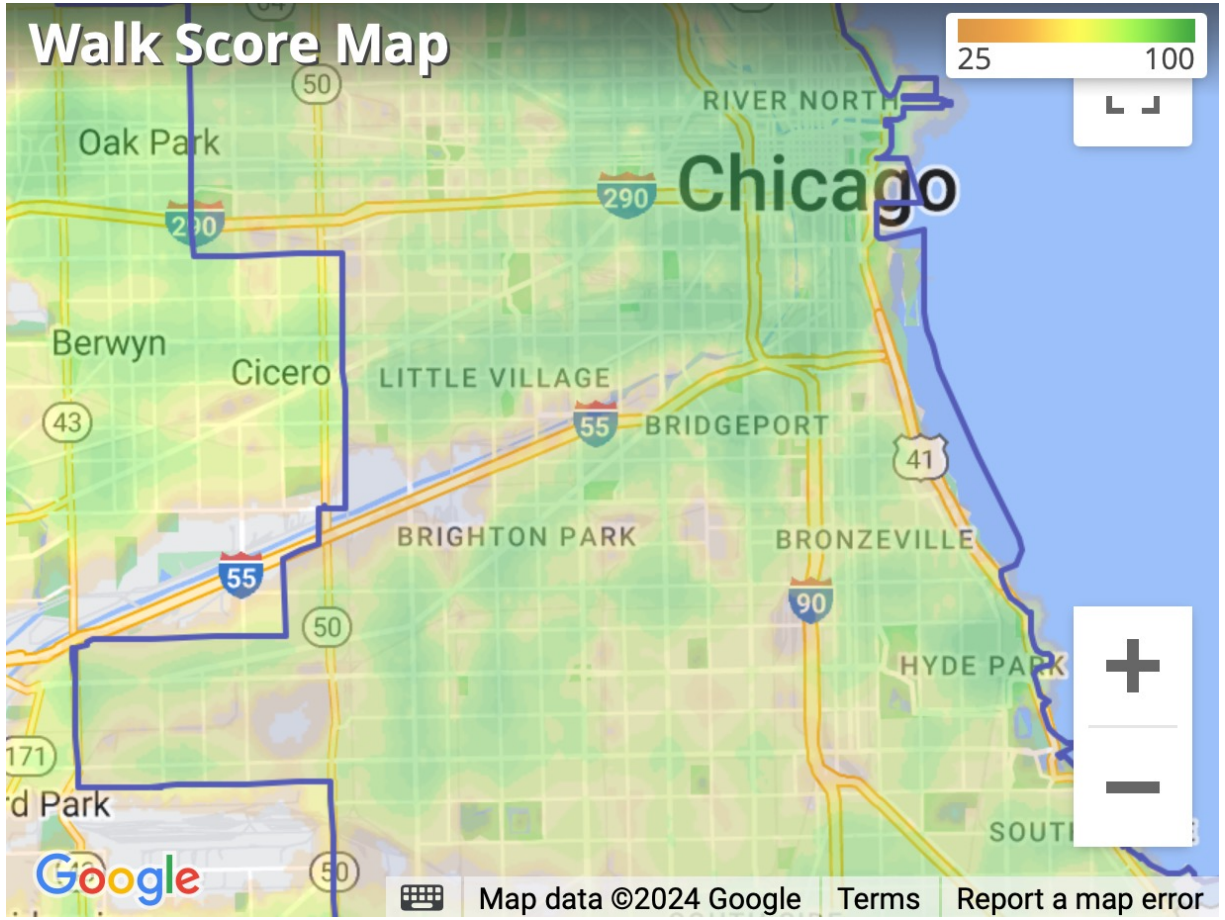


Assign scores



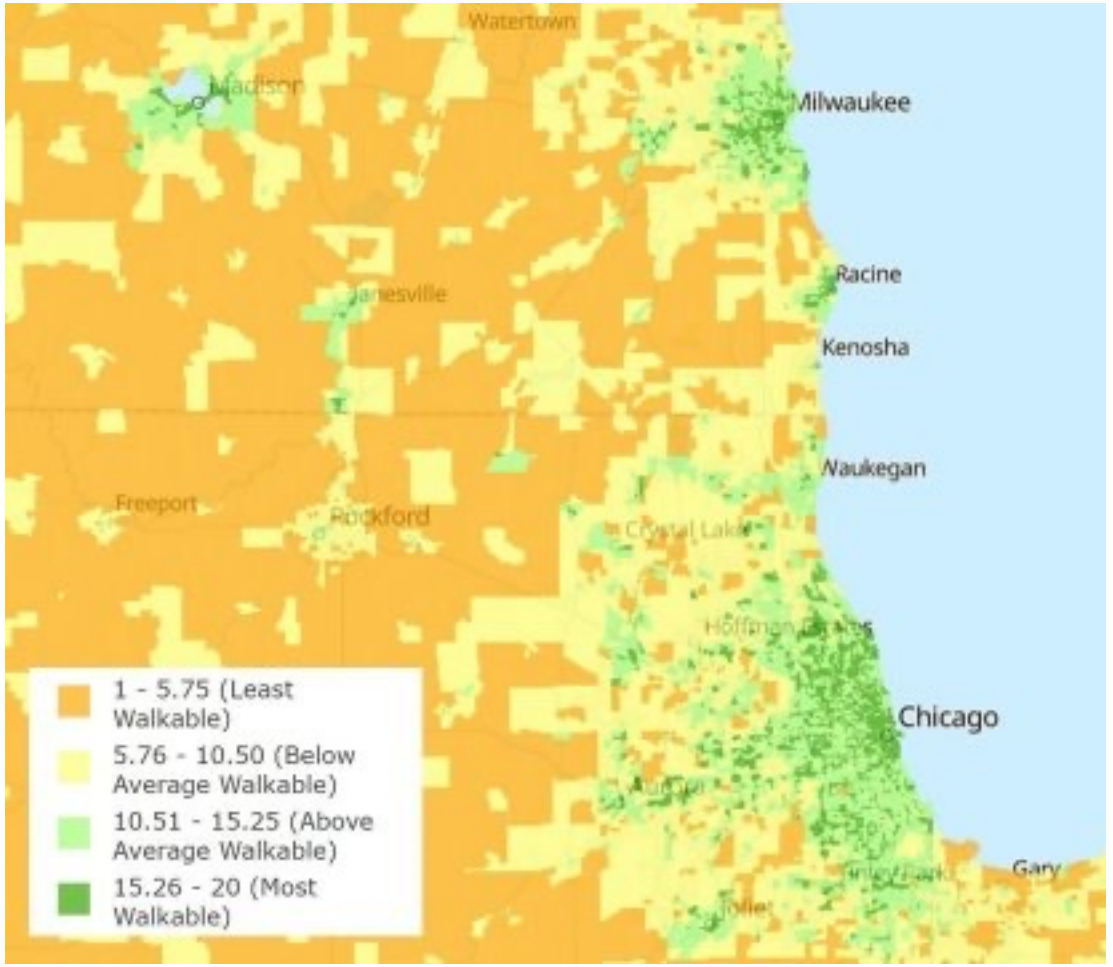
WalkScore.com





Smart Location Database National Walkability Index

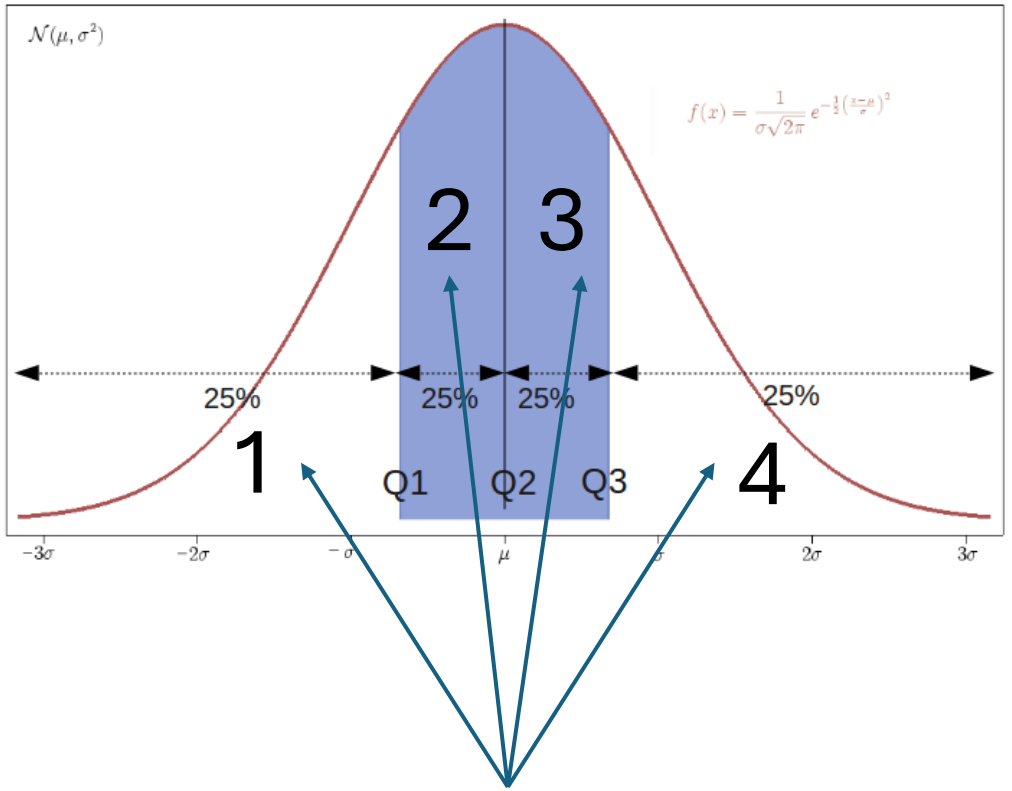
- Calculates a walkability score for each neighborhood as an average of:
  - Intersection density
  - Proximity to transit stops
  - Diversity of land uses
- Each neighborhood is defined as a “Census Block Group,” an area of land with between 500 and 3,000 residents



