

# An Applied Knowledge Framework to Study Complex Systems

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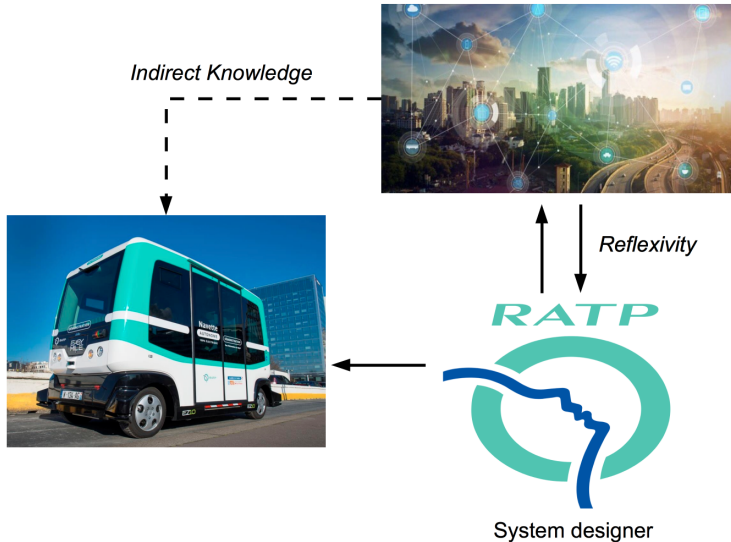
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# Reflexivity in System Engineering ?



Source : [www.ratp.fr](http://www.ratp.fr)

# Processes of Knowledge Production

*The study of processes of knowledge production as an asset to study complex systems ?*

→ Philosophical and epistemological approaches to the nature of knowledge : [Kuhn, 2012]'s structure of scientific revolutions, [Feyerabend, 2010]'s advocacy for diverse viewpoints.

→ Quantitative approaches : beyond simple bibliometrics  
[Cronin and Sugimoto, 2014]

*Following [Morin, 1991], the Knowledge of Knowledge arise from and for the study of Complex Systems : knowledge of the complex is complex knowledge (requisite complexity [Gershenson, 2015])*

# Knowledge Frameworks

**Knowledge Framework :** *A systemic framework containing an epistemological component dealing with the nature of knowledge or knowledge production.*

→ Knowledge management : [Durantin et al., 2016] coupling engineering with design paradigms ; [Carlile, 2004] knowledge at the boundaries of disciplines.

→ Meta-modeling frameworks : [Cottineau et al., 2015] multi-modeling ; [Golden et al., 2012] unified formal description of Complex Systems.

→ Applied frameworks : [Moulin-Frier et al., 2017] typology of approaches in Artificial Intelligence.

# Research objective

- Existing frameworks specific to a field or discipline, or to a given approach or methodology.
- Different levels of applicability.

## Research objective :

*Based on knowledge domains proposed by [Livet et al., 2010], develop a generic Applied Knowledge Framework, capturing some structure of knowledge (epistemological level) with a direct link with concrete applications (discipline level).*

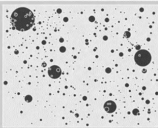
# Approach and Methodology

**Approach :** An inductive approach from a case study in Theoretical and Quantitative Geography, developed in the last 20 years (Evolutive Urban Theory [Pumain, 1997])

**Methodology :** Mixed methods. Interview with main contributors of the theory, from different disciplines (D. Pumain, C. Cottineau in Geography, R. Reuillon in Computer Science) ; quantitative analysis of citation network.

# Evolutionary Urban Theory

## Spatio-temporal scales



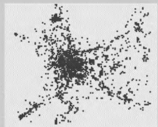
1 day

## Emerging properties

Hierarchy  
Functional diversity  
Spatial pattern

## Organization levels

**Macro: System of cities**  
(urban networks)

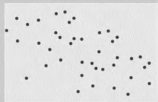


1 hour

Centrality  
Function  
Morphology  
"Ambiance urbaine"

**Meso: City**  
(urban areas)

## Descriptors



Life cycle  
Profession  
Power

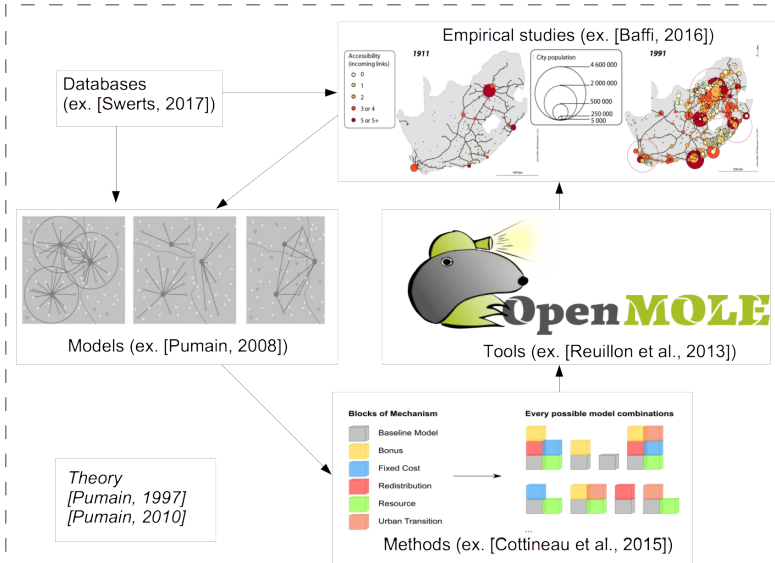
**Micro: Actors**  
(households, firms, institutions)

