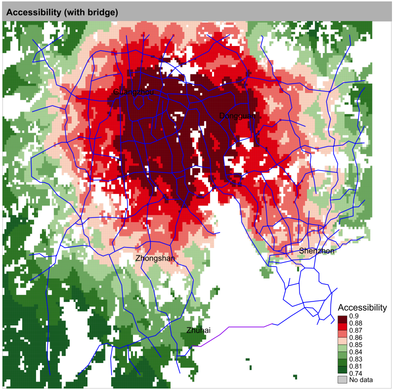
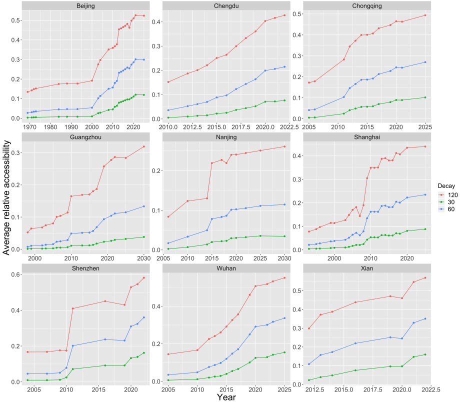
A meta-analysis of models for interactions between transportation networks and territories

J. Raimbault[1,2,3*]
j.raimbault@ucl.ac.uk

[1]CASA, UCL
[2]UPS CNRS 3611 Complex Systems Institute Paris
[3]UMR CNRS 8504 Géographie-cités

ECTQG 2019
Co-evolution of cities and networks
September 7th 2019





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

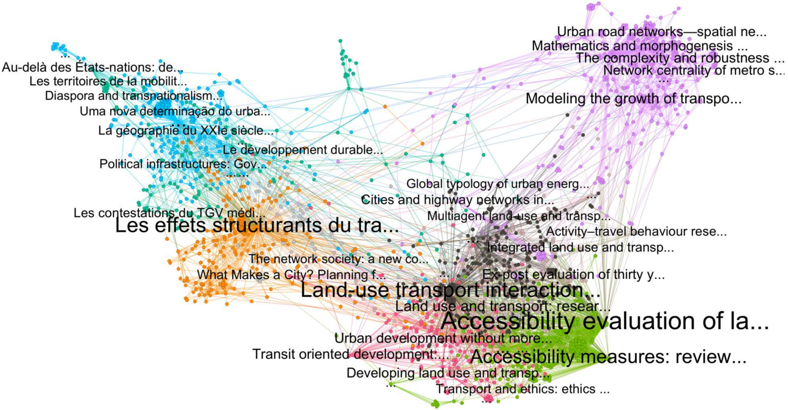
Interaction processes

Stylized interaction processes between transportation networks and territories

	Networks $\rightarrow$ Territories	Territories $\rightarrow$ Networks	Networks $\leftrightarrow$ Territories
Micro	Mobility patterns	Network congestion ; Negative externalities	Mobility and social structure
Meso	Relocations ; Local effects of infrastructures	Potential breakdown	Metropolitan planning ; TOD
Macro	Interactions between cities ; Tunnel effect	Hierarchical differentiation of accessibility	Large scale planning ; Structural dynamics ; Bifurcations

Diverse modeling approaches

Complementary modeling approaches



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

Towards a modelography

$\rightarrow$ beyond mapping of the literature, what are typical patterns of models characteristics depending on disciplines?

$\rightarrow$ systematic reviews and meta-analysis widely used in STEM [Rücker, 2012], less in social sciences and humanities (in geography see [Cottineau, 2017], [Schmitt and Pumain, 2013])