Source: US Environmental Protection Agency

Smart Location Database National Walkability Index (NWI)

- Four variables:
  - **Intersection density**: number of walkable intersections divided by land area
  - **Proximity to transit stops**: distance from population-weighted center of CBG to nearest transit stop
  - **Entropy of households and commercial job**s (households, retail, office, industrial, service, entertainment)
  - **Entropy of households and all jobs** (previous categories plus education, healthcare, and public administration)
- Each CBG is ordered for each variable and assigned a **quantile rank** (20 quantiles)



Quantile rank

note: each quantile has the same number of data

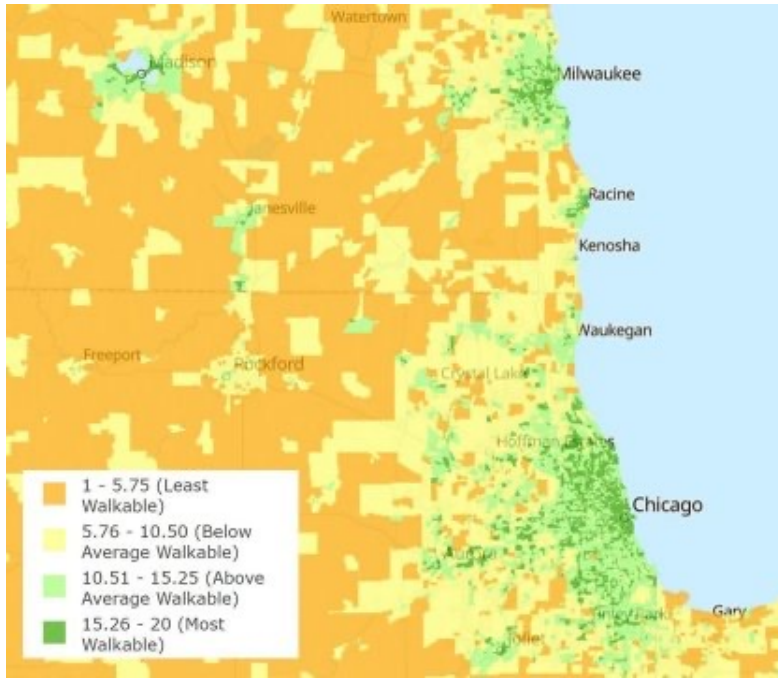
Source: Wikimedia Commons

Smart Location Database National Walkability Index (NWI)

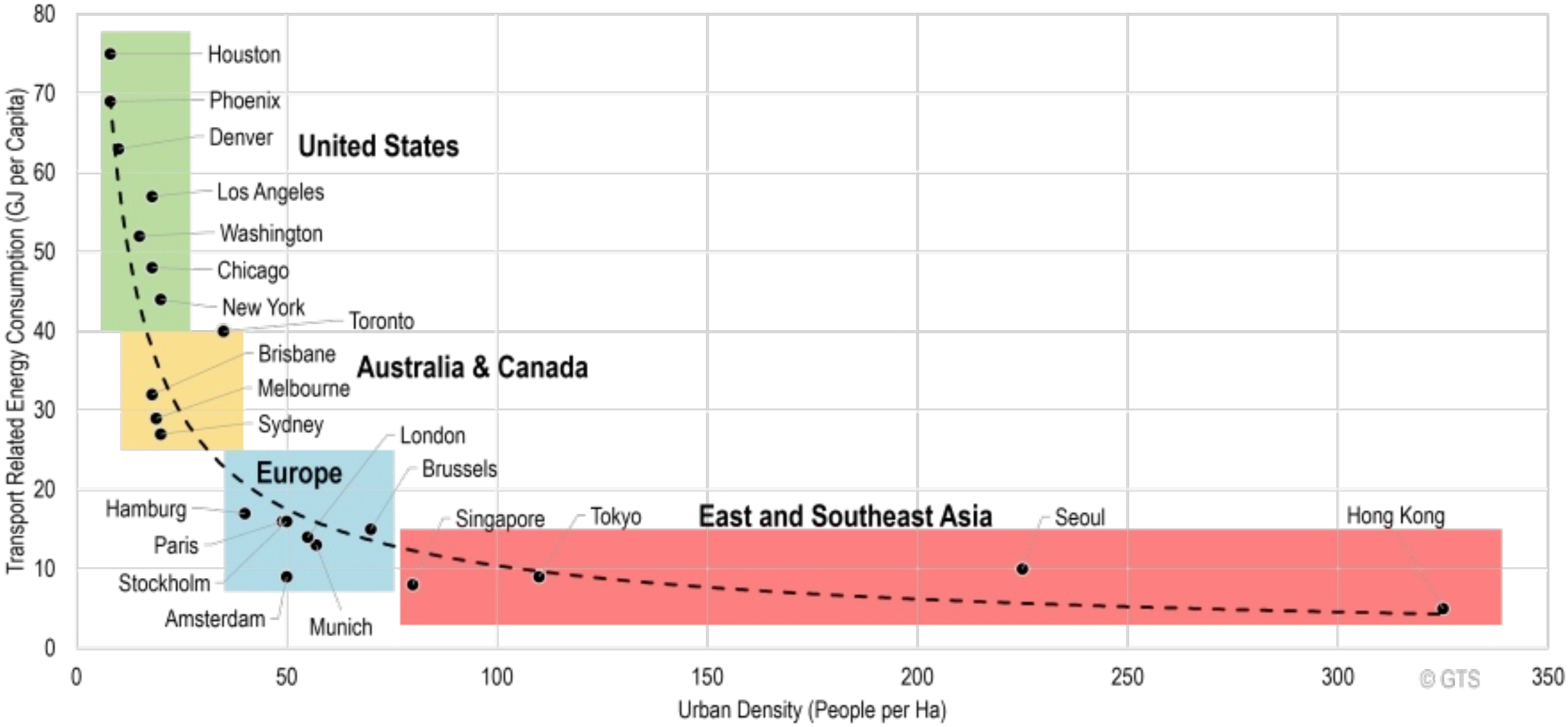
- Entropy: measure of the evenness of the distribution
  - Higher entropy: more equal number of each type (households, jobs in different categories)

$$NWI = \frac{w}{3} + \frac{x}{3} + \frac{y}{6} + \frac{z}{6}$$

- w: quantile rank of intersection density (1-20)
- x: quantile rank of proximity to transit (1-20)
- y: quantile rank of household+commercial entropy (1-20)
- z: quantile rank of household+all entropy (1-20)



Energy benefits of density



15-min city

- The 15-min city is a **concept** of urban planning that aims to create places where all essential services are located within a 15-min walk or bike ride from each other, reducing the need for personal vehicles
- Essential services:
  - Living
  - Working
  - Education
  - Commerce
  - Healthcare
  - Entertainment

