Adaptive Planning Policy and Practice. The opportunities provided by Big data and dynamic simulation models in an era of digital cities

Dr. Elisabete A. Silva
es424@cam.ac.uk

Dep. of Land Economy, CSIC, Robinson College
University of Cambridge

OUTLINE

1. The argument in favor of adaptive policy and need for 'Big/live Data'
2. Complexity theory: The right moment in time to link planning decision and urban models

   -Matching the key attributes of PPS -DSS with Dynamic Simulation and Planning Decisions (Policy Support) & some level of 'Soft' AI

3. Key areas to address: Metrics, Methods, Calibration, Validation, Randomness , uncertainty, data-mining
4. The examples of models: The SLEUTH model; The CVCA model; **CCID model**; IUBEA, The DG-ABC model, **climate change negotiation** and COP (more than big trends are the selection of packages, adaptation in time/space and 10% efficiency gain)

1. The argument in favor of adaptive policy for spatial planning

- Cities and landscapes evolve - in time and space (across scales and along the same scale)

- The rational models of the 50-70s - systems theory or participative theory they are both based on the '**presumption of certainty**' - they provide one answer to the decision maker (static snapshot of time – a map, a result)

- Historical evolution is due to theory, practice, professional qualifications/numbers, computation, data constraints

- The simplified reality of static world resulting from overlays of data is not enough

- ‘Today’ is a result of complex physical and social interactions that have in account past events and future expectations

- Pure causation is not enough and cumulative effects, ‘carrying capacity’, self-organization, etc. play important roles

↓

- Complexity theory

2. Complexity theory: The right moment in time to link planning decision and urban models

- Mismatch between technology, theory, data of the 70s resulted in Lees' "Requiem for large scale models"

- XXI century of Big Data, high computation capability, vast numbers of experts, more data-aware policy , **metrics, calibration, validation, randomness**

- Key contributions: Von Neumann and Morgenstern (1944, 1966), Ulam (1960, 1974), Turing (1941), Prigogine (1977, 1999, 1984), Tobler and Burks (1979), Kauffman (1984, 1993),Wolfram (1994), Holland (1995, 1999), and Crutchfield (1995); John Nash exploring research results by Merrill Flood and Melvin Dresher at RAND corporation (1950s);

▪Starting the study of complex systems in Spatial Analysis ….

▪Waldo Tobler in contact with Arthur Burks was exposed to Von Neumann's works, and published 'Cellular Geography' (1979).

▪At NCGIA-Santa Barbara, Helen Couclelis and Keith Clarke, published respectively 'Cellular Worlds' (Couclelis, 1985) and develop the first fully operational and implementable CA (Clarke and Gaydos, 1998). While et. since the 1990's focus in the 'adaptive' CA as a basis basis of integrated dynamic regional analysis (1997)

▪Michael Batty initially at NCGIA-Buffalo and afterwards at CASA-UCL, developed the theory and practice that culminated in the publication of the seminal books 'Fractal Cities' (1994) and 'Cities and complexity' (2005). Recently, Wolfram's book 'A New Kind of Science' (2002)

▪ES = 3rd Generation (consolidation, reassemble, expansion, randomness, validation)

- Theory
- focus
- Physical /regions
- Systems theory
- Advocacy of Planning
- Beyond modernity
- People/ social
- Participative Planning

- Processes
- Rational Planning
- Incremental Planning
- Mix-Scanning (Zoom in-out, Top/down-b/up)

