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Nathalie Picard

LUTI MODELS
LAND USE AND TRANSPORT INTERACTION

Overview of the lecture

- General principles of LUTI models
  - Objectives
  - Variables modeled/simulated
  - Practical use of models
- Comparison of different LUTI models
  - With respect to different criteria
  - ➔ respective advantages/drawbacks
- Zoom on EUrbanSimM
- Application in Ile-de-France : Grand Paris Express (+ Grand Est and limiting countries: CH, GE, LU, BE)

GENERAL PRINCIPLES OF LUTI MODELS

Land **U**se and **T**ransport **I**nteractions

Objectives of LUTI models

- Analyze interactions between
  - Urban development
  - Agents Location (households, firms)
  - Transport
  - Real estate market (dwellings, offices, other activities)
  - Labor market
- Predict/simulate long-term evolutions (typically 30 years)
  - Simulate rather than predict because decisions made by public authorities, stake holders, and the rest of the world (as well as surprises such as the pandemic or war and energy crisis) are crucial but unpredictable
- Evaluate public policies related to:
  - Transport
  - Dwellings
  - Employment
  - Environment
  - Health (lockdown, mobility restrictions)

Variables modeled/simulated

- Households and/or individuals location
- Jobs and/or firms/establishments location
- Building of dwellings, offices, plants, retail stores,…
- Land use
- Real estate prices
  - Houses/flats * renting/buying
  - Offices, retail stores, warehouses
- Transport demand and network equilibrium
  - 4-step/dynamic model: interacting or integrated (LUT**I**)
  - Congestion on Private Car network and possibly on Public Transport network

Practical use of models

- Difficulties
  - Access to and treatment of data
  - Calibration/estimation of parameters
- Descriptive / predictive / normative model
- Criteria for selecting a LUTI model
  - Relevance of LUTI models to answer specific questions related to public policies (CBA, equity)
  - Degree of precision/heterogeneity : trade-off complexity / accuracy of results (aggregate effects / equity, redistributive effects of policies)

COMPARISON OF DIFFERENT LUTI MODELS

Some LUTI models (not exhaustive)

- MEPLAN (Marcial Echenique & Partners, UK)
- TRANUS (Tomas de la Barra, Modelistica, Venezuela)
- RELU-TRANS (Alex Anas, USA)
- PIRANDELLO (Vincent Piron & Jean Delons, France)
- UrbanSim (Paul Wadell, University of Washington and Berkeley, USA/THEMA, CY/Strasbourg team in Paris)
  - → EUrbanSimM: European Urban Simulation interacted with METROPOLIS

Main differences between models (detailed in the net slides)

- Agent behavior/markets modeling
- Dynamic evolution versus final point
- General / partial equilibrium / no equilibrium
- Unicity/Multiplicity of equilibrium
- Agents heterogeneity
- (Aggregation level and GUA)
- Required data
- (Policies which can be simulated)

Agent behavior/markets modeling

- Choices made by individuals/households
  - Tenure status, dwelling type, residential location, job location, job type, daily mobility (mode choice)
- Choices made by firms
  - Establishment location, number of jobs, wages, quality and quantity of goods produced, prices
- Choices made by public authorities
  - At different levels: State, Region, Agglomerations, Cities
  - In different domains: Transport infrastructures, building permits, urban development policy, social dwelling, fiscal competition
  - Using different tools: public investments, contribution to PPP, regulation
- Other private decision makers and stake holders (transport companies, promotors, large firms,…)
  - Private investments, contribution to PPP, lobbying
- Real estate/labor supply markets
  - Supply, demand, equilibrium, market clearing
  - Real estate: Hedonic price regressions: implicit price for each characteristic, WTP
  - Labor market: Different sources of friction, unemployment, etc.

Dynamic evolution versus final point

- Models relying on equilibrium conditions: final point
  - Do not model/analyze the transition period
- Disequilibrium models analyze the dynamics of evolution
  - Rigidity result from:
    - Regulation
      - Labor market, real estate market
      - Submarkets partially interacting
    - Transaction costs
  - Partial adjustment:
    - Excess demand increases price; excess supply reduces price, but not enough to equalize supply and demand
    - A price increase reduces demand and increases supply
  - "Aiming at a moving target": equilibrium is never reached if it moves faster than adjustments towards equilibrium

General / partial equilibrium / no equilibrium

- Partial equilibrium on a specific market:
  - Prices (including wages) adjust supply/demand
  - Separate analysis and equations in different markets
- General Equilibrium: partial equilibrium + interactions between markets
  - Firms pay wages to residents
  - Residents consume final goods produced by firms
  - Intermediary goods produced by some firms are used as inputs by other firms
  - Non-linear system involving a large number of equations and variables
- Disequilibrium: prices cannot fully adjust supply and demand, especially in the short run (adjustment takes time, and conditions may evolve faster➔ aiming at a moving target)
  - Labor market: unemployment, frictions
  - Real estate markets: capacity constraints, vacancies
- Rationality versus realism; liberalism versus Providence State

Unicity/Multiplicity of equilibrium

- Partial equilibrium: Unique equilibrium price guaranteed on each market
- General equilibrium: Unicity of global equilibrium guaranteed only under extremely restrictive and usually unrealistic conditions. Main difficulties:
  - Non-linearity of equations
  - Heterogeneity of agents
- In case of multiple equilibrium, the point actually reached in the long-run depends on:
  - initial conditions ➔ justifies public interventions
  - dynamics of public policies and other endogenous or exogenous changes

  → disequilibrium models ere better suited than equilibrium models to evaluate dynamic public policies

  → the COVID crisis will shape future urban development

Agents heterogeneity