Source: Technical University of Munich

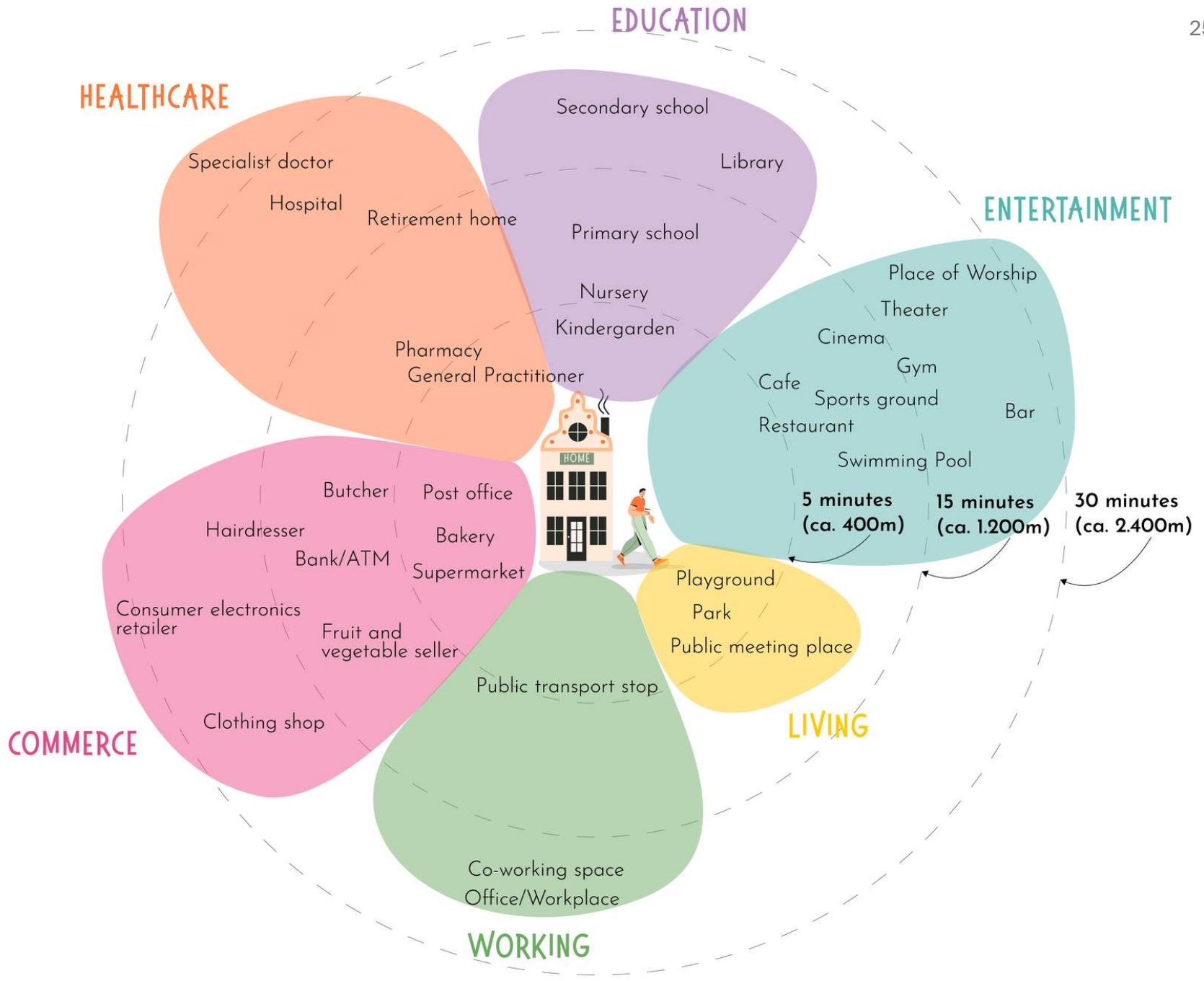
15-min city

- Proposed by Carlos Moreno
- Four key characteristics
- **Proximity**: Things must be close to each other
- **Diversity**: Land uses must be mixed
- **Density**: There must be enough people to support a diversity of businesses in a compact land area
- **Digitalization**: Digital tools enable data collection, smarter operation of systems, and citizen participation

Source: Moreno 2021

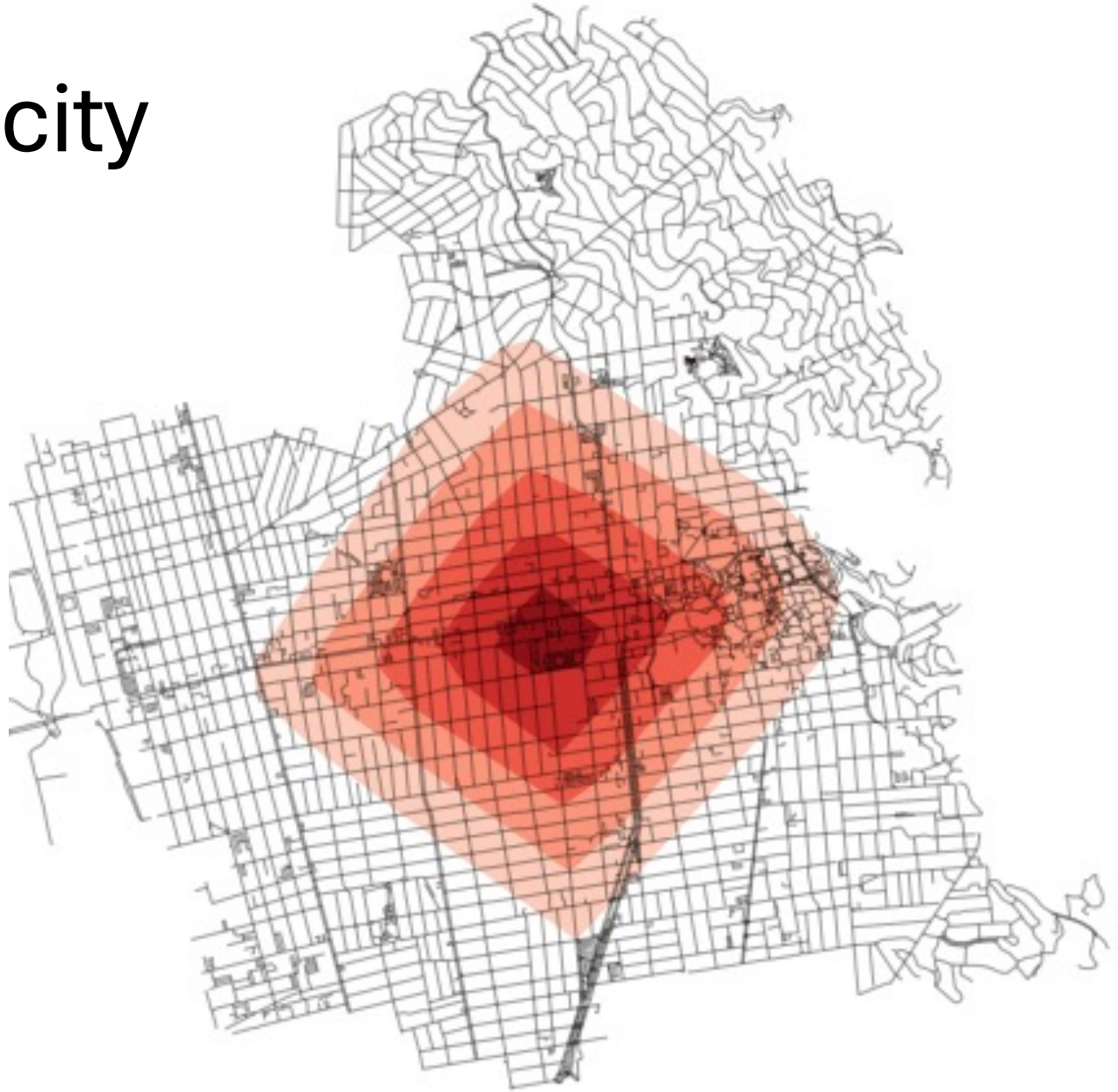
15-min city

- “15-min” is arbitrary
- Needs vary for amenities within a particular type
- Example: Kindergartens vs universities



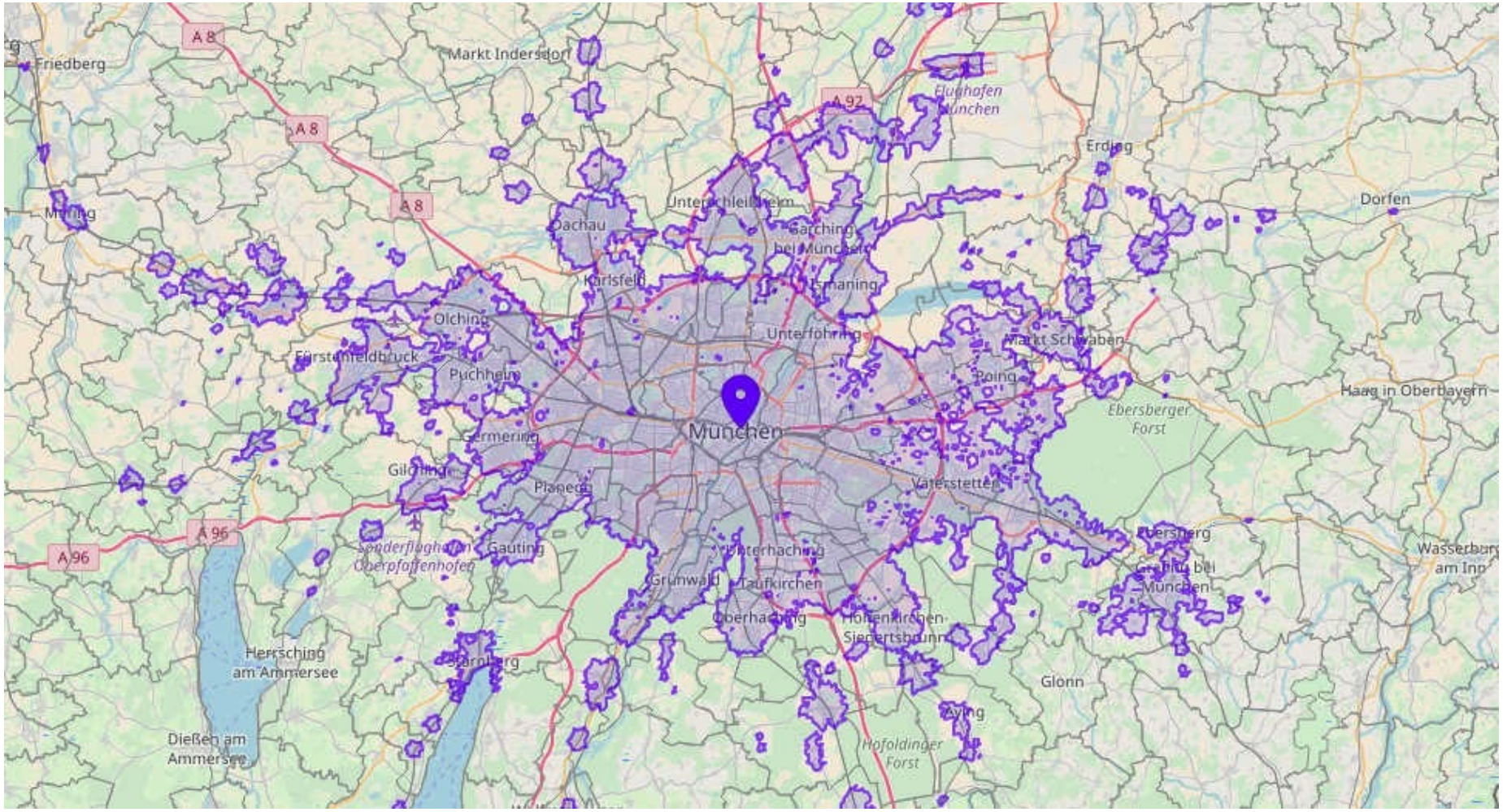
Measuring the 15-min city

- Isochrones tell you what is contained within a trip by a particular mode for a specific time
- Iso: equal
- Chrone: time
- The figure to the right shows 5, 10, 15, 20, and 25-min walks in Berkeley, CA, USA



