CASA0011: Agent-Based Modelling for Spatial Systems

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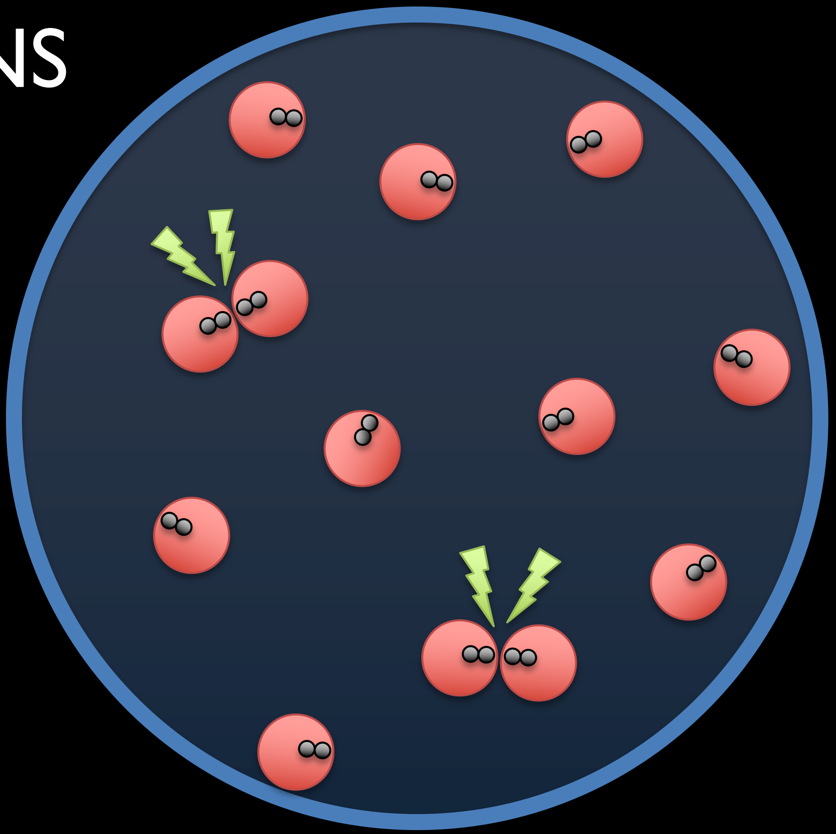


The ABM Course

Week 1: Introduction to ABMs

Week 2: Cellular Automata

Week 3: ABM Methodology

Week 4: Agent Behaviours

Week 5: ABMs as Research Tools

READING WEEK

Week 6: Testing ABMs / Presenting Results

Week 7: Modelling Competitive Agents

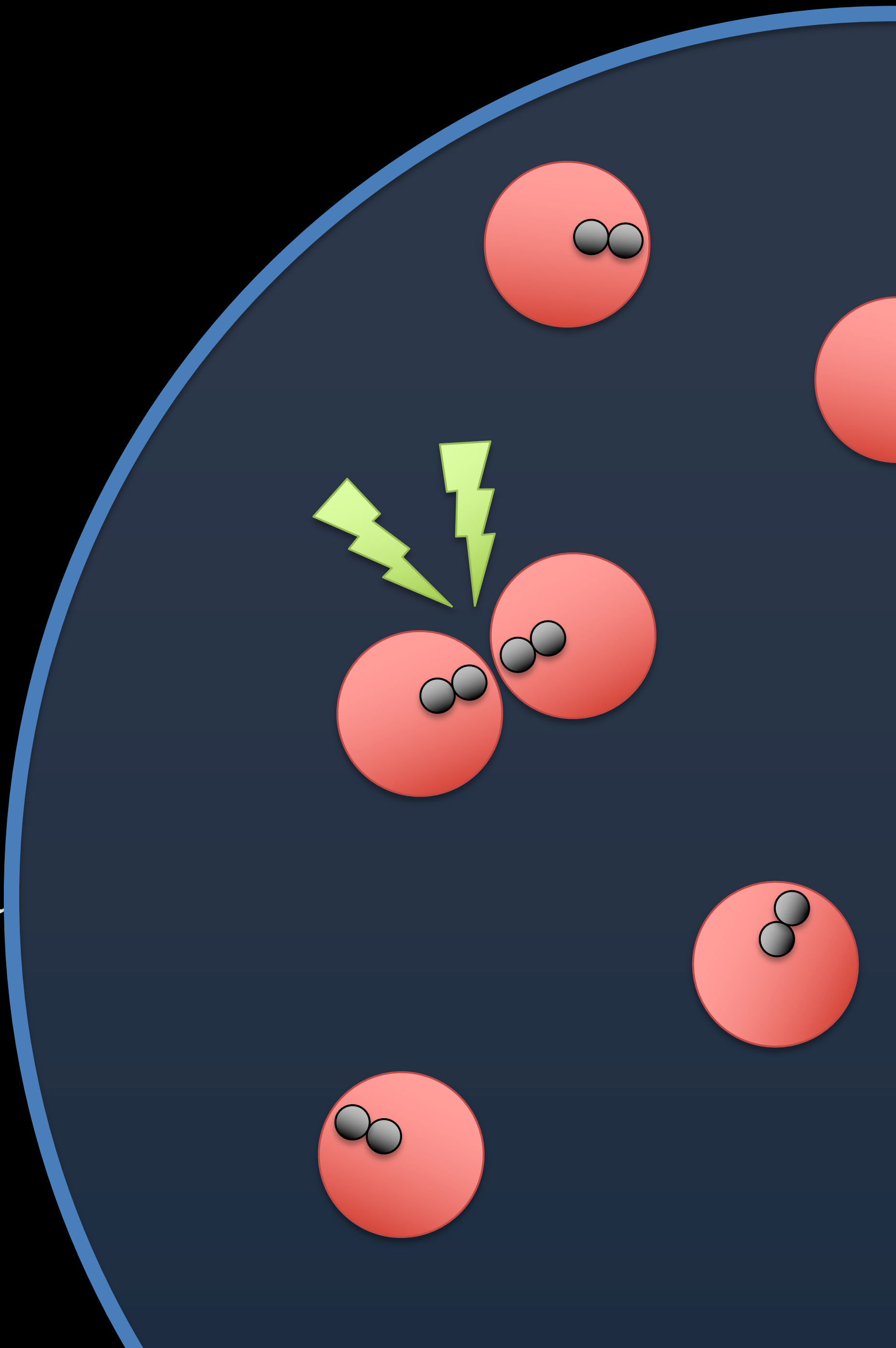
Week 8: (Mixed)

