Soft artificial intelligence, linking socio-economic and land spatial-led data analysis for urban planning

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Murray Edwards, Buckingham House

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

Department of Land Economy
University of Cambridge

OUTLINE

1. The argument in favor of adaptive policy and need for ‘Big 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)
3. ‘Wicked problems’ and the wrong “decision makers’ model”
4. Key areas to address: Metrics, Methods, Calibration, Validation, Randomness , uncertainty, data-mining
5. The examples of models: The SLEUTH model; The CVCA model; **CCID model**; IUBEA, The DG-ABC model, **climate change negotiation** and COP
6. Concluding remarks

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- ‘Wicked problems’ and the wrong “decision makers model”

- **Rittel and Webber’s 1973 conception of “wicked problems**” to explain why conventional scientific approaches failed to solve problems of pluralistic urban societies.
- Try to confront (urban) social problems with the wrong tools because we have misunderstood the very nature of the problems
- “wicked problems have no stopping rule,” and “wicked problems do not have an enumerable (or an exhaustively describable) set of potential solutions”

- **The concept of certainly in an uncertain world**
- **The timing of Lee’s requiem and Rittel and Webber’s Wicked problems**

3. 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)

- focus
- Physical regions
- People/ social

- Theory
- Systems theory
- Advocacy of Planning
- Beyond modernity
- Participative Planning