Source: Goeff Boeing

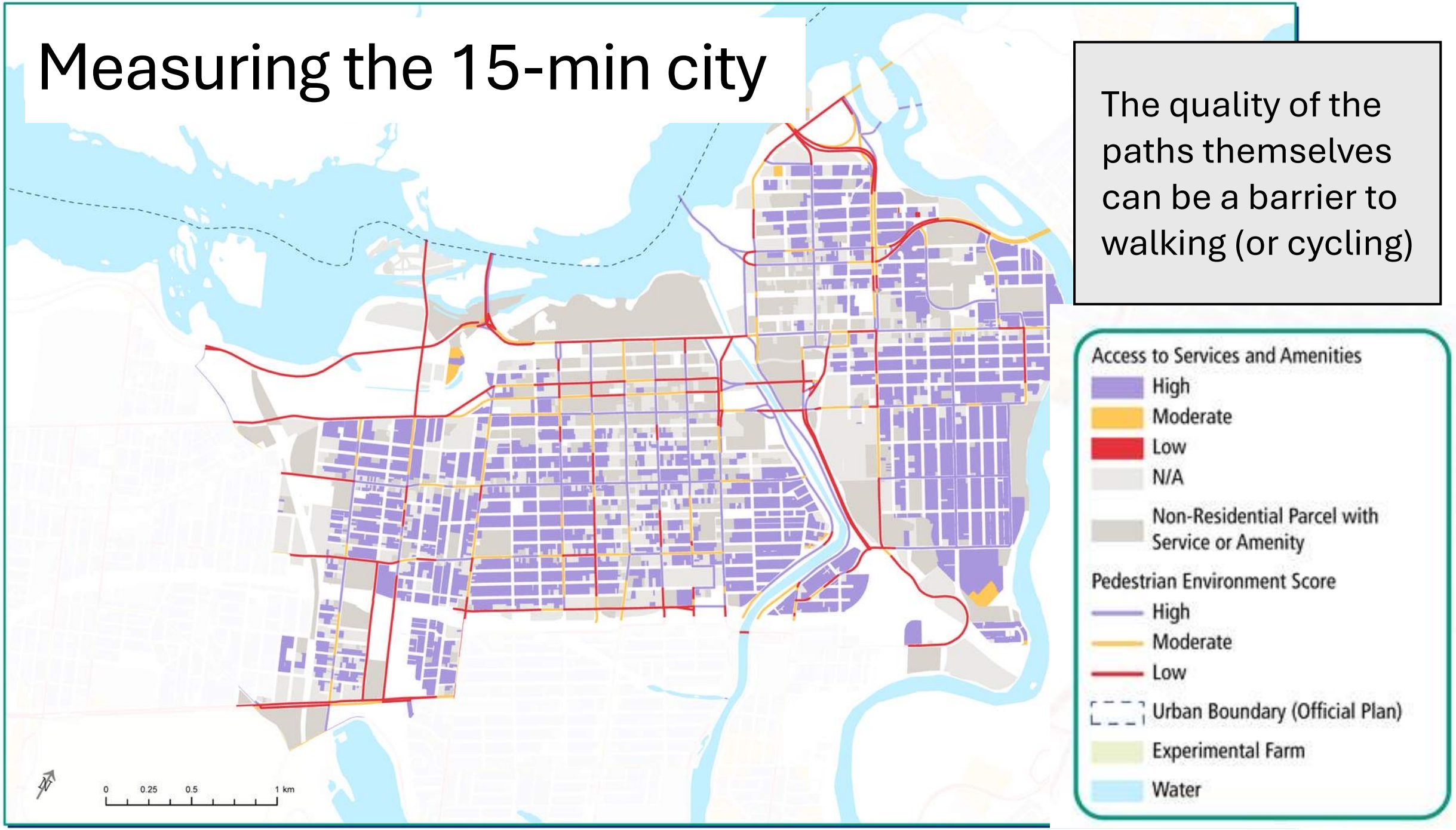
Public transport isochrones



Source: Geoapify

Measuring the 15-min city

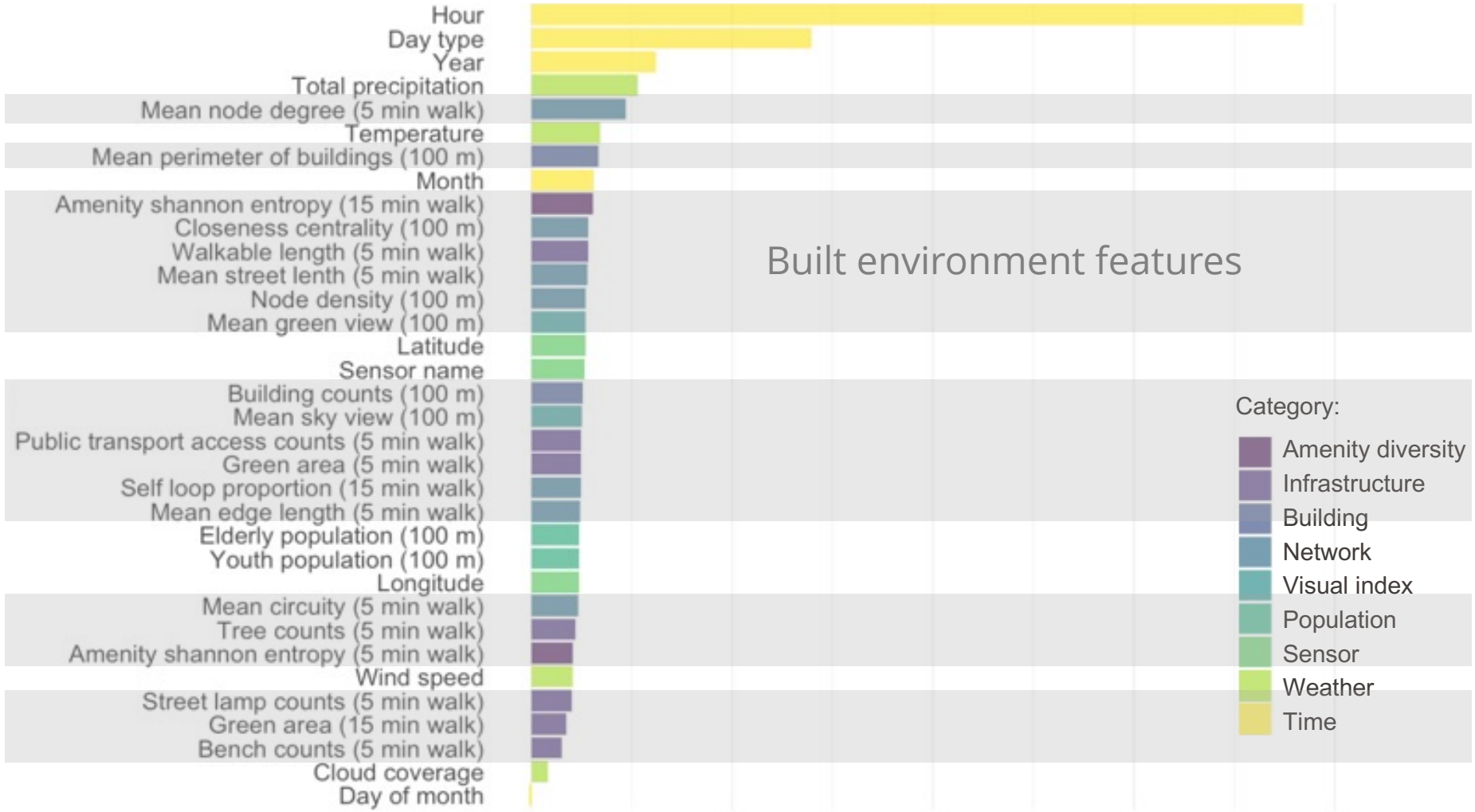
The quality of the paths themselves can be a barrier to walking (or cycling)



