

Integrating and validating urban simulation models towards sustainable territorial policies

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LaSTIG Seminar

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Scientific identity

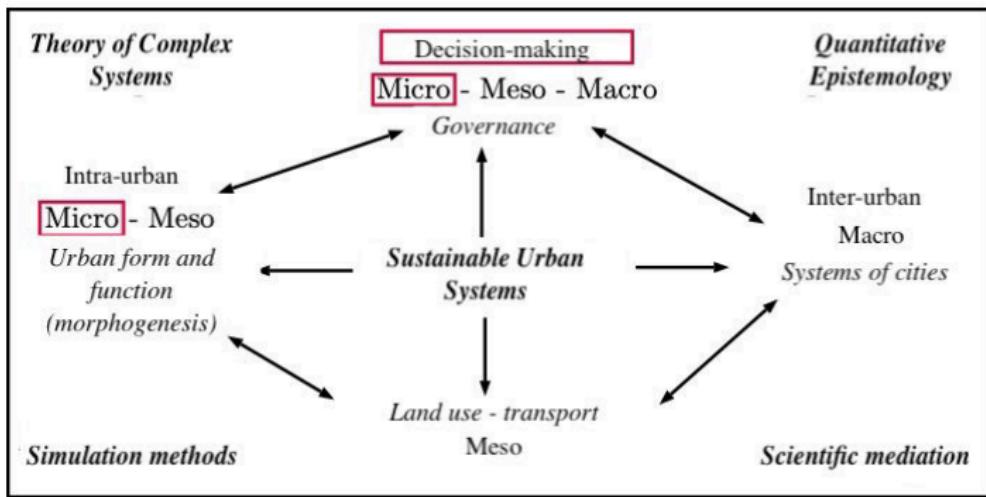
Trajectory

- Engineer specialised in urban systems
- PhD in Geography (Géographie-cités) and transportation (LVMT)
- Postdoc 1 simulation (ISC-PIF)
- Postdoc 2 Urban Analytics (CASA)
- Joining LaSTIG as CRDD on 01/01/2022

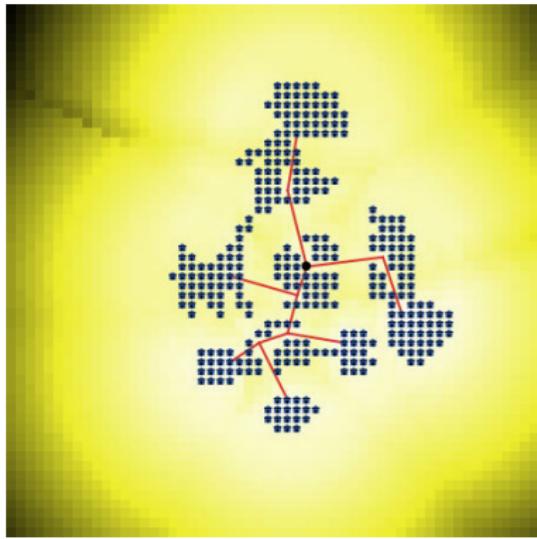
Disciplines and collaborations

Theoretical and quantitative geography, Transport geography, geosimulation, quantitative epistemology, Artificial life, Environmental science

Methods: Complex systems, Multi-scale dynamical models, Validation and exploration of simulation models, Complex networks, Spatial statistics, Machine learning

