

# Integrating and validating urban simulation models

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*Large scale urban models are intrinsically flawed and do not reach their goals of long-term application to planning: Requiem for large scale models in 1973 [Lee Jr, 1973]*

*Urban analytics and Smart Cities approaches may follow the same path if they ignore the past and the complexity of cities [Batty, 2014]*

To foster relevance of large urban models:

- Transparency on data and implementation, reproducibility
- Validation of models and sub-models: from small simple models well validated to larger integrated models

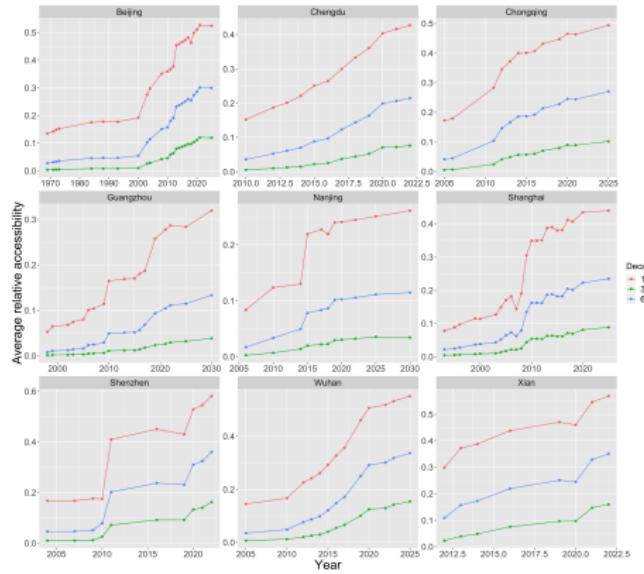
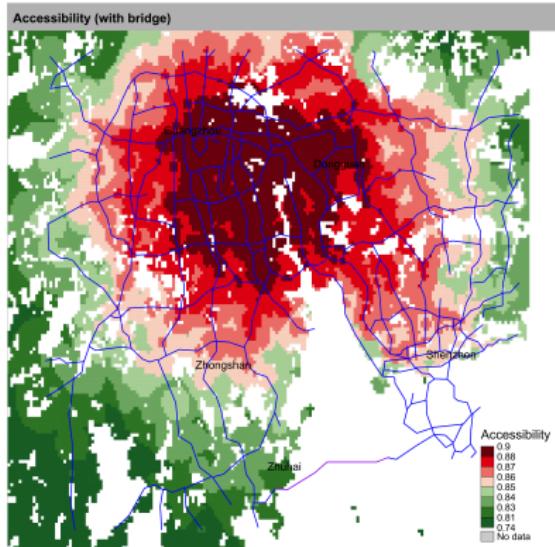
→ Open, reproducible urban models can be shared, coupled into modular integrated models, tested and validated [Banos, 2013]

## Research project

*Constructing urban models integrating disciplines and scales following the complex systems roadmap [Bourgine et al., 2009], towards an application to sustainable multi-scale policies*

- Horizontal integration (model coupling and interdisciplinarity)
- Vertical integration (multi-scale models)
- Model exploration and validation methods