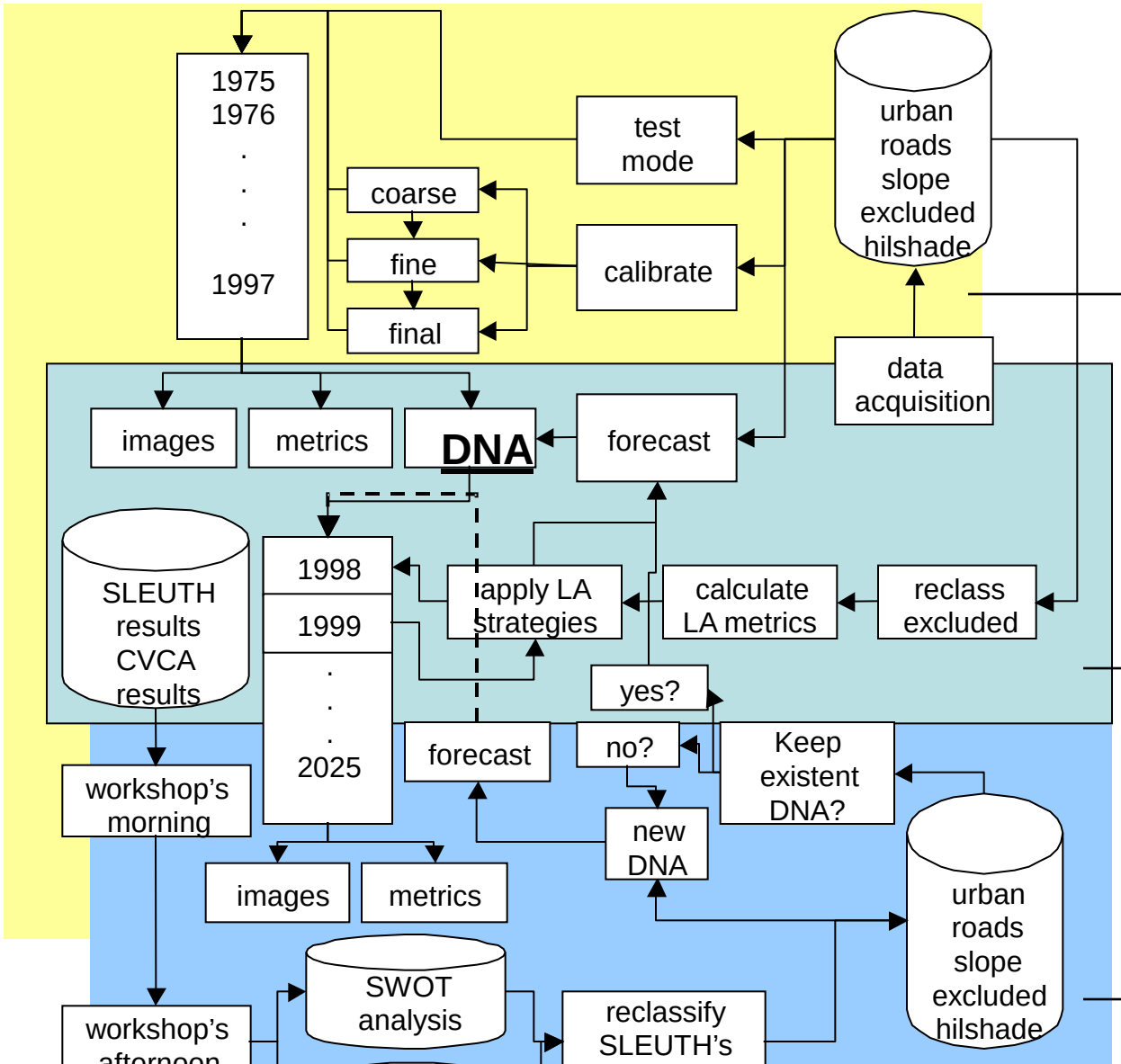
- Models
- Deterministic
- Stochastic

- time 50s

Feedback loops of learn/adapt/enrich_knowledge

- Complexity Theory
- Data science

Operational Dynamic Urban Models

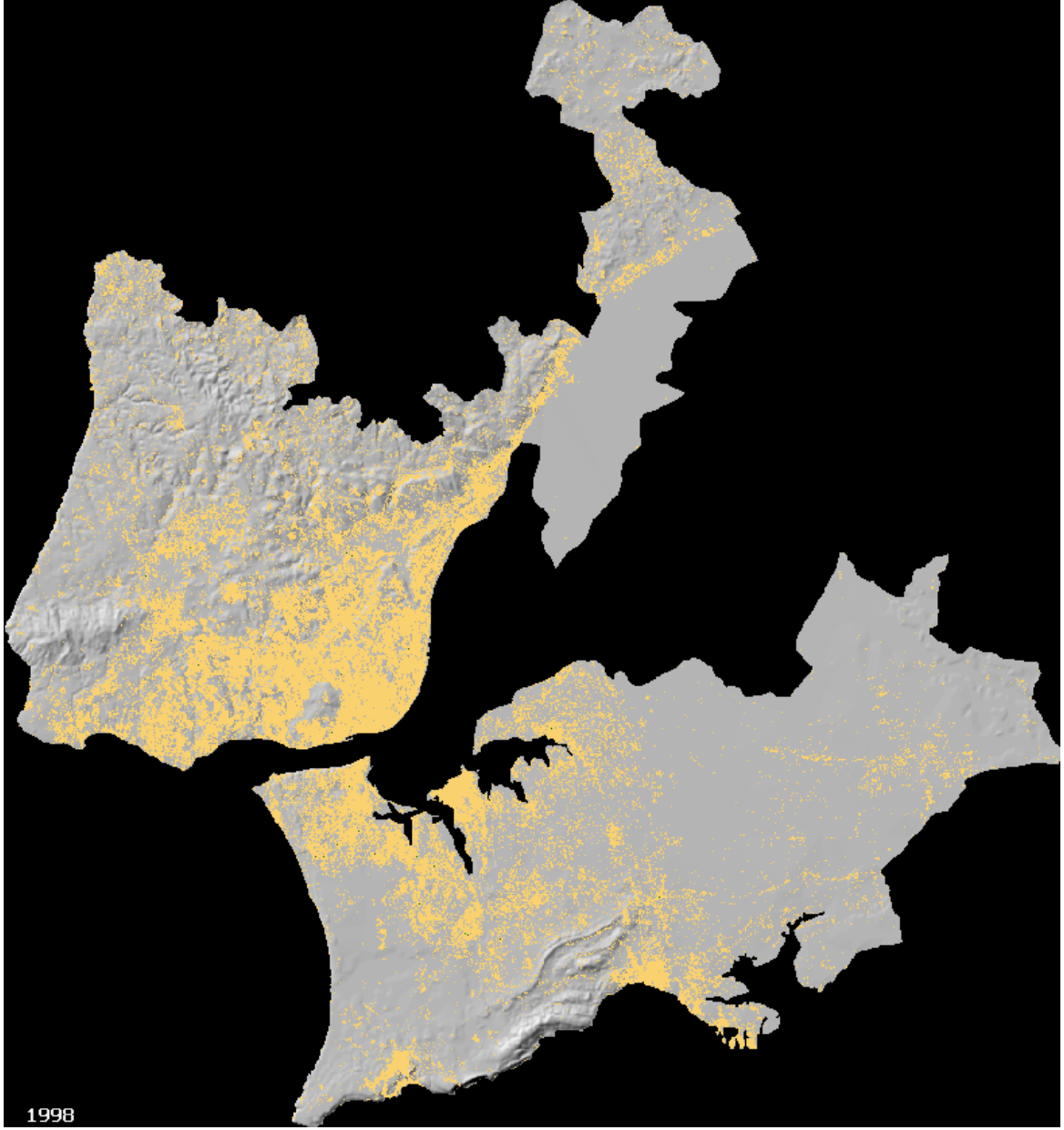


SLEUTH Urban Model

CVCA Environmental Model

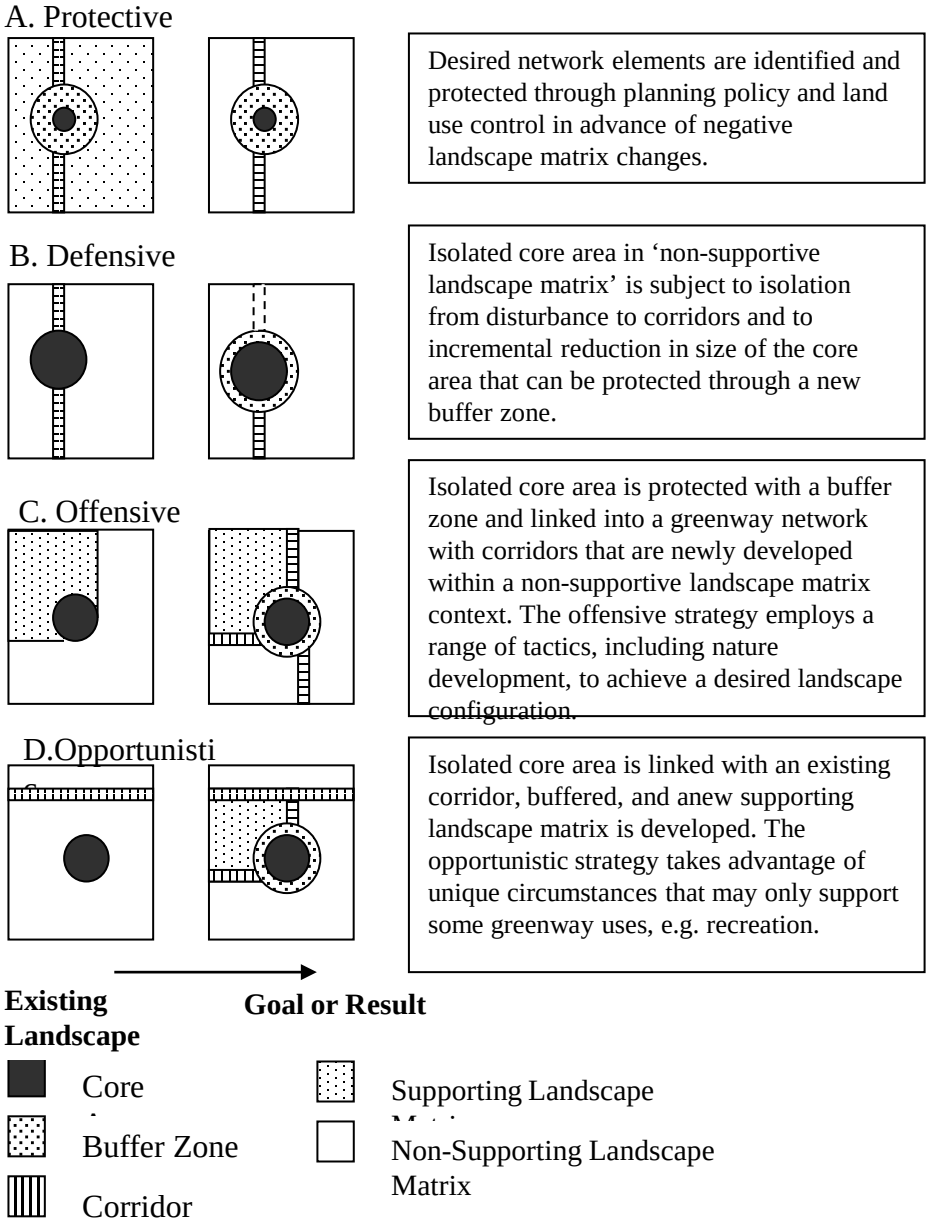
Expert Inclusion 'people's model'

UNIVERSITY OF CAMBRIDGE

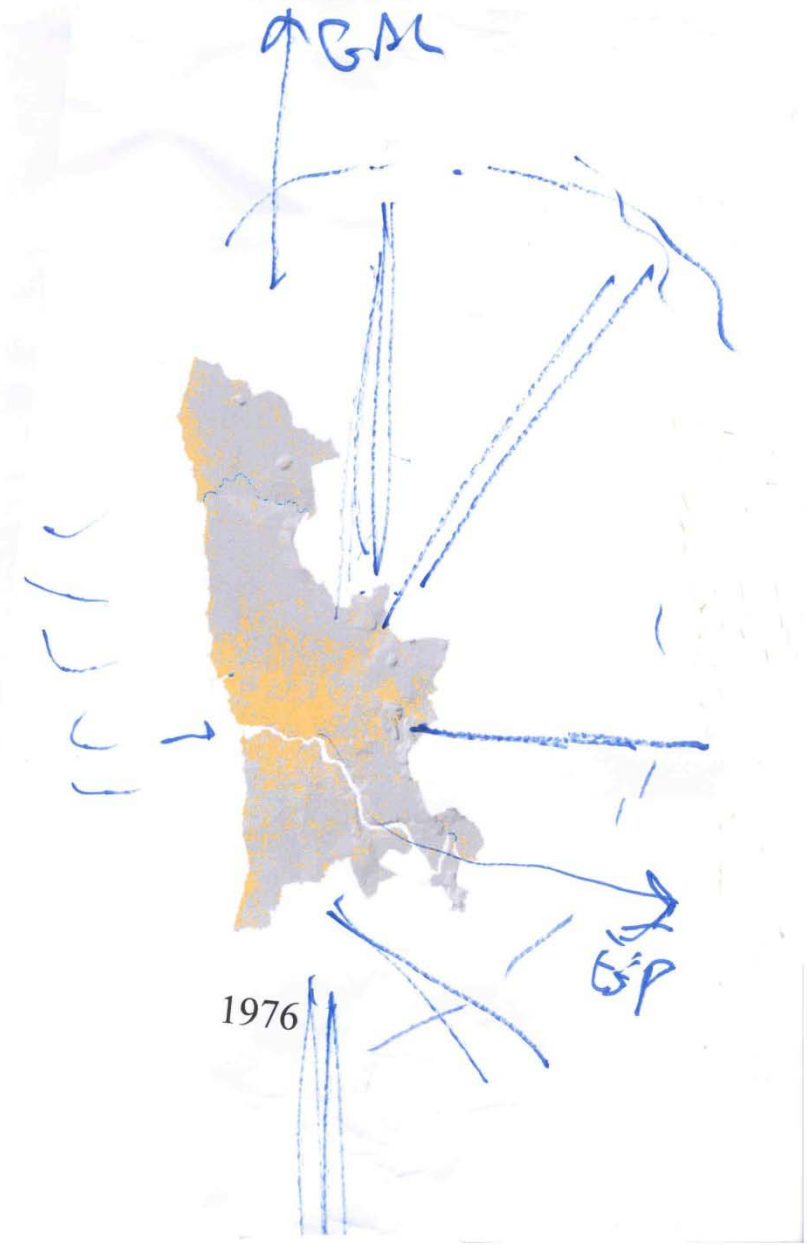


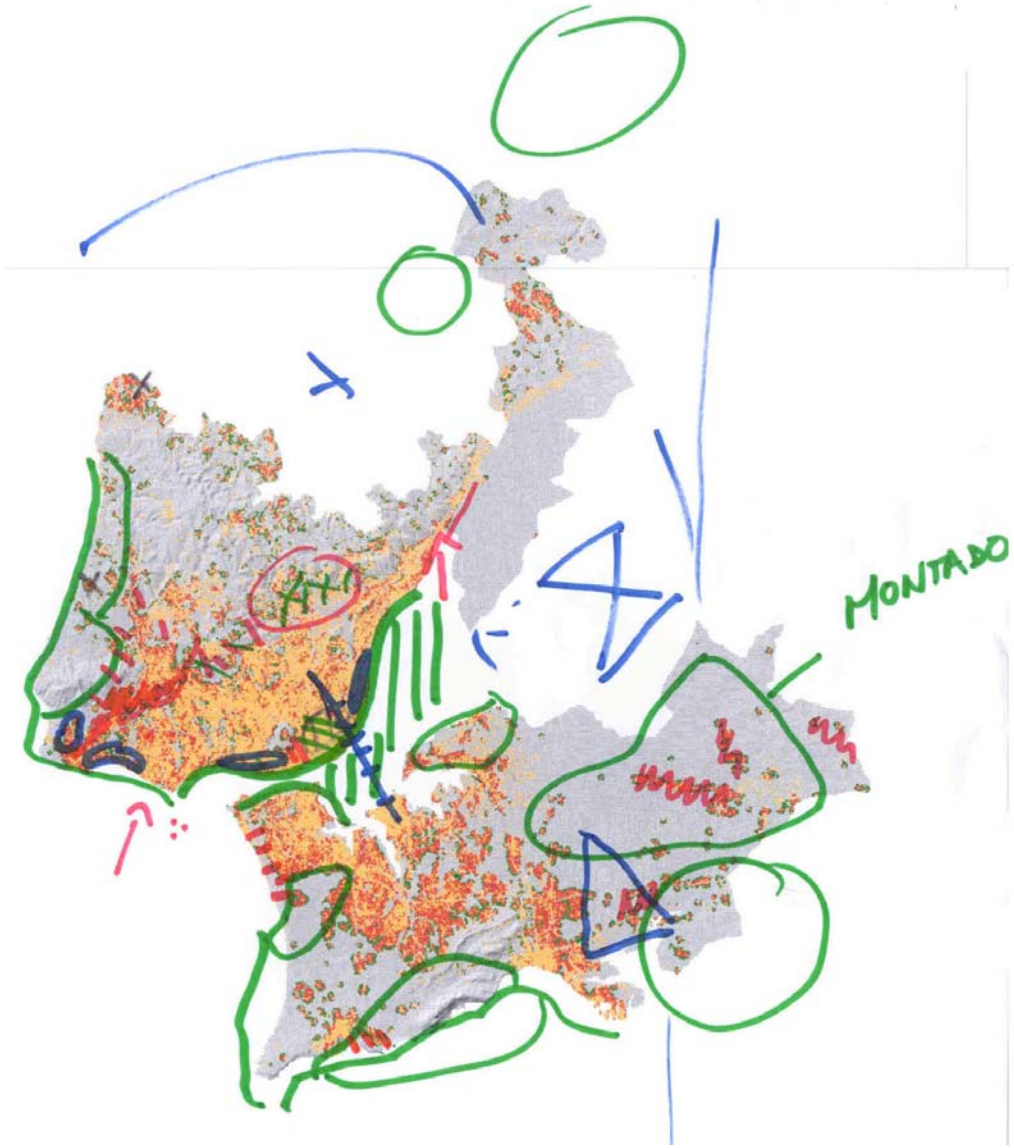
- **1. SLEUTH**

Transition Rules:	Number of pixels (pixels with a probability of change to urban)	Action step
1. Protective	0 but NN > MNND	than add protective pixels around all outer patch and add protective pixels until arriving at closest neighbor
2.Defensive	<=50% *,**	than add defensive pixels to all outer patch cell where transition cell exists
3.Offensive	>50%	add offensive pixel to all outer patch cells and add offensive cells until nearest neighbor
4.Opportunistic	0 but NN = NNI	(and no transition cell nearby) than link to nearest neighbor
5. Grow		



TWO MAP DRAWINGS RESULTING FROM THE WORKSHOP'S AFTERNOON

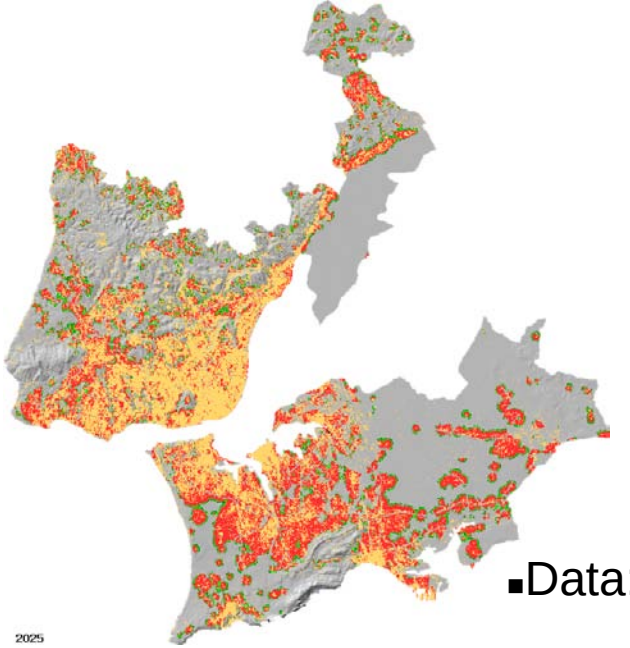




SWOT RESULTS

Strengths	Votes %	Weakness	votes %	Opportunities	Votes %	Threats	votes
Transport system (road network, airport, harbor)	19.5	Mobility, accessibility and transport	32.6	Improve transportation system	17.6	Uncontrolled urban sprawl	29.9
Tourism and world heritage (Lisbon and Porto)	17.8	Lack of urban quality	17.0	Urban renewal	15.7	Natural risks (e.g. coastal, flooding, earthquake)	16.4
Capital city	13.0	Uncontrolled urban sprawl	11.3	Cultural tourism/ events	11.8	Urban violence and drugs	14.2