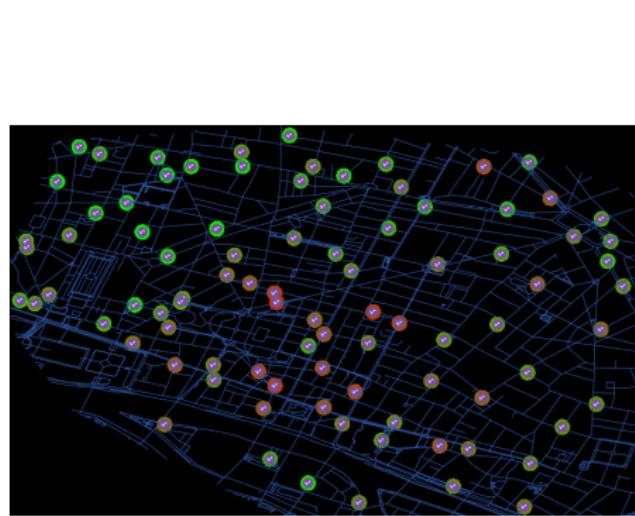


First projects



Hybrid urban morphogenesis model

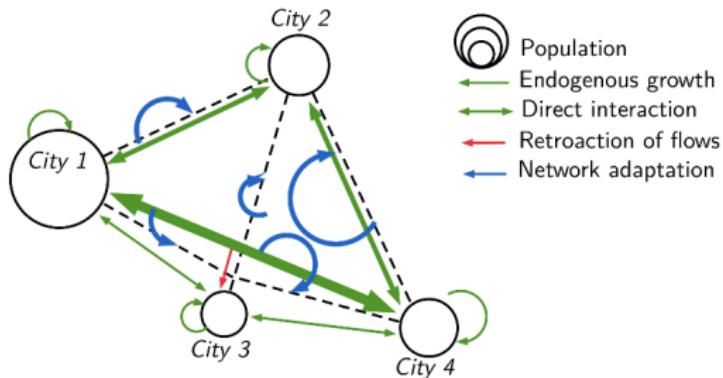
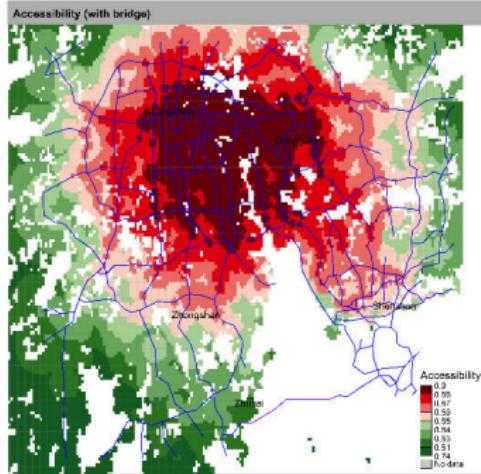
Raimbault, J., Banos, A., & Doursat, R. (2014, June). A Hybrid Network/Grid Model of Urban Morphogenesis and Optimization. In 4th International Conference on Complex Systems and Applications (pp. 51-60).



Agent-based modeling bike sharing

Raimbault, J. (2015). User-based solutions for increasing level of service in bike-sharing transportation systems. In Complex Systems Design & Management (pp. 31-44). Springer, Cham.

Land-use transport interactions



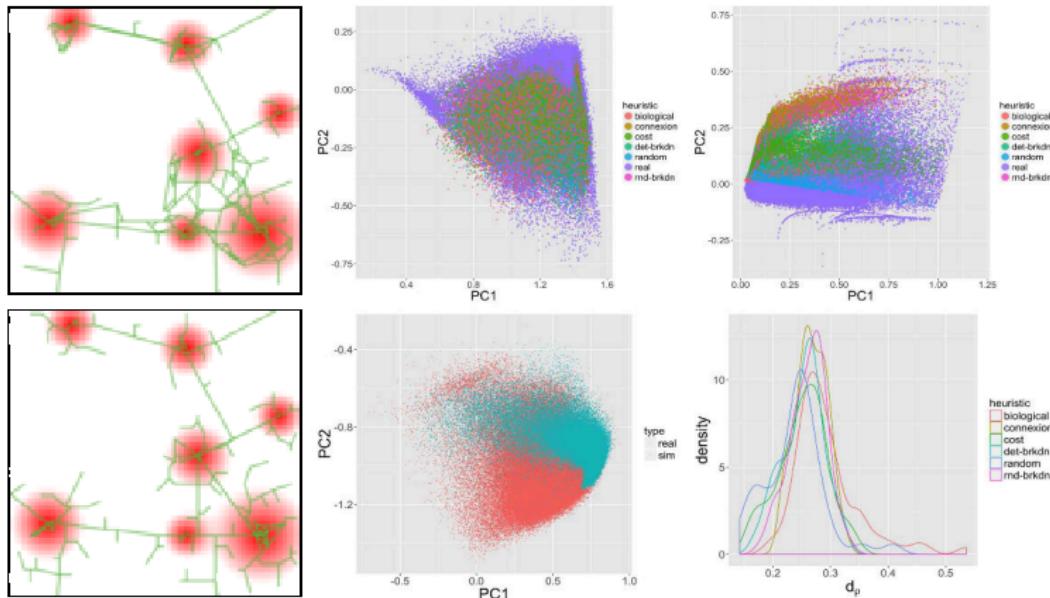
A modeling approach to the issue of structuring effects of transport infrastructures: co-evolution of networks and territories

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

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 *Handbook of Cities and Networks*. Edward Elgar Publishing.