# Interactions between networks and territories

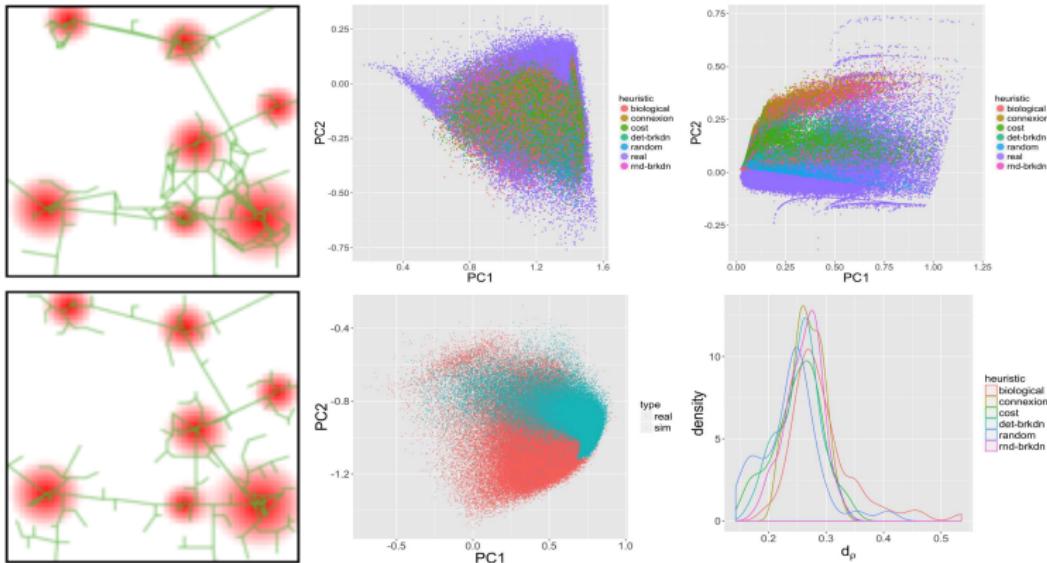


*Accessibility as part of complex processes of co-evolution between transportation networks and territories.*

Raimbault, J. (2019). Evolving accessibility landscapes: mutations of transportation networks in China. In Aveline-Dubach, N., ed. *Pathways of sustainable urban development across China - the cases of Hangzhou, Datong and Zhuhai*, pp 89-108. Imago. ISBN:978-88-94384-71-0

# Mesoscopic models: morphogenesis

*A morphogenesis model with reaction-diffusion and multi-modeling of network growth: complementarity of heuristics, calibration for Europe on forms and their correlations*

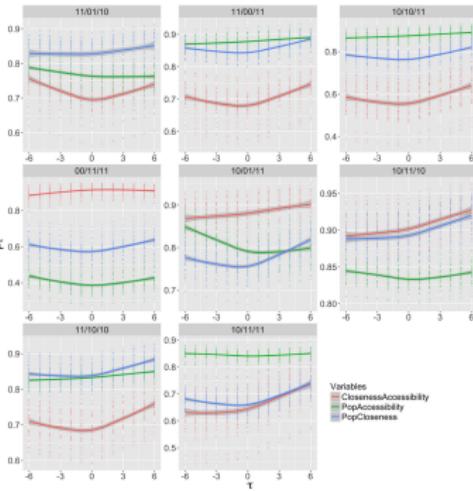
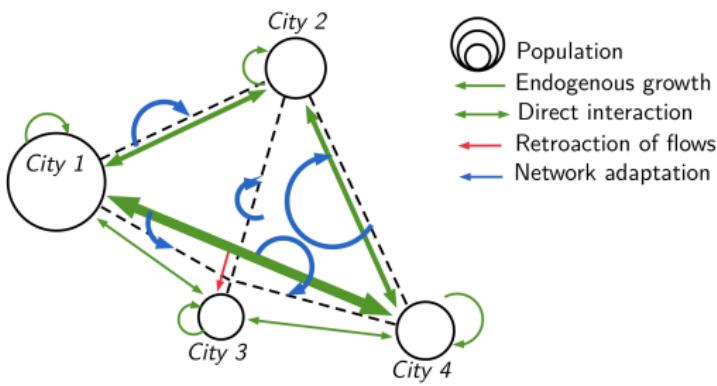


Raimbault, J. (2018). Calibration of a density-based model of urban morphogenesis. PloS one, 13(9), e0203516.

