Delineating a ‘15-Minute City’:

An Agent-based Modeling Approach to Estimate the Size of Local Communities

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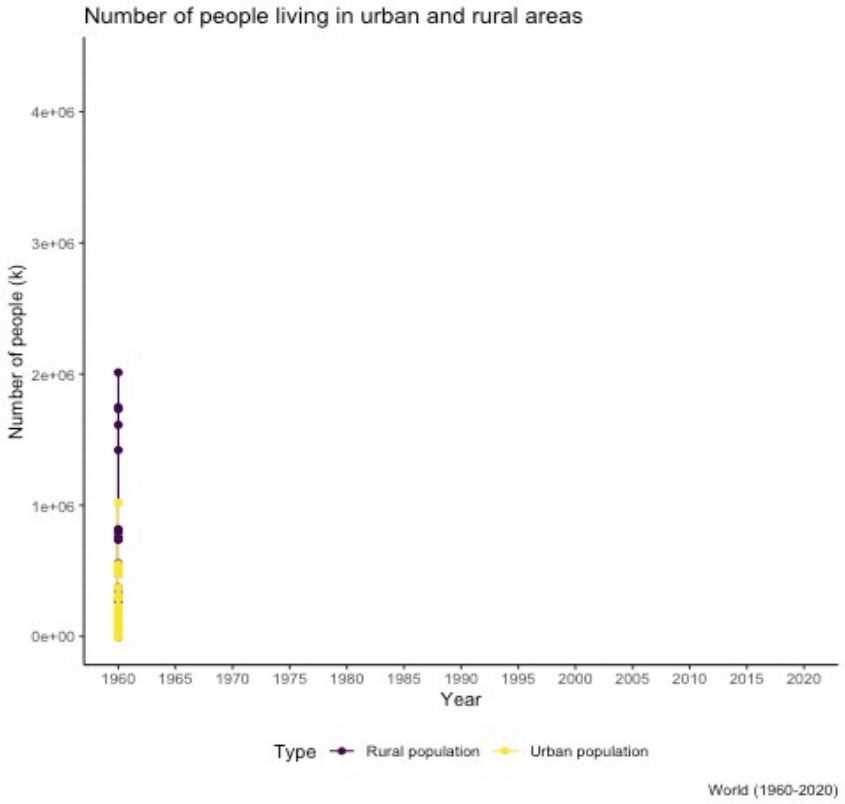
A 15-Minute City?

- First proposed by Professor Carlos Moreno[1] in 2016.
- Refers to the idea that people can access most of their daily essentials (e.g., shopping, work, education, entertainment) within 15 minutes, commuting from their own doorstep either via walking, cycling, or other modes of transportation (e.g., bus, rail).



Genomic epidemiology of coronavirus

https://www.newsroom.co.nz/the-new-zealand-strains-how-the-coronavirus-got-here

[1] M. Carlos, "Pour un Nouveau Chrono-Urbanisme.," La Tribune, 2016. https://www.latribune.fr/regions/smart-cities/la-tribune-de-carlos-moreno/la-ville-du-quart-d-heure-pour-un-nouveau-chrono-urbanisme-604358. html (accessed Sep. 13, 2021)

Background

PARIS

The current Mayor of Paris, Anne Hidalgo, advocated the concept of ‘15-minute city’ aiming to create a high-quality urban life for residents in her re-election campaign in 2020.

Photograph: Jeffrey Milstein/REX/Shutterstock

PORTLAND

Portland’s Climate Action Plan has highlighted the ‘20-minute neighborhood’ as its long-term plan to build vibrant neighborhoods.

Photo: David Gn Photography/Getty

MELBOURNE

Melbourne has included the notion of the ‘20-minute neighborhoods’ in its long-term plan with the aim to develop Melbourne towards a more sustainable, productive, and livable city.

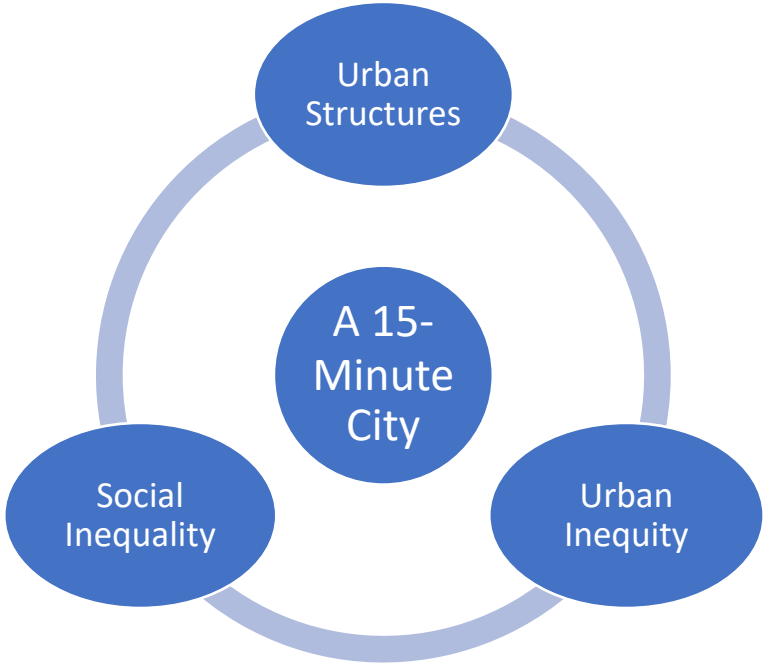
Photo link: https://ethosurban.com/insight/19-02-2020-plan-melbourne-2017-2050-addendum-2019-new-details-released-which-further-support-plan-melbournes-framework-and-policies

SINGAPORE

Land Transport Authority of Singapore proposed the Master Plan 2040 with the vision to grow ‘20-minute towns’ and a ‘45-minute city’ to strengthen the social cohesion of its society.