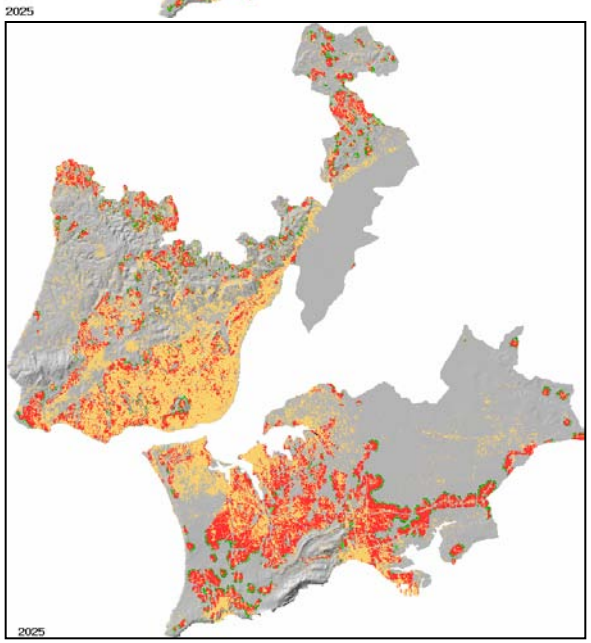
- The image of the city

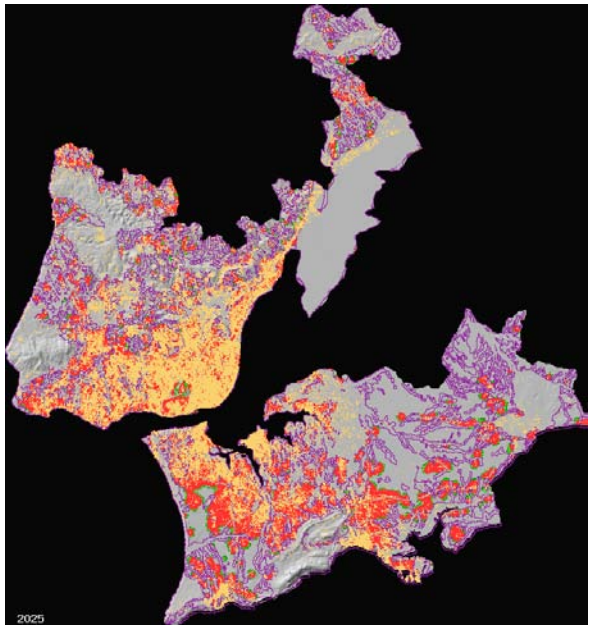


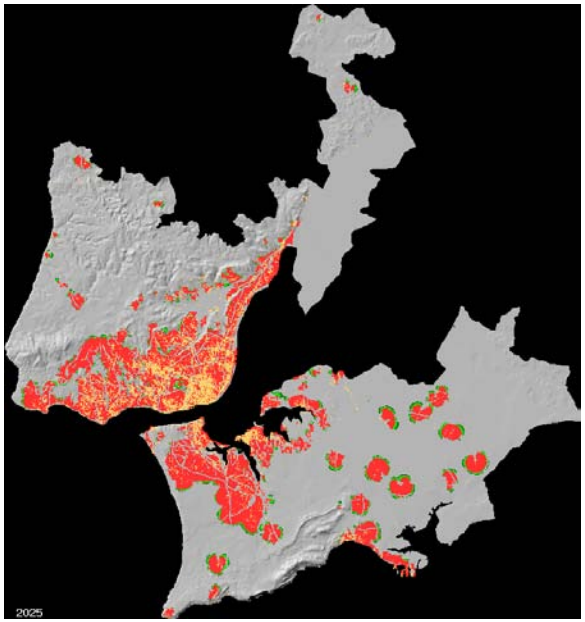
- The image of a city-region
- Identification/quantification
- Urban forms (existent /possible)

- *“same future” – different simulations*

- Data: satellite images and other LU-LCover (year-by-year)





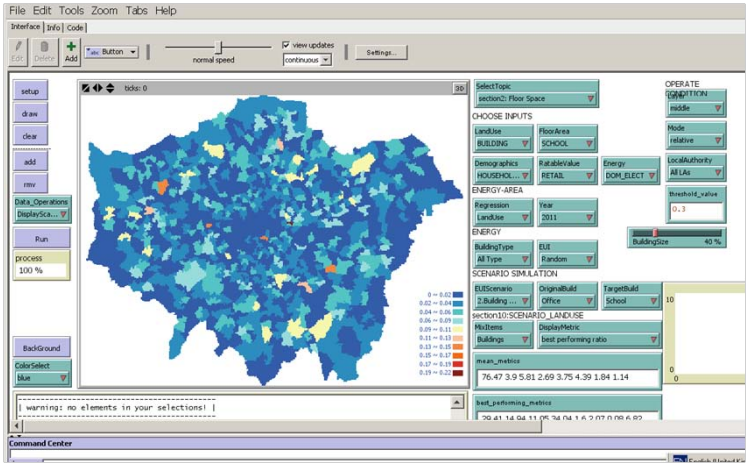


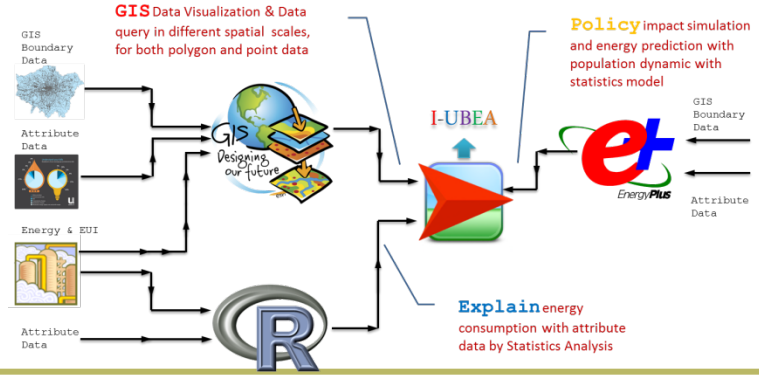
▪Choudhary, Ye, Wei, Silva

▪An Integrated Spatial Analysis Environment for Urban-Building Energy Analysis in Cities (I-UBEA)

▪RESEARCH OBJECTIVES

▪Data: LU/LC + energy + socio-economics (month-by month)





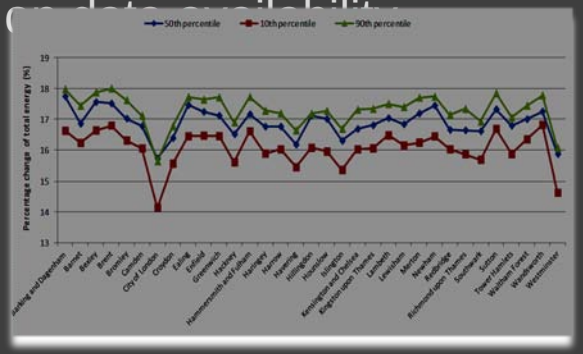
- To track energy change
  - Energy change of London
  - Energy change per local authority / buildings
- To estimate and analyze Energy Usage Intensities (EUI)
  - EUI of Local Authorities
  - EUI of sub-categories of buildings
- To explain energy consumption
  - Explain how the distribution of land use influences energy consumption in local authorities and the entire city of London
  - Explain how the distribution of floor area influences energy consumption
- To evaluate energy performance
  - Evaluate energy performance of London while adapting different energy change policies.
  - Interactive Simulation Model for predicting of energy performance in the future on the basis of population change.

Energy scenario analysis (what-if analysis)

- This method is more flexible compared to regression analysis because it is suitable for the situation where *energy* consumption data are unavailable in some spatial scales or some areas of a city.

Baseline scenario

- The baseline scenario is based on prior knowledge on energy use intensity in terms of building types.
- Three methods are provided:
  - benchmark values
  - median values
  - Monte Carlo method
- Analysts may choose one or all these three methods based on data availability



- (1) Electrification
- (2) Building type conversion
- (3) Energy efficient

- This scenario is to explore how the total energy or carbon emissions would change if building sector would use electricity instead of gas for heating.

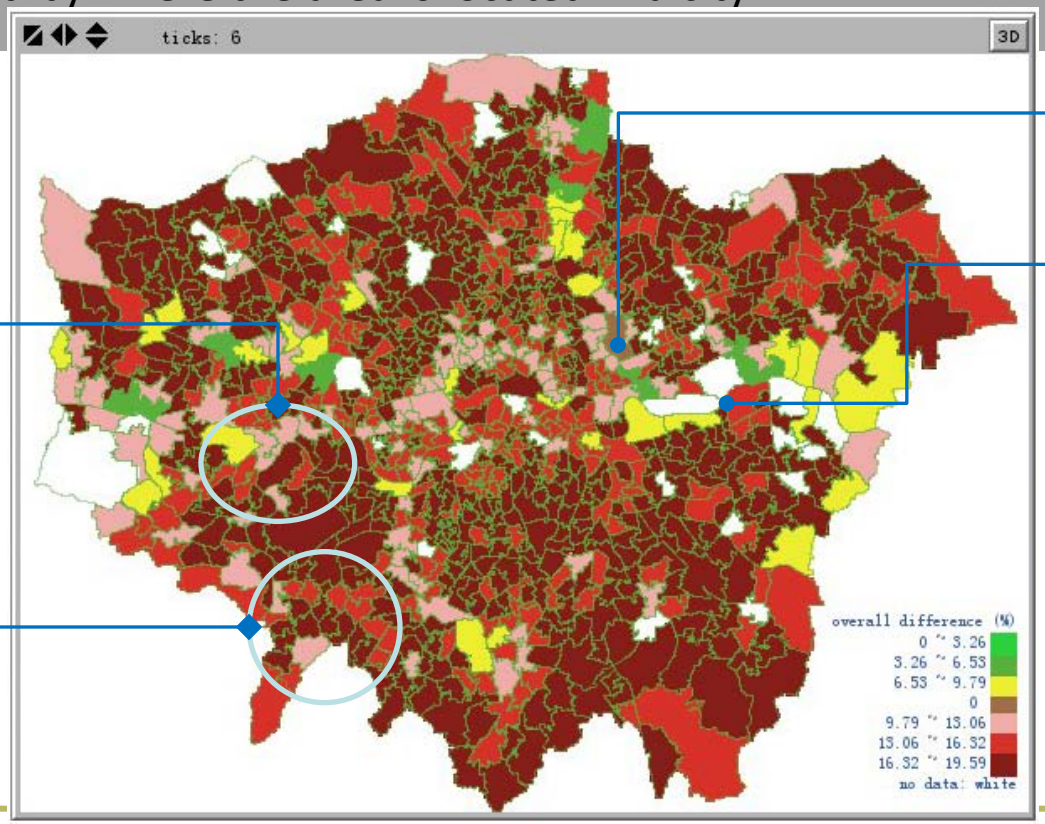
- **This Scenario** investigates the change of building types on the energy consumption in cities.