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# Macroscopic interaction model

*System of cities interaction model including network evolution; production of multiple co-evolution regimes and calibration for France.*

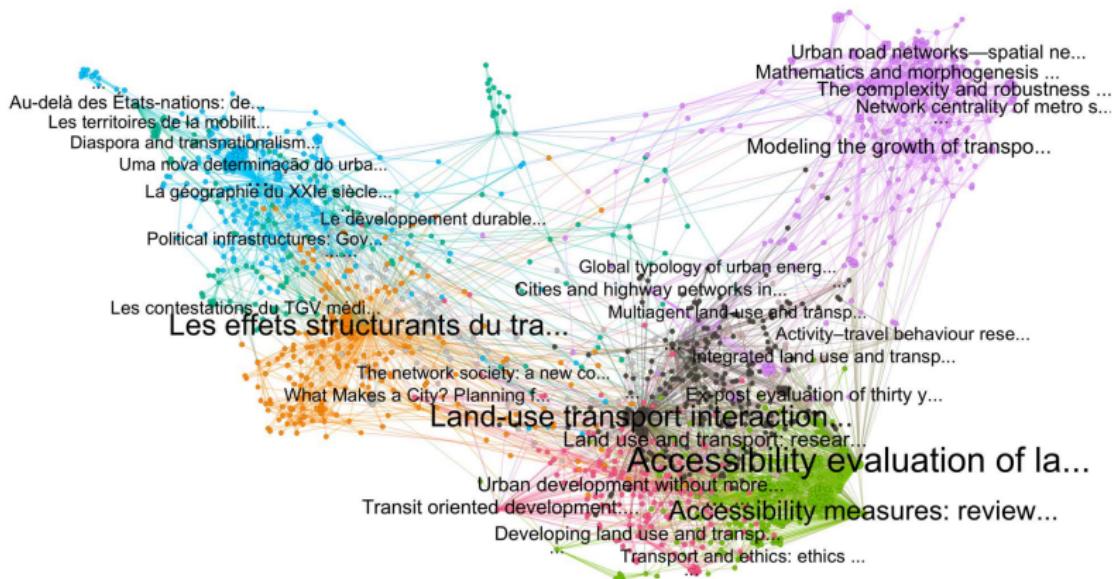


Raimbault, J. (2020). Indirect evidence of network effects in a system of cities. Environment and Planning B: Urban Analytics and City Science, 47(1), 138-155.

Raimbault, J. (2021). Modeling the co-evolution of cities and networks. In Niel, Z., Rozenblat, C., eds. *Handbook of Cities and Networks*, Edwar Elgar Publishing, *in press*.

# Horizontal integration: interdisciplinarity

*Literature mapping and systematic review tools to enhance integration*



Raimbault, J. (2019). Exploration of an interdisciplinary scientific landscape. *Scientometrics*, 119(2), 617-641.

**Case study:** *Construct a modular four-step multimodal transportation model using open source projects and data*

## Integrated models:

- MATSim model (MATSim Community) for the transportation system  
<https://www.matsim.org/> [Horni et al., 2016]
- SPENSER model (University of Leeds) for the synthetic population  
<https://github.com/nismod/microsimulation>
- QUANT model (CASA, University College London) for spatial interactions to generate home-work plans  
<http://quant.casa.ucl.ac.uk/> [Milton and Roumpani, 2019]
- spatialdata library (OpenMOLE community) for data processing  
<https://github.com/openmole/spatialdata>  
[Rimbault et al., 2020b]