*Source :*  
[Pumain, 2008]

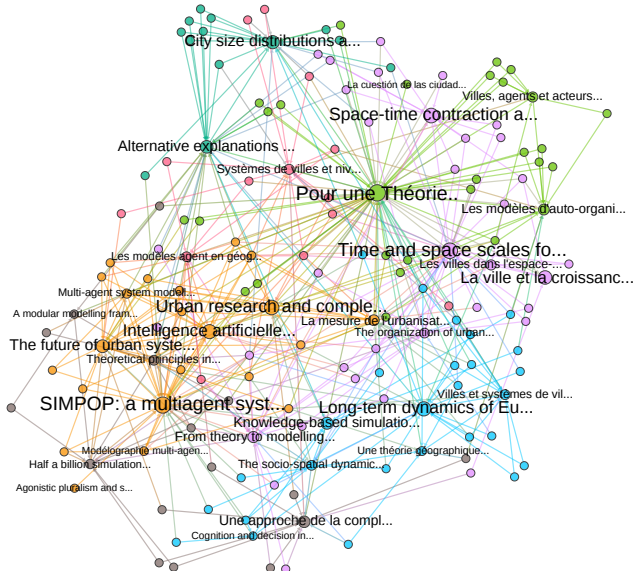
# Iterative Construction of Knowledge



# Existence of Knowledge Domains ?



# Citation Network Analysis



*Core citation network of Evolutive Urban Theory*

$|V| = 155, |E| = 449$

7 communities,  
modularity 0.39

# Engineering the Metropolitan

**Table:** Illustration of Knowledge Framework Application

Engineering Issue	Knowledge Domains	Transferability	References
Autonomous Transportation	Empirical, Modeling	Integrated Modeling	[Belmonte et al., 2008]
Innovative Modeling	Modeling, Methods	Method development	[Balbo et al., 2016]
Functional Requirements	Empirical, Tools	Ergonomic tools	[Foot, 2005]
Societal Adaptation	Theoretical, Empirical	Stakeholders involvement	[Foot, 1994], [Hatchuel et al., 1988]
Technical Requirements	Empirical, Modeling	Integrated Modeling	[Moreno Regan, 2016]

# Constraints on the Framework

- Integration of disciplines, as Complex Systems are by essence at the crossing of multiple fields
- Integration of knowledge domains, i.e. that no particular type of knowledge must be privileged in the production process
- Integration of methodology types, in particular breaking the artificial boundaries between “quantitative” and “qualitative” methods, which are particularly strong in classical social sciences and humanities.

# Epistemological Foundations

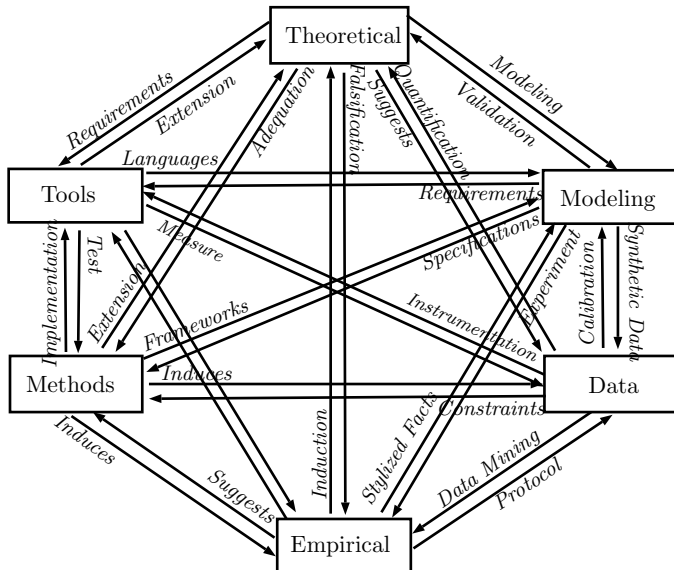
# Knowledge Domains

## *Definition of Knowledge Domains :*

- **Empirical.** Empirical knowledge of real world objects.
- **Theoretical.** Conceptual knowledge, implying cognitive constructions.
- **Modeling.** The model is the formalized *medium* of the scientific perspective, as diverse as Varenne's classifications of models functions [Varenne, 2010] (see below).
- **Data.** Raw information that has been collected.
- **Methods.** Generic structures of knowledge production.
- **Tools.** Implementation of methods and supports of others domains.

# Co-evolution of Knowledge

# Visualization





# Discussion

## Applications



## Developments



# Conclusion



- Code, data and results available at <https://github.com/JusteRaimbault/CityNetwork>
- Paper on arXiv at <https://arxiv.org/abs/1706.09244>
- Acknowledgments : The author would like to thank D. Pumain and R. Reuillon for giving of their time for the interviews, and anonymous reviewers for the useful comments and insights.

# Reserve slides

## Reserve Slides

# Function of Models

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