Photo: super misc

However…

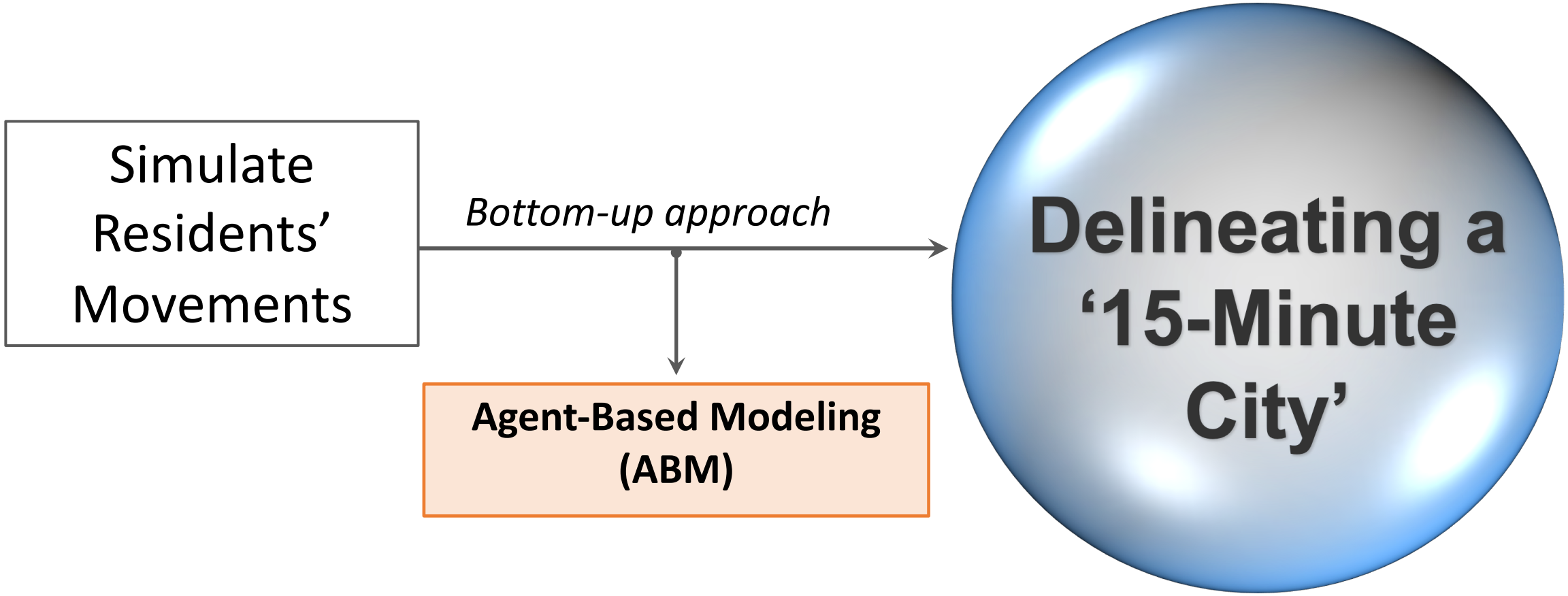


E.g., people who stay in New York City may be able to gain most of their daily needs within 15-minute travelling, while people who live in the small and midsized cities in US may require more time to get their essentials.

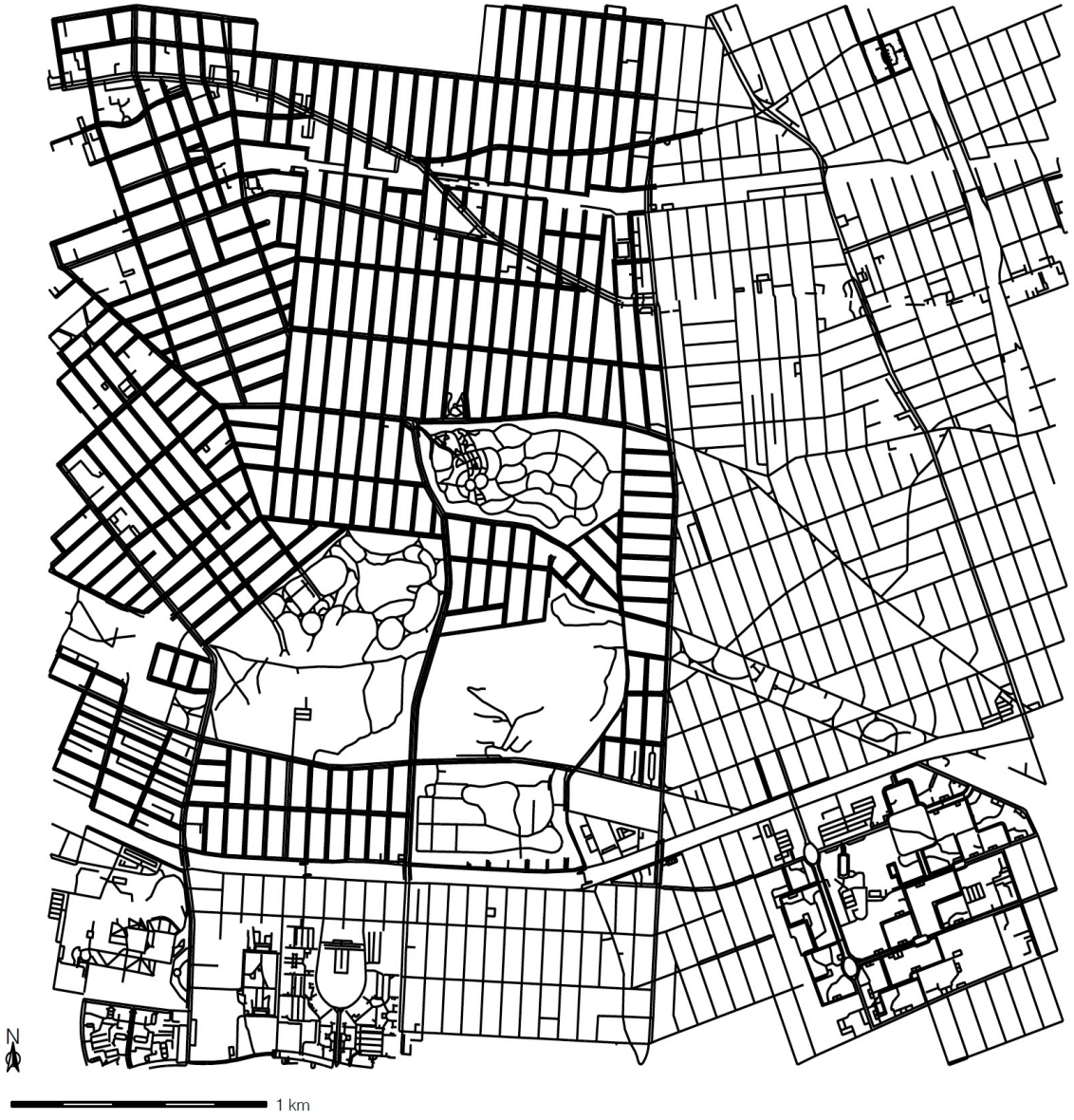
Challenges could vary from different communities, cities or countries.

- What is the specific size of a '15-minute city'?
- How much does the size vary from diverse traveling modes (e.g., walking, cycling, or driving)?
- How much does the size fluctuate between cities or across countries?

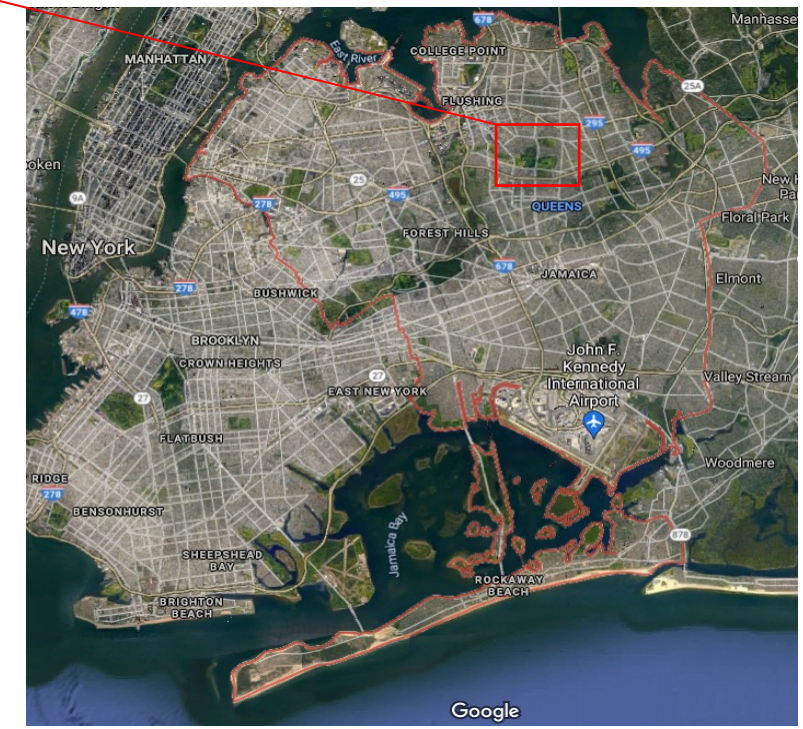
The benchmark of quantifying a 15-minute city has not reached a consensus.