Research on walkability at ETHOS

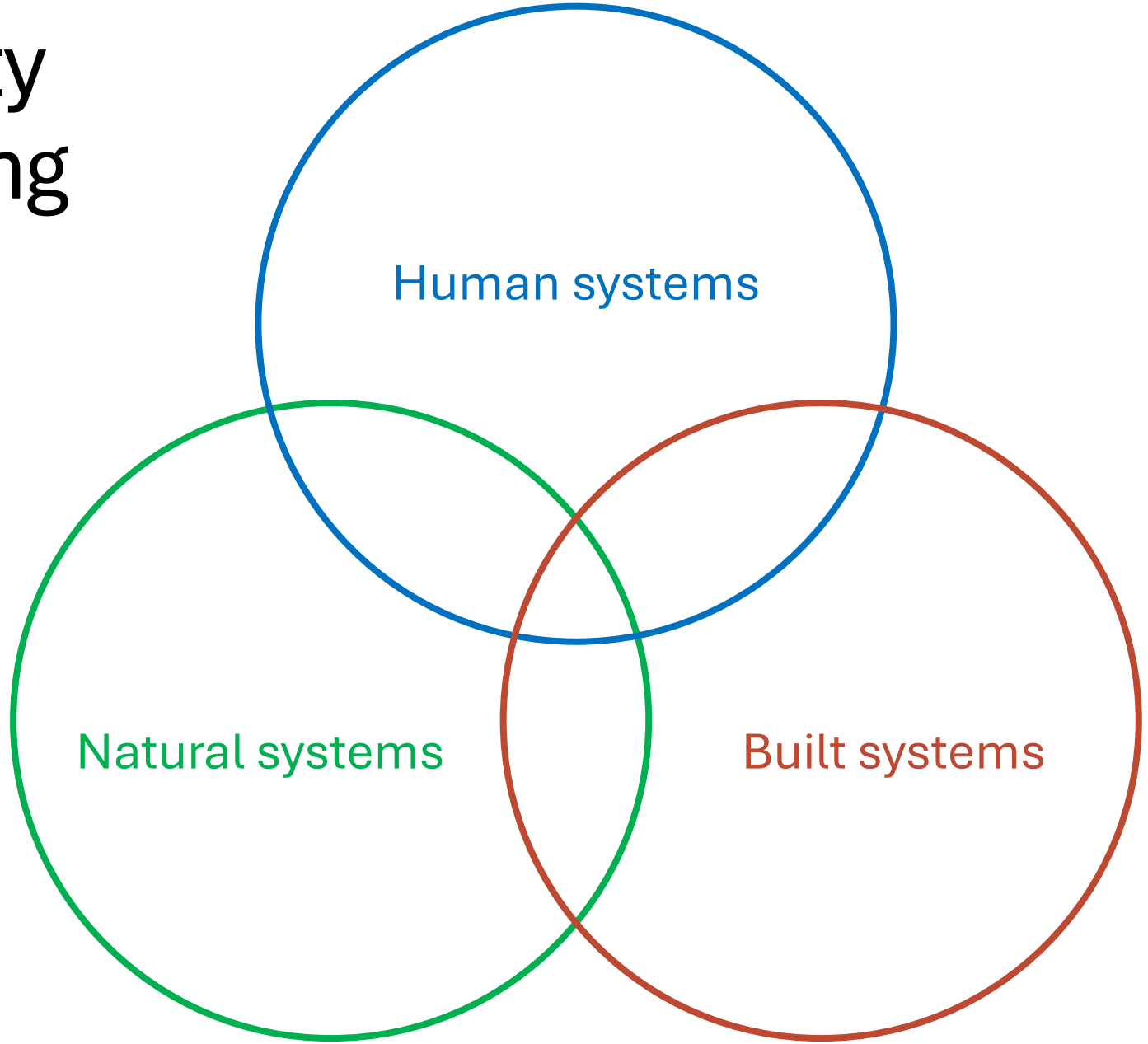
Walking behavior

Feature importance (from machine learning)



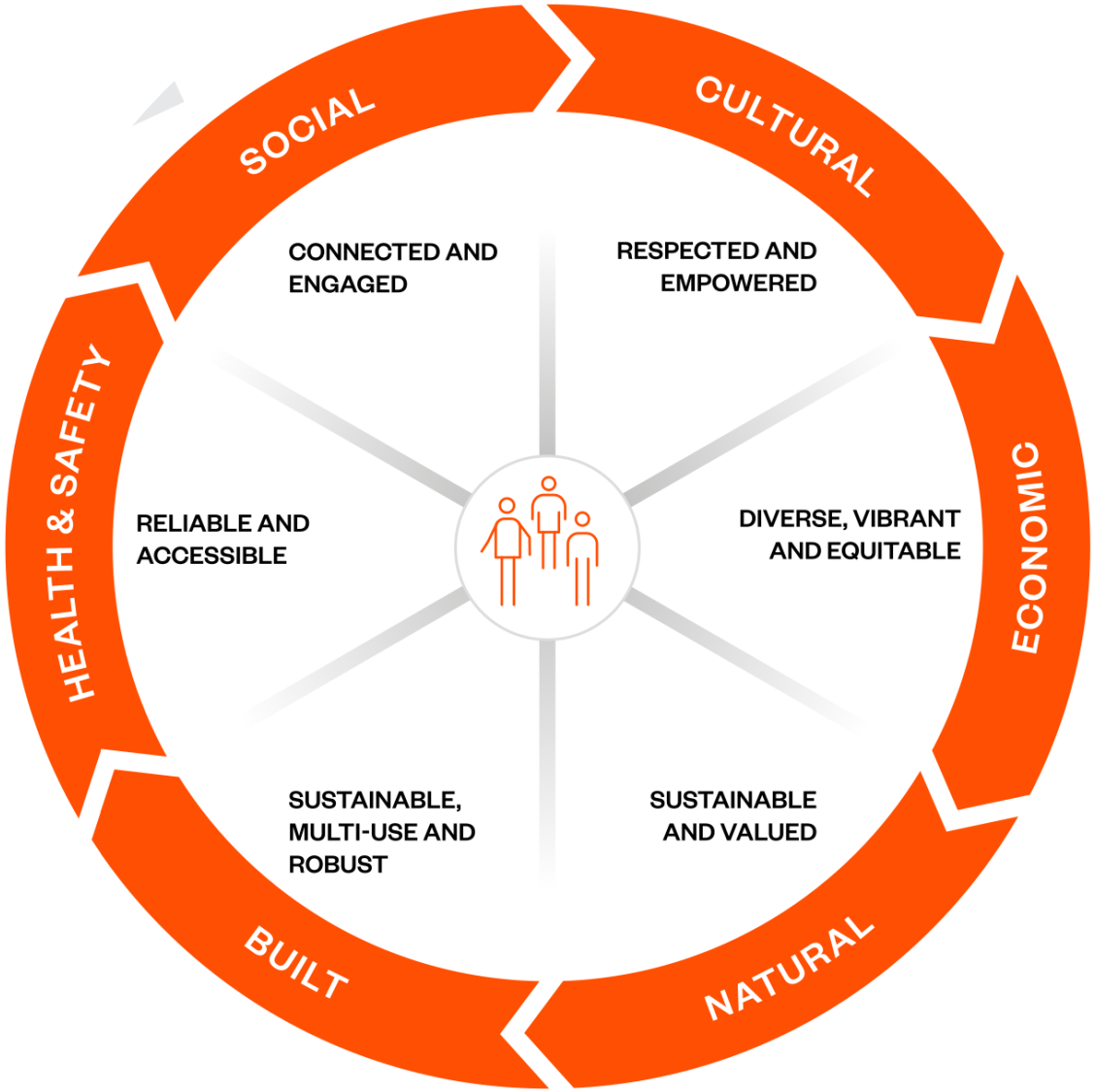
Sustainable mobility and systems thinking

- Complex transportation systems involve relationships between human, natural, and built systems
- Example: sustainability mobility and social resilience



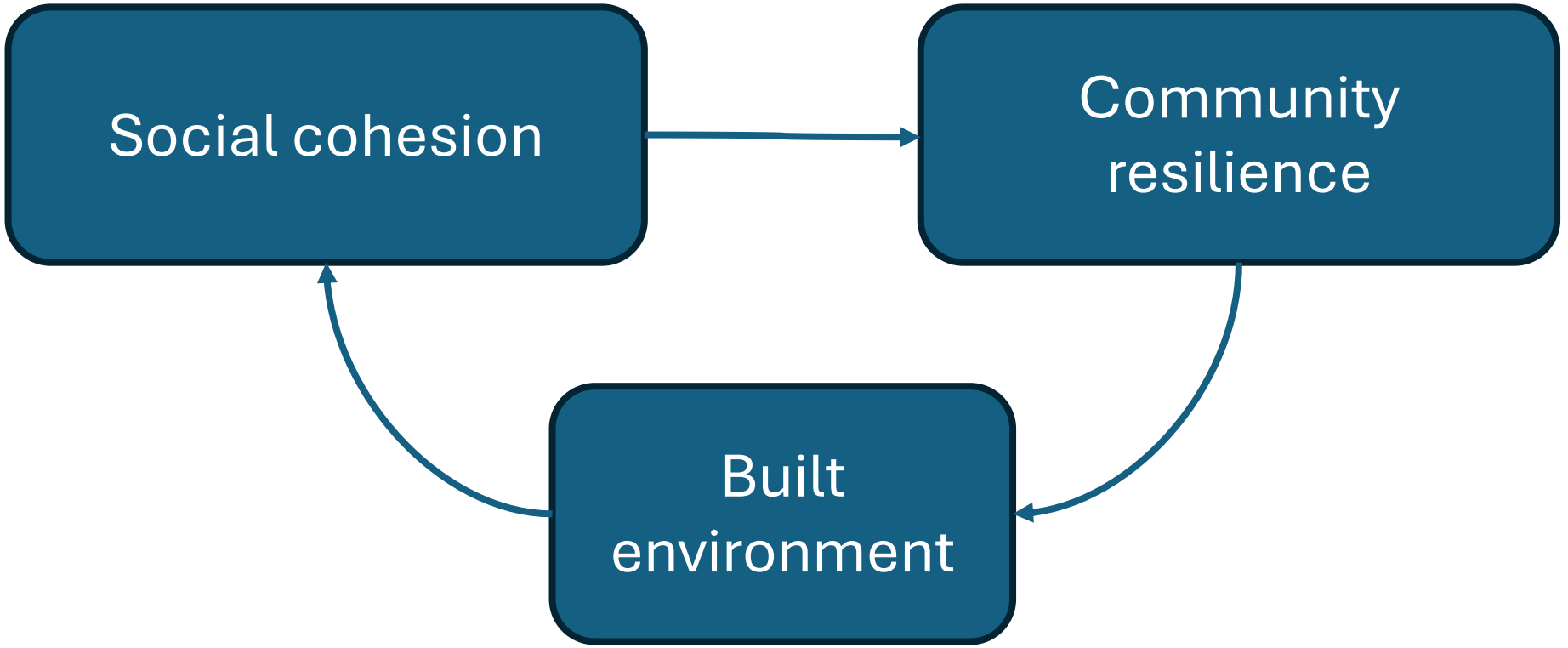
Resilient communities

"Strong social systems within a community – those that promote high levels of **social cohesion**, integration and trust – are among the most important determinants of how well a community will perform in the face of disasters."