- This scenario allows analysts studying the influences of change of energy use intensities for different building types.

- Note: The benchmark values are based on low,
- typical, and high values (EUI) from previous literature.

Result: Energy optimization based on building types at MSOA level in London

- To compute the overall difference of floor area percentage to best-performing area in terms of gas use intensity at London MSOA level.
- The overall differences of floor area percentage based on gas use intensity still presents the characteristics of spatial distribution to some extent, though not clustered as large area.
- Spatial distribution demonstrates that energy consumptions in an area are to some extent influenced by where the area is located in a city.



▪best-performing MSOA

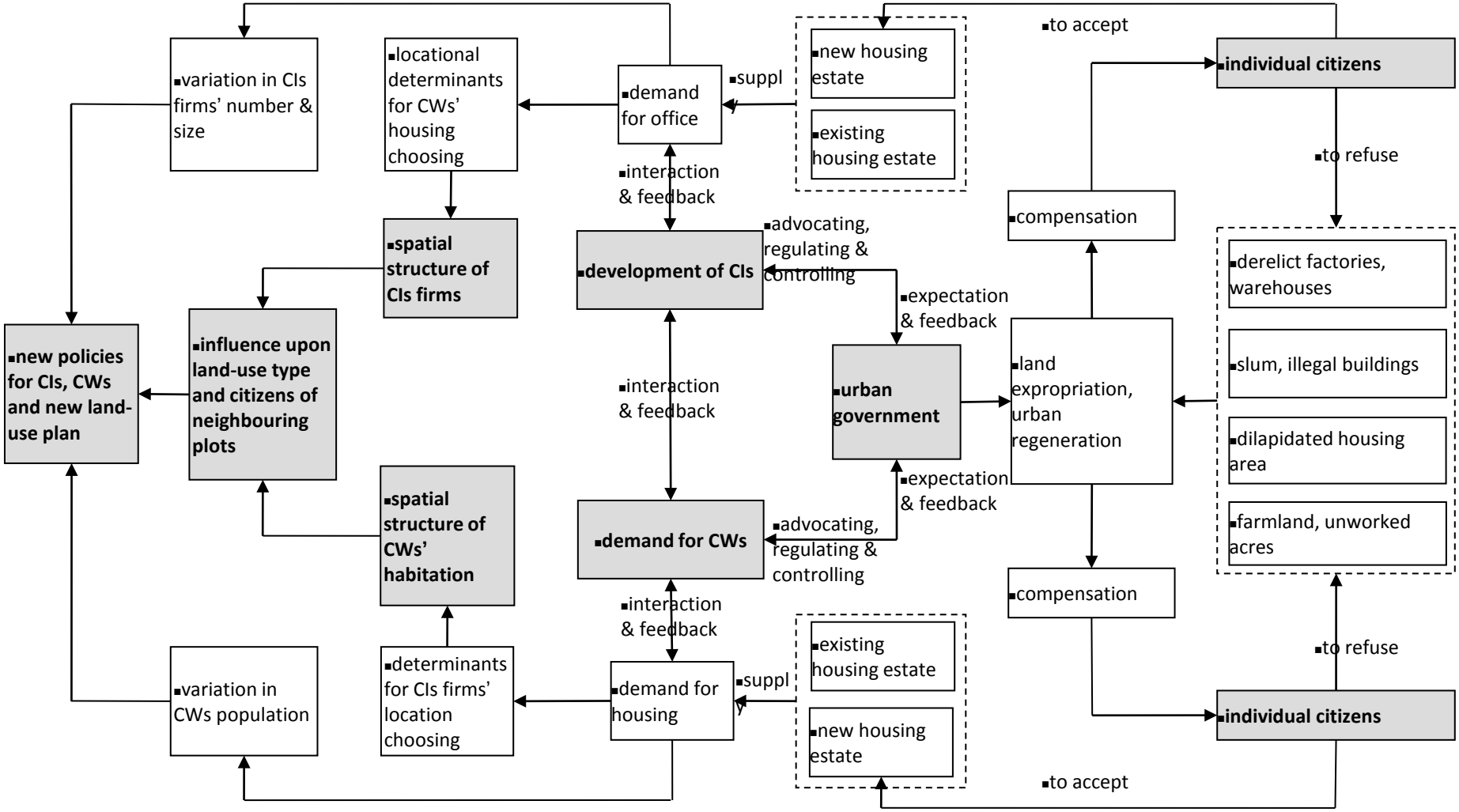
▪MSOA without gas consumption data

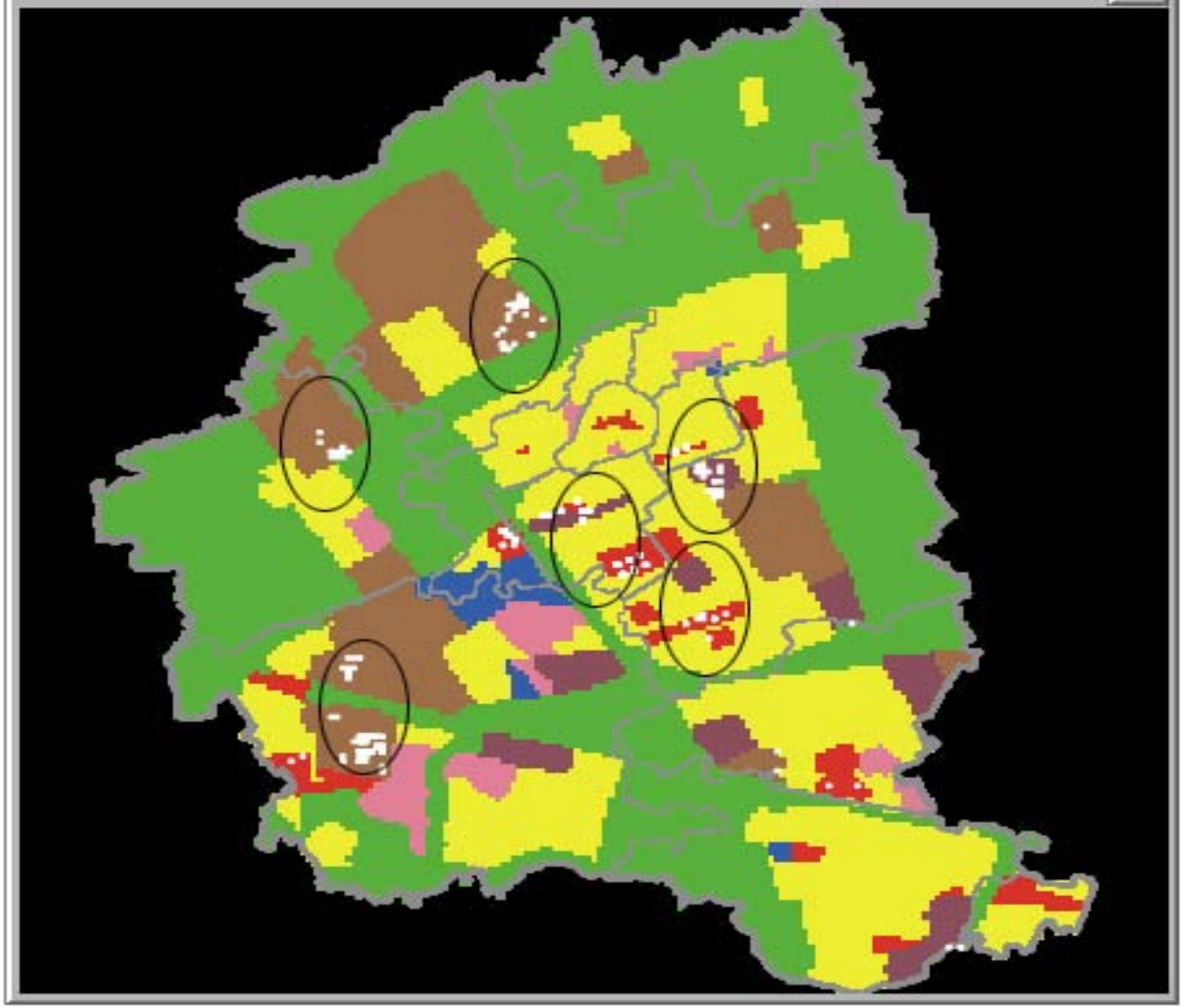
▪MSOAs with similar overall difference are likely to cluster together.

▪small difference

▪large difference

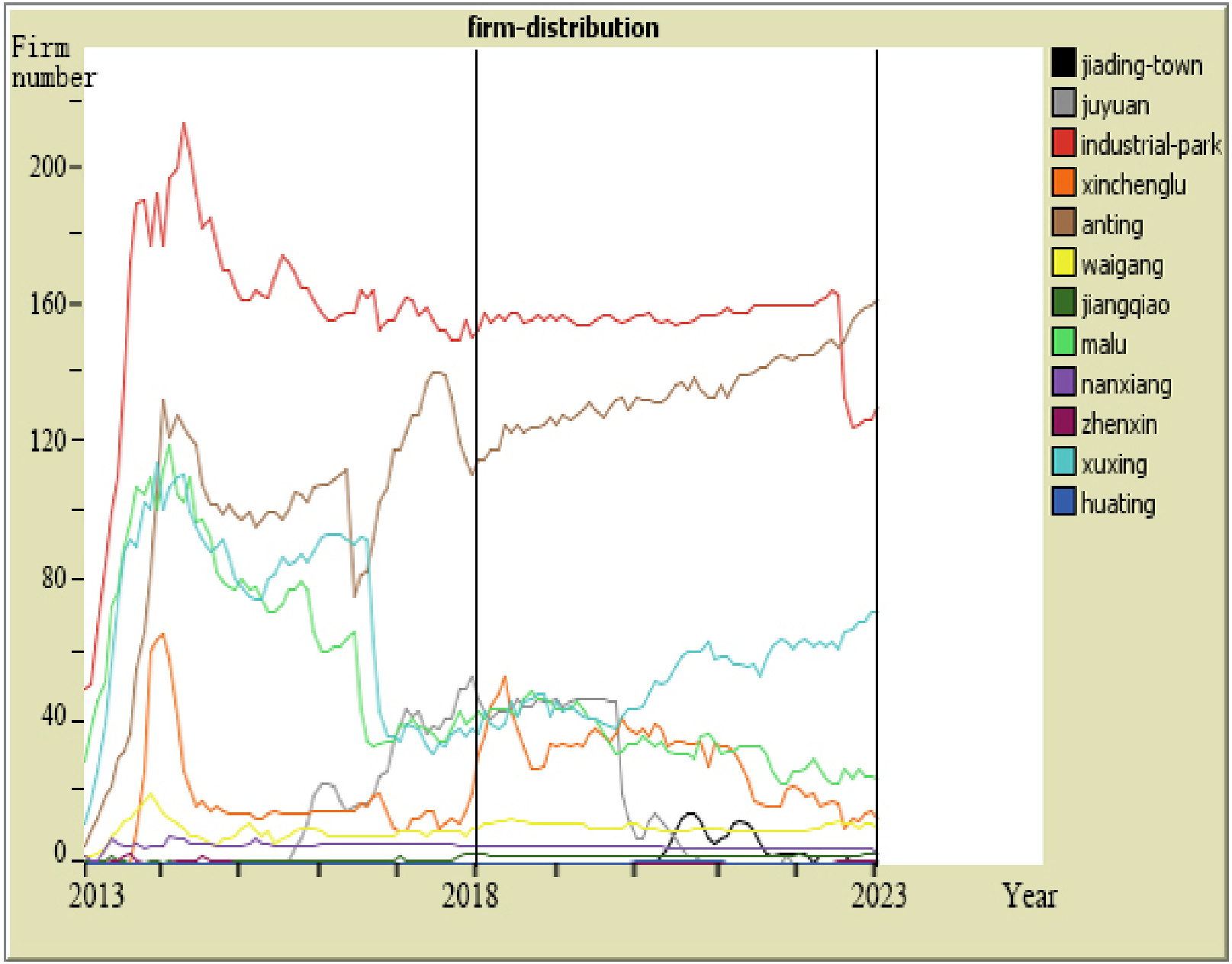
Liu, Wang and Silva -- CI Agent Base Model