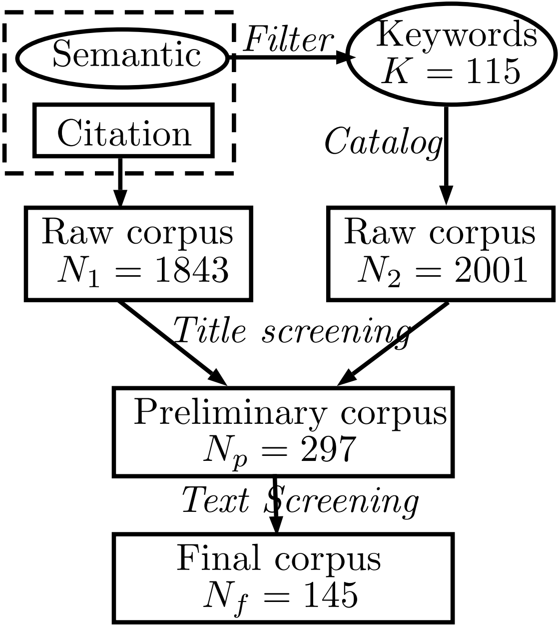
Research objective:

Construct a corpus of models of interaction between transportation networks and territories, with comparable characteristics; study determinants of these.

Corpus construction method

1. Extract most relevant keywords from the previous citation network-semantic scientific mapping (see [Raimbault, 2019b] and [Raimbault, 2017b])
2. For each keyword, get a fixed number $n = 20$ of references from a catalog request
3. Merge the corresponding corpus with the references from the citation network
4. Manual screening on titles, abstracts and full texts if necessary ($N_f = 145$)

Corpus construction method



Systematic review

Lessons from the systematic review:

- Catalog bias seem unavoidable
- Availability of full texts is a crucial point (`http://sci-hub.tw/` saved the study)
- Journals and editors increase visibility and request bias, grey literature has different status depending on the field
- Manual screening is also useful to discover important papers that can be missed in classical review
- Systematic review results are significantly different from the subjective manual review (both are complementary)

Extracted characteristics

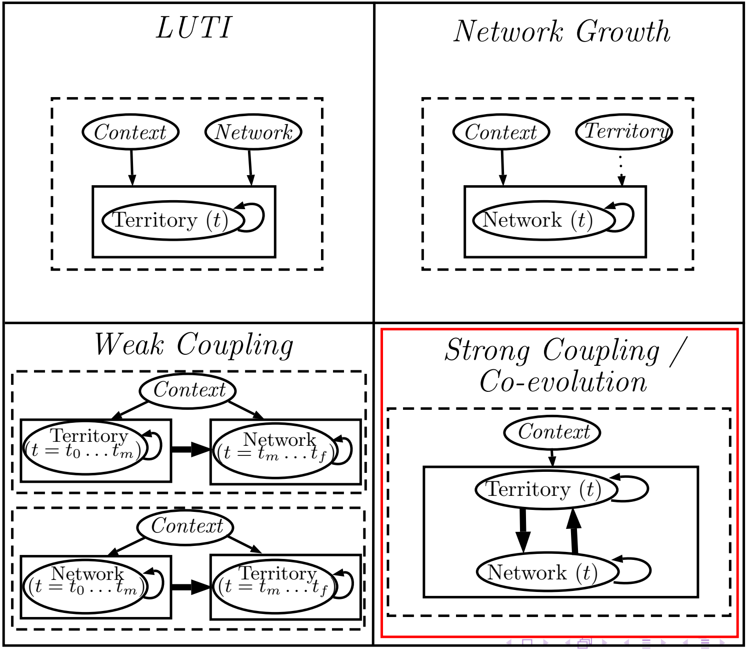
For each model we extract:

- strength of coupling among: `{territory ; network ; weak ; coevolution}`
- maximal time scale
- maximal spatial scale
- domain "a priori" (domain of journal)
- methodology used
- case study when relevant
- thematic question and processes

From multilayer scientific landscaping (semantic classification recomputed for this corpus) we obtain:

- citation domain
- semantic domain
- index of interdisciplinarity

Strength of model coupling



Exploratory analysis

Descriptive analysis:

- 26% with no case study
- overrepresentation of Netherlands (6.9%)
- majority of accessibility studies (65% of studies)
- very diverse processes and domains
- macroscopic geographical studies are in minority