Resilient Communities Framework, Resilient Cities Catalyst and Minderoo Foundation

Resilience example: social cohesion

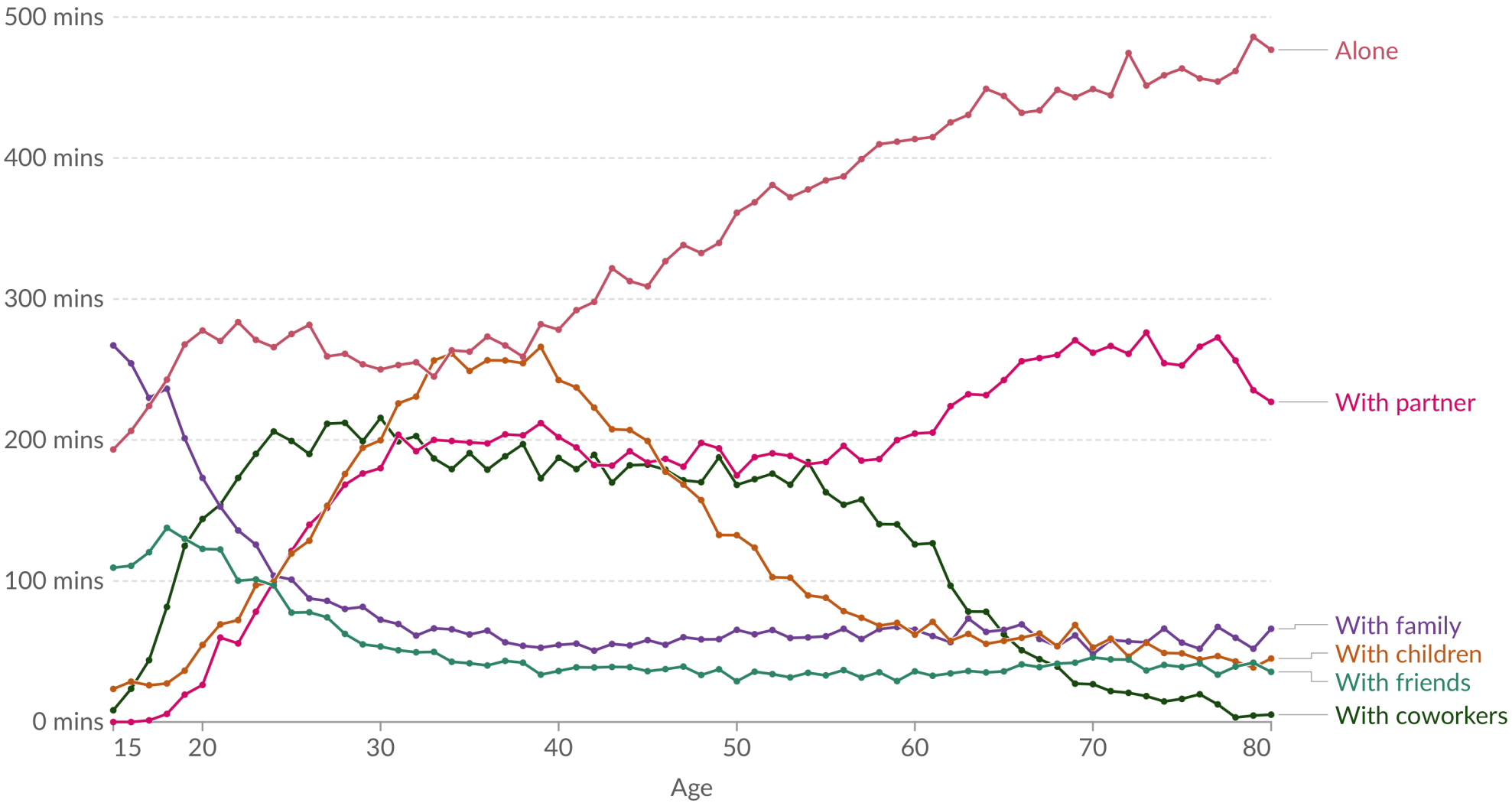


Transportation, urban planning, and cohesion

- Option A
  - Live in a single-family home outside the city. Drive from your home to your workplace. After work, drive from your home to the nearest supermarket to buy groceries, then drive home.
- Option B
  - Live in a multi-family residential building in a neighborhood of the city. Walk 2 blocks to the nearest public transport stop for commute to work. After work, take public transport home. Stop at market and bakery on the walk home.
- In which transportation and urban planning situation would you have an easier time getting to know your neighbors?

Who Americans spend their time with, by age

Measured in minutes per day, based on averages from surveys in the United States between 2009 and 2019.



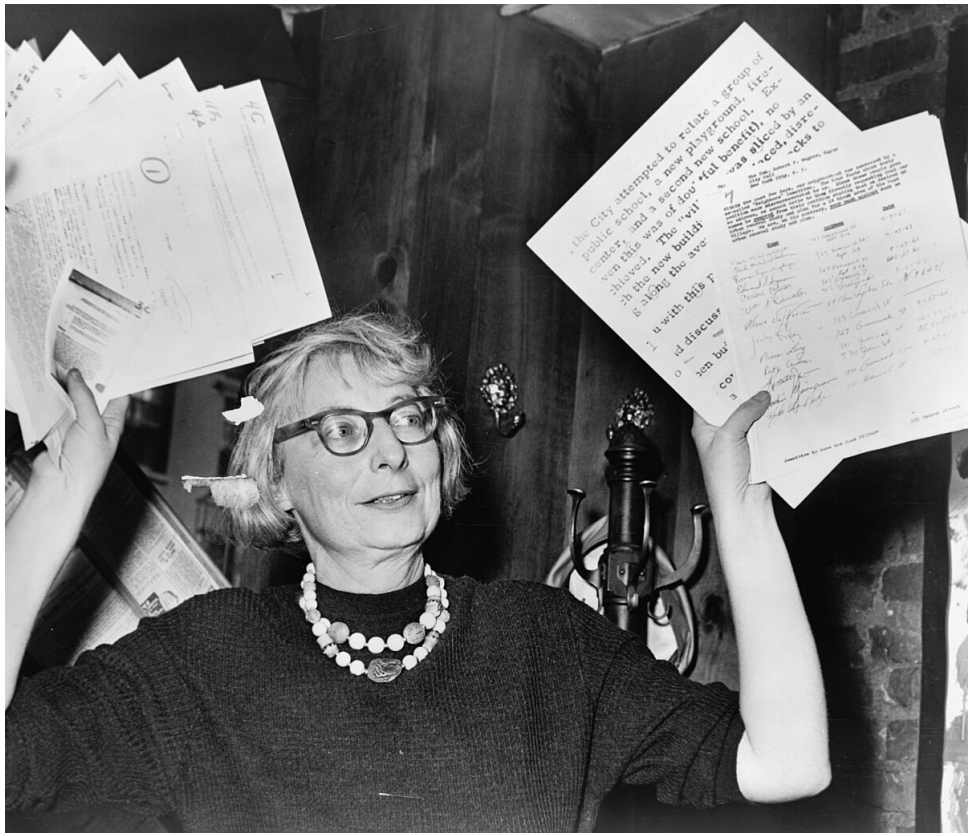
Data source: American Time Use Survey (2009-2019) and Lindberg (2017)

OurWorldinData.org/time-use | CC BY

Note: Relationships used to categorize people are not exhaustive. Additionally, time spent with multiple people can be counted more than once (e.g., attending a party with friends and partner counts toward both "friends" and "partner").