Week 9: Verification and Validation

Week 10: Traffic Modelling

OBJECTIVES

1. understand the role of scale in modelling
2. explore how space is used in real examples
3. consider how we source our data for spatial modelling



Course Objectives

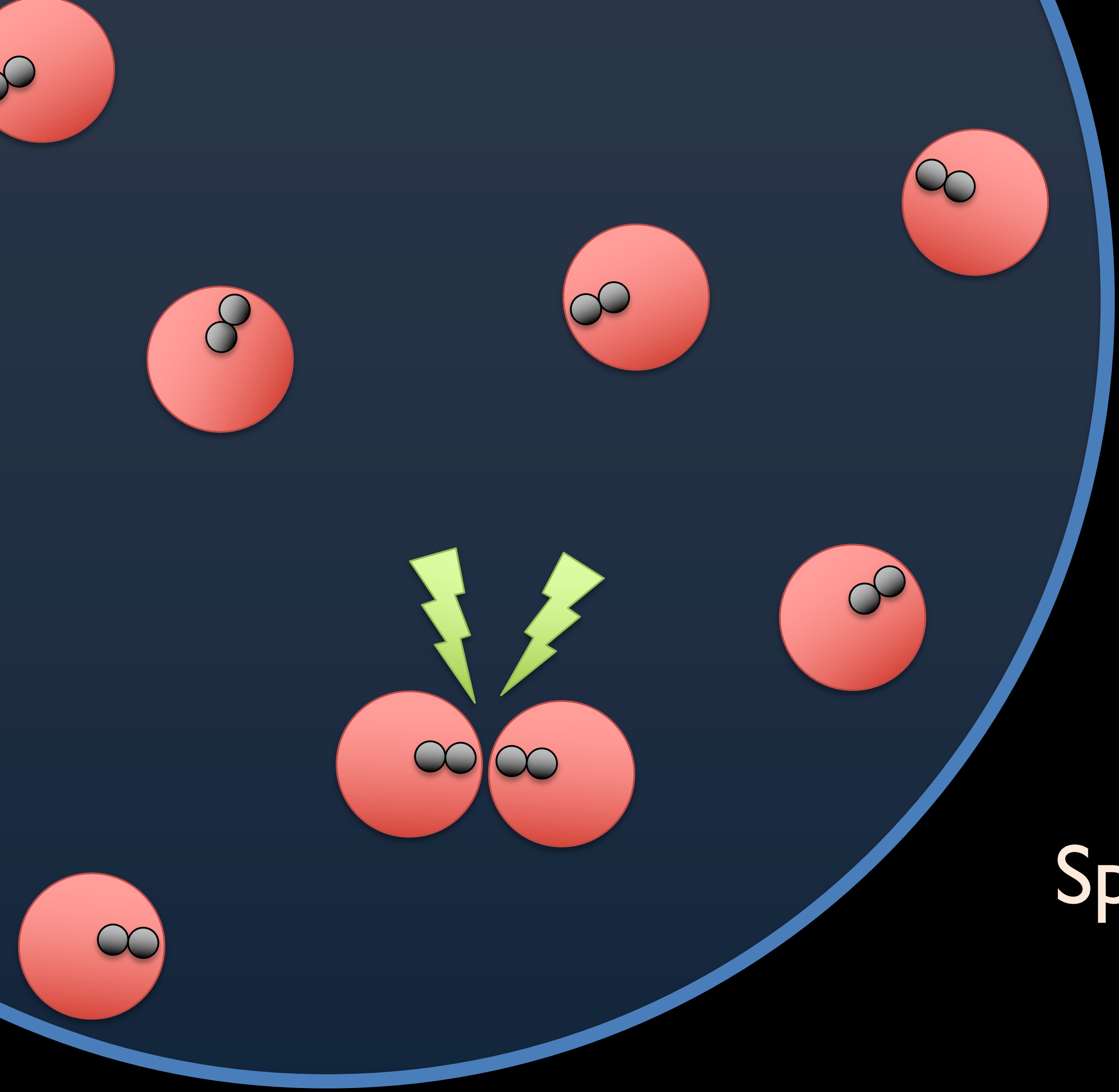
You should...

1. understand the principles of agent-based modelling (ABM)

2. be able to describe the type and range of systems to which ABM can be profitably and appropriately applied

3. be able to conceptualise and model urban systems with complex dynamics

4. show evidence of being able to translate these understandings into the practical methodology of modelling