Simulate Residents' Movements
Bottom-up approach
Agent-Based Modeling (ABM)
Delineating a '15-Minute City'

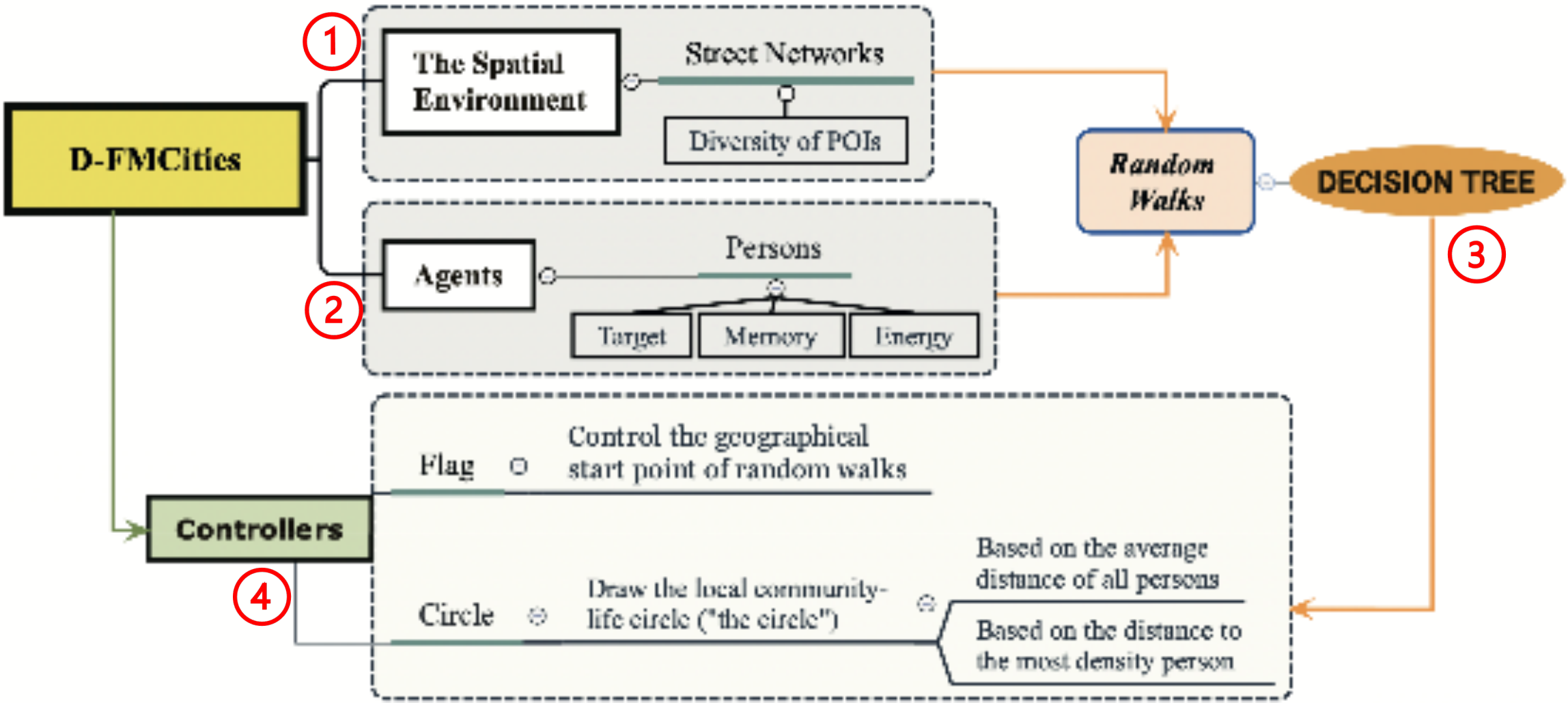
Study Area



- Queens, New York, 4 x 4 km
- Bounding box:
  [-73.82137, 40.73188, -73.77389, 40.76776]
- Diverse culture and diversified economy



Model Structure



The Spatial Environment

Street Network Construction

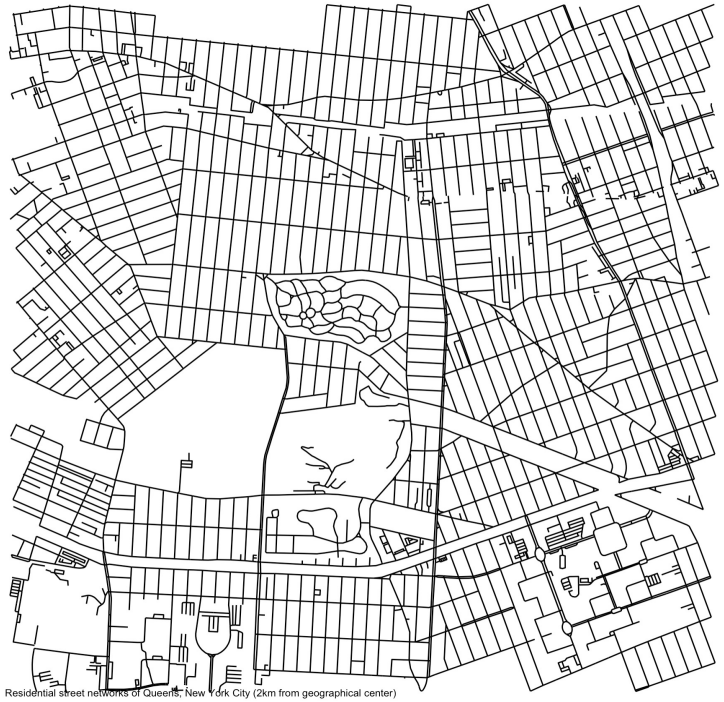
OSMnx
(Boeing, G. 2017)

Queens, NY
[-73.82137, 40.73188, -73.77389, 40.76776]

Highway	Description
Primary & primary link	The next most important roads in a country's system (often link larger towns) The link roads leading to/from a primary road from/to a primary road or lower-class highway.
Secondary & secondary link	The next most important roads in a country's system (often link towns) The link roads leading to/from a secondary road from/to a secondary road or lower-class highway.
Tertiary & tertiary link	The next most important roads in a country's system (often link smaller towns and villages) The link road leading to/from a tertiary road from/to a tertiary road or lower-class highway.
Residential	Roads which serve as an access to housing, without function of connecting settlements. Often lined with housing
Service	For access roads to, or within an industrial estate, camp site, business part, car park, alleys, etc.

Residential street networks of Queens, New York City (2km from geographical center)

Simplified Version



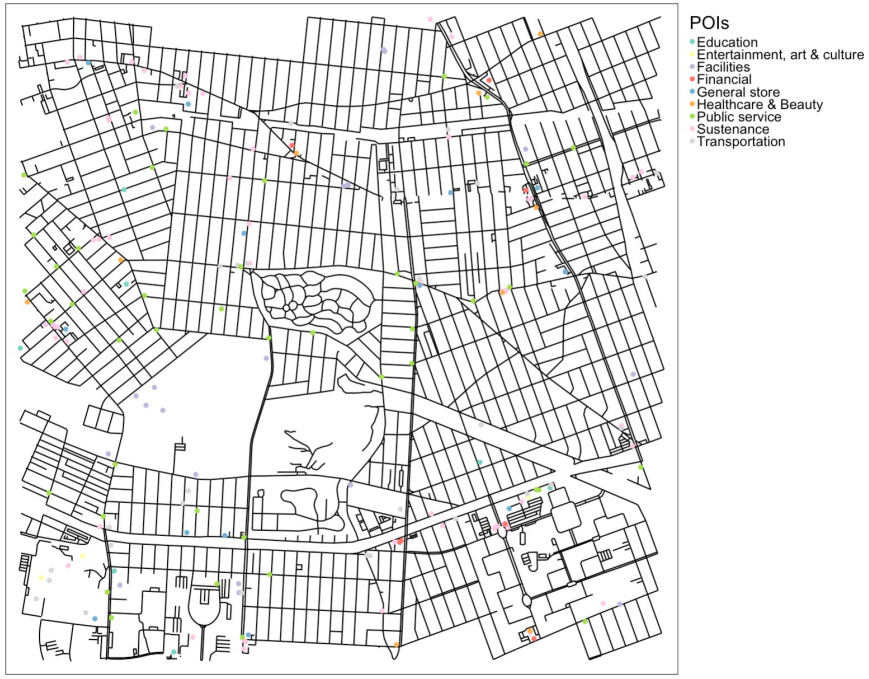
Residential street networks of Queens, New York City (2km from geographical center)

The Spatial Environment

Diversity of POIs as an indicator of the attractiveness of an area.