Urban morphogenesis

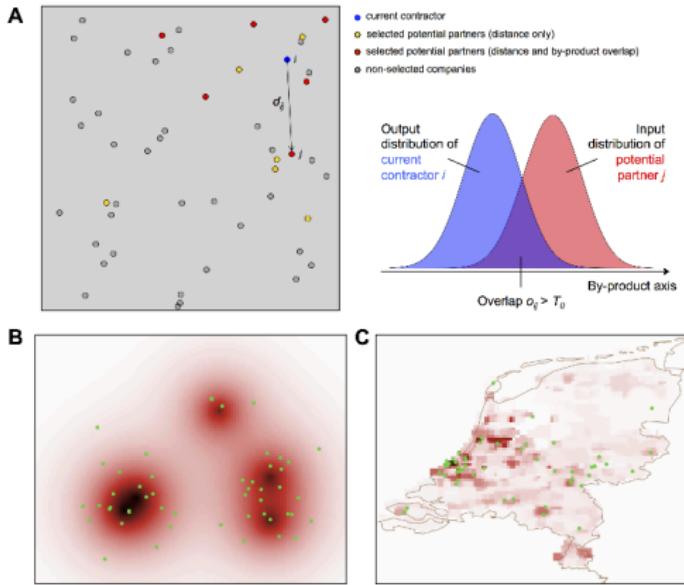


A morphogenesis model with reaction-diffusion and multi-modeling of network growth: complementarity of heuristics, calibration for Europe on forms and their correlations

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

Raimbault, J. (2019). An urban morphogenesis model capturing interactions between networks and territories. In *The Mathematics of Urban Morphology* (pp. 383-409). Birkhäuser, Cham.

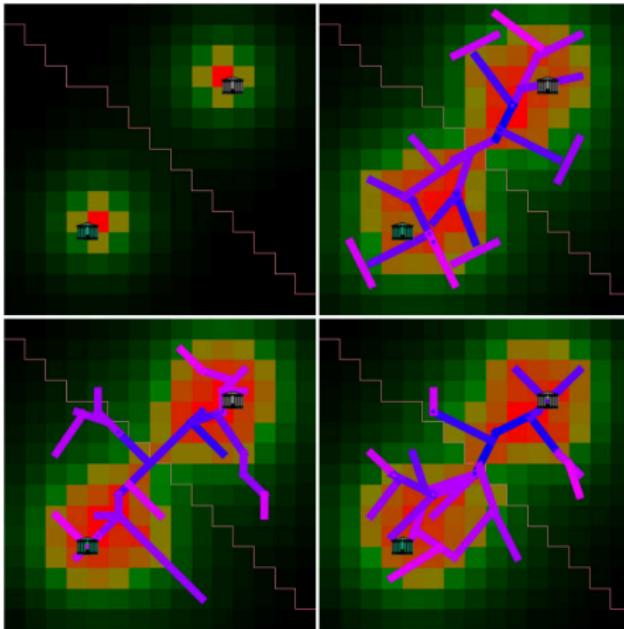
Urban systems and sustainability



Agent-based modeling for circular economy processes from an interdisciplinary viewpoint

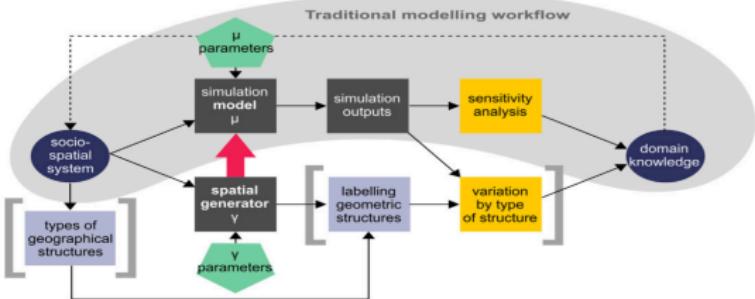
Raimbault, J., Broere, J., Somveille, M., Serna, J. M., Strombom, E., Moore, C., Zhu, B. & Sugar, L. (2020). A spatial agent based model for simulating and optimizing networked eco-industrial systems. *Resources, Conservation and Recycling*, 155, 104538.