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

- Models
- Deterministic
- Stochastic

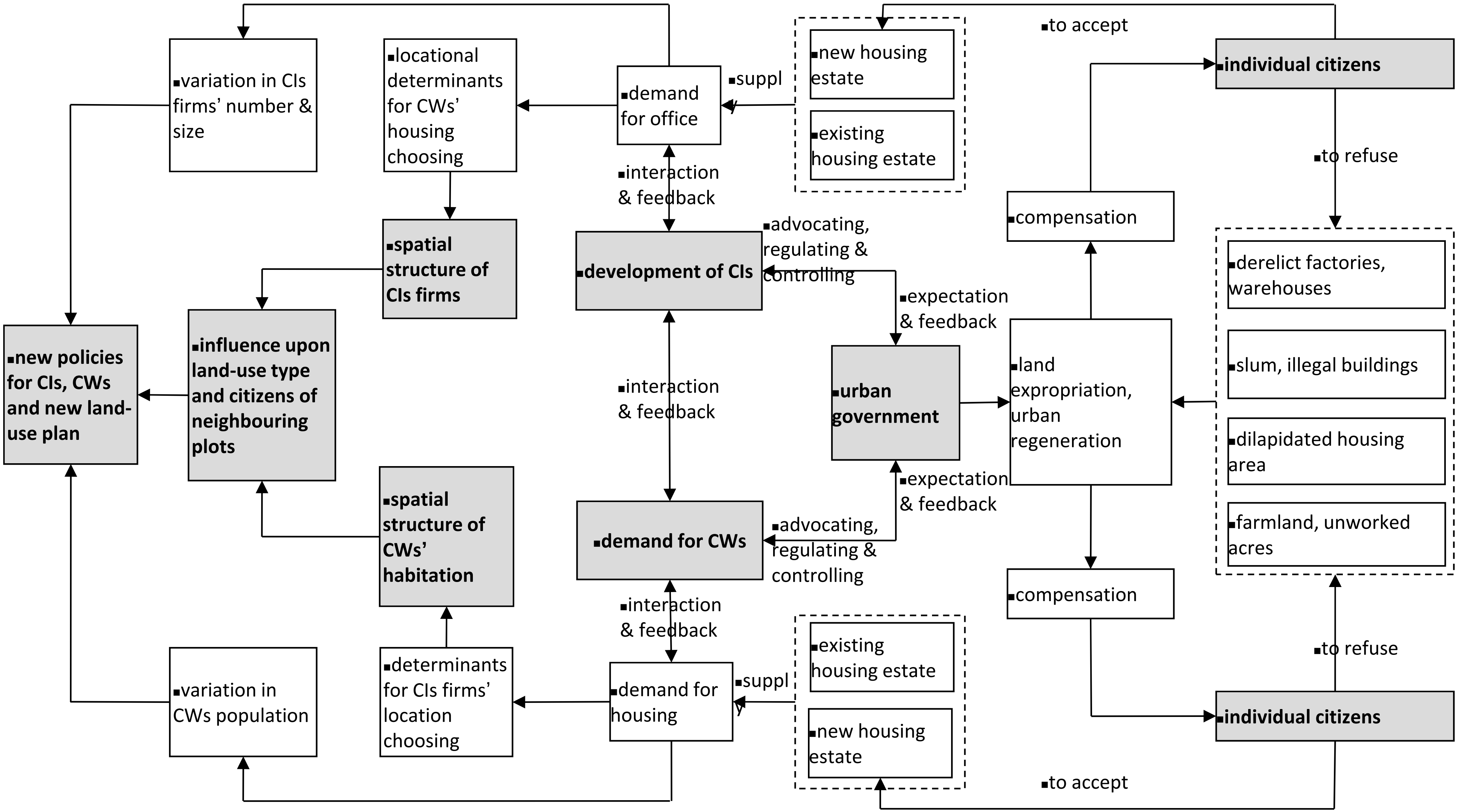
- time 50s

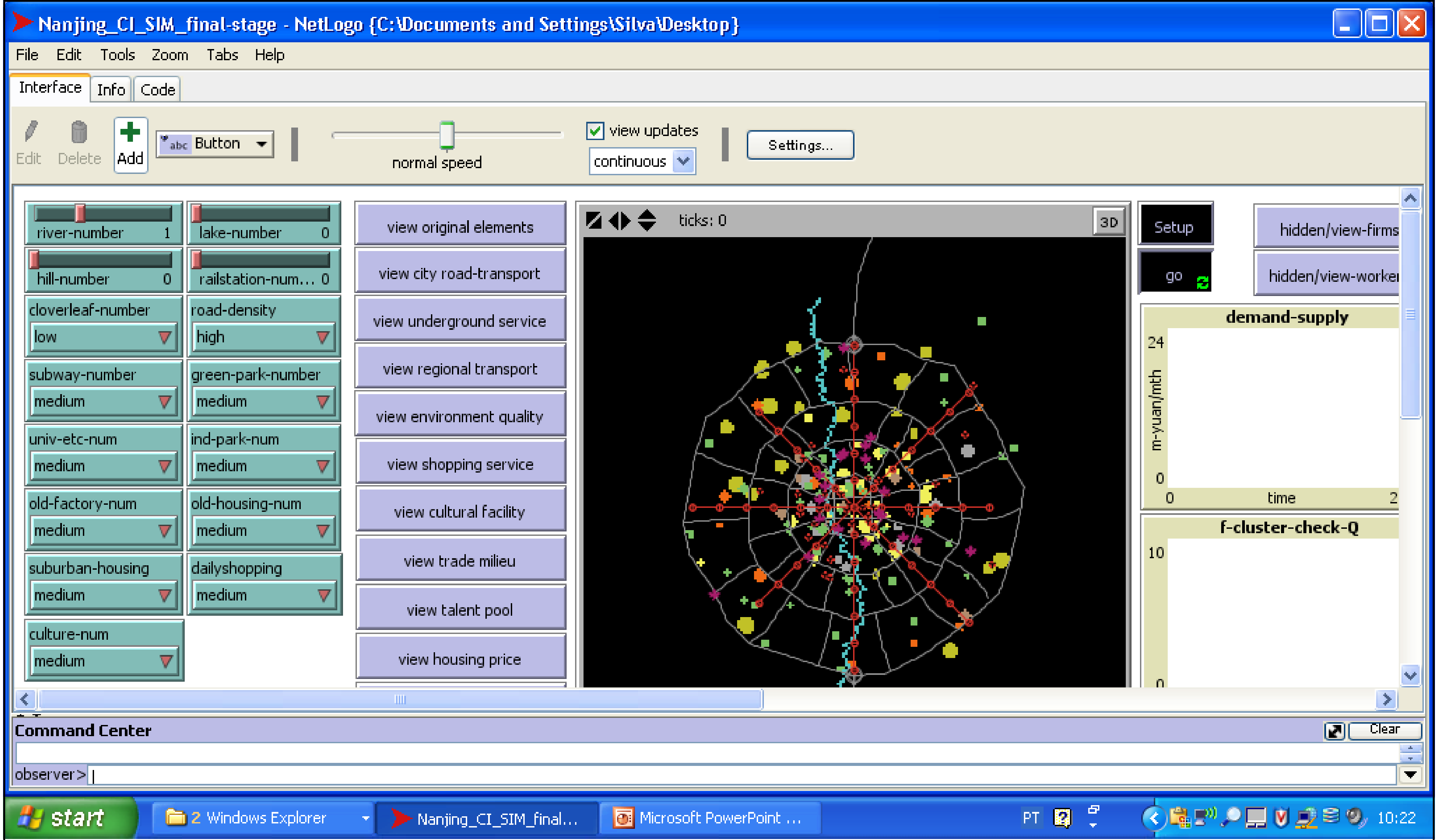
Feedback loops of learn/adapt/enrich_knowledge