Transportation, urban planning, and cohesion

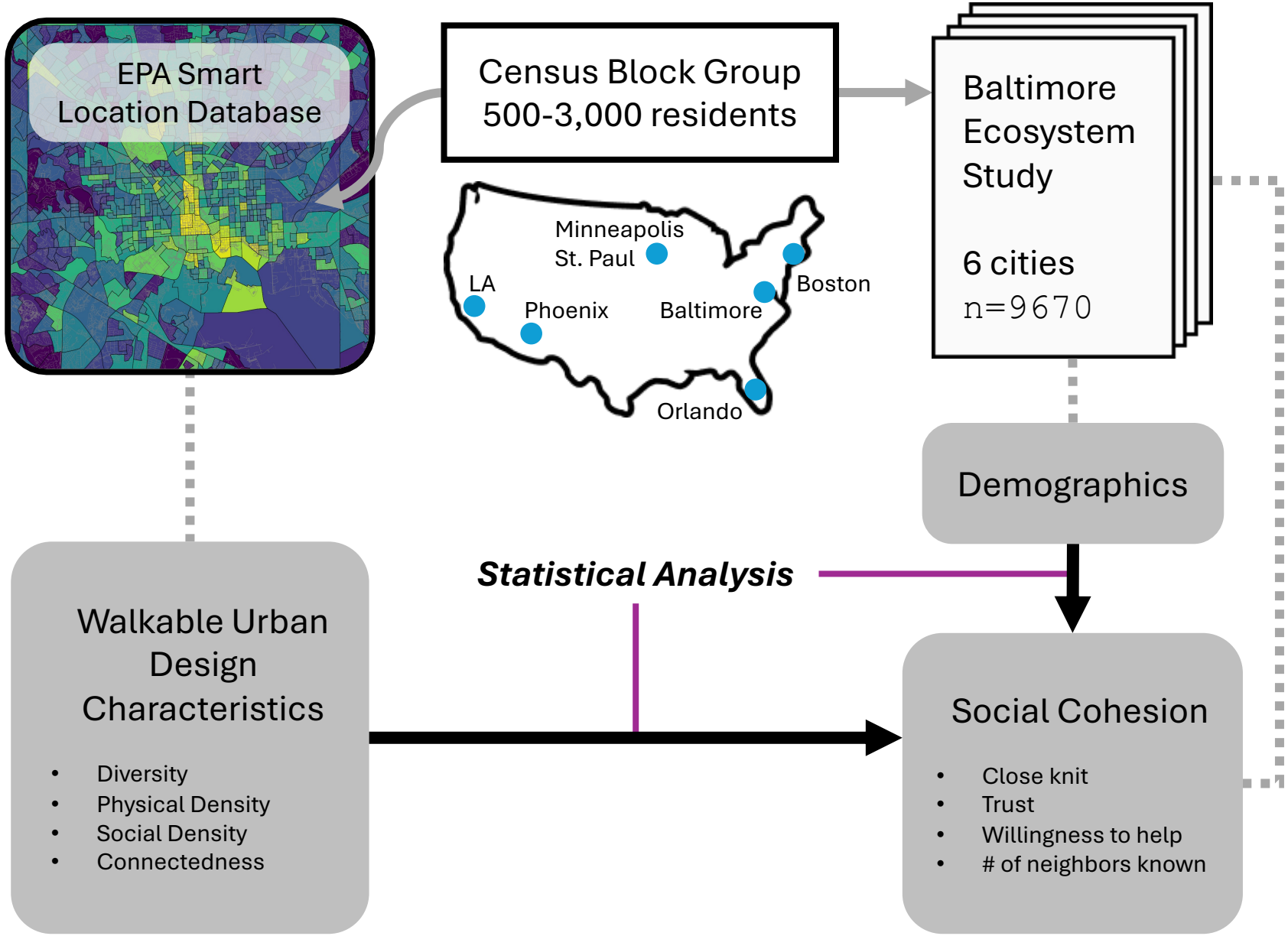
- Proponents of the 15-min city, “New Urbanism,” and walkable cities have argued that active mobility results in:
  - stronger social bonds
  - tighter social networks
  - more social cohesion
- Some scholars have warned that highly dense places are overwhelming to city dwellers
- What does the data say?



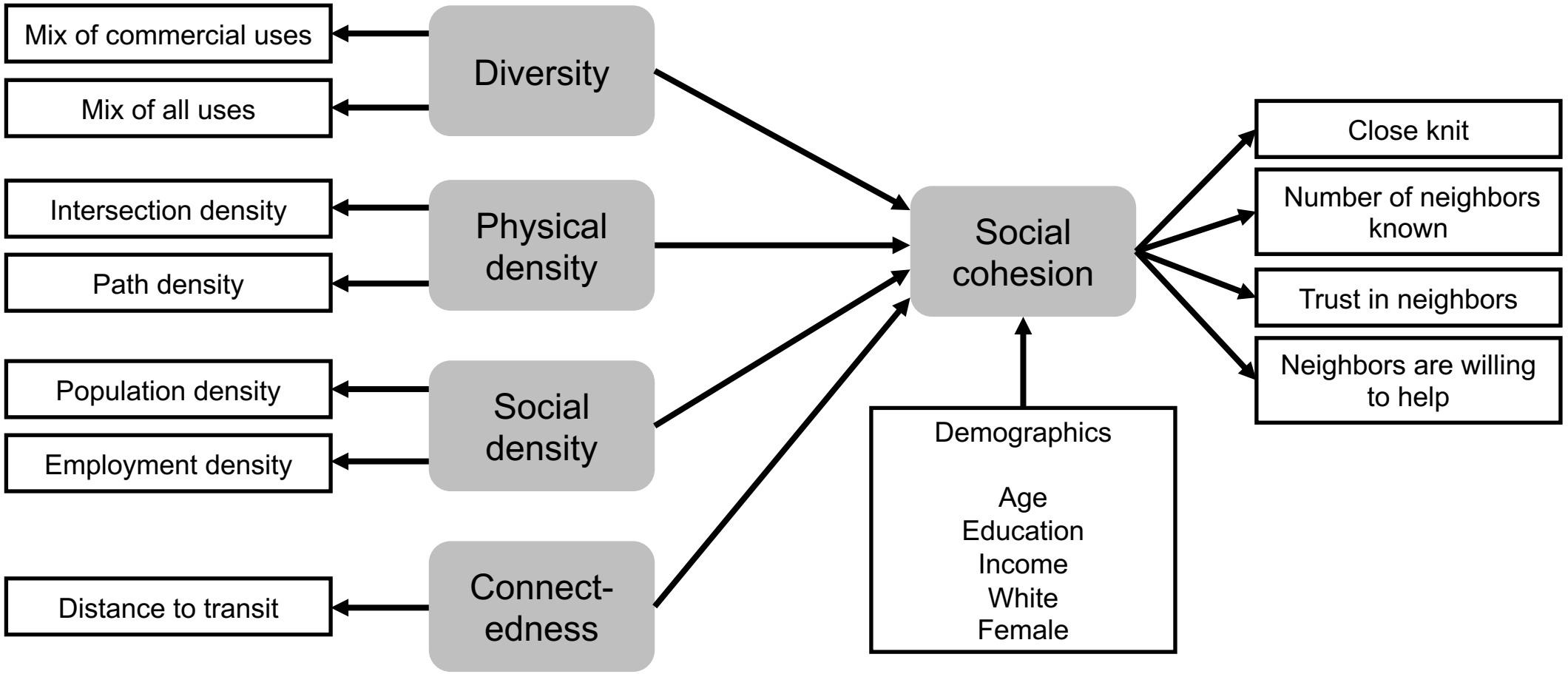
Jane Jacobs, author of “The Death and Life of Great American Cities” Source: Wikimedia Commons

Research example

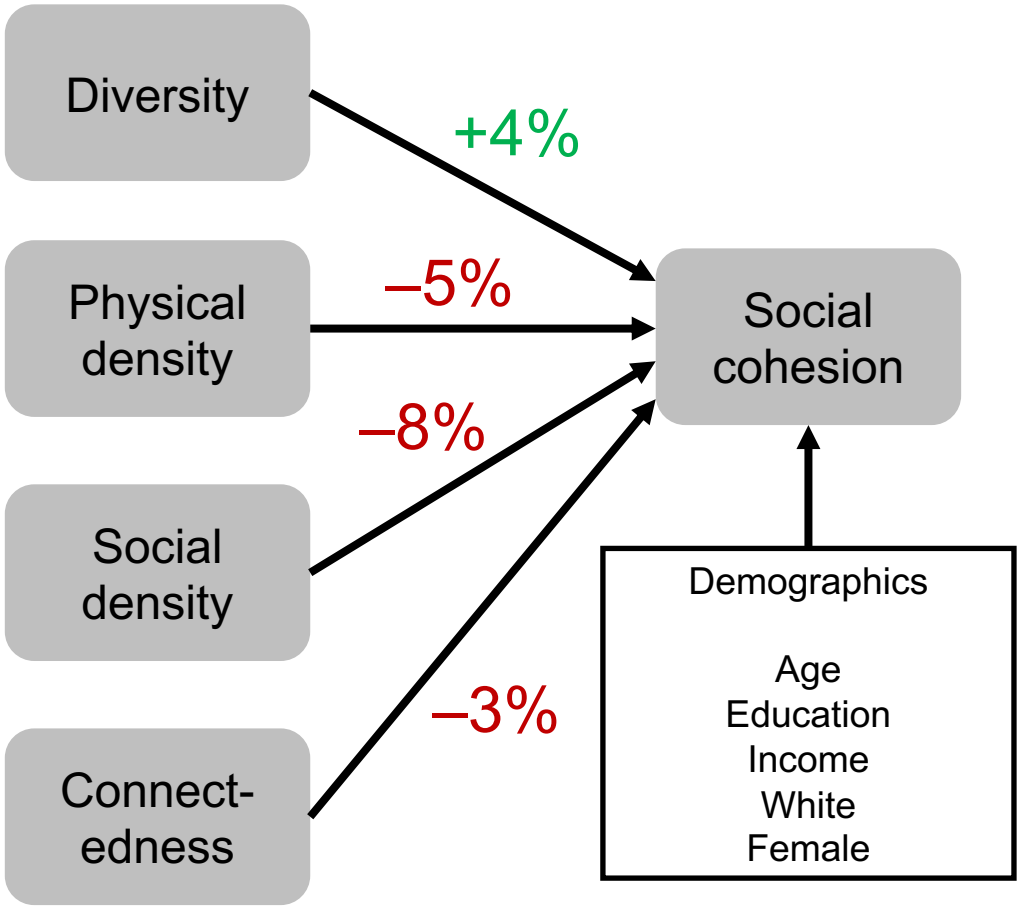
Does walkable design impact social cohesion?