- Data: economic statistic data +300 firms and +2000 (+++questionnaires and semi-structured interviews) (month-by-month)

- **2013** *Simulating the dynamics between the development of creative industries and urban spatial structure: an agent-based model (with H. Liu). S. Geertman et al. (eds.), Planning Support Systems for Sustainable Urban Development, Lecture Notes in Geoinformation and Cartography, DOI: 10.1007/978-3-642-37533-0_4, _ Springer-Verlag Berlin Heidelberg, pp. 51-72*


firm-distribution
Firm number
200
160
120
80
40
0
2013
2018
2023
Year
jiading-town
juyuan
industrial-park
xinchenglu
anting
waigang
jiangqiao
malu
nanxiang
zhenxin
xuxing
huating

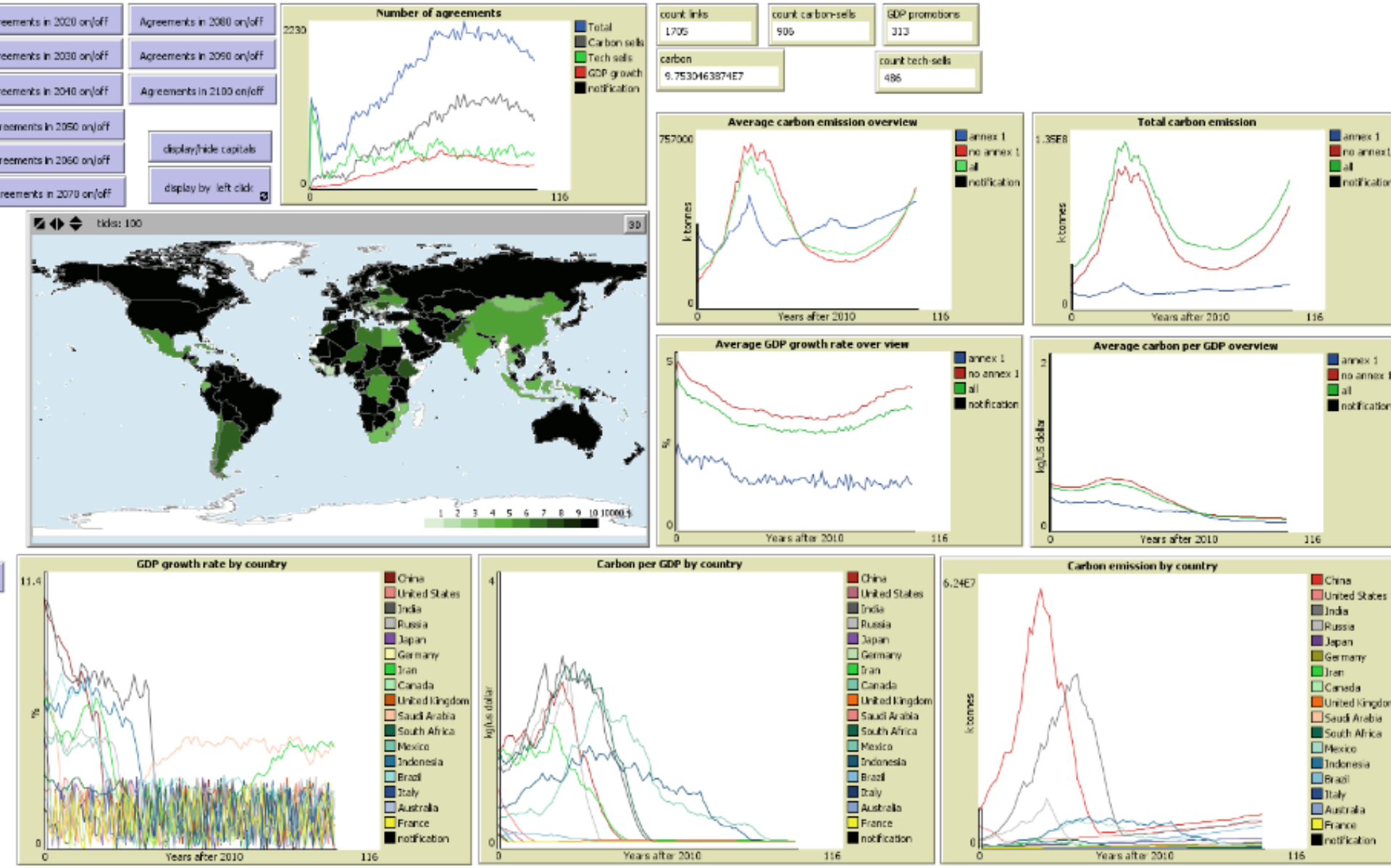
Agents and terms for negotiation

Crawford-Brown, Liu, Silva

- Agents:196 countries
  - Annex1 (42)
  - No Annex1 (149)
  - Others (5)
- Terms for negotiation
  - Technology trade
  - Carbon trade
  - GDP growth support
- Negotiation rules

Table 1 The three adoptable strategies and their influence on the two involved countries

country		Carbon Sells	Technology Sells	GDP growth support
A as sender	Technology (Carbon/GDP)	↑	--	--
	Extra Carbon emission	--	--	↓
	GDP growth rate	--	↑	--
B as receiver	Technology (Carbon/GDP)	--	↑	--
	Extra Carbon emission	↑	--	↑
	GDP growth rate	↑	↓	↑



- Data: minutes of meetings + socio-economic data + agreements data
- (year-by-year)

Three scenarios

Annex 1 / non-Annex 1

Parameter's name	Connection to the dynamics	scenario A: Low Ambition	scenario B: Medium Ambition	Scenario C: High Ambition
gdp-per-capita-emission-concerned (USD/Capita*Year)	A global variable for recording the critical value for GDP/capita. Countries with GDP/capita lower than this value will not join in the bilateral negotiation.			
carbon-per-capita-critical value (t CO_2/Capita*Year)	A global variable for recording the critical value for carbon emission / capita. Only countries with carbon emission/capita lower than this value can be free from the responsibility to reduce carbon emission.			
critical-carbon-emission-per-gdp (t CO_2/USD)	A global variable for recording the critical value for carbon emission / GDP. Each country involved in the negotiation process is responsible to reduce its carbon emission intensity to a level lower than this value			
critical-minimum-co2pergdp (t CO_2/USD)	A global variable to describe the ultimate ability of our society to reduce carbon emission / GDP			
mean-agreement-duration (Years)	A global variable to describe the average duration of the agreements signed between two countries. The duration of each signed agreement may be different but their mean duration is constrained to this critical value.			
gdp-growth-rate-decrease-rate-critical (%/Year)	A global variable for recording the acceptable decrease rate of GDP growth rate for all the countries due to signed agreements. A country will not sign too many agreements which may reduce its GDP growth rate by more than this critical value.			
carbon-emission-increase-rate-critical (%/Year)	A global variable for recording the acceptable increase rate of carbon emission for all the countries due to signed agreements. A country will not sign too many agreements which may increase its GDP growth rate by more than this critical value.			

	Name	Description	Example	length
1	MSID	Mobile identification number, IMSI or by IMSI one-way encryption as a result, a unique identifier mobile phone (TMSI)		32
2	TimeStamp	Timestamp, signaling successful time markers, accurate to seconds, GPS time synchronization	YYYYMMDDHHMMSS, e.g. 20051125112203,	14
3	LAC	Location area code		5
4	CellID	A GSM Cell ID (CID) is a generally unique number used to identify each Base transceiver station (BTS) or sector of a BTS within a Location area code (LAC) if not within a GSM network.		5
5	EventID	The event type	e.g. 002	3
6	Flag	whether can obtain IMSI		3
7	CR	carriage return		1

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74A615BB3FD9B280A12C11C795A2533B,20140315113351,06147,45409,061,000
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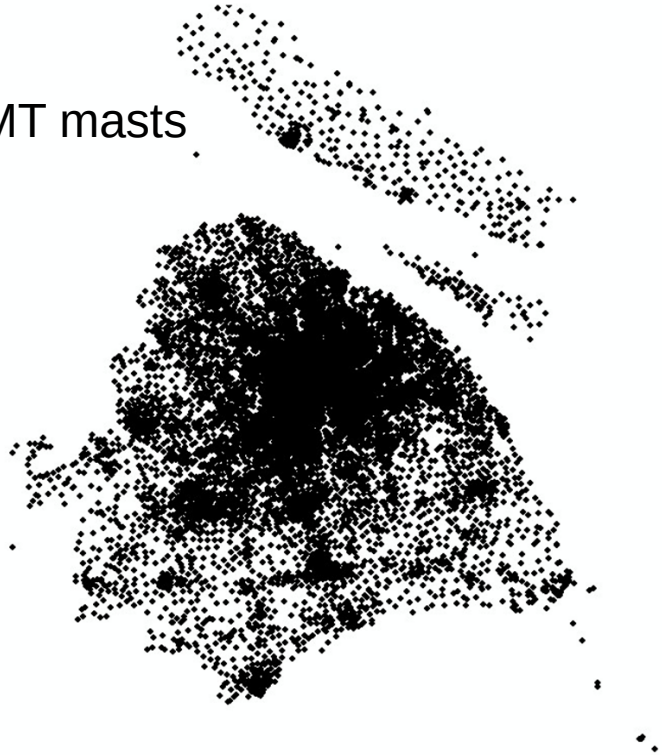
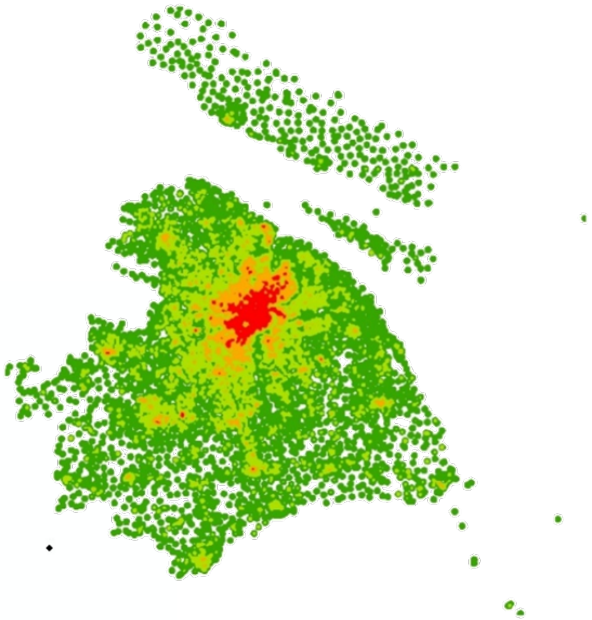
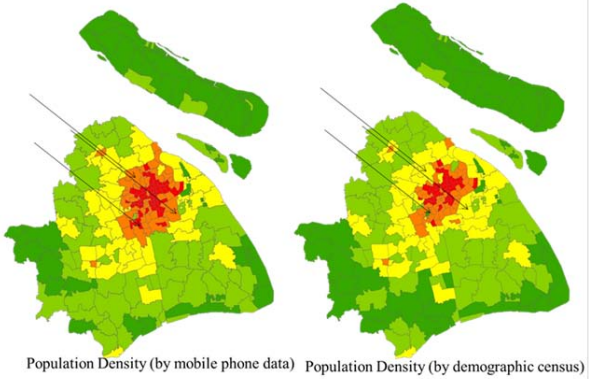
- MT masts