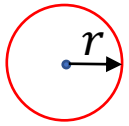
Point of Interests (POIs)

POI	Count
Education	7
Financial	7
Public Service	43
Entertainment, Art & Culture	7
General store	13
Sustenance	60
Facility	20
Healthcare & Beauty	9
Transportation	28



Assumption: People are more likely to visit a place with more diverse POIs as they can have more options

Diversity of POIs



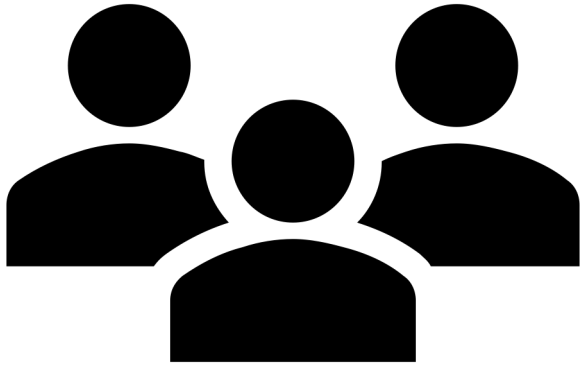
r = 30m buffer around each POI point

Shannon's diversity index

$$H = -\sum_{i=1}^{s} p_i \ln p_i$$

Min-max normalization

Agents

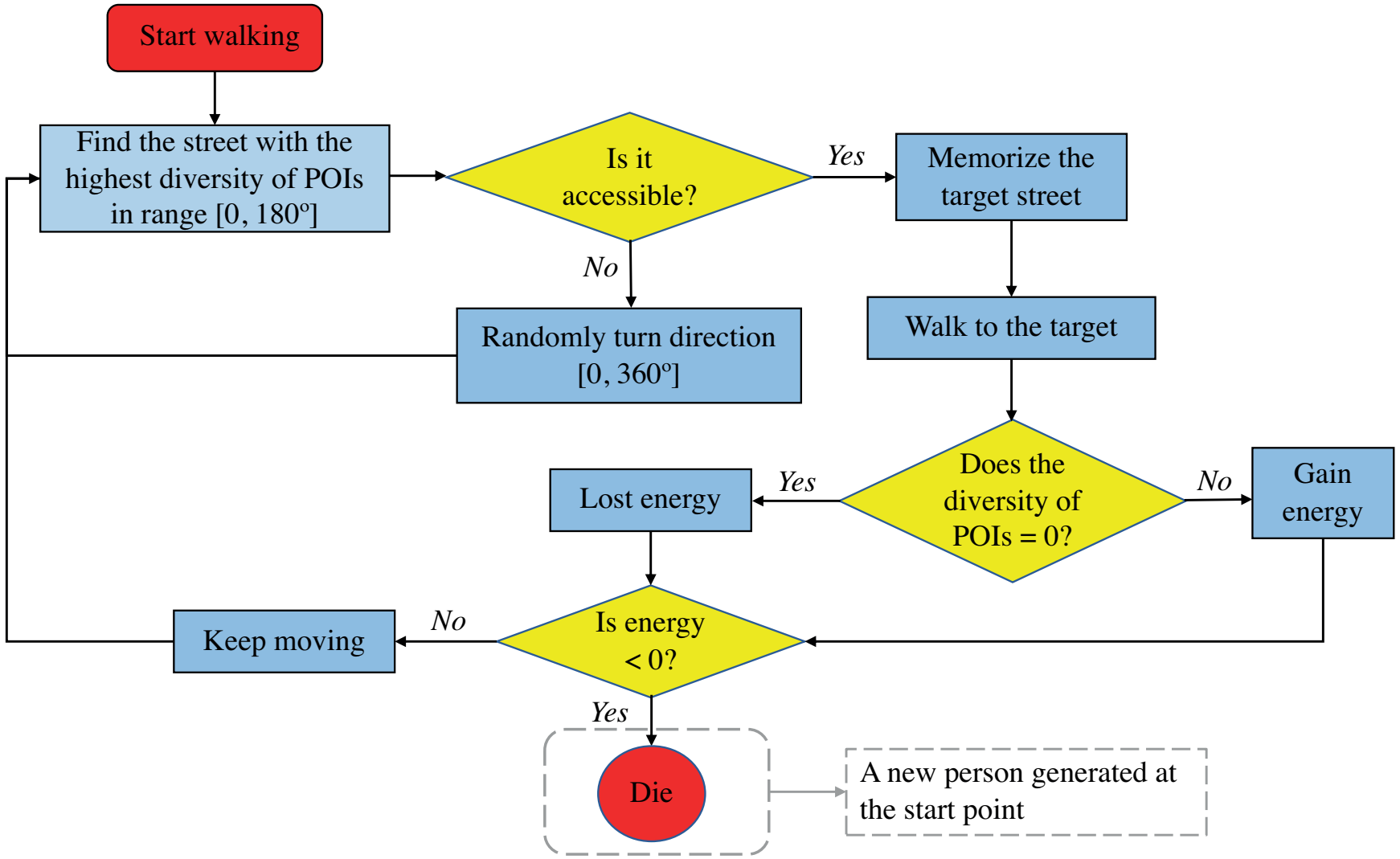


- **Name**: Persons
- **Attributes**: Target, Memory, Energy
- **Actions**: Random walks

Target	Memory	Energy
• Determines where to walk at each time step.	• Stores visited streets to build a cognitive map.	• Indicates a person's enthusiasm to keep randomly walking. • User-settable

Decision Tree

- *Start point*: the geographical center of the study area. But it is *adjustable*.
- *Assumption*: a person is more likely to walk towards streets with a more diverse land-use mix.
- *Hypothesis*: a street with a high diversity of POIs is more likely to arouse people's enthusiasm for walking as they can do more things there (e.g., shopping, recreation).
- An agent dies: indicates the agent has gotten bored or tired and intends to go back home.