Disciplines: 17.9% Transportation, 20.0% Planning, 30.3% Economics, 19.3% Geography, 8.3% Physics

Semantic domains: TOD (27.6%), networks (20.7%), hedonic models (11.0%), infrastructure planning (5.5%), HSR (2.8%)

Models characteristics

Discipline	economics	geography	physics	planning	transportation
network	5	3	12	1	4
strong	4	3	0	0	2
territory	35	22	0	28	20

Citation	accessibility	geography	infra planning	LUTI	networks	TOD
network	0	0	0	0	24	0
strong	0	0	0	2	5	0
territory	13	1	6	18	2	3

Semantic	hedonic	hsr	infra planning	networks	tod
network	1	0	0	14	2
strong	0	0	0	5	1
territory	15	4	8	11	37

+ Methods and spatial scale significantly correlated with discipline

Statistical analysis

	TEMPSCALE		SPATSCALE	INTERDISC		YEAR
	(1)	(2)	(3)	(4)	(5)	(6)
YEAR	0.674			−0.004*	−0.002*	
TYPEstrong		100.271***			−0.026	
TYPEterritory	−38.933***	−14.988			0.044	10.898***
TEMPSCALE			−5.179	−0.0003		0.035
FMETHODeq						−6.224
FMETHODmap						4.747
FMETHODro						6.128
FMETHODsem						1.009
FMETHODsim						5.153
FMETHODstat						−0.357
DISCIPLINEengineering	−52.107*	−9.609	−154.461	0.144		13.486
DISCIPLINEenvironment	17.110	17.886	−5.878	0.092		−3.668
DISCIPLINEgeography	3.640	9.126	1,445.457***	0.036		1.121
DISCIPLINEphysics	46.879*	77.897***	292.559	−0.103		3.392
DISCIPLINEplanning	1.304	4.553	−143.554	−0.047		−2.850
DISCIPLINEtransportation	−14.718	8.753	568.329	0.062		5.503*
INTERDISC	2.357					−12.876
SEMCOMcomplex networks					−0.217	
SEMCOMhedonic				−0.179	−0.184*	−5.769
SEMCOMhsr				−0.100	−0.122	6.135
SEMCOMinfra planning				−0.032	−0.096	−4.123
SEMCOMnetworks				−0.038	−0.107	4.711
SEMCOMtod				−0.105	−0.152	−1.653
Constant	−1,305.126	22.103*	235.357	8.962**	5.531**	2,004.945***
Observations	64	94	94	64	98	64
R^2	0.385	0.393	0.100	0.314	0.155	0.510
R^2 adj.	0.282	0.336	0.027	0.136	0.068	0.281

Random forest regression

Random forest to classify type of model: citation class has an importance of 45%, discipline 31% and semantic 23%

Random forest regression for interdisciplinarity: low explicative power (7.6%); importance of variables: discipline 39%, semantic 31% and citation 29%

Synthesis: modeled processes

	Networks → Territories	Territories → Networks	Networks ↔ Territories
Micro	**Economics:** real estate market, relocalization, employment market	NA	**Computer Science :** spontaneous growth
	Planning: regulations, development		
Meso	**Economics:** real estate market, transportation costs, amenities	**Economics:** network growth, offer and demand	**Economics:** investments, relocalizations, offer and demand, network planning
	Geography: land-use, centrality, urban sprawl, network effects	**Transportation:** investments, level of governance	**Geography:** land-use, network growth, population diffusion
	Planning/transportation: accessibility, land-use, relocalization, real estate market	**Physics:** topological correlations, hierarchy, congestion, local optimization, network maintenance	
Macro	**Economics:** economic growth, market, land-use, agglomeration, sprawl, competition	**Economics:** interactions between cities, investments	**Economics:** offer and demand
	Geography: accessibility, interaction between cities, relocalization, political history	**Geography:** interactions between cities, potential breakdown	**Transportation:** network coverage
	Transportation: accessibility, real estate market	**Transportation:** network planing	