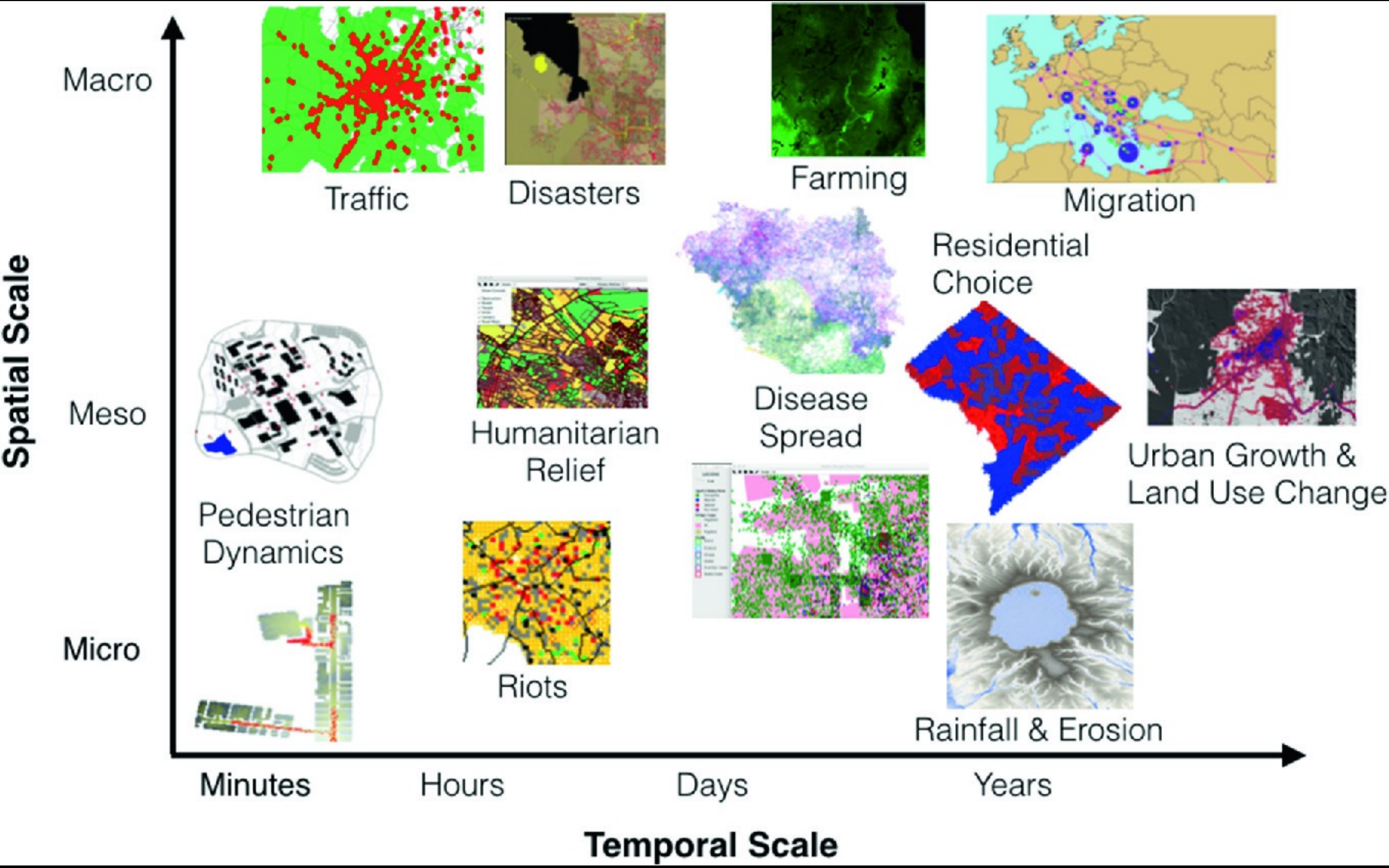
LECTURE 8

Spatial Modelling and GIS

Overview (of this part of the lecture)

Modelling at different scales
– in both SPACE and TIME

- How do we choose the appropriate scale?
- How do we match the scales of space and time to one another?



Crooks, A., Heppenstall, A., Malleson, N., Manley, E. (2021). Agent-Based Modeling and the City: A Gallery of Applications. In: Shi, W., Goodchild, M.F., Batty, M., Kwan, MP., Zhang, A. (eds) Urban Informatics. The Urban Book Series. Springer, Singapore. https://doi.org/10.1007/978-981-15-8983-6_46

INCORPORATING SPACE INTO YOUR MODEL

An example: tiers of modelling mobility

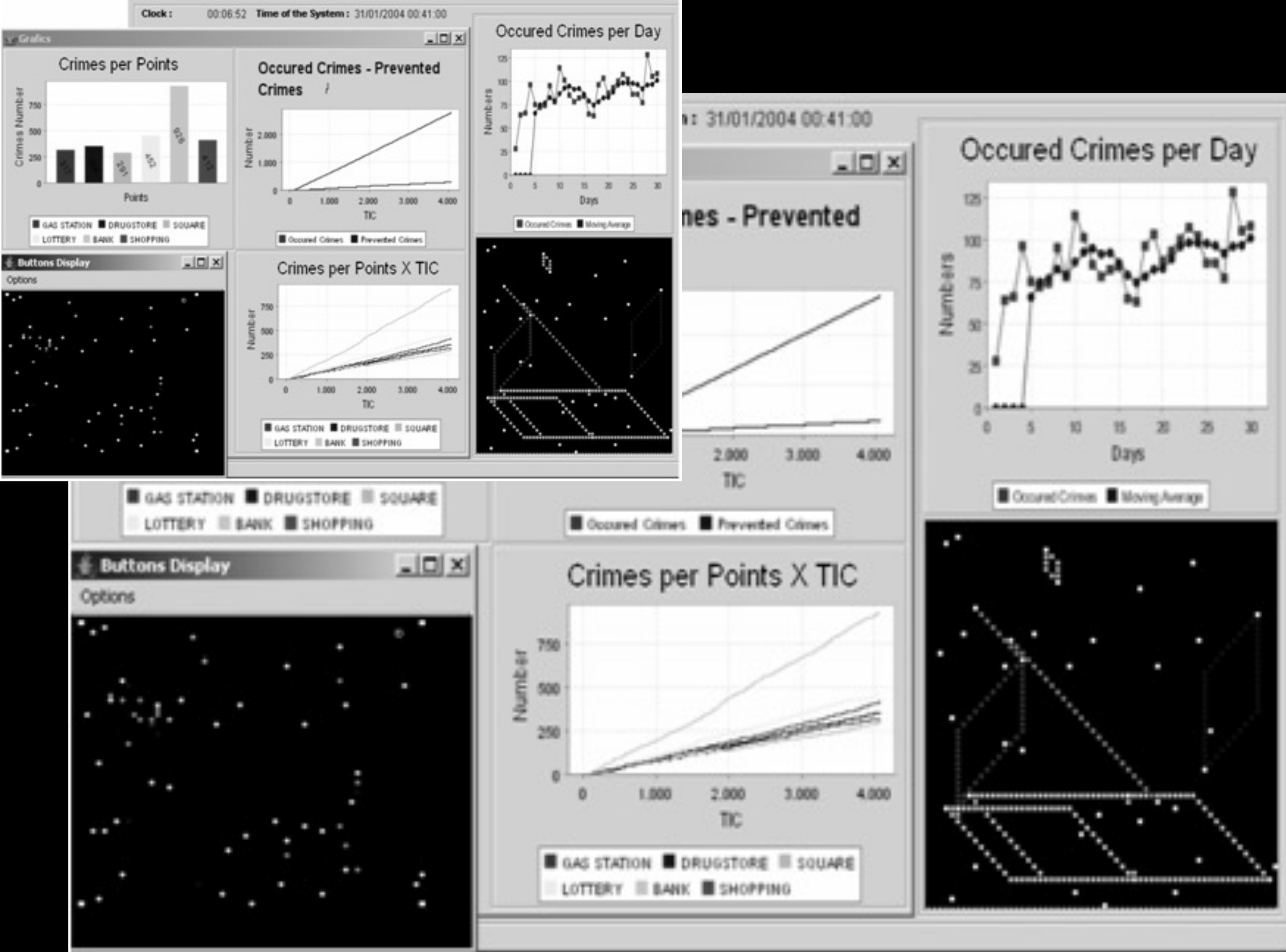
Tier	Qualities	Examples
0	Spatial environments **without constraints** on movement	Agents move between home work, and other location types at a constant speed on a lattice
1	Environment **constrained topologically**, e.g. by a network or areas of exclusion	Agents move between home, work etc. locations at a constant speed along a road/rail/walk network
2	**Topological** environmental structures incorporating **weights** which constrain movement	Agents move between home, work, etc. locations along a transport network, minimising an economic cost function
3	The weights of the topological structure **vary over the different dimensions** of the simulation	Agents move between home, work etc. locations along a network with fluctuating traffic levels, minimising a cost function with economic and temporal components