Transportation governance



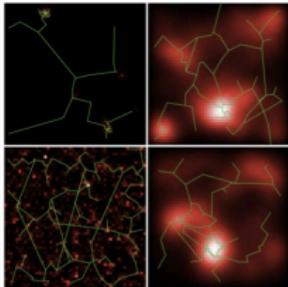
Simulating the decision-making processes of transport governance stakeholders

Spatial sensitivity analysis

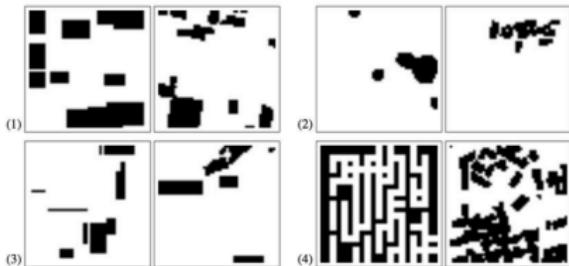


Raimbault, J., Cottineau, C., Le Texier, M., Le Nechet, F., Reuillon, R. (2019). Space Matters: Extending Sensitivity Analysis to Initial Spatial Conditions in Geosimulation Models. *Journal of Artificial Societies and Social Simulation*, 22(4).

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

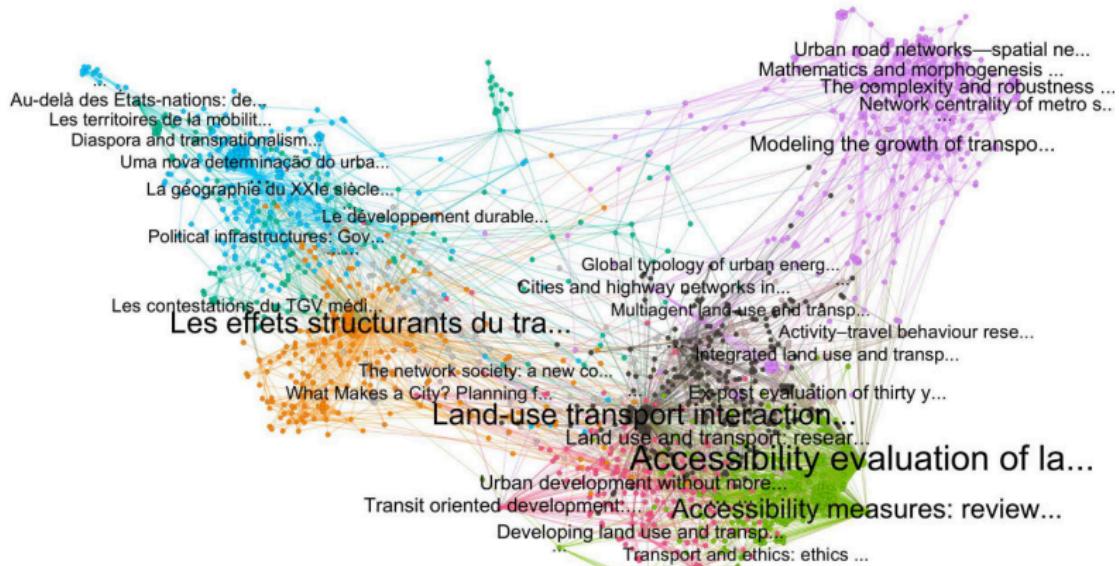


Raimbault, J. (2019). Second-order control of complex systems with correlated synthetic data. *Complex Adaptive Systems Modeling*, 7(1), 1-19.



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

Quantitative epistemology



Machine learning and natural language processing for knowledge mapping

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

Bergeaud, A., Potiron, Y., & Raimbault, J. (2017). Classifying patents based on their semantic content. *PloS one*, 12(4), e0176310.