Discussion

Developments

→ Multiple experts corpus construction

→ Automatic extraction of features and classification

→ Automatic extraction of model modular structure, identify potential couplings

Lessons for modeling

→ multidisciplinary aspect of effectively co-evolutive models

→ importance of multiple scales and processes

Epilogue I: effectively modeled processes

Process	Scales	Concept	Proposed models
Preferential attachment/Gibrat	Meso/Macro	Urban growth	Morphogenesis/Interactions
Diffusion/Sprawl	Meso	Urban Form	Morphogenesis
Closeness centrality/Accessibility	Meso/Macro	Accessibility	Morphogenesis/Interactions
Direct flows	Macro	Interactions	Interactions
Indirect flows/Tunnel effect/Betweenness centrality	Meso/Macro	Network effects	Morphogenesis/Interactions
Network proximity	Meso	Accessibility	Morphogenesis
Actives/employments relocations	Meso	Residential mobility	Lutecia
Transportation governance	Meso	Governance	Lutecia

Model	Structuring effects	Individual co-evolution	Population co-evolution	Systemic co-evolution
RBD [Raimbault et al., 2014]	X	X	X	NA
Interactions [Raimbault, 2018a]	x	NA	NA	NA
Weak coupling [Raimbault, 2016]	x	NA	NA	NA
SimpopNet [Raimbault, 2018c]	X	X	x	n.t.
Macro co-evolution [Raimbault, 2018b]	X	X	X	n.t.
Meso co-evolution [Raimbault, 2019c]	X	X	x	NA
Lutecia [Le Néchet and Raimbault, 2015]	n.t.	X	n.t.	NA
Empirical: Grand Paris [Raimbault, 2017a]	X	x	o	NA
Empirical: South Africa [Raimbault and Baffi, 2017]	X	x	o	n.t.
Empirical: France [Raimbault, 2018b]	o	x	o	n.t.

Conclusion

→ systematic and broad overview of diverse approaches to modeling networks and territories

→ difficulty of systematic review and meta-analysis in social sciences, but new tools and methods for a reflexive positioning are crucial [Raimbault et al., 2019]

→ towards a quantitative, applied and reflexive epistemology

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

Raimbault, J., Chasset, P.-O., Cottineau, C., Commenges, H., Pumain, D., Kosmopoulos, C., & Banos, A. (2019). Empowering open science with reflexive and spatialised indicators. Environment and Planning B: Urban Analytics and City Science. https://doi.org/10.1177/2399808319870816

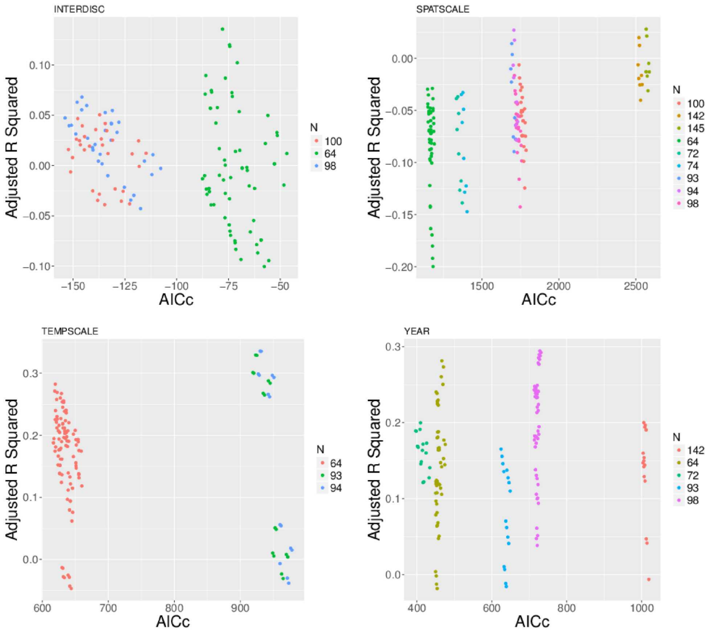
Code and data available at
`https://github.com/JusteRaimbault/CityNetwork/tree/master/Models/QuantEpistemo/HyperNetwork/Modelography`