Wise, S., Crooks, A., Batty, M. (2017). Transportation in Agent-Based Urban Modelling. In: Namazi-Rad, MR., Padgham, L., Perez, P., Nagel, K., Bazzan, A. (eds) Agent Based Modelling of Urban Systems. ABMUS 2016. Lecture Notes in Computer Science(), vol 10051. Springer, Cham. https://doi.org/10.1007/978-3-319-51957-9_8

Tier 0 Example: Melo et al., 2008

- Agents
  - **Police**: move around on predetermined route; disrupt nearby crimes as they are committed
  - **Criminals**: choose target; move; decide to commit crime; commit crime
  - **Points of Interest**: attracts criminal attention at different rates
- Environment is a grid space, measured in meters and seconds
- Individuals move through the grid space toward attractors/goals

Melo A, Belchior M, and Furtado V, 2006. Analyzing police patrol routes by simulating the physical reorganization of agents, in Sichman J S and Antunes L (eds.), Multi-Agent-Based Simulation VI, Springer, Berlin, Germany.

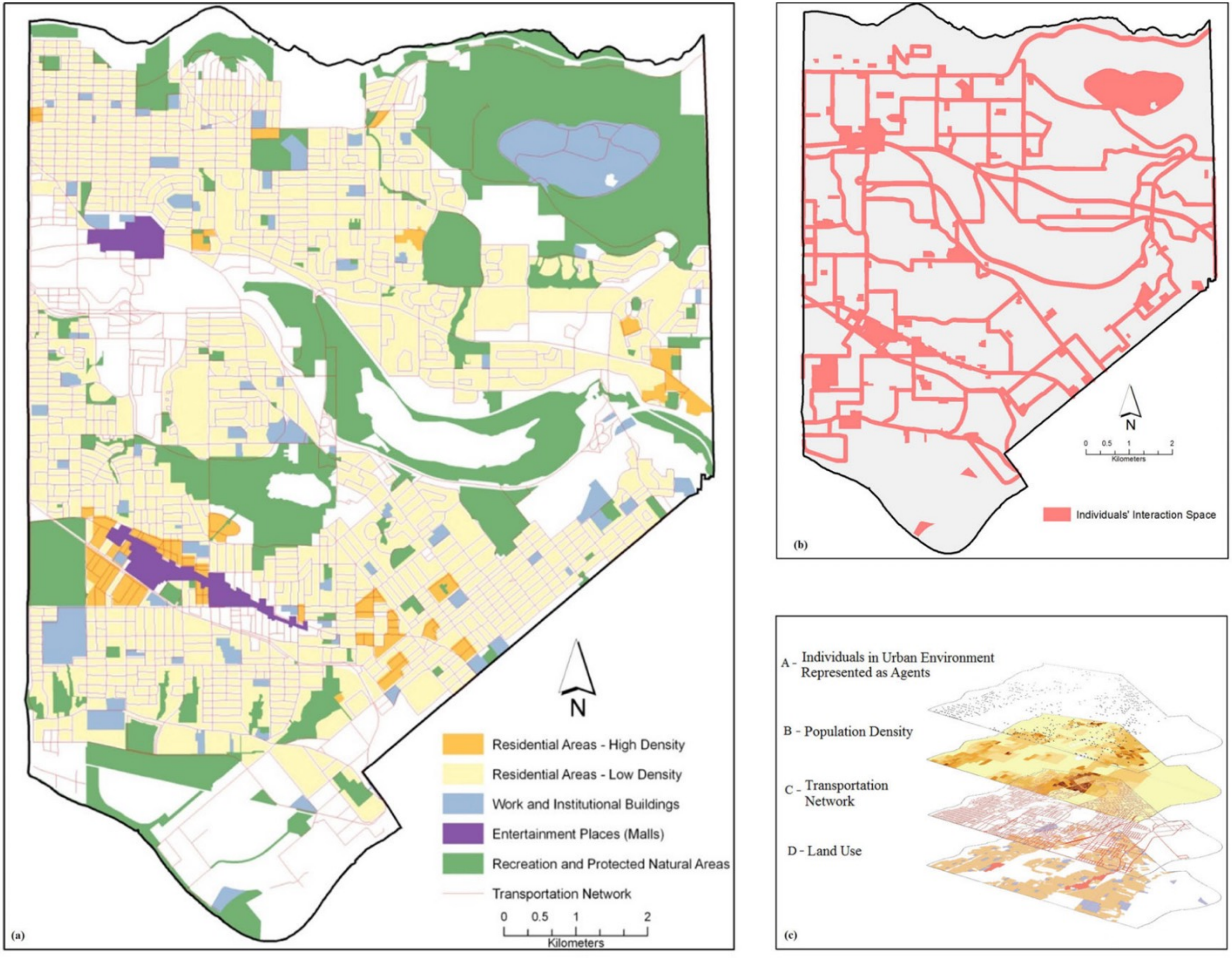


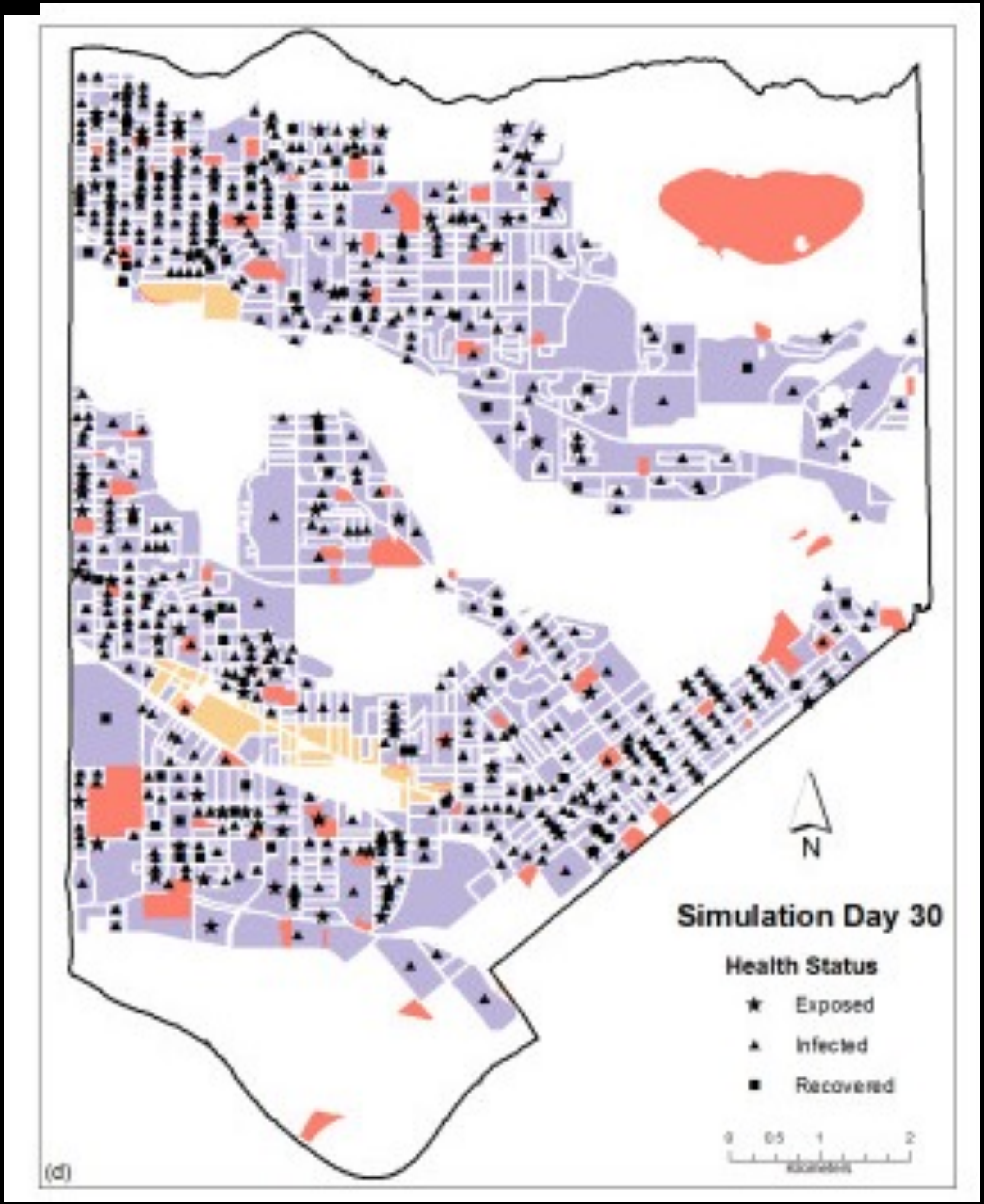
Melo A, Belchior M, and Furtado V, 2006. Analyzing police patrol routes by simulating the physical reorganization of agents, in Sichman J S and Antunes L (eds.), Multi-Agent-Based Simulation VI, Springer, Berlin, Germany.

Tier 1 Example: Perez and Dragicevic, 2009

- Agents: **Individuals**
  - ***Methods***: select next location; move; spread disease
  - ***Attributes***: health status (susceptible, exposed, infected, immune); home location; work/school location
- Environment: residential, employment/education, commercial
- Individuals spread disease to one another based on their physical proximity and the population density at that location
- No further demographic or personal characteristics

Perez L and Dragicevic S, 2009. An agent-based approach for modeling dynamics of contagious disease spread, International Journal of Health Geographics, 8: 50.


Residential Areas - High Density
Residential Areas - Low Density
Work and Institutional Buildings
Entertainment Places (Malls)
Recreation and Protected Natural Areas
Transportation Network
N
0 0.5 1 2
Kilometers
(a)
Individuals' Interaction Space
N
0 0.5 1 2
Kilometers
(b)
A - Individuals in Urban Environment Represented as Agents
B - Population Density
C - Transportation Network
D - Land Use
(c)



Perez L and Dragicevic S, 2009. An agent-based approach for modeling dynamics of contagious disease spread, International Journal of Health Geographics, 8: 50.