- Complexity Theory

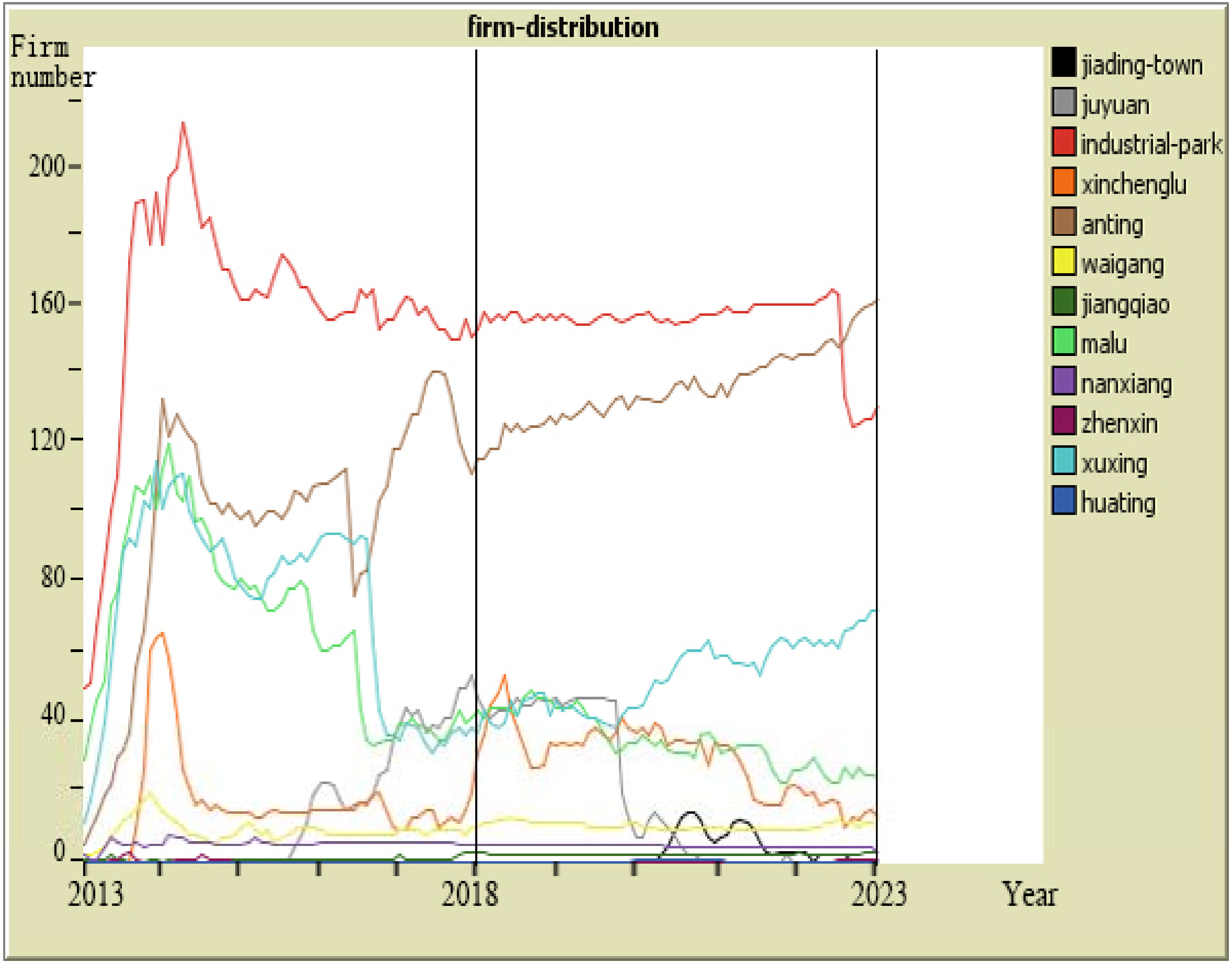
Operational Dynamic Urban Models

CI Agent Base Model





▪**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*



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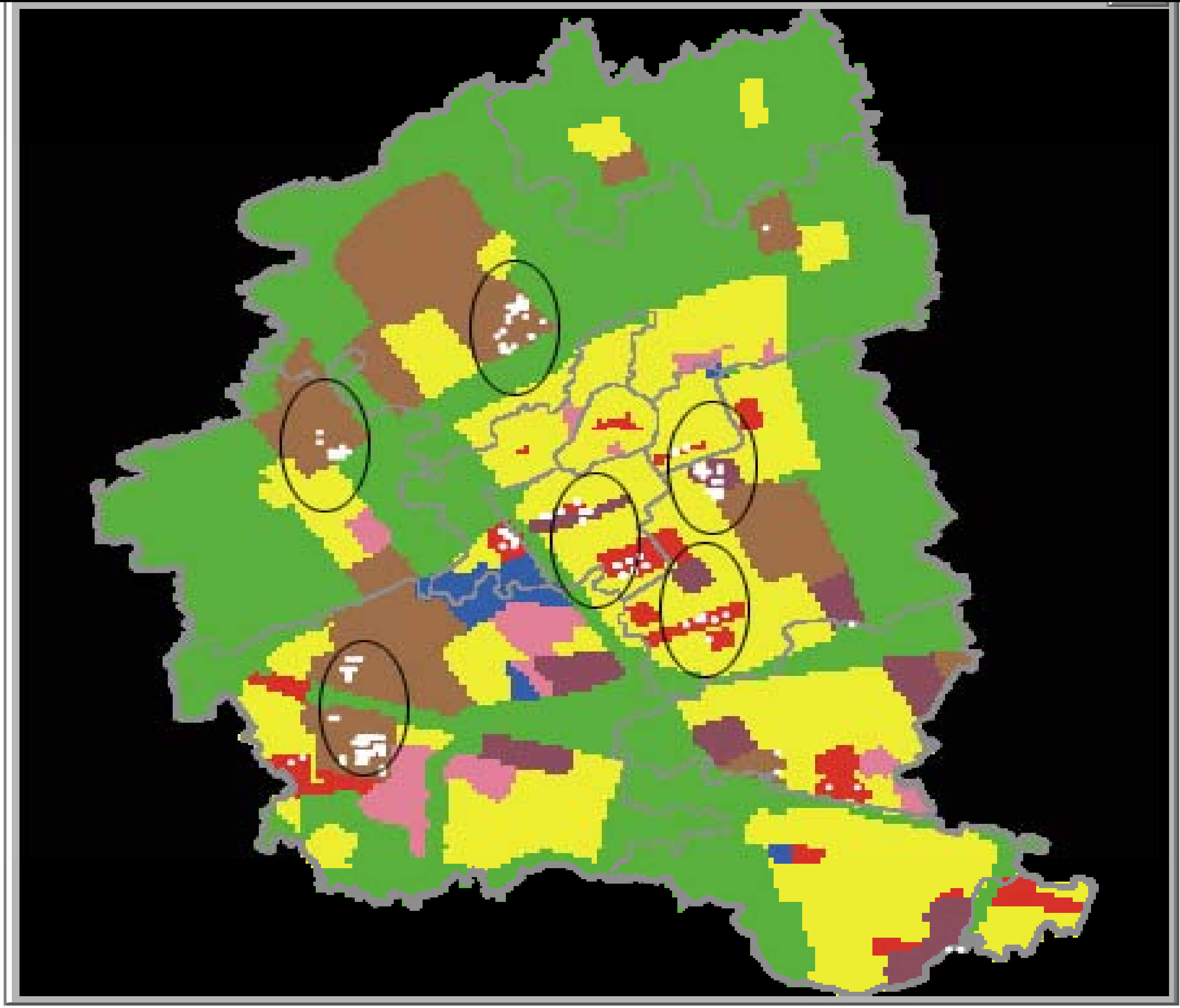


▪**2013** *Simulating the dynamics between the development of creative industries and urban spatial structure: an agent-based model* *(with H. Liu). S. Geertman