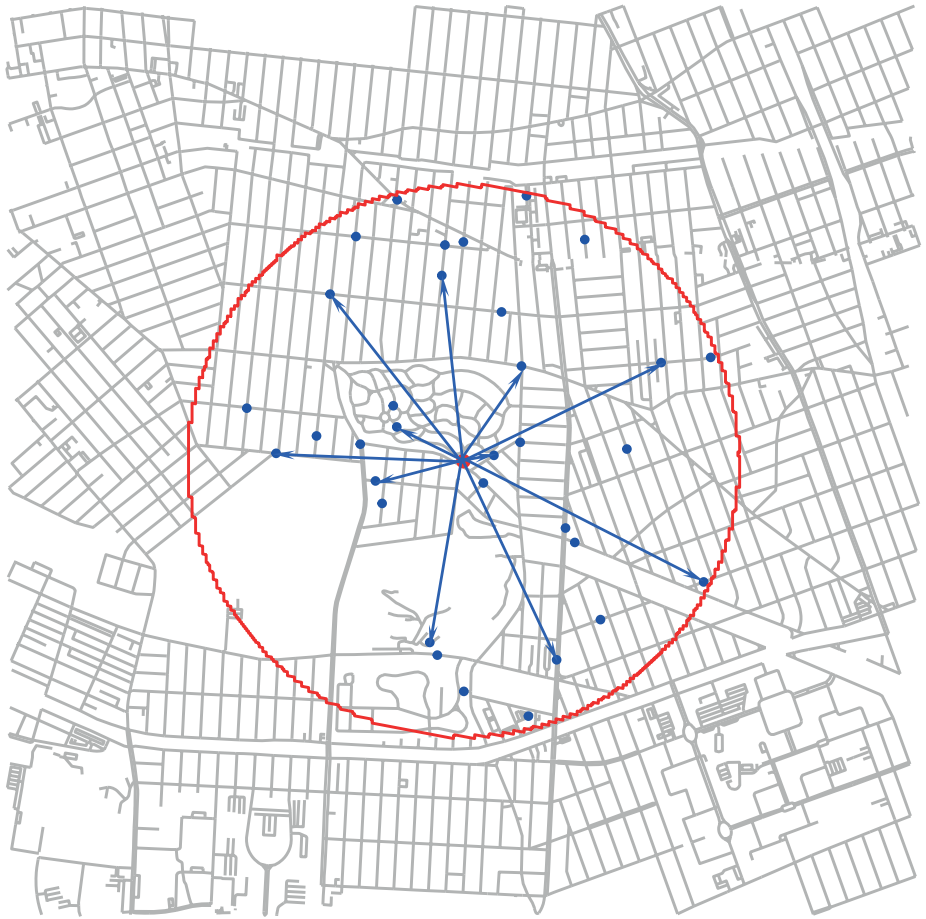


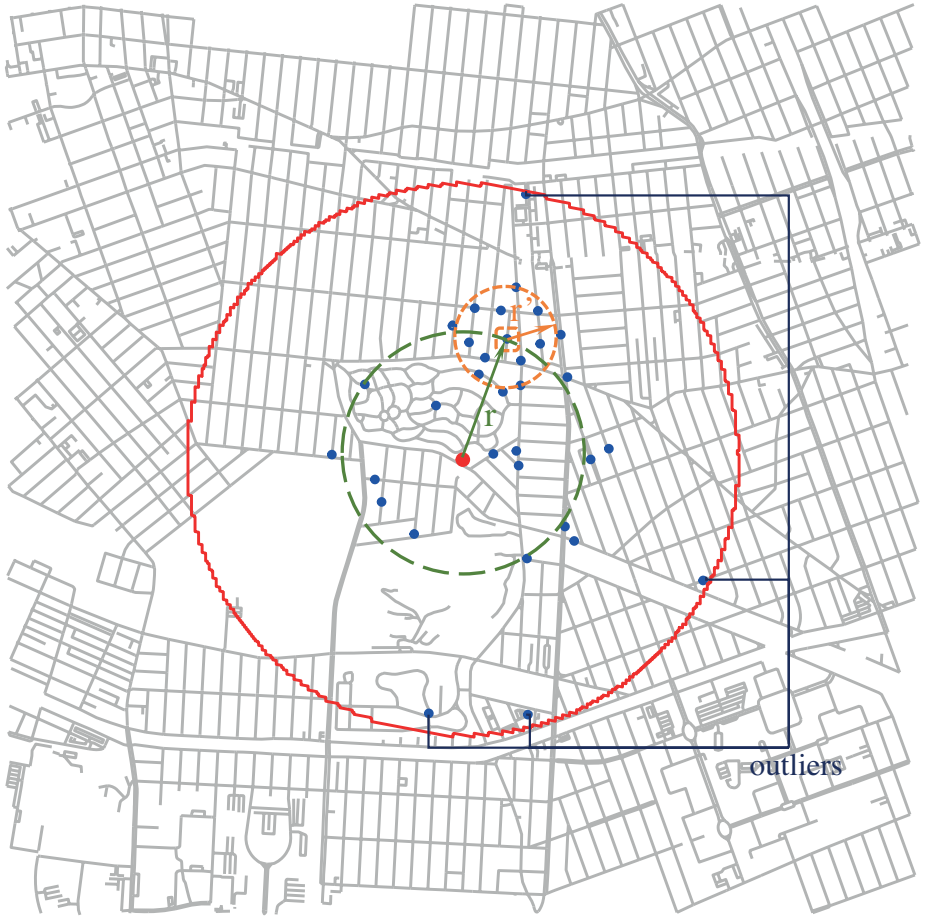
Effectively reveals the basic informed movements at the micro-level especially in instances when individuals are first exploring a new area.

Controller

Method 1: The average distance of all agents on the streets (Sensitive to outliers)

Method 2: The distance between the start point and the agent within the model with the highest population density around itself.





Model Interface

Delineating a ‘15-Minute City’

Pre-setup

Please choose the number of people (default = 100): num-person 500

Do you wanna show people's IDs? On Off show-ID?

Which you wanna show POIs value? base-map: show POIs

Do you wanna show rings on the background? On Off show-rings?

How large the rings? (default radius = 50) ring-radius 50

Do you wanna paint the path that people have walked through? On Off show-path?