Tier 2 Example: Haase et al., 2010

Agents

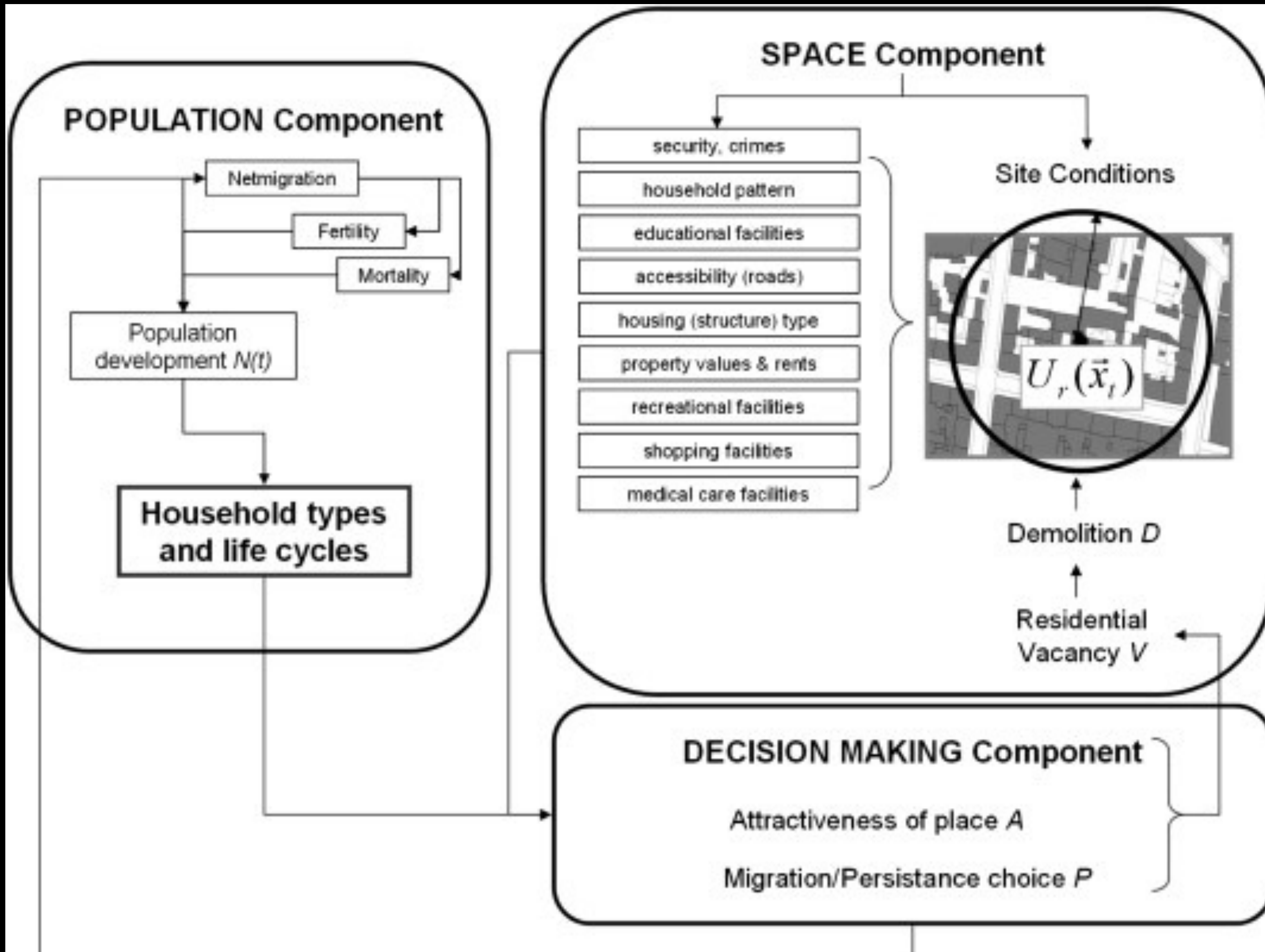
- **Persons**: age, sex, income
- **Households**
  - ***Attributes***: set of persons => type (e.g. family household with dependent children, elderly single person, unrelated adult roommates, etc.)
  - ***Methods***: assess whether to move
- **House**
  - ***Attributes***: location, vacancy rate
  - ***Methods***: demolish in case of 90% vacancy

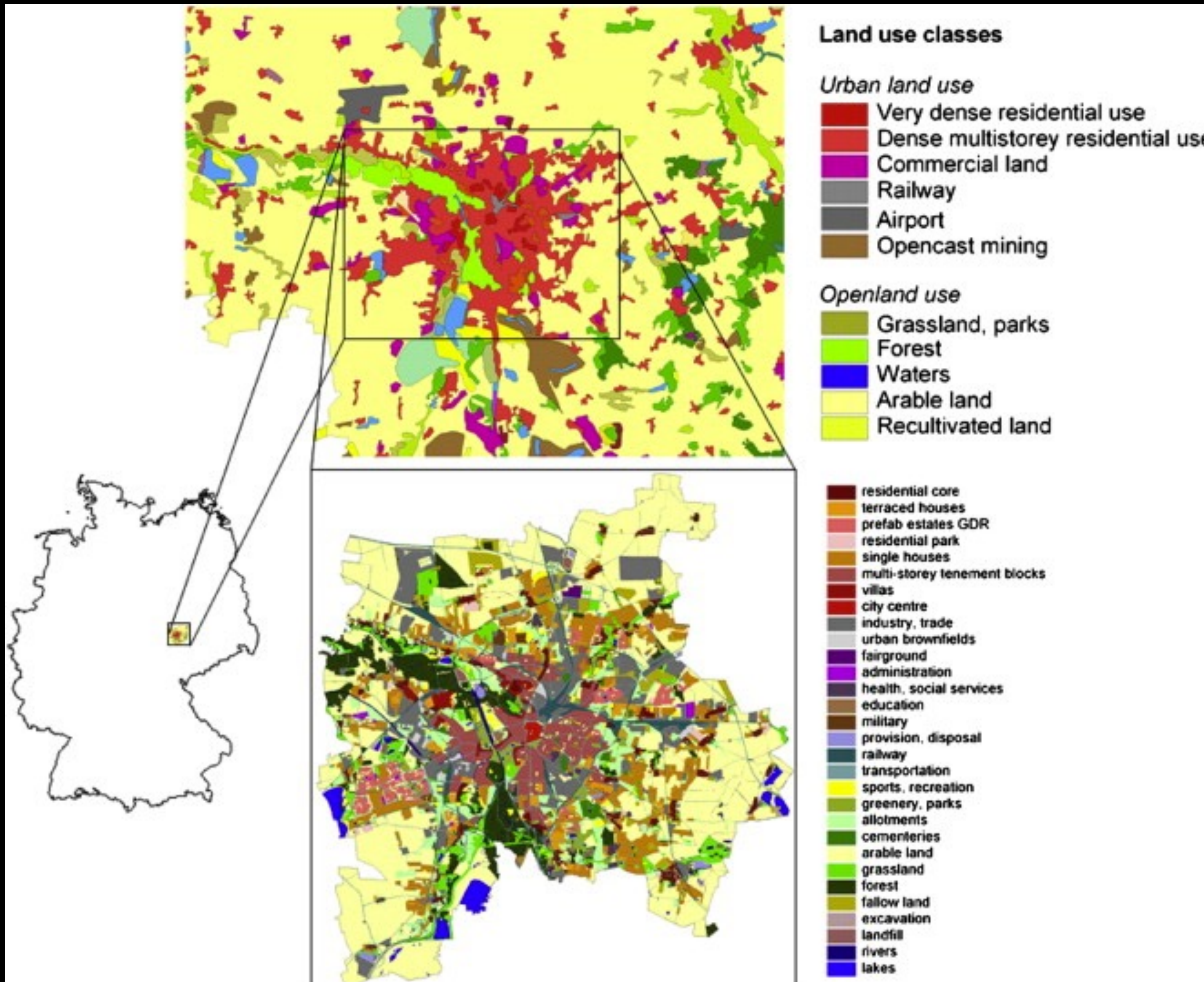
Environment

"Housing choices are determined by variables including **social environment (social class, lifestyle, household type), income, financial budget** and the **accessibility of public infrastructure**."