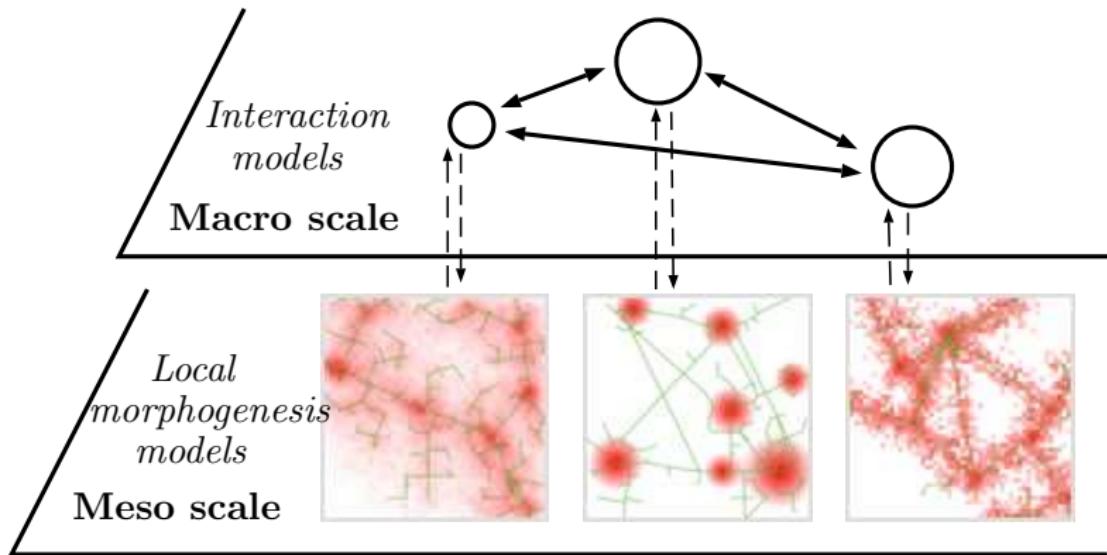
# Issues when coupling models

	QUANT	SPENSER
Time scale	10 years	40 years
Spatial scale	UK	UK
Spatial resolution	MSOA	MSOA
Agent granularity	Aggregated counts	individual level
Static/Dynamic	Equilibrium (static)	Dynamic
Randomness	Deterministic	Monte-Carlo
Transportation	3 modes	NA
Economics	Accessibility-based relocations	NA
Demographics	NA	Data-driven
Migration flows	Accessibility-based relocations	Data-driven

- Weak coupling Luti → microsimulation
- Weak coupling Microsimulation → Luti
- Strong coupling: as much choices as potential “coupling processes”

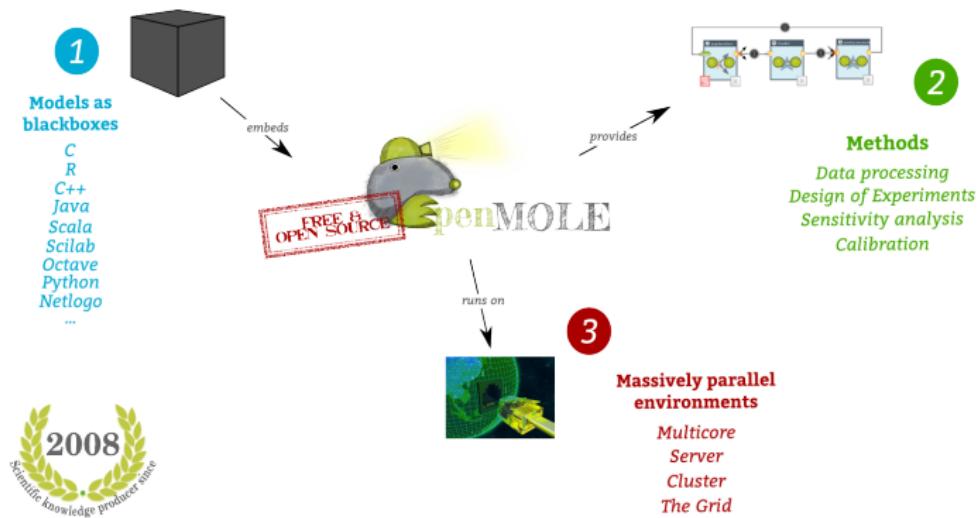
# Vertical integration: multi-scale models

*Processes specific to scales, coupling requires dedicated ontologies*

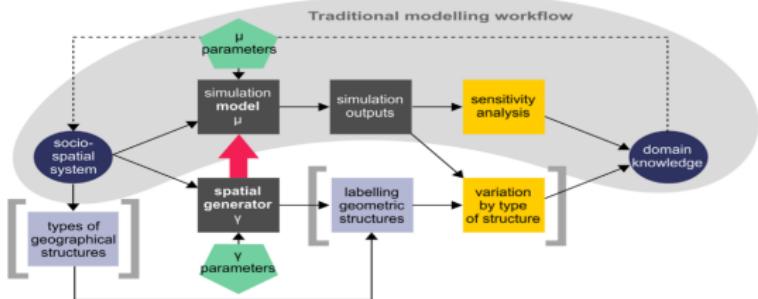


Raimbault, J. (2021). Strong coupling between scales in a multi-scalar model of urban dynamics. arXiv preprint arXiv:2101.12725.