How do you wanna paint the path? path-type: diffusion

How much energy does an agent gain every time step? energy-gained 20

How much energy does an agent lost every time step? energy-lost 0.5

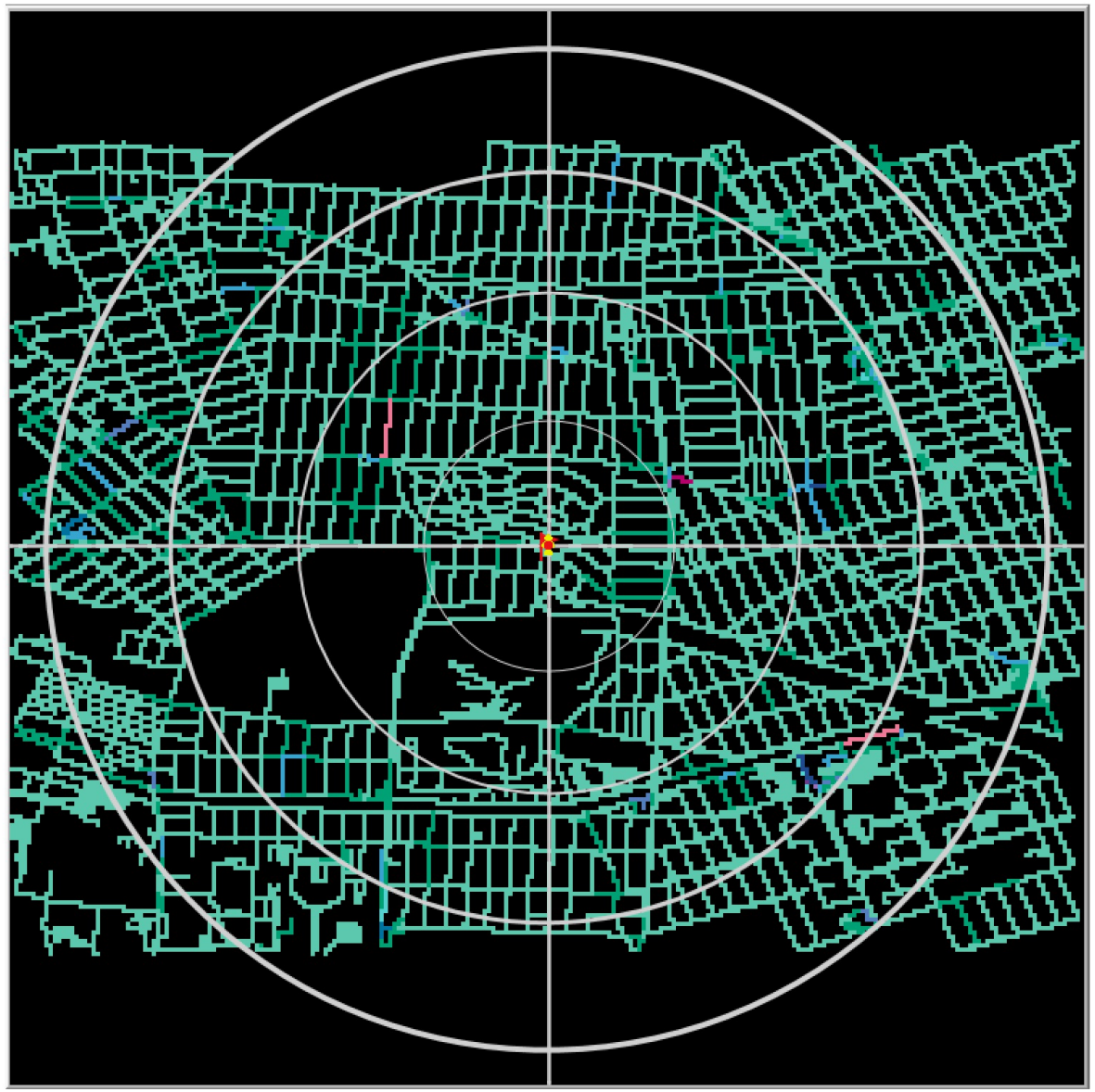
Choose a situation: Situation: Original

Setup | Move | Go

Draw the Cicle

How do you wanna draw the circle? (default uses the verage walking distance) distance-type: average

If you choose 'density', please choose the focus range: density-distance 50

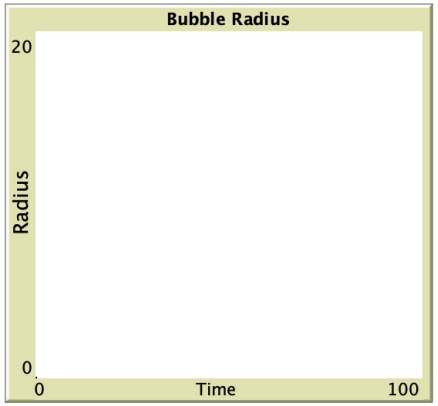


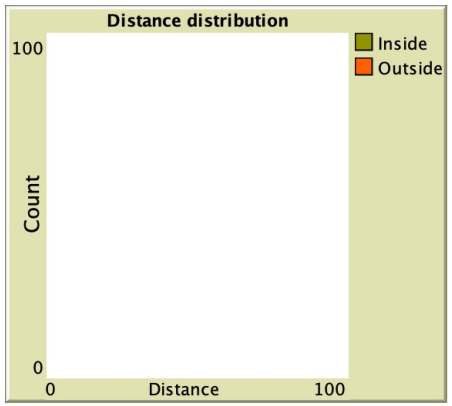
Walking time

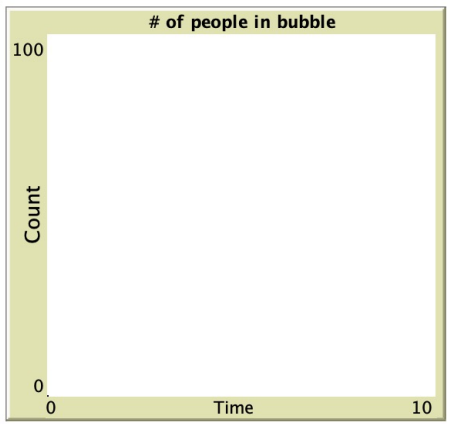
MINUTE 0 | SECOND 0

Outputs

Actual bubble radius (m) 0 | Actual S.D. Distance (m) 0







Spatial resolution: 16m x 16m

Model Demo

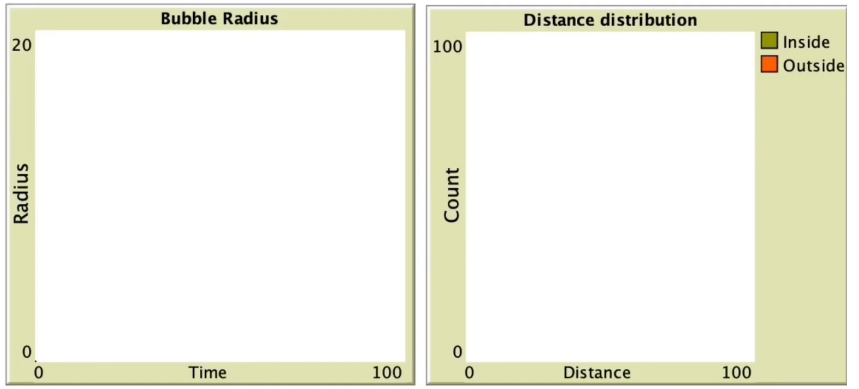
Delineating a '15-Minute City'