et al. (eds.), Planning Support Systems for Sustainable Urban Development, Lecture Notes in Geoinformation and Cartography, DOI: 10.1007/978-3-642-37533-0_4,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

Agents and terms for negotiation

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

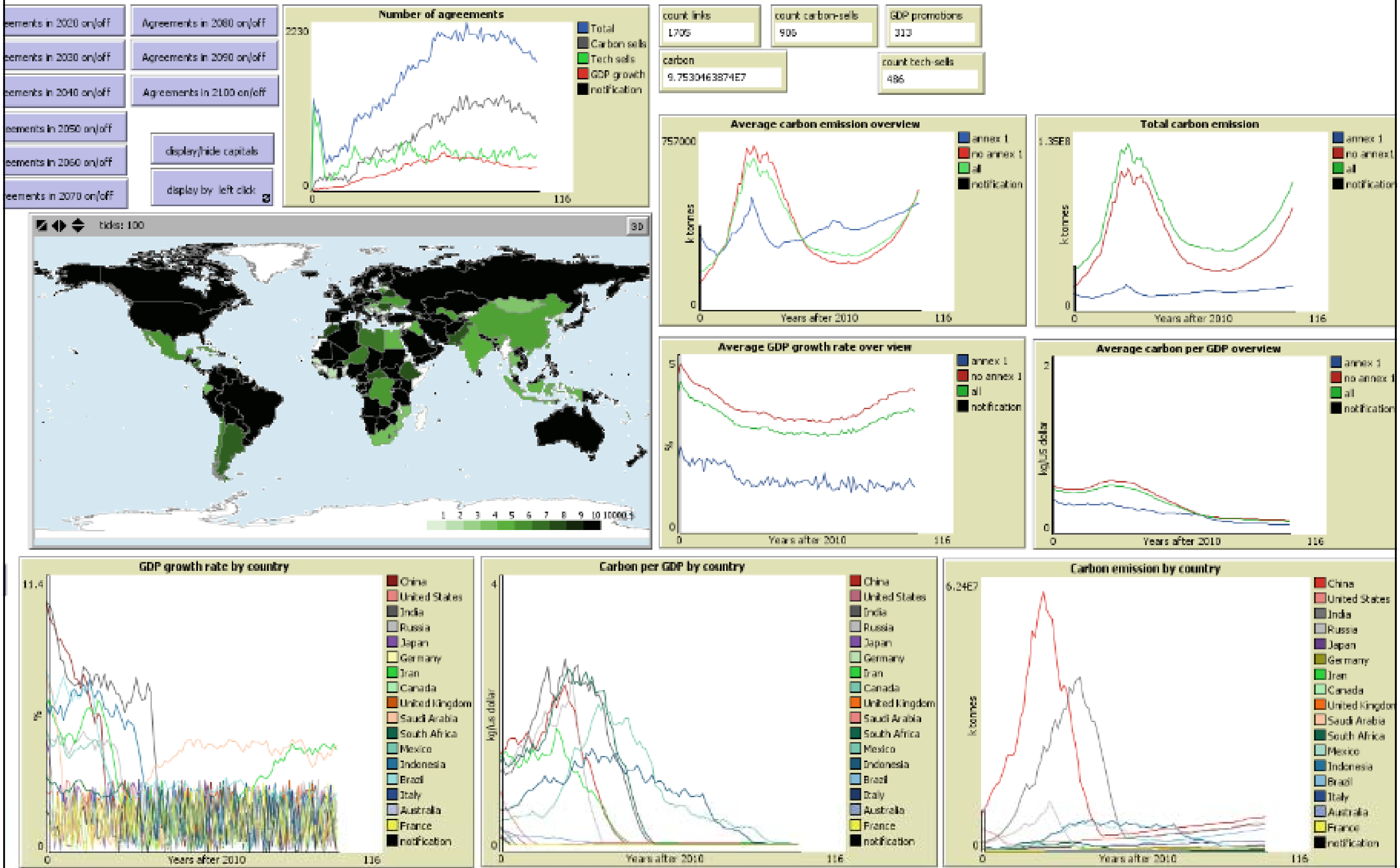
Table 1 The three adoptable strategies and their influence on the two involved countries