Reserve Slides

Modalities of properties

- Type of model (`TYPE`): strong, territory, network.
- Publication year (`YEAR`), integer number.
- Citation community (`CITCOM`), defined within the citation network: Accessibility, Geography, Infra Planning, LUTI, Networks, TOD.
- A priori discipline (`DISCIPLINE`): biology, computer science, economics, engineering, environment, geography, physics, planning, transportation.
- Semantic community (`SEMCOM`): brt, complex networks, hedonic, hsr, infra planning, networks, tod.
- Methodology used: ca (Cellular Automaton), eq (analytical equations), map (cartography), mas (Multi-agent simulation), ro (operations research), sem (Structural Equation Modeling), sim (simulation), stat (statistics).
- Interdisciplinarity index (`INTERDISC`): real number in $[0,1]$.
- Temporal scale (`TEMPSCALE`): given in years, is set to 0 for static analyses.
- Spatial scale (`SPATSCALE`): continent (10000), country (1000), region (100), metro (10). These modalities are numerically transformed in km by the values given in parenthesis (stylized scales).

Linear model selection



References I

- Cottineau, C. (2017).
  Metazipf. a dynamic meta-analysis of city size distributions.
  PloS one, 12(8):e0183919.

- Le Néchet, F. and Raimbault, J. (2015).
  Modeling the emergence of metropolitan transport autorithy in a polycentric urban region.

- Raimbault, J. (2016).
  Génération de données synthétiques corrélées.
  In *Rochebrune 2016, Journées d'Etude sur les Systèmes Complexes Naturels et Artificiels*.

- Raimbault, J. (2017a).
  Identification de causalites dans des donnees spatio-temporelles.

References II

Raimbault, J. (2017b).
Invisible bridges? scientific landscapes around similar objects studied from economics and geography perspectives.
In *European Colloquium in Theoretical and Quantitative Geography 2017*.

Raimbault, J. (2018a).
Indirect evidence of network effects in a system of cities.
Environment and Planning B: Urban Analytics and City Science, page 2399808318774335.

Raimbault, J. (2018b).
Modeling the co-evolution of cities and networks.
arXiv preprint arXiv:1804.09430.

References III

Raimbault, J. (2018c).
Unveiling co-evolutionary patterns in systems of cities: a systematic exploration of the simpopnet model.
arXiv preprint arXiv:1809.00861.

Raimbault, J. (2019a).
Evolving accessibility landscapes: mutations of transportation networks in China.
In Aveline-Dubach, N., editor, *PATHWAYS OF SUSTAINABLE URBAN DEVELOPMENT ACROSS CHINA: THE CASES OF HANGZHOU, DATONG AND ZHUHAI*, pages 89–108. Imago Editor.

Raimbault, J. (2019b).
Exploration of an interdisciplinary scientific landscape.
Scientometrics, 119(2):617–641.

Raimbault, J. (2019c).
An urban morphogenesis model capturing interactions between networks and territories.
In *The Mathematics of Urban Morphology*, pages 383–409. Springer.

Raimbault, J. and Baffi, S. (2017).
Structural segregation: Assessing the impact of south african apartheid on underlying dynamics of interactions between networks and territories.

Raimbault, J., Banos, A., and Doursat, R. (2014).
A hybrid network/grid model of urban morphogenesis and optimization.
In *4th International Conference on Complex Systems and Applications*, pages 51–60.

Raimbault, J., Chasset, P.-O., Cottineau, C., Commenges, H., Pumain, D., Kosmopoulos, C., and Banos, A. (2019).
Empowering open science with reflexive and spatialised indicators.
Environment and Planning B: Urban Analytics and City Science, 0(0):2399808319870816.

Rücker, G. (2012).
Network meta-analysis, electrical networks and graph theory.
Research synthesis methods, 3(4):312–324.

Schmitt, C. and Pumain, D. (2013).
Modélographie multi-agents de la simulation des interactions sociétés-environnement et de l'émergence des villes.
Cybergeo: European Journal of Geography.