- Housing locations (with associated rents)
- Infrastructure
- Land Use
- Transportation
- Greenery

Haase D, Lautenbach S, and Seppelt R, 2010. Modeling and simulating residential mobility in a shrinking city using an agent-based approach, Environmental Modelling and Software, 25(10): 1225-1240.


POPULATION Component
Netmigration
Fertility
Mortality
Population development N(t)
Household types and life cycles
SPACE Component
security, crimes
household pattern
educational facilities
accessibility (roads)
housing (structure) type
property values & rents
recreational facilities
shopping facilities
medical care facilities
Site Conditions
$U_r(\vec{x}_t)$
Demolition D
Residential Vacancy V
DECISION MAKING Component
Attractiveness of place A
Migration/Persistance choice P



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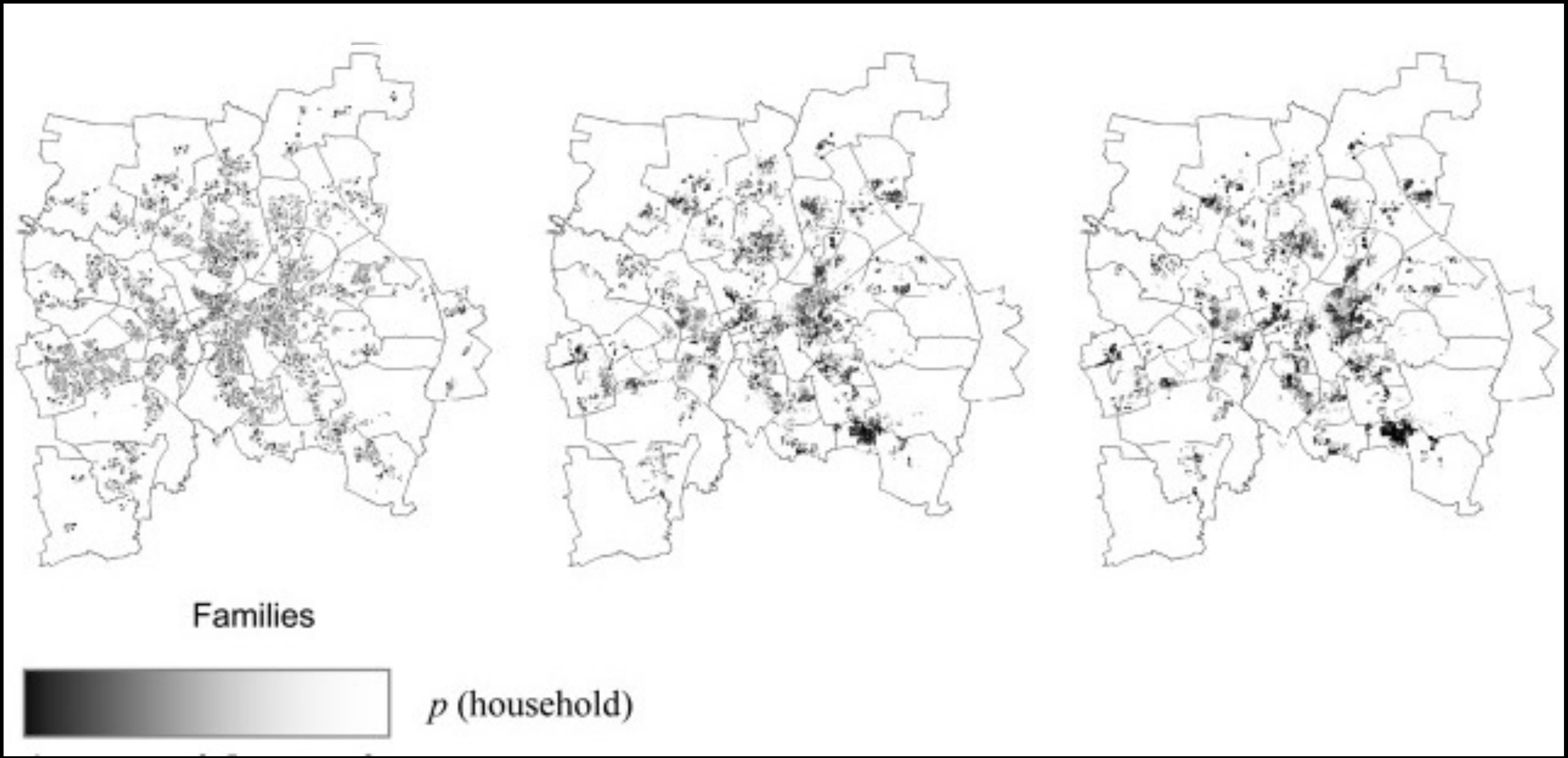


Haase D, Lautenbach S, and Seppelt R, 2010. Modeling and simulating residential mobility in a shrinking city using an agent-based approach, Environmental Modelling and Software, 25(10): 1225-1240.

Tier 3 Example: (notional #1!)

Agents

- Individuals
  - ***Attribute**s*: transportation budget, home location, risk tolerance, demographics, memory of commutes
  - ***Methods***: consider jobs, change jobs, commute
- Buses
  - ***Methods***: move along route, take on passengers
- Bus service
  - ***Methods***: add/cancel bus services based on profitability

Purpose: explore impact of different bus routings on employment for low-income commuters

Environment

- Employment locations
- Residential locations
- Public transit infrastructure

Tier 3 Example: (notional #2!)