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	↑	↓	↑

Condition-action rules

Table 2 The condition-action rules for each country

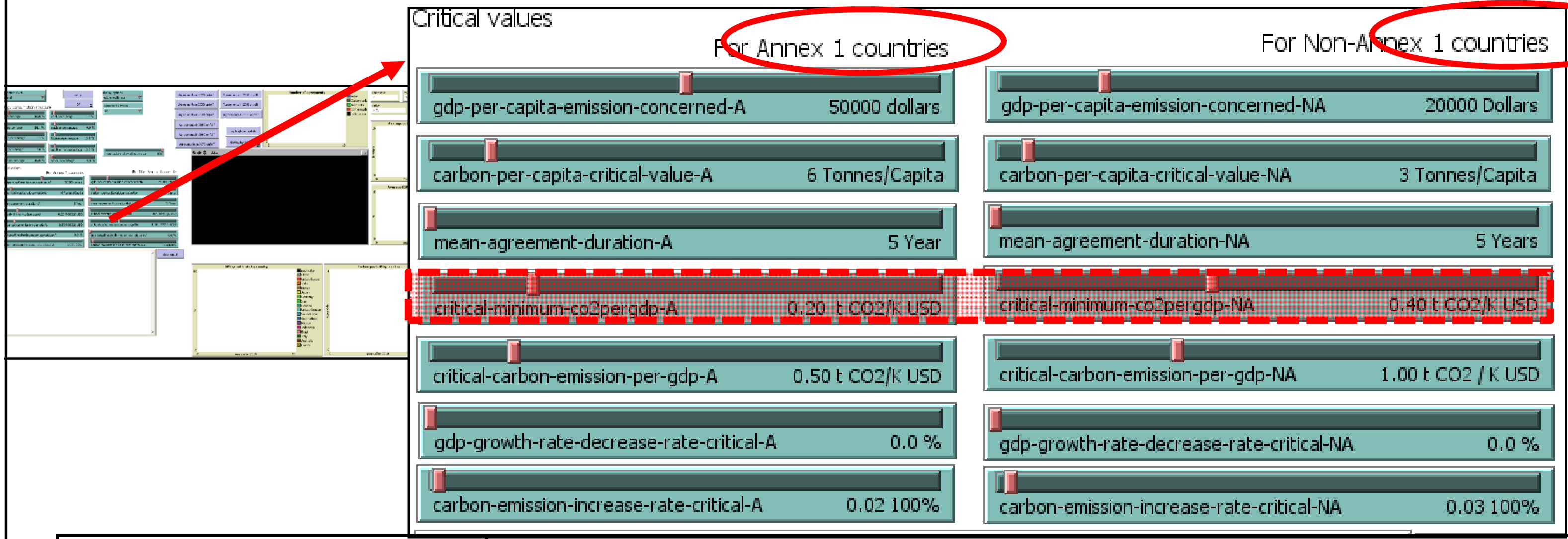
Condition			Actions (Strategies)
GDP/capita < Critical value ▪Not included in the Negotiation process, Focusing on GDP growth			1. Look for carbon sells 2. Look for GDP growth support 3. Quit technology application
GDP/capita >= Critical value	GDP-growth-rate < Critical value	Carbon-emission/GDP < critical value ▪Negotiation, aiming to lift GDP growth rate	1. Look for carbon sells 2. Look for GDP growth support 3. Renegotiate existing agreements aiming to promote GDP growth rate 4. Reduce technology application (in)
		Carbon-emission/GDP >= critical value ▪Negotiation, to lift GDP growth, consider carbon reduction	1. Look for carbon sells 2. Look for GDP growth support 3. Reduce technology application aiming to promote GDP growth rate
	GDP-growth-rate >= Critical value	Carbon-emission/GDP < critical value ▪Negotiation, following current agreements and strategies	1. Keep carbon sells (in) 2. Keep GDP growth support (in) 3. Keep technology application (in)
		Carbon-emission/GDP >= critical value ▪Negotiation, aiming to carbon reduction	1. Renegotiation carbon sells (in) aiming to reduce carbon 2. Renegotiate GDP growth support (in) aiming to reduce carbon 3. Look for technology application (in)