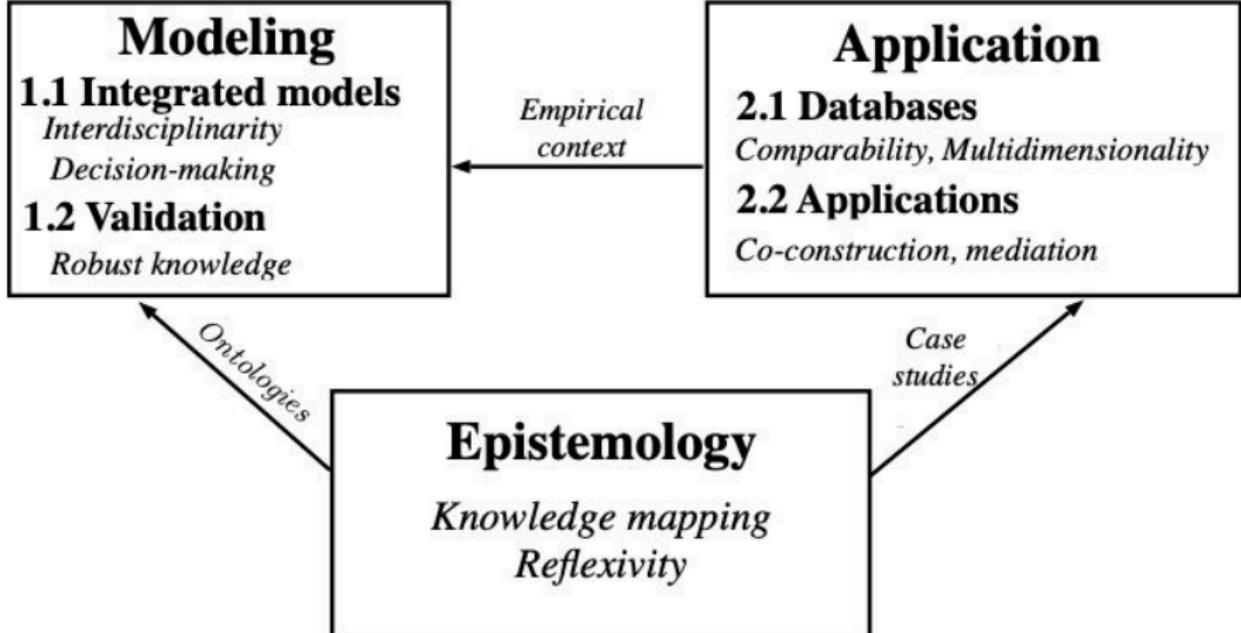
Raimbault, J., Chasset, P. O., Cottineau, C., Commenges, H., Pumain, D., Kosmopoulos, C., & Banos, A. (2021). Empowering open science with reflexive and spatialised indicators. *Environment and Planning B: Urban Analytics and City Science*, 48(2), 298-313.

Sustainable urban systems: (i) multiple contradictory objectives; (ii) implemented by stakeholders at different scales, within various information and power contexts; (iii) adaptive on multiple time scales.

Models are essential tools to (i) capture complexity; (ii) construct integrated perspectives; (iii) link data, empirical stylised facts and decision-making.

→ **Integrated models** to simulate multiple dimensions of **urban systems** towards decision-making in the context of **sustainable transitions**.

Project structure



Integrating models and theories

- Horizontal: interdisciplinarity, complementary dimensions
- Vertical: multiple scales of territorial systems
- Knowledge domains: multiple and hybrid methods

Several open issues

- (In)compatibility of approaches
- Model coupling
- Multi-scale models

*Simulation and high-performance computing: contribution to the
OpenMOLE software*



Development of new methods:

- Methods for the validation of spatial simulation models
- Optimisation and calibration methods (stochasticity)
- Coupling simulation models with machine learning (surrogate models, hybrid methods)

Raimbault, J., & Pumain, D. (2019). Methods for Exploring Simulation Models. *Geographical Modeling: Cities and Territories*, 2, 125-150.

Axis 2.1: Harmonised databases

Upstream integrated models

- Systematic review of existing databases for different SDGs
- Construction of open, harmonised and multidimensional databases, on consistent and comparable geographical entities

Dimension	SDGs	Existing
Population	All	<i>Global Human Settlement Layer</i> [Florczyk et al., 2019]
GDP	8 (Growth)	[Kummu et al., 2018]
Income	10 (Inequalities)	[Van Zanden et al., 2014]
Transport	11 (Sustainable cities)	No harmonised dataset
Emissions	14 (Climate)	EDGAR [Janssens-Maenhout et al., 2019]
Innovation	9 (Innovation)	No geolocated patent database