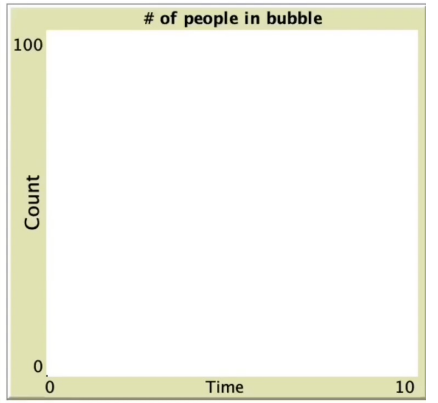
Walking time

MINUTE 0 SECOND 0

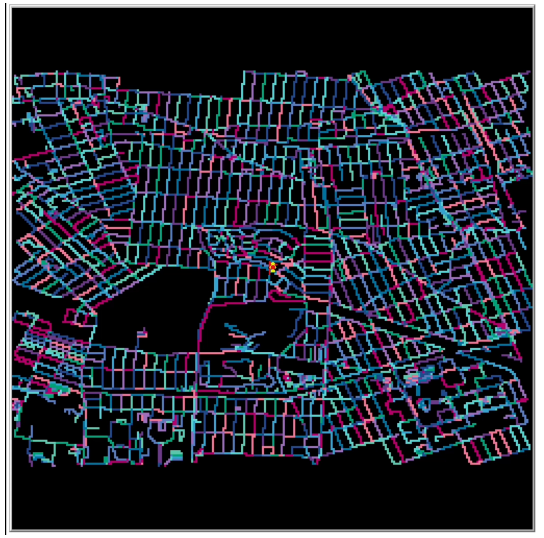
Outputs

Actual bubble radius (m) 0 Actual S.D. Distance (m) 0

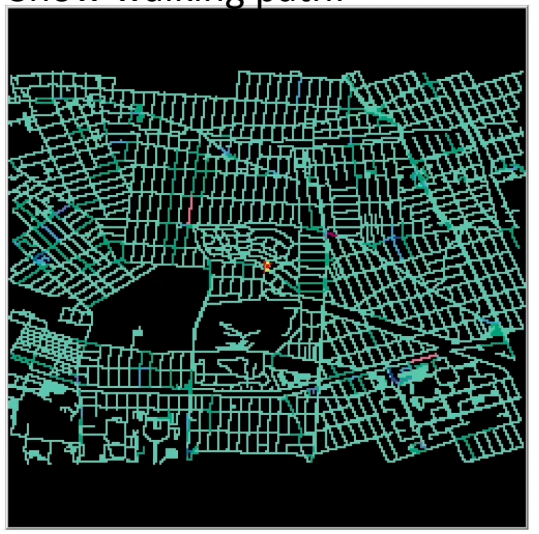




Random distributed POIs

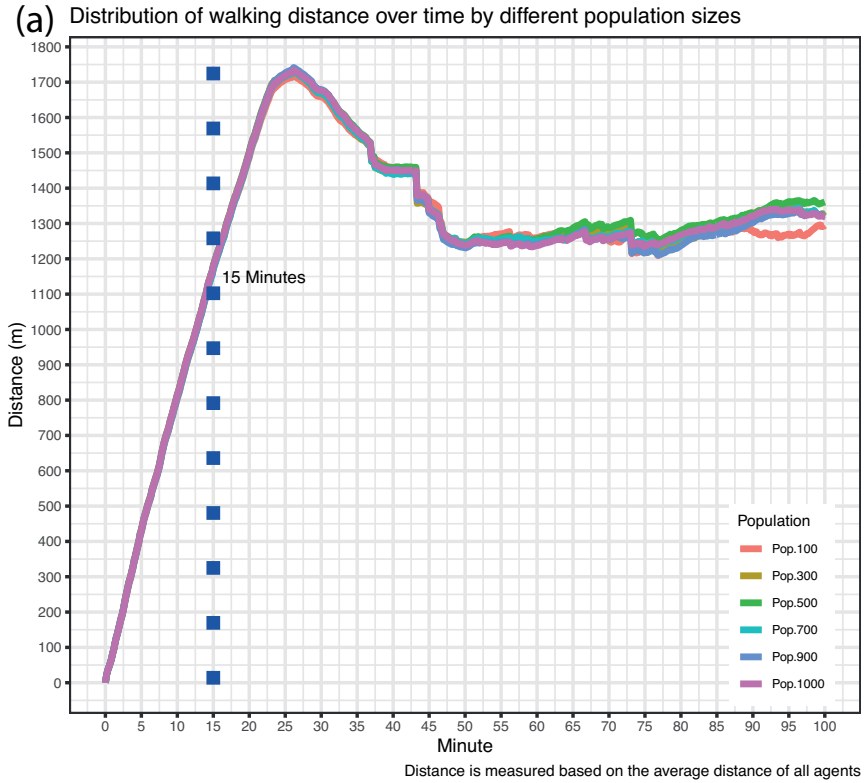


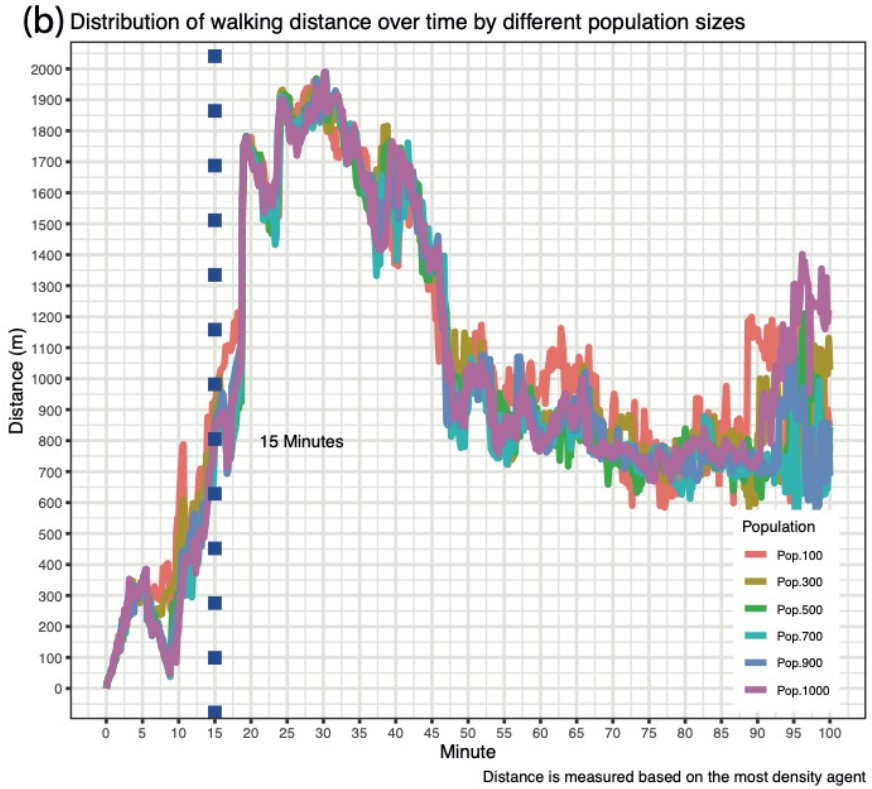
Show walking path:



Scenario 1 – Different Sizes of the Population

Rationale: a greater population will cover larger area and represent a more diverse set of a city's inhabitants.





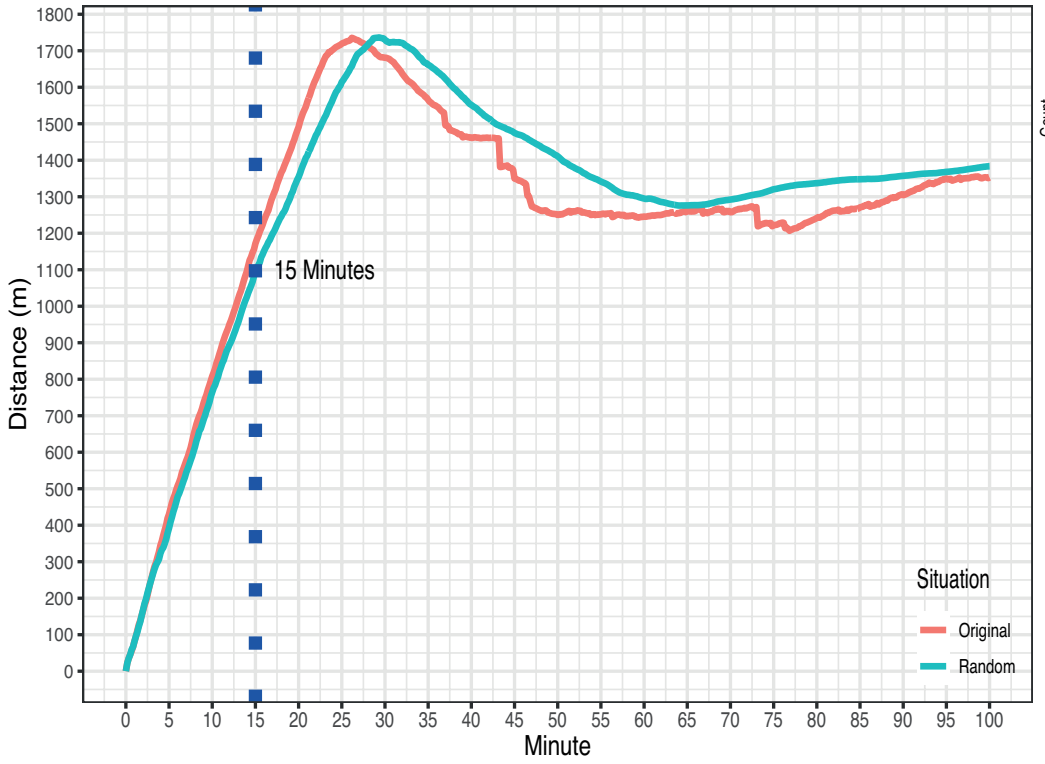
The average walking distance is around 1.15km for 15-minutes walks. The distance increases sharply over time and approaches its maximum (~1.75km) at ~27 minutes. Then it decreases with a relatively slower rate.