- Xiao, Silva

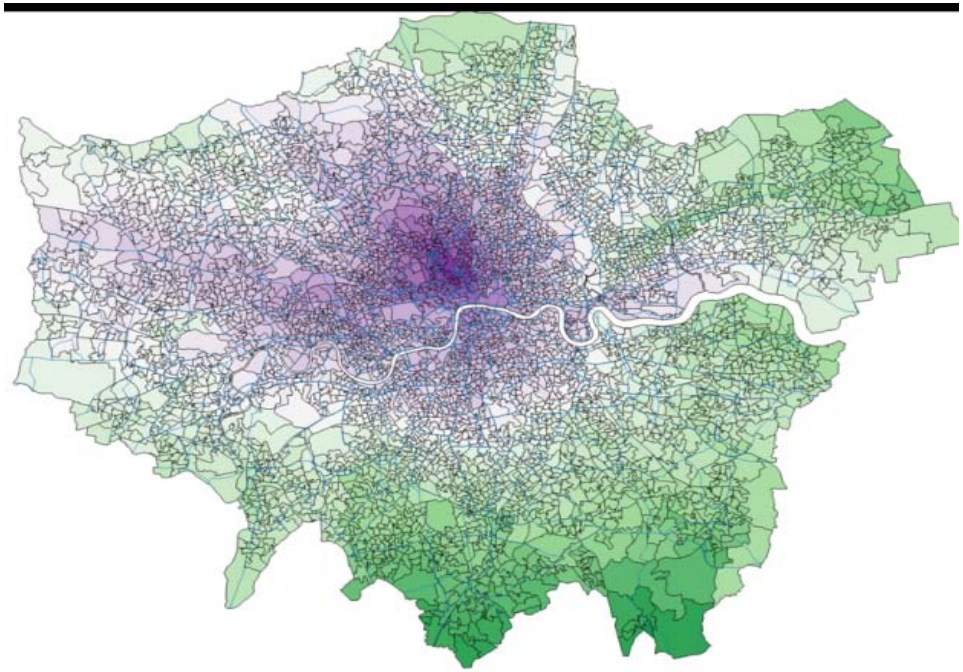




- Data: 70% of all geo-data telecommunications traffic
- (minute-by-minute)

Data structure – adding to the mobile google feeds

Casey, Silva, Soga, Guthrie



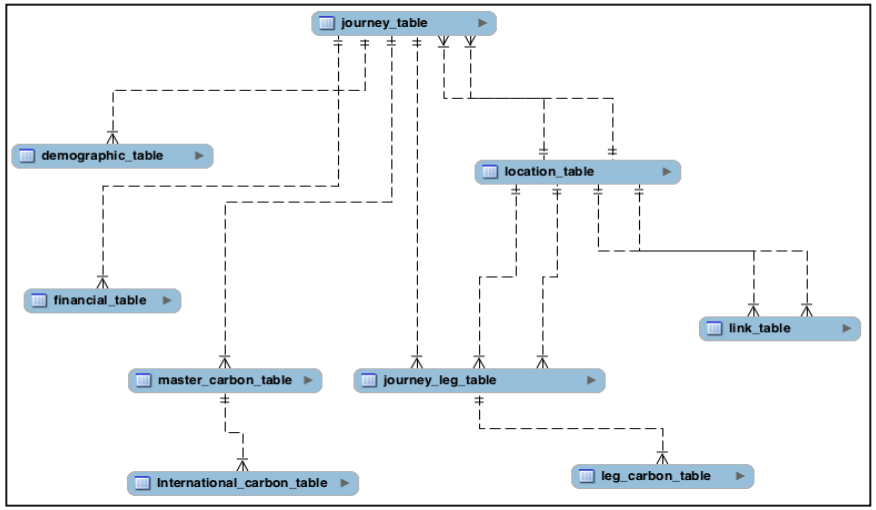


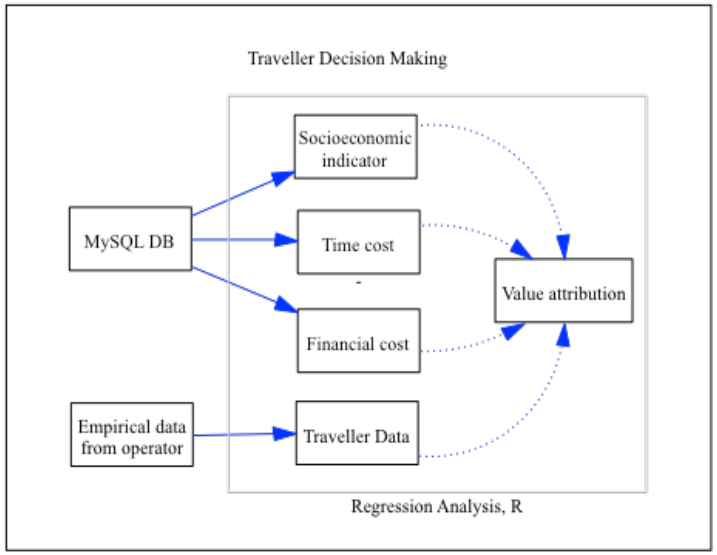
Table 4 Temporal Resolution

Temporal	Index						
Daily	0630	0800	1100	1300	1500	1730	1900
Weekly	Mon/Tue	Wed/Thur	Friday	Saturday	Sunday		
Monthly	Jan/Feb	Mar/Apr	May/Jun	Jul/Aug	Sep/Oct	Nov/Dec	

Table 5 Simplified illustration of Journey_table data

Journey_ID	Time_stamp	Distance	Duration	Origin_ID	Destination_
5	1425207218	3697	502	3456	1
6	1425207218	3174	529	1732	2
7	1425207219	5073	723	252	3

Journey_leg_table



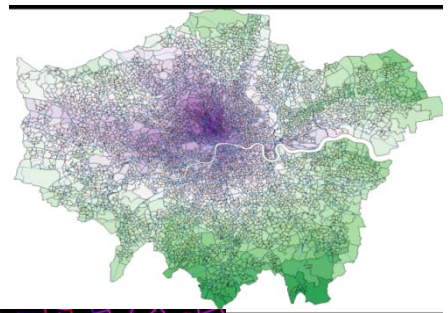
▪Planning & Transport - Operational Dynamic Urban Models

▪Agent based transport modelling with real-time big-data

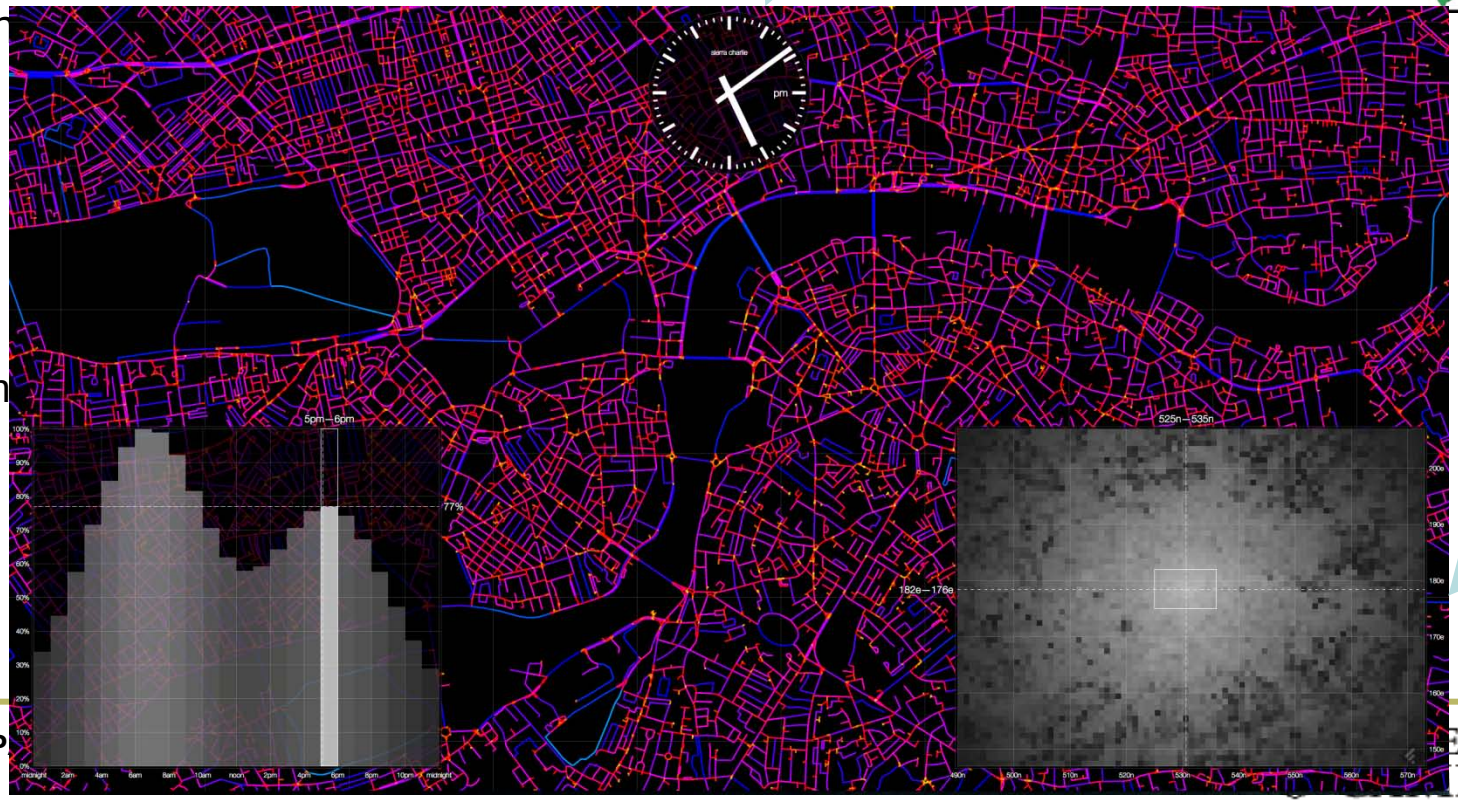
▪***Main goal***: Life cycle transport carbon comparisons

▪***Key innovations***:

- ▪Dynamic model
- ▪Real-time crowd-sourced inputs
- ▪Scen



▪Time



▪Traffic

▪Distribution

▪Global Map

Scenario Testing – what if?

▪1. What if we close Westminster Bridge?

▪2. This agent's new route

▪Example what if questions:

1. New railways lines
2. Autonomous vehicles
3. Smarter data for travelers
4. New congestion charges
5. Emission taxes

▪*London, UK-*

▪*By: Casey,* Soga, Guthrie, Silva, Zhao, Kumar, Bak

ata: Google feeds (geo-positioning data) + other data (Dft) (minute-by-minute+hour-by-hour

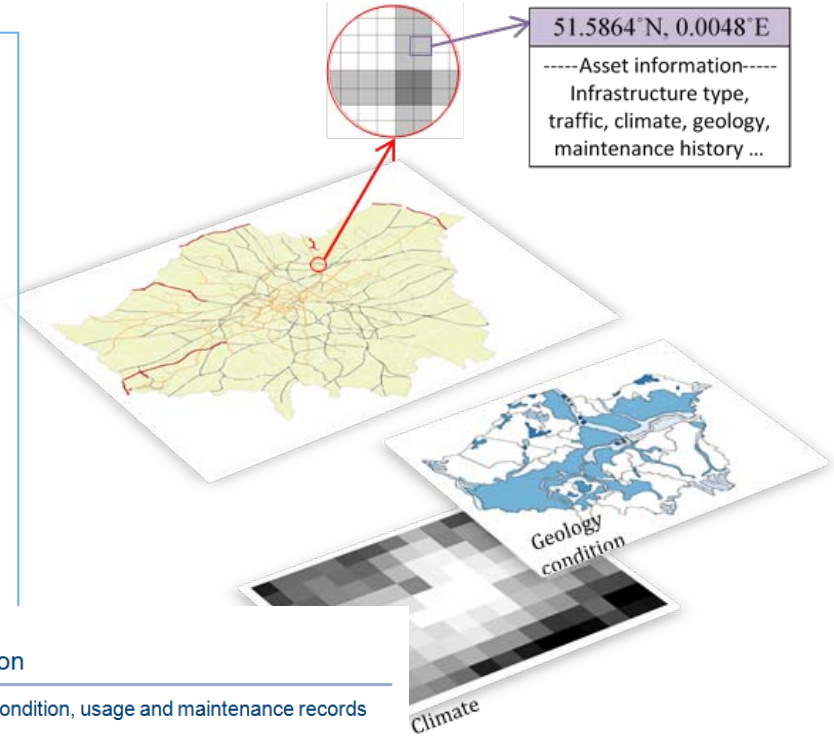
▪Planning & Transport - Operational Dynamic Urban Models

▪Network level transport infrastructure degradation simulation and maintenance planning

ALL-IN-ONE degradation model for roads, railways and undergrounds;

BOTTOM-UP simulation of infrastructure condition change, retaining information for as small as meter-level sections;

CITY-SCALE modelling empowered by advanced spatial dynamic simulation techniques, allowing fast scenario testing of maintenance strategies.