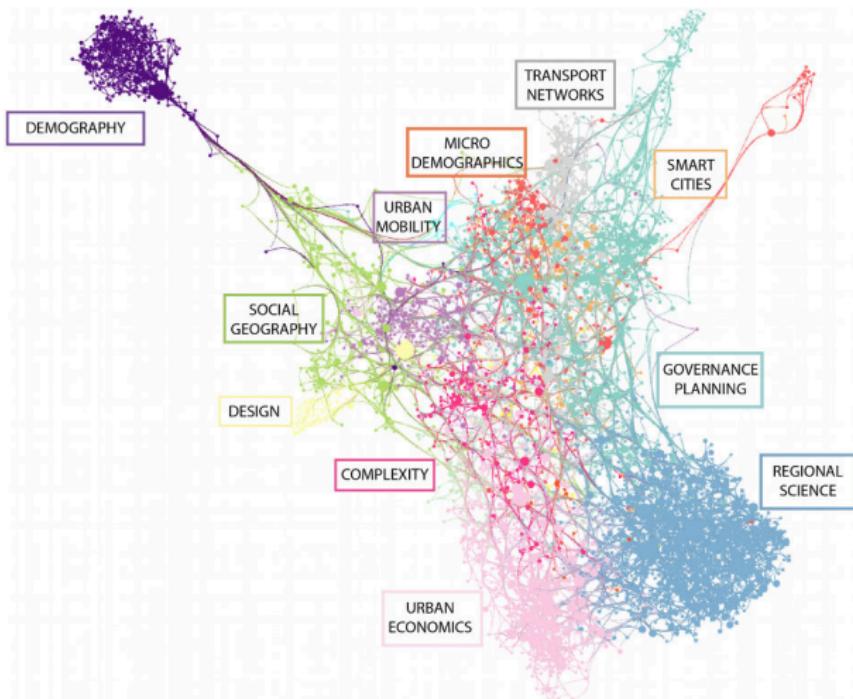
Examples of different SDGs dimensions and existing databases

Downstream integrated models

- Companion modeling, implication of stakeholders
- Decision-making: interactive models for planning, exploration interfaces
- Specific exploration methods (e.g. inverse problem)
- Scientific mediation

Axis 3: Knowledge mapping

Methods, tools and studies for open science and reflexivity



Implementing horizontal model integration

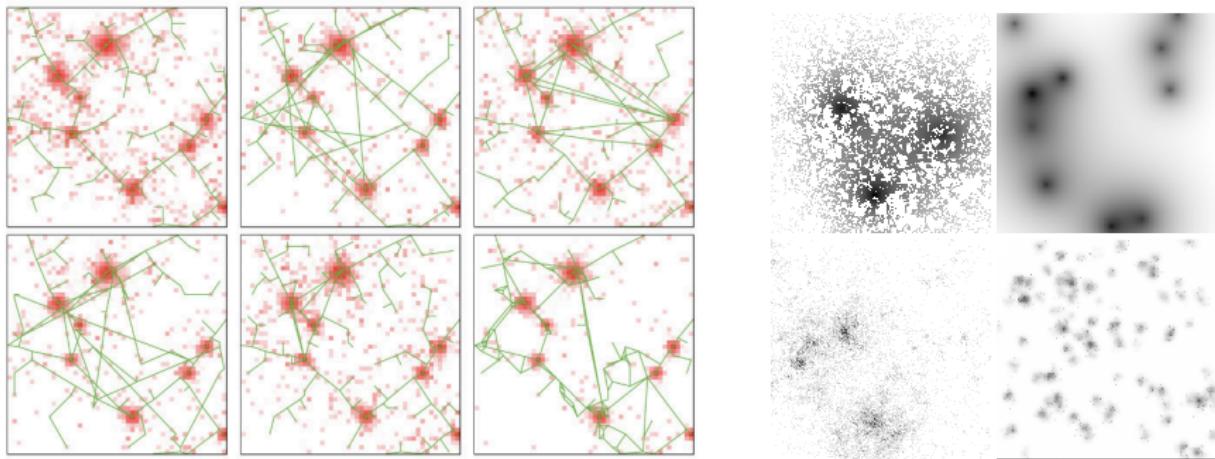
Current work : constructing a multimodal four step transport models by linking open components and data with scientific workflow engines

Integrated models:

- MATSim model (MATSim Community) for transport
[W Axhausen et al., 2016]
- SPENSER model (University of Leeds) for synthetic population
[Spooner et al., 2021]
- QUANT model (CASA, University College London) for spatial interactions [Batty and Milton, 2021]
- spatialdata library (OpenMOLE community) for data processing
[Raimbault et al., 2020b]

Raimbault, J., & Batty, M. (2021). Estimating public transport congestion in UK urban areas with open transport models. GISRUK 2021 Proceedings.