The walking distance follows a comparable trend to that in left figure, but with a relatively shorter distance for 15 minutes walks (credit to the exclusion of the 'outliers).

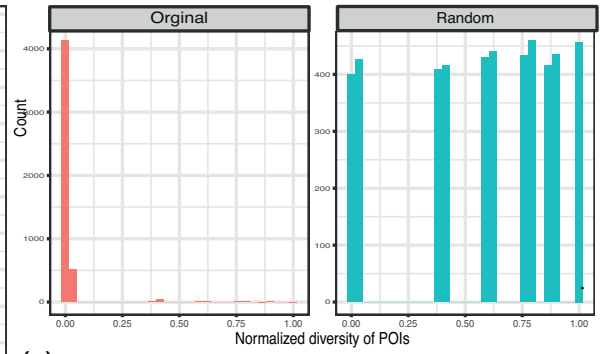
Scenario 2 – Different Spatial Distribution of Diversity of POIs

Rationale: the notion of how the urban morphology impacts human behavior.

(a) Distribution of walking distance over time under different situations



(b) Distribution of Diversity of POIs



(c) Street networks with random diversity of POIs

- A delay in the random situation.
- The distance has slightly slower increasing and decreasing rates in the random situation.
- It takes a longer time for the distance to become stable (~60 minutes) in the random situation (~45 minutes in the original situation).
- The distribution of POIs in the original situation is more dispersed while it is relatively equal in the random situation.

Major takeaways:

- The results do match the model logic as designed.
- The expanding rate of distance could be a valuable reflection of the distribution of natural environmental conditions
- The plateau time might potentially work as a threshold for defining a walkable community.

Conclusion

- *D-FMCities* model demonstrates the capability to monitor how people walk in their environment and has the potential to *estimate* the size of a walkable community based on the specific indicator (i.e., the diversity of POIs).
- The model sets the stage for the development of more in-depth cognitive maps for human behaviors and movement decisions to precisely delineate a '15-minute city' in future work.

Model Demo

Model Code

Future Work

- Consider more details about the built environment & transport infrastructure: *street view imagery* (Google street view, Mapillary).
- Understand social interactions between individuals to explore how movement is impacted when people walk in groups: *big data techniques* (Twitter, cell phone data).
- Enriching agents' features (e.g., socio-economic status, demographic characteristics, heterogeneous motivations & expectations.): *population synthesis techniques*.
- Scaling to larger areas or different cities and countries with more agents: *efficiency and computing power*.

https://www.c40.org/other/agenda-for-a-green-and-just-recovery#:~:text=C40%20mayors%20have%20collectively%20identified,and%20lifting%20up%20essential%20workers

Post-COVID urban recovery

C40 Cities: "Creating 15-minute cities" where all residents of the city are able to meet most of their needs within a short walk or bicycle ride from their homes.

The concept of human-centered cities[1] envisions a high quality of life blueprint to build **accessible, liveable, healthy, and sustainable** communities at the human scale.

We hope the **D-FMCities** model, when fully developed, could be helpful to take a small step towards this larger research agenda.

https://pin.it/x0IEehP

[1] "Gehl — Making Cities for People, Gehl. https://gehlpeople.com/.

D-FMCities

1

The Spatial Environment

Diversity of POIs: People are more likely to visit a place with more diverse POIs as they can have more options

Agents

2

Cognitive maps as the representation of space perceived by agents while interacting with their spatial environments through various dynamic actions (e.g., random walks).

Decision Tree

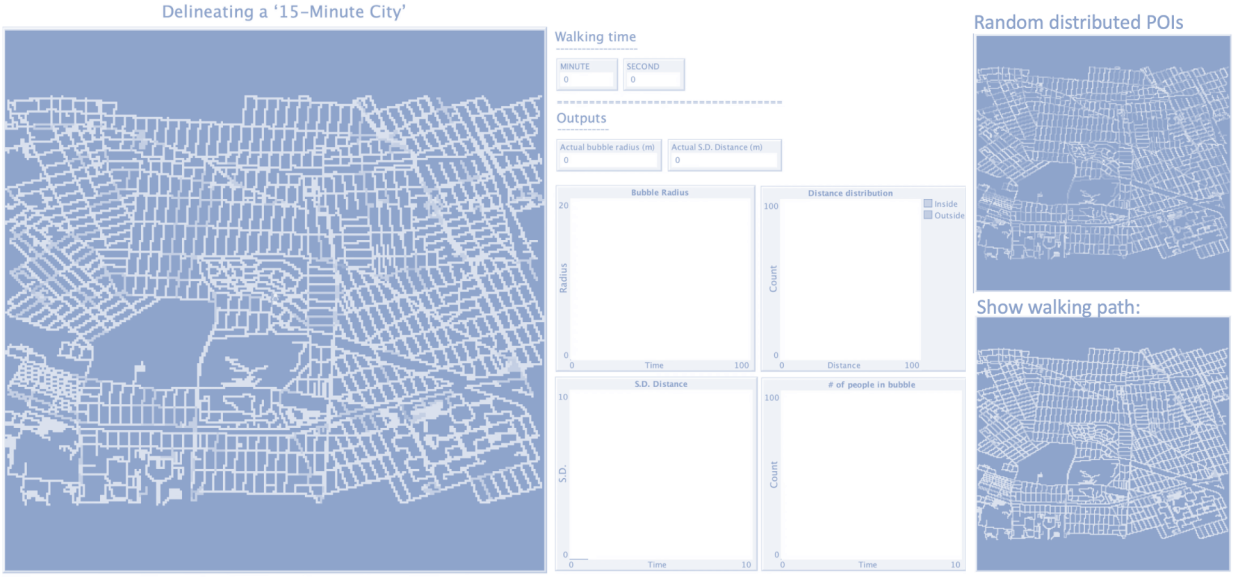
3

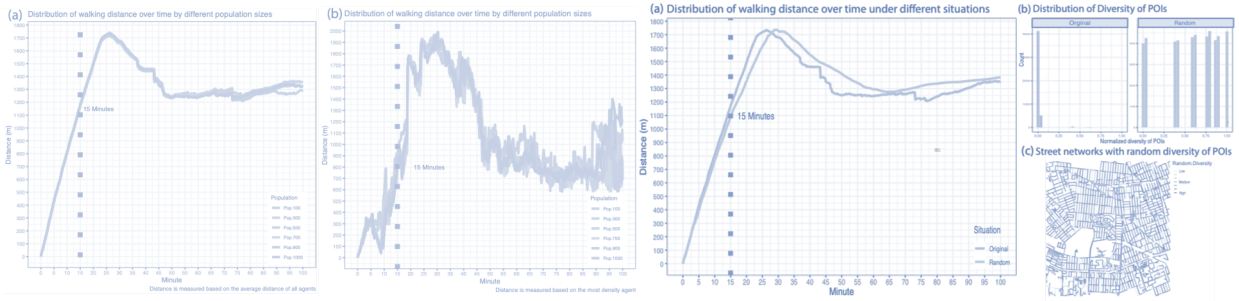
Assumption: a person is more likely to walk towards streets with a more diverse land-use mix.
Hypothesis: a street with a high diversity of POIs is more likely to arouse people's enthusiasm for walking as they can do more things there (e.g., shopping, recreation).

Controllers

4

Method 1: The average distance of all agents on the streets (Sensitive to outliers)
Method 2: The distance between the start point and the agent within the model with the highest population density around itself.





THANK YOU FOR YOUR ATTENTION

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