I Mapping the existing information

- Transport network, climate and environment, infrastructure condition, usage and maintenance records
  - → **Significant factors affecting the degradation of transport infrastructures**

II Simulating infrastructure conditions using Cellular Automata

- Knowledge of the degradation behaviours of transport infrastructures
- Computational intensive calibration for the specific study area/case
  - → **A network level model for predicting infrastructure conditions in the study area**

III Addressing challenges and constrains

- New trends in urban transportation and asset management : smart censors, early detection of defects …
- Maintenance backlog, limited budget, regional competition for funding allocation, …
  - → **Scenario testing and decision making support**

▪*London, UK-*

▪*By: Zhao, Soga, Silva*

▪Data: 1:500 – 1:50000

▪Hour-by-hour/day-by-day

▪Linking mobility, infrastructure and degradation models (Soga, Zhao, Elisabete)

A. Global variables

Name	Description
vboundary	Vector data layer of Greater London boundary
vrail	Vector data layer of railway network
vgeology	Vector data layer of superficial geology
rtemperature	Raster data layer of temperature
wrail_geology	Exponent weight assigned to the geology factor during railway degradation
wrail_temperautre	Exponent weight assigned to temperature during railway degradation
orial_con	Overall condition of the railway network, calculated as the percentage of rai sections in "good" condition band
difference	Difference between simulated conditions and observations, calculated as the percentage of railway sections whose simulated condition do not match the observed condition.

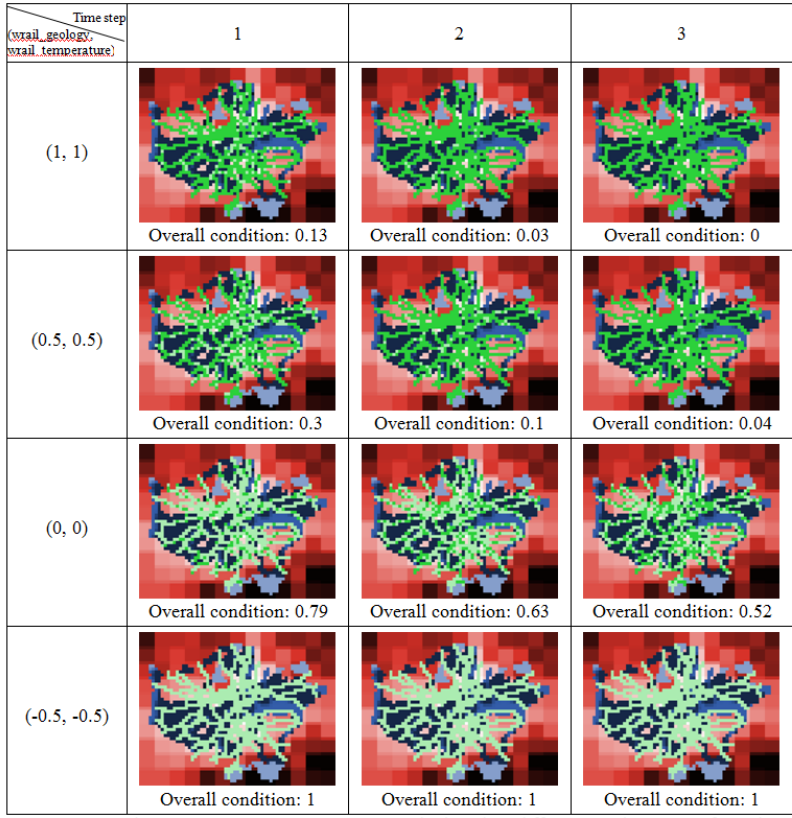
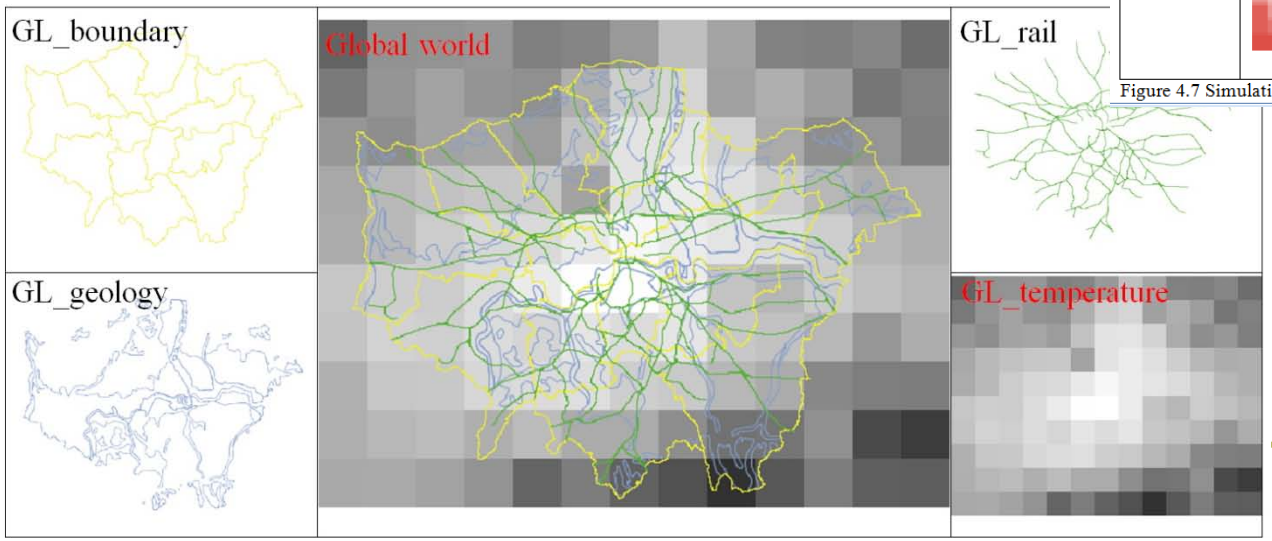


Figure 4.7 Simulation outcomes at time step 1, 2 and 3 based on different combinations of weighing



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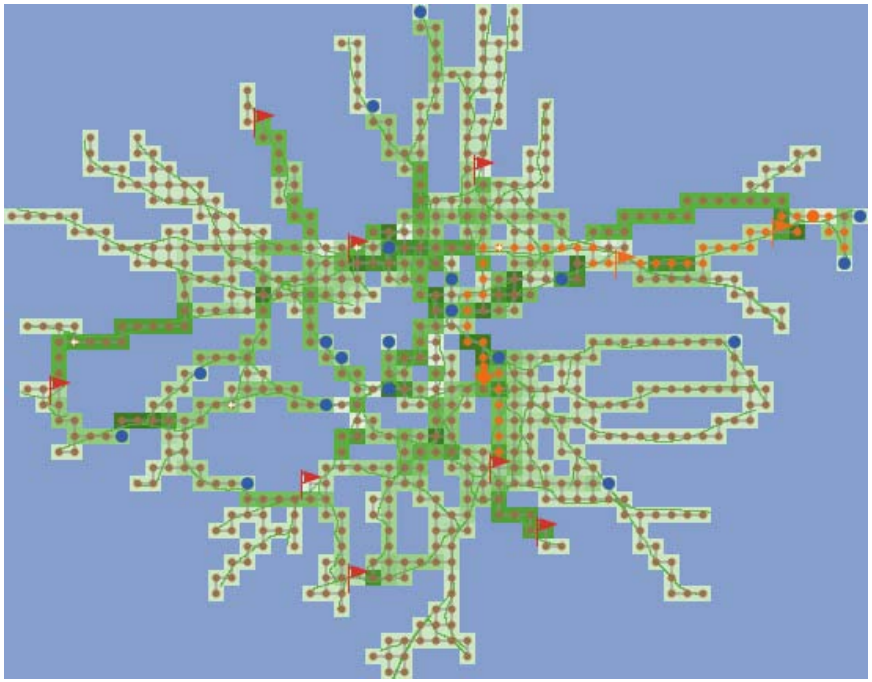
Example

- Smart routing
  - Traffic on already degraded roads/railways is not desirable:
    - Less comfortable
    - More damage to the vehicle
    - More detrimental to degradation
    - Higher environmental impacts
  - Shall we guide the traffic to use better conditioned routes?



▪Planning & Transport -

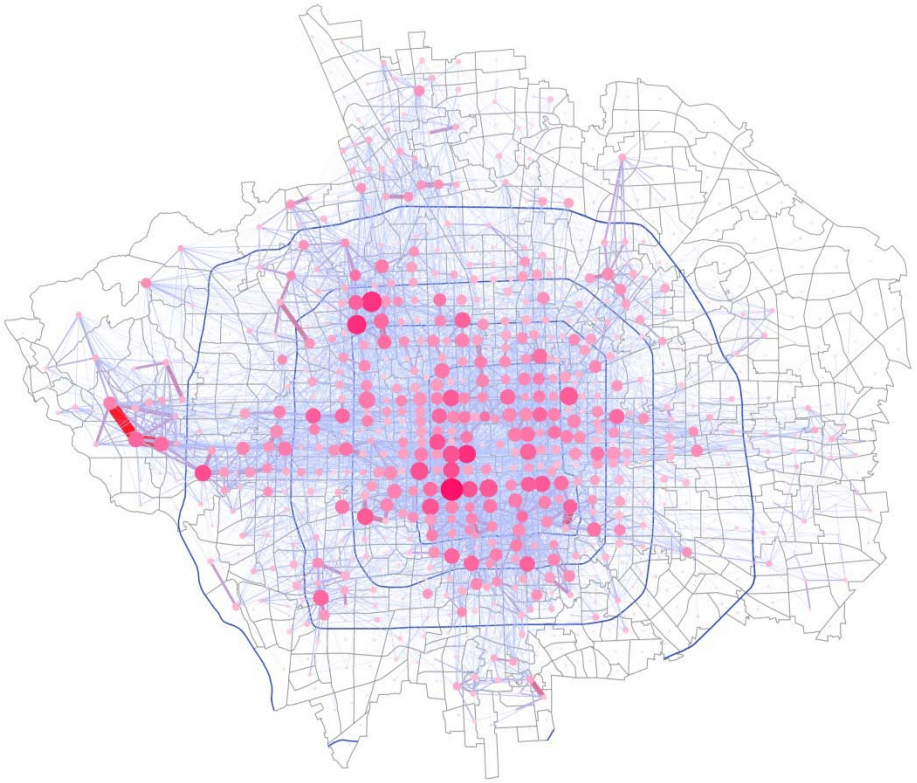
▪Operational Dynamic Urban Models – Activity Base

▪**"Can we reduce the number of unnecessary movements in a city?", "can we opti. location of infrastructures?"**