Agreements in 2080 on/off
Agreements in 2090 on/off
Agreements in 2100 on/off
display/hide capitals
display by left click
Number of agreements
Total
Carbon sells
Tech sells
GDP growth
notification
count links
1705
count carbon-sells
906
GDP promotions
313
carbon
9.7530463874E7
count tech-sells
486
ticks: 100
Average carbon emission overview
Total carbon emission
Average GDP growth rate over view
Average carbon per GDP overview
annex 1
no annex 1
all
Years after 2010
k tonnes
kg/us dollar
GDP growth rate by country
Carbon per GDP by country
Carbon emission by country
China
United States
India
Russia
Japan
Germany
Iran
Canada
United Kingdom
Saudi Arabia
South Africa
Mexico
Indonesia
Brazil
Italy
Australia
France

H. LIU1

Parameters for the critical values



Parameter's name	**Connection to the dynamics**
gdp-per-capita-emission-concerned	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	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	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	A global variable to describe the ultimate capability of our society to reduce carbon emission / GDP
mean-agreement-duration	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	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	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 extra carbon emission by more than this critical value.

Slide 18

H. LIU1 Windows User, 18/01/2015

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.			

CAs (raster base)

(i) A grid or raster space – organised by cells which are the smallest units in that grid/space;

(ii) *(ii)* Cell States – cells must manifest adjacency or proximity. The state of a cell can change accordingly to transition rules, which are defined in terms of neighbourhood functions;

(iii) *(iii)* The neighbourhood and dependency of the state of any cell on the state and configuration of other cells in the neighbourhood of that cell;

(iv) *(iv)* Transition rules that are decision rules or transition functions of the CA model and can be deterministic or stochastic;

(v) *(v)* Sequences of time steps. When activated, the CA proceeds through a series of iterations

- study of random complex CA came an understanding of its basic patterns: as they appear to fall into four qualitative classes, in what concerns one-dimension (1-D) CA evolution leads to: *(i)* a homogenous state; *(ii)* a set of separated simple stable or periodic structures; *(iii)* a chaotic pattern; *(iv)* complex localised structures, sometimes long-lived (Wolfram, 1984:5)

ABM-GAs (Vector-object based) are constituted of:

- *(i)* agents that do not have the constraints of neighbourhood effects,
- *(ii)* behavioural roles among agents and the environment itself, *(iii)* independence from central command/control, but able to act if action at a distance is required,
- *(iv)* states of agents tend to represent behavioural forms.

The most basic model environment of an ABM-GA will have a set of attributes per agent (or group of agents), (one)a set of decision trees and trigger points that will allow to set the context for a new movement (upgrade of the spatial/temporal environment) in time/space .

Key challenges for methods in the Social Sciences

Benchmark of Classification: Modeling Approach

Classifications of Models	Models	References
Mathematical/ statistical models	POLIS	Prastacos (1985)
	PLUM	Prastacos (1985)
	STIT	Nuzzolo and Coppola (2005)
GIS-based models	CLUE	Verburg et al. (2001)
	CURBA	Landis (2001)
	METROSCOPE	Larson, Cser, and Conder (2000)
	PECAS	Hunt and Abraham (2003)
	UPLAN	Walker et al. (2007)
Cellular automata-based models	CVCA	Silva, Wileden, and Ahern (2008)
	DUEM	Batty, Xie, and Sun (1999)
	LOV	White, Straatman, and Engelen (2004)
	LEAM	Deal (2001)
	LUSD	He et al. (2004)
	SLEUTH	Silva and Clarke (2002)
	UED	He et al. (2008)
Agent-based models (ABM)	FEARLUS	Polhill, Parker, and Gotts (2005)
	PUMA	Ettema et al. (2005)
	LUCITA	Lim et al. (2002)
	LUCIM	Hoffmann, Kelley, and Evans (2002)
	SYPRIA	Manson (2005)
	FEARLUS	Polhill, Parker, and Gotts (2005)
Rule-based models	CUF	Landis (2001)
	CommunityViz	Kwartler and Bernard (2001)
	INDEX	Allen (2001)
	Place3S	Snyder (2001)
	SAM-IM	MAG
	UPLAN	Walker et al. (2007)
	What if?	Klosterman (2001)
Integrated models	CVCA	Silva, Wileden, and Ahern (2008)
	DG-ABC	Wu and Silva (Forthcoming)
	ILUTE	Miller (2001)
	ITLUP	Putman (1983)
	SLUDGE	Parker and Najlis (2003)
	UrbanSim	Waddell (2002)

Table 2. Models with Different Levels of Analysis

Benchmark of Classification: Level of Analysis of Models

Classifications of Models	Models	References
Micro level	CUFM	Landis (1994)
	ILUMASS	Wagner and Wegener (2007)
	ILUTE	Miller et al. (2004)
	IRPUD	Wegener (1998)
	METROSIM	Anas (1982)
	PUMA	Ettema et al. (2005)
	SIMPOP	Sanders et al. (1997)
	TLUMIP	Weidner et al. (2006)
	Urbansim	Waddell et al. (2003)
Macro level	CLUE/CLUE-S	Verburg et al. (2001)
	GEOMOD2	Pontius, Cornell, and Hall (2001)
	IIASA	Fischer and Sun., (2001)
	LOV	White, Straatman, and Engelen (2004)
	LTM	Pijanowski et al. (2000)
Cross level (or multilevel models)	BabyLOV	White, Straatman, and Engelen (2004)
	WiVsim	Spahn and Lenz (2007)

Table 4. Models with Different Temporal Scales

Benchmark of Classification: Temporal Scales

Classifications of Models	Models	References
Long term	FEARLUS	Polhill, Parker, and Gotts (2005)
	LUCIM	Hoffmann, Kelley, and Evans (2002)
	MEPLAN	Echenique and Hunt (1993)
	UGM	Clarke and Gaydos (1998)
Medium term	Agent-LUC	Rajan and Shibasaki (2001)
	CLUE	Verburg et al. (2001)
Short term	SelfCormas experiment	D'Aquino et al. (2003)
	SAM-IM	MAG

Table 5. Models with Different Spatial or Aspatial Emphasis

Benchmark of Classification: Spatial and Aspatial highlights		
Classifications of Models	Models	References
Spatial oriented	CLUE	de la Barra (2001)
	NELUP	O'Callaghan (1995)
	SLEUTH	Silva and Clarke (2002)
Aspatial oriented	DELTA	Simmonds (1999)
	EMPIRIC	Rothenberg-Pack (1978)
	LINE	Madsen and Jensen (2000)
	MEPLAN	Echenique and Hunt (1993)
	TRANUS	de la Barra (2001)
Integrated models	CVCA	Silva, Wileden, and Ahern (2008)
	DG-ABC	Wu and Silva (Forthcoming)
	IMAGE-GTAP/LEI	Klijn et al. (2005)
	ILUTE	Miller (2001)
	METROSCOPE	Larson, Cser, and Conder (2000)

Table 6. Models with Different Planning Tasks Emphasis

Benchmark of Classification: Planning Tasks		
Classifications of Models	Models	References
Land-use/land-cover change	LEAM	Deal (2001)
	LUCAS	Berry et al. (1996)
	SIMLAND	Wu (1998)
	SLUCE	Brown (2005)
	What if?	Klosterman (2001)
Urban growth	CUF	Landis (2001)
	DG-ABC	Wu and Silva (Forthcoming)
	SLEUTH	Silva and Clarke (2002)
	UPLAN	Walker et al. (2007)
	UrbanSim	Waddell et al. (2003)
Transportation land use	IRPUD	Wegener (1998)
	ILUTE	Miller (2001)
	METROSIM	Anas (1982)
	TLUMIP	Weidner et al. (2006)
Impact assessment	CommunityViz	Kwartler and Bernard (2001)
	INDEX	Allen (2001)
	Place3S	Snyder (2001)
Comprehensive projection	METROPILUS	Putman and Shih-Liang (2001)
	SOLUTION	Echenique (2004)
	SPARTACUS	Lautso (2003)

AI approach	Solutions/characteristics	References
Artificial life		
Cellular automata (CA)	Spatial dynamics representation	Batty (2007) Silva and Clarke (2005)
Agent-based modelling (ABM)	A-spatial dynamics representation	Berger (2001) Brown (2006) Brown and Robinson (2006)
Ant colony optimisation	Optimisation	Liu *et al.* (2007) Matteucci and Mussone (2006)
Particle swarm optimisation	Optimisation	Chau (2006a) Hu *et al.* (2008) Pinto (2006)
Bee colony optimisation	Optimisation	Lucic and Teodorovic (2001)
Intelligent stochastic optimisation processes		
Genetic algorithm (GA)	Optimisation, cost of function control, behaviour control	Al-Kheder *et al.* (2007) Balling *et al.* (2004) Matthews (2001)
Simulated annealing	Optimisation	Buergle *et al.* (2005) Cantarella *et al.* (2006) Duh and Brown (2007)
Hill climbing algorithm	Optimisation	Los and Nguyen (1981) Williamson *et al.* (1998)
Tabu search and path relinking	Optimisation	Cantarella *et al.* (2006)
OptQuest engine	Optimisation	Yun and Park (2006)
Stochastic diffusion search	Optimisation	Hurley and Whitaker (2002)
Evolution computing and spatial DNA		
Artificial neural network (ANN)	Optimisation	Pijanowski *et al.* (2002) Tillema (2003) Yeh and Li (2003)
Spatial DNA	Evolutionary view to urban systems	Caglioni *et al.* (2006) Silva (2004) Silva and Clarke (2002, 2005) Wilson (2008)
Shuffled complex evolution	Optimisation	Liong and Atiquzzaman (2004) Madsen (2000)
Artificial immune system	Optimisation	Jia *et al.* (2006) Pal (2008)
Knowledge-based intelligent systems		
Fuzzy logic	Knowledge engine	Aiazzi *et al.* (2003) Dimitriou *et al.* (2008) Tang *et al.* (2007)
Expert systems	Knowledge engine	Kalogirou (2002) Lee *et al.* (2008) Witlox (2003)
Heuristics	Knowledge engine	Ahmad and Simonovic (2001) Arentze *et al.* (2006)

AI approach	Solutions/characteristics	References
Rule-based reasoning	Knowledge engine	Brown (2006) Kawano *et al.* (2005) Prasad and Sinha (2002)
Case-based reasoning	Knowledge engine	Li *et al.* (2004) Roda *et al.* (2001)
Others		
Reinforcement learning	Knowledge engine	Liu and Ma (2007) Miyagi (2004)
Analytical learning	Knowledge engine	Tao *et al.* (2007)

SPATIAL PATTTERNS		SPATIAL METRICS (scale)			
Patterns	Growth/ Shrinkage	Local (patch/tract)	Neighbourhood/intra-urban area	Whole urban area	Data needed (av
Increase in urbanized area (also measured as greenfield/pervious area consumption)	Growth	N/A		Urban area (LM)	Urbanized land fo time periods Urbanized land (p
				Number of patches (LM)	
				Urban land use change (GS)	
New development adjacent to urbanised areas	Growth			Percentage like of adjacency (LM))	Urbanized land fo time periods Urbanized land (
				Length common edge (LM)	
				Landscape expansion index (LM)	
				Mean land. exp. ind. (LM)	
				Area weighted mean land. exp. ind. (LM)	
				Leapfrog index (GS)	Land uses for diff periods (MMU)
Size of urban area (change)	Growth	N/A	N/A	Change is size of urban area (LM)	Urbanized land fo time periods Urbanized land (
Shape irregularity/complexity	Growth	?	AWMP fractal dimension (LM)	AWMP fractal dimension (LM)	Urbanized land (
			AWM shape index (LM)	AWM shape index (LM)	
			Fractal dimension (LM)	Fractal dimension (LM)	
			Mean shape index (LM)	Mean shape index (LM)	
			Shape index (LM)	Shape index (LM)	
			Mean perimeter to area ratio (LM)	Mean perimeter to area ratio (LM)	
			Mean radius of gyration (LM)	Mean radius of gyration (LM)	
				Edge density (LM)	

SPATIAL PATTTERNS		SPATIAL METRICS (scale)			
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			AWM shape index (LM)	AWM shape index (LM)	
			Fractal dimension (LM)	Fractal dimension (LM)	
			Mean shape index (LM)	Mean shape index (LM)	
			Shape index (LM)	Shape index (LM)	
			Mean perimeter to area ratio (LM)	Mean perimeter to area ratio (LM)	
			Mean radius of gyration (LM)	Mean radius of gyration (LM)	
				Edge density (LM)	

Some Papers

- **2015** Spatial Metrics to Study Urban Patterns in Growing and Shrinking Cities. (with J. Reis). Urban Geography. in press (OA-4011)
- **2015** *Comparative Study on Machine Learning Methods for Urban Building Energy Analysis. (together with Lai Wei, Wei Tian, Elisabete Silva , QingXin Meng, and Song Yang and Ruchi Chaowdrie)* **-** Procedia Engineering, **OA 4221 2015** Creative industries urban model: structure and functioning.(With H. Liu) Urban Design and Planning. (2014 - OA-1398) 168 (DP2): 88-100
- **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
- **2012** Surveying Models in Urban Land Studies. *(with N. Wu) Journal of Planning Literature.27 ( ): 1-14*
- **2010** Artificial intelligence solutions for Urban Land Dynamics: A Review *(with N. Wu)*. Journal of Planning Literature. 2010 24: 246-265.
- **2008** Strategies for Landscape Ecology in Metropolitan Planning: Applications Using Cellular Automata Models. (with J. Wileden, J. and J. Ahern), *Progress in Planning*, 70(4):133-177 - ISSN: 0305-9006
- **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
- **2002** Calibration of the SLEUTH Urban Growth Model for Lisbon and Porto, Portugal. (with K. Clarke) Computers, *Environment and Urban Systems*, 26 (6): 525-552 - ISSN: 0198-9715
- 0965-4313

Some book chapters

- **2014** Measuring space: a review of spatial metrics for urban growth and shrinkage (with J. Reis). In: *The Routledge Handbook of Planning Research Methods.* (Eds. Patsy Healey, Neil Harris and Pieter van den Broeck), *Routlege*
- ***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*
- **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*
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- Elisabete (es424@cam.ac.uk)
- www.landecon.cam.ac.uk/directory/esilva

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

- New Book: "The Routledge Handbook of Planning Research Methods"

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