OpenMOLE software [Reuillon et al., 2013]: (i) *Innovative exploration methods*; (ii) *Scaling of methods on high performance computing environments*; (iii) *Scripts to embed and couple models*.

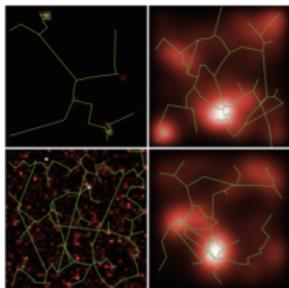


# Validation: towards spatial sensitivity analysis

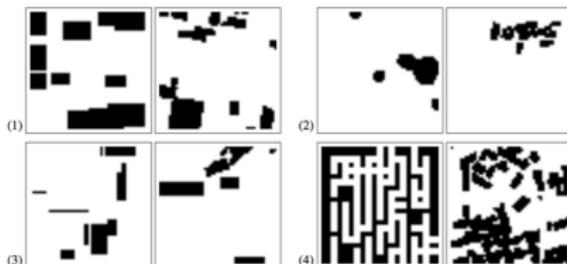


Raimbault, J., Cottineau, C., Le Texier, M., Le Nechet, F., Reuillon, R. (2019). Space Matters: Extending Sensitivity Analysis to Initial Spatial Conditions in Geosimulation Models. *Journal of Artificial Societies and Social Simulation*, 22(4).

Raimbault, J., Perret, J., & Reuillon, R. (2020). A scala library for spatial sensitivity analysis. *GISRUK 2020 Proceedings*, 32.



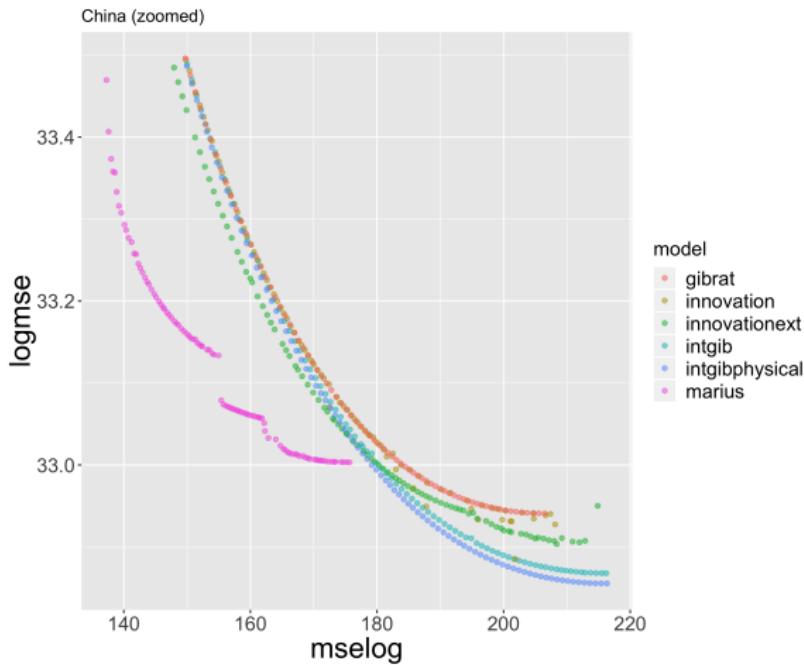
Raimbault, J. (2019). Second-order control of complex systems with correlated synthetic data. *Complex Adaptive Systems Modeling*, 7(1), 1-19.