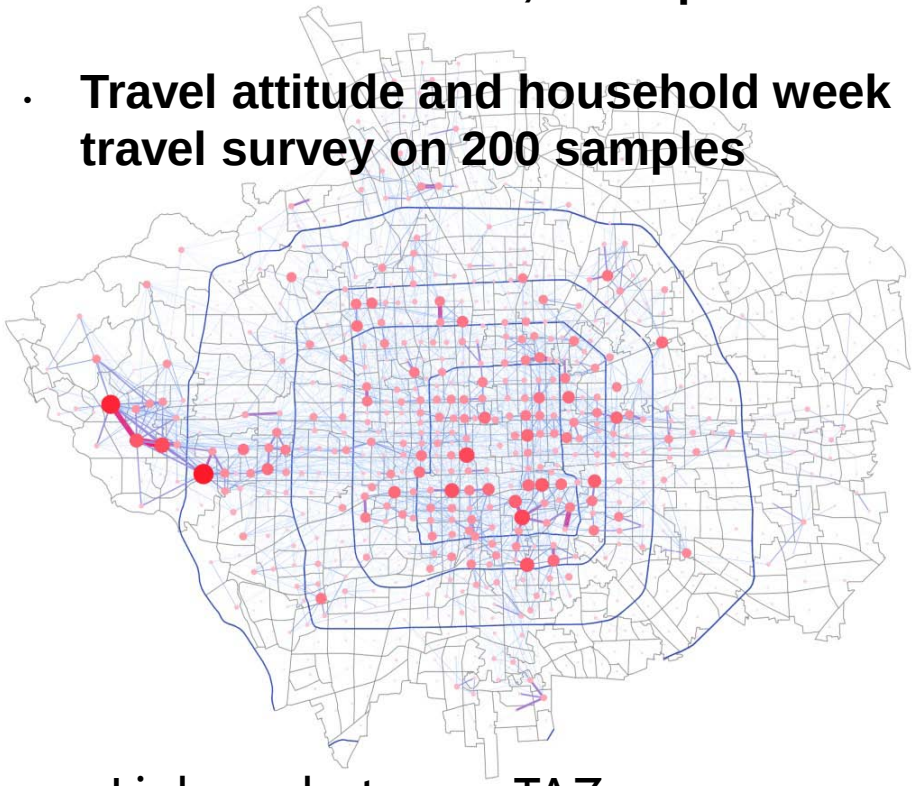
- **Beijing 24 h travel**

▪Data:

- **Travel diary data containing ca 60,000 individuals and 200,000 trips**
- **Travel attitude and household week travel survey on 200 samples**



▪Linkage between TAZs on weekdays



▪Linkage between TAZs on weekends

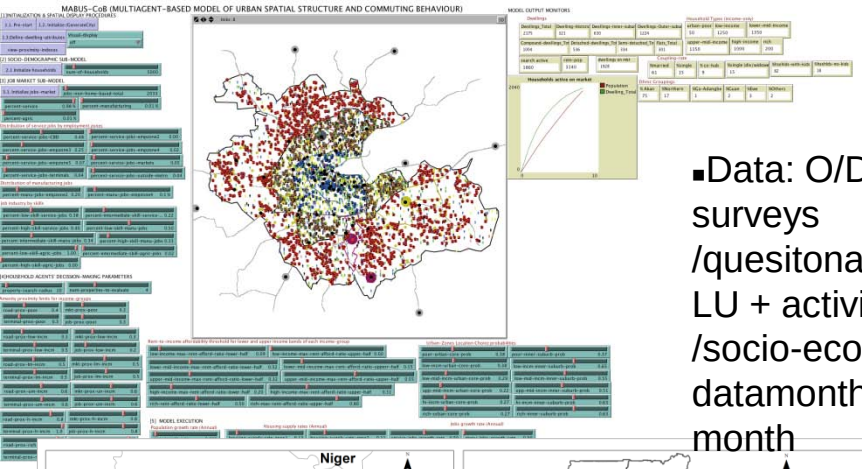
▪*Beijing, China - By: L. Liu, Silva*

▪Planning & Transport - Operational Dynamic Urban Models

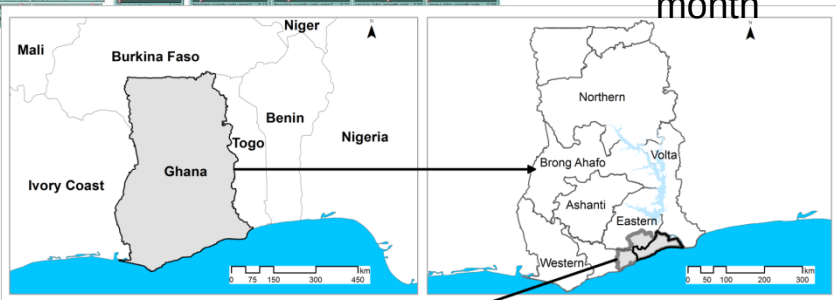
▪Land Use & Activity Based Planning

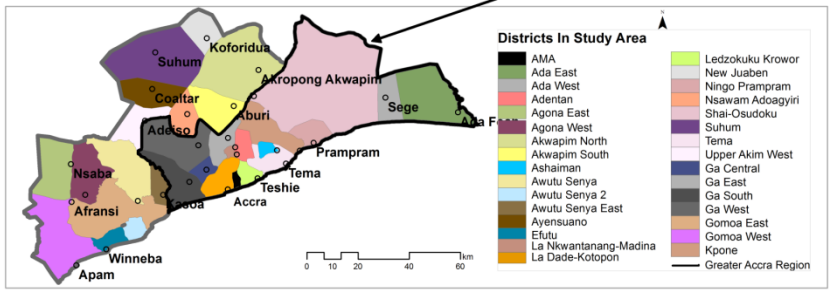
▪"Can we reduce the number of unnecessary movements in a city?", "can we optimze. location of infrastructures?"

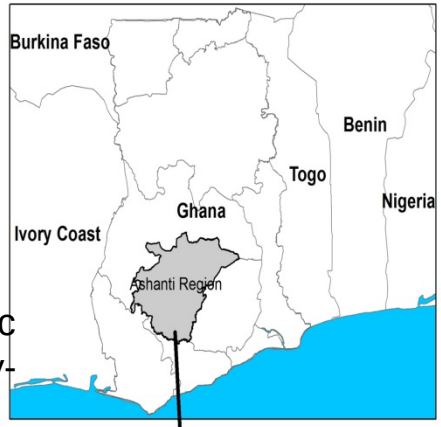
▪Case Study: Kumasi Metropolis, Ghana West Africa

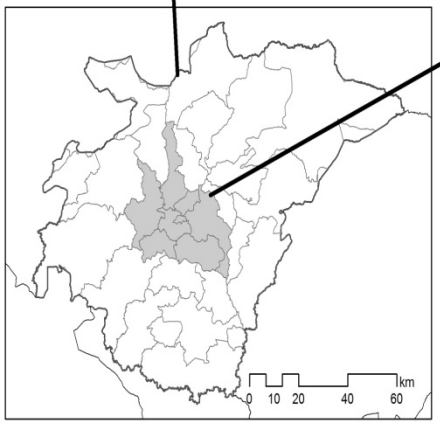


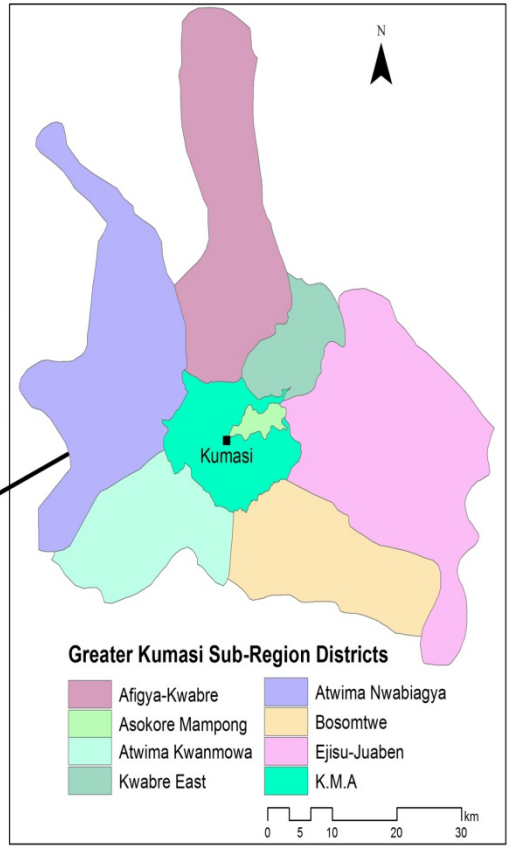
▪Data: O/D surveys /quesitonaires+ LU + activity /socio-economic datamonth /-by-month











▪Accra City Region and Kumasi Metropolics

▪By: Acheampong, Agyemang, Silva

Some Papers

- **2016** Incorporating GIS data into an agent-based model to support planning policy making for the development of creative industries (with Helin Liu and Qian Wang). Journal of Geographical Systems (JGSY). 18(3), 205-228 DOI: 10.1007/s10109-016-0229-7
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- **2013** Simulating the dynamics between the development of creative industries and urban spatial structure: an agent-based model (with H. Liu). S. Geertman et al. (eds.), Planning Support Systems for Sustainable Urban Development, *Lecture Notes in Geoinformation and Cartography*, DOI: 10.1007/978-3-642-37533-0_4, Springer-Verlag Berlin Heidelberg *pp. 51-72*
- **2013** Selecting artificial intelligence urban models using waves of complexity. *Urban Design and Planning.* 166 (1): 1-2
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- **2005** Complexity, Emergence and Cellular Urban Models: Lessons Learned from Appling SLEUTH to two Portuguese Cities. (with K. Clarke) *European Planning Studies*, 13 (1): 93-115 – ISSN: 0965-4313
- **2004** The DNA of our Regions: artificial intelligence in regional planning. *Futures*, 36(10):1077-1094. – ISSN: 0016-3287
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- ***2014*** DG-ABC: An Integrated multi-agent and cellular automata urban growth model *(with N. Wu). Technologies in Urban and Spatial Planning: Virtual Cities and Territories? (Eds. Nuno Norte Pinto, José António Tenedório, António Pais Antunes and Josep Roca), IGI-Global, pp.57-9*
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- **2011** Cellular Automata Models and Agent Base Models for urban studies: from pixels, to cells, to Hexa-Dpi's. In: *Urban Remote Sensing: Monitoring, Synthesis and Modeling in the Urban Environment*. Edited by: Dr. XiaojunYang. Wiley-Blackwell. pp. 323-345. ISBN: 978-0-470-74958-6
- **2010** Waves of complexity. Theory, models, and practice. In: Roo, Gert de, and Elisabete A. Silva (2010), *A Planner's Encounter with Complexity*, Ashgate Publishers Ltd, Aldershot (UK). pp. 309-331.. ISBN: 978-1-4094-0265-7
- **2010** Complexity and CA, and application to metropolitan areas. In: Roo, Gert de, and Elisabete A. Silva (2010), *A Planner's Encounter with Complexity*, Ashgate Publishers Ltd, Aldershot (UK). pp..187-207. ISBN: 978-1-4094-0265-7

- Elisabete (es424@cam.ac.uk)
- www.landecon.cam.ac.uk/directory/esilva

- LISA Lab
- www.landecon.cam.ac.uk/research/lisa

- Forthcoming Book: "Comprehensive Geographic Information Systems“ (vol.3), Elsevier

Books:

“*Developing and inventory and typology of Land-Use Planning Systems and Policy Instruments in Countries “ OECD, 2015*

"The Routledge Handbook of Planning Research, 2014 Methods"http://www.routledge.com/books/details/9780415727952/

“A Planner’s Encounter with Complexity”, Ashgate, 2010 http://www.ashgate.com/isbn/9781409402657