Agents

- Individuals
  - ***Attribute**s*: transportation budget, work location, home location, memory
  - ***Methods***: decide on mode, attempt to take cycle
- Cycle station
  - ***Attributes***: number of cycles currently present, price of cycle
  - ***Methods***: adjust cycle price

Purpose: explore variable pricing for shared cycling programs

Environment

- Employment locations
- Residential locations
- Public transit infrastructure information
  - Locations by mode
  - Pricing/time

Some things to keep in mind

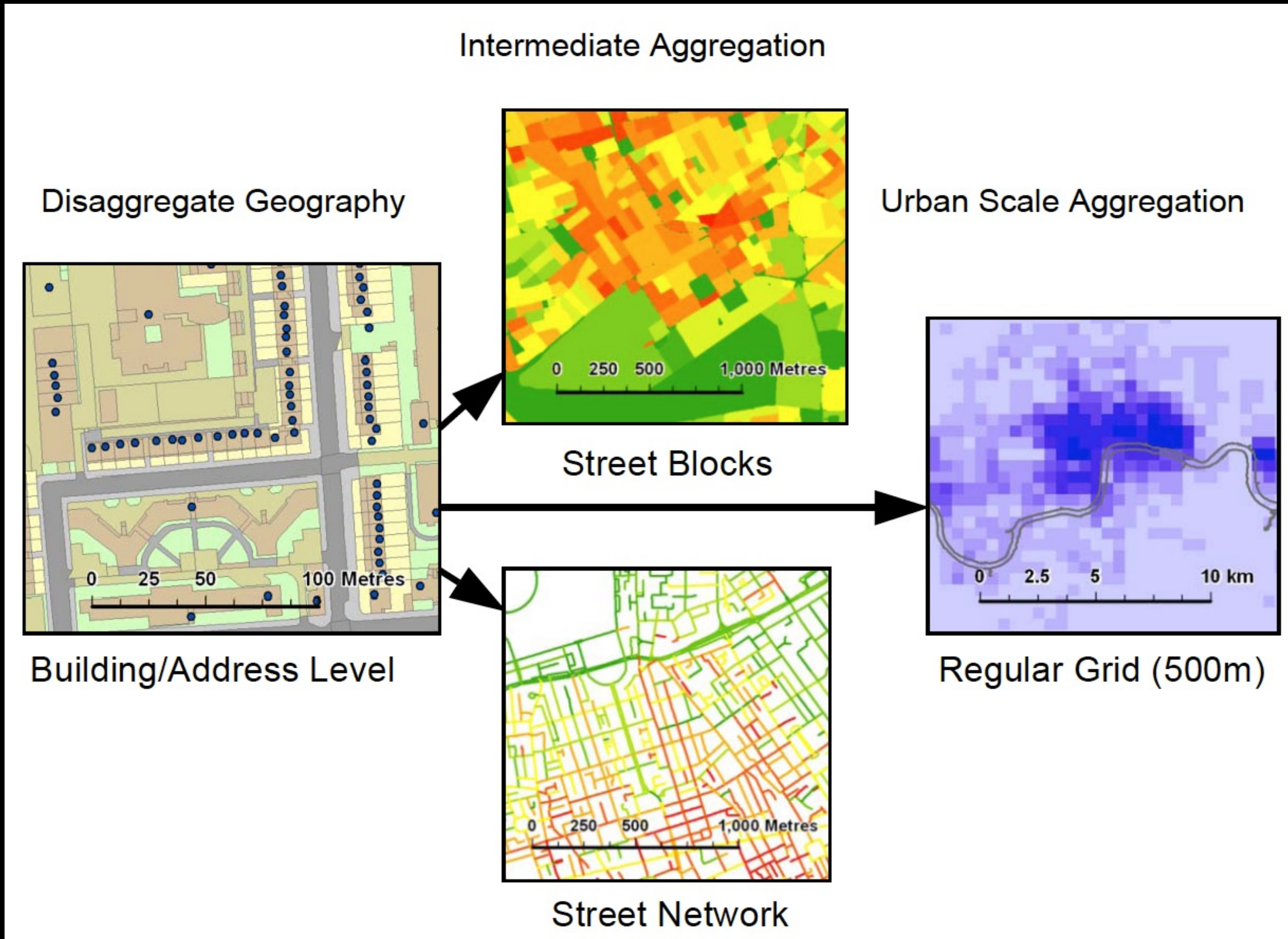
- When you decide to model a feature, at what granularity are you going to measure it?
  - Short sharp peaks, or continuous pressure?
- How might abstracting the feature help or hinder the model?
  - What aspects of this feature are important and unimportant for this work?
  - What can be cut or simplified away? PARSIMONY!!!

WHERE DOES THIS DATA COME FROM, THOUGH?

Where do we get the data?

	Form		Function	
	Traditional	**Crowdsourced**	**Traditional**	**Crowdsourced**
Explicit	National mapping datasets Cadastral records	Open-source, collaborative, user-generated mapping (e.g. OpenStreetMap, Google Maps)	Socioeconomic data (e.g. census, tax records, land use data, address-point products)	Location-based social networking applications (e.g. Foursquare, Geo-wiki WikiMapia) Citizen geo-narratives
Implicit	Authoritative geo-narrative (e.g. edited books, tourist guides)	Geolocated trajectories Open-source unstructured geo-narrative (e.g. travel blogs)	Travel guides (e.g. Lonely Planet, Michelin Guide) Digital trails	Social media content (e.g. Twitter, Flickr) Activity patterns (e.g. transaction and transportation data)

Andrew Crooks, Dieter Pfoser, Andrew Jenkins, Arie Croitoru, Anthony Stefanidis, Duncan Smith, Sophia Karagiorgou, Alexandros Efentakis & George Lamprianidis (2015) Crowdsourcing urban form and function, International Journal of Geographical Information Science, 29:5, 720-741, DOI: 10.1080/13658816.2014.977905



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Final thoughts

- Creating the input data is a huge part of the labour of creating an ABM.
- Think about this BEFORE you start coding your model.
- Remember to consider uncertainty, bias, and gaps – how might the way the data was gathered impact your simulation?

You, as the modeller, have to decide what's reasonable and appropriate to use.

THAT'S IT!