Horizontal integration: multi-modeling and benchmarks



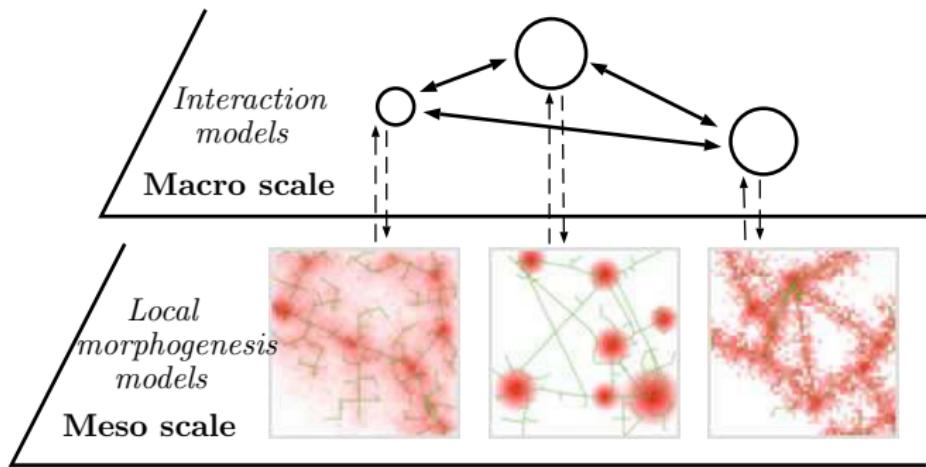
Benchmarking network and urban morphogenesis models

Raimbault, J. (2018). Multi-modeling the morphogenesis of transportation networks. In Artificial Life Conference Proceedings (pp. 382-383). MIT Press, Cambridge.

Raimbault, J. (2020). A comparison of simple models for urban morphogenesis. arXiv preprint arXiv:2008.13277.

Raimbault, J. (2021). Complementarity of generative models for road networks. arXiv preprint arXiv:2109.15206.

Vertical integration: towards multi-scale models



Processes specific to scales, coupling implies dedicated ontologies

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

Raimbault, J. (2021). A multiscale model of urban morphogenesis. arXiv preprint arXiv:2103.17241.

Integration within LaSTIG

Position: (i) validation and sensibility analysis linked to incomplete data; (ii) integrated models to explore territorial scenarios; (iii) heterogenous components within an interdisciplinary perspective

Projets within the Strudel team: (i) SimPLU and PARCELLE project; (ii) SUDOCU ANR project: thematic entry of networks-territories interactions; (iii) interdisciplinarity and open science, OpenMOLE platform

Institutional integration: links within Gustave Eiffel University (IFST-TAR LVMT, ENPC); Model applications to be integrated into *Géoplate-forme* (SIMV); Operational results usable by DPAPP; Open and reproducible models and data: contribution to *Géocommuns*

National collaborations: ISC-PIF; Centre d'économie de l'innovation, Collège de France; UMR IDEES, Université de Rouen; LVMT et ENPC, Université Gustave Eiffel; UMR Géographie-cités

International collaborations: CASA and Institute for Global Prosperity, University College London; DAFNI Infrastructure, UKCRCIC; UTSEUS, Shanghai University; CNRS MITI project-Tokyo University

- **Integrated models** capturing complexity of **urban sustainability** towards **decision-making**.
- **Robust** knowledge from models obtained with the development of **validation and exploration methods**.
- **Applied** knowledge through the construction of **harmonised databases** upstream and **transfer methods** downstream.
- A **reflexive and interdisciplinary** framework through knowledge mapping.

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Urban Studies, page 0042098020982252.
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-  Pumain, D. and Raimbault, J. (2020).
Conclusion: Perspectives on urban theories.
In *Theories and Models of Urbanization*, pages 303–330. Springer.
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In *Handbook of Cities and Networks*. Edward Elgar Publishing.
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-  Rimbault, J. and Perret, J. (2019).
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-  Van Zanden, J. L., Baten, J., Foldvari, P., and Van Leeuwen, B. (2014).
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