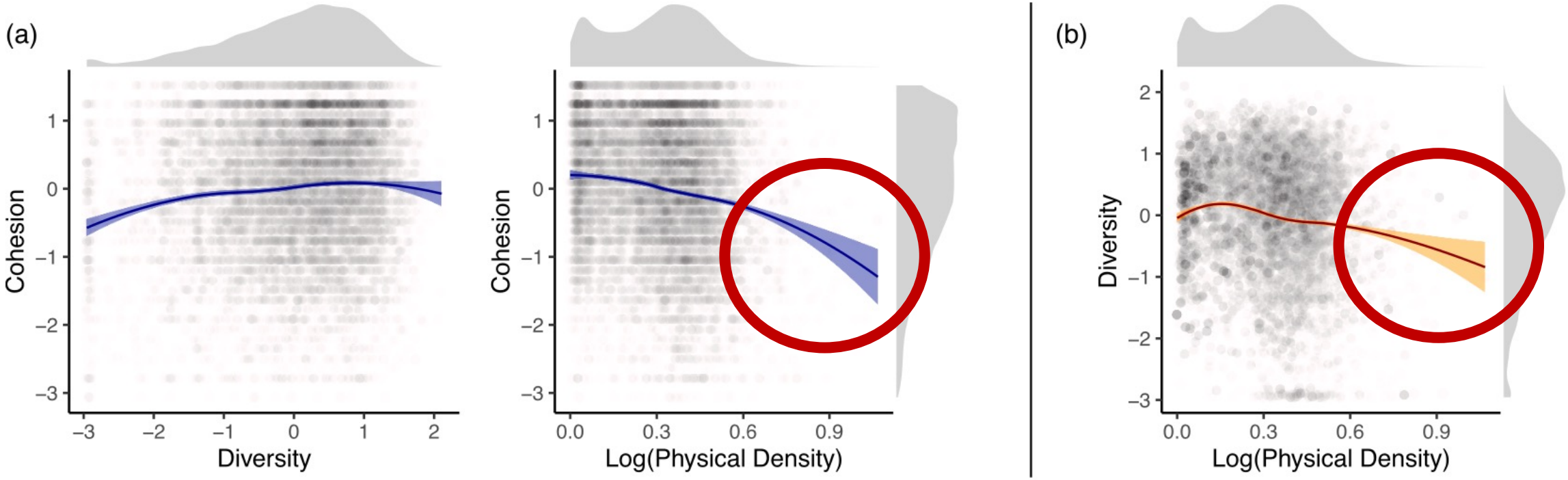
Modeling


Mix of commercial uses
Mix of all uses
Diversity
Intersection density
Path density
Physical density
Population density
Employment density
Social density
Distance to transit
Connect-edness
Social cohesion
Demographics
Age
Education
Income
White
Female
Close knit
Number of neighbors known
Trust in neighbors
Neighbors are willing to help

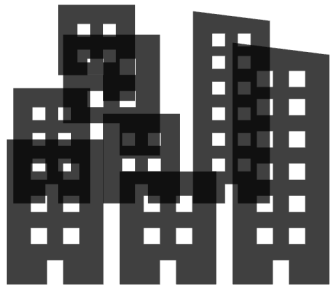
Results


Diversity
Physical density
Social density
Connect-edness
+4%
–5%
–8%
–3%
Social cohesion
Demographics
Age
Education
Income
White
Female

Results


(a)
Cohesion
Diversity
Cohesion
Log(Physical Density)
(b)
Diversity
Log(Physical Density)

Takeaways



Density

Higher density associated with less cohesion

vs.

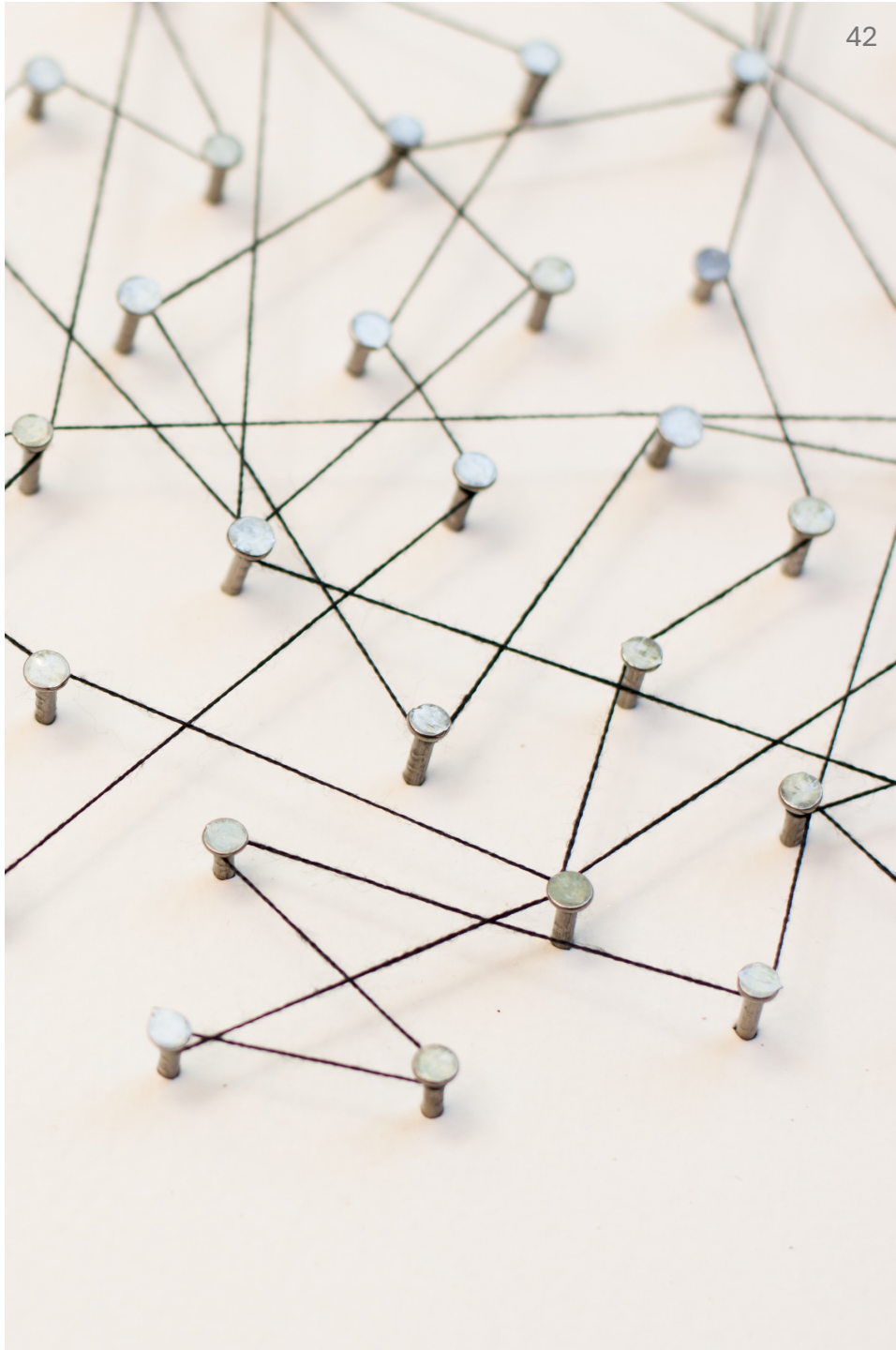
Diversity

Higher diversity (mix of use) associated with more cohesion

➢ Adds nuance to discussion on how we can improve our cities

Sustainable mobility

- Mobility systems are complex
- Transportation impacts many systems including energy, environment, social, economic, and health
- Understanding (and continuing to study) the complex nature of links between systems can create holistically people-centered cities
- Systems thinking (including causal loop diagrams) is a tool to make sense of this complexity



15-min city backlash

- In 2023, conspiracy theories about the 15-min city emerged
- These described the model as an instrument of government oppression
  - Confining people to particular parts of the city by limiting mobility
- The 15-min city concept claims no limitation of movement and aims to make mobility easier

He Wanted to Unclog Cities. Now He's 'Public Enemy No. 1.'

Researchers like Carlos Moreno, the professor behind a popular urban planning concept, are struggling with conspiracy theories and death threats.

Share full article

Source: New York Times

Review of concepts from lecture

Lecture 01: introduction and the climate crisis

- Drivers of the climate crisis
- CO2 and other greenhouse gas emissions
- Trends in energy, CO2 emissions, and global temperatures
- Economic growth and CO2 emissions
- Climate change impacts
- **Definitions of sustainability**
- Motivations for addressing sustainability in civil engineering

Lecture 02: Sustainability indicators

- Foundational measures: GDP
- Sufficiency
- Human Development Index
  - Construction of index
- Health: HDI approach, DALYs
- Education
- **Inequality: Gini coefficient**
- Biodiversity
- Ecological footprint

Lecture 03: Energy demand and buildings

- Energy units, unit conversions
- Building electricity consumption
- Cement and steel production
- Heating and cooling fundamentals
- Heat transfer
- **Heat pumps and COP**
- Active vs. passive heating and cooling

Lecture 04: Energy supply

- Energy supply definitions
- **Levelized cost of electricity and discounting**
- Wind energy
- Solar energy
- Hydropower
- Matching electricity supply and demand

Lecture 05: Transportation

- Transportation energy sources
- Vehicle fuel efficiency and electric vehicles
- The transportation system
- Systems thinking
- **Causal loop diagrams**

Lecture 06: Sustainability mobility

- Feedback loops
- Active mobility
- **Walkability metrics**
- Link between active mobility and social systems