Raimbault, J., Perret, J. (2019). Generating urban morphologies at large scales. In *Artificial Life Conference Proceedings* (pp. 179-186).

# Towards models for sustainable policies

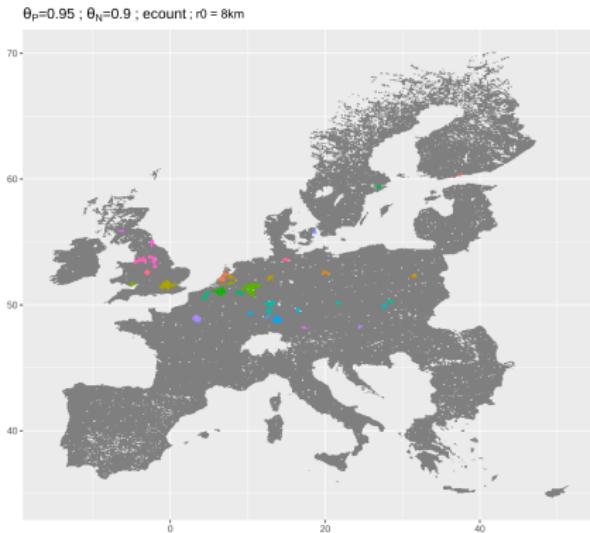
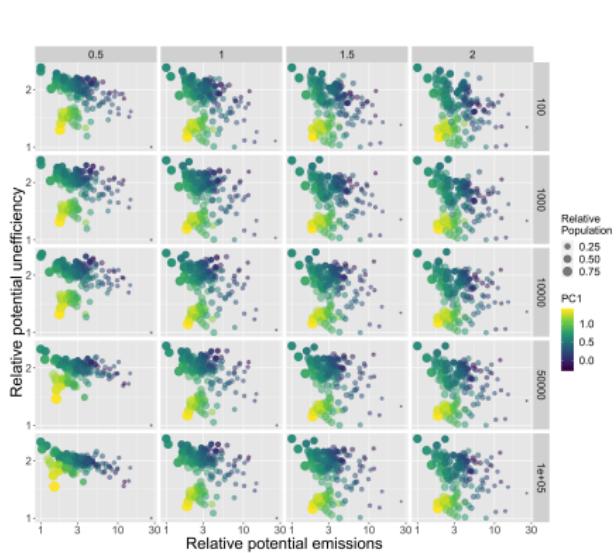
## Benchmark of growth models for systems of cities



Rambault, J., Denis, E., & Pumain, D. (2020). Empowering Urban Governance through Urban Science: Multi-Scale Dynamics of Urban Systems Worldwide. *Sustainability*, 12(15), 5954.

# Towards models for sustainable policies

## *Identifying endogenous sustainable mega-city regions in Europe*



Raimbault, J. (2019). Multi-dimensional Urban Network Percolation. Journal of Interdisciplinary Methodologies and Issues in Sciences, 5(5).

- Multiple ways to model urban systems: **towards more interdisciplinary coupling and comparison of models.**
- At which scale? **Towards multi-scale models.**
- Which knowledge from simulation models? **Model exploration and validation methods.**
- Open question: transfer of knowledge to policies.

**To use OpenMOLE (free and open software) and contribute:**

<https://next.openmole.org>

**All models open source at**

<https://github.com/JusteRaimbault>

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*Pour des pratiques de modélisation et de simulation libérées en géographie et SHS.*  
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-  Batty, M. (2014).  
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-  Bourgine, P., Chavalarias, D., Perrier, E., Amblard, F., Arlabosse, F., Auger, P., Baillon, J.-B., Barreteau, O., Baudot, P., Bouchaud, E., et al. (2009).  
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-  Rimbault, J. (2019b).  
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*arXiv preprint arXiv:2101.12725.*

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*Journal of Artificial Societies and Social Simulation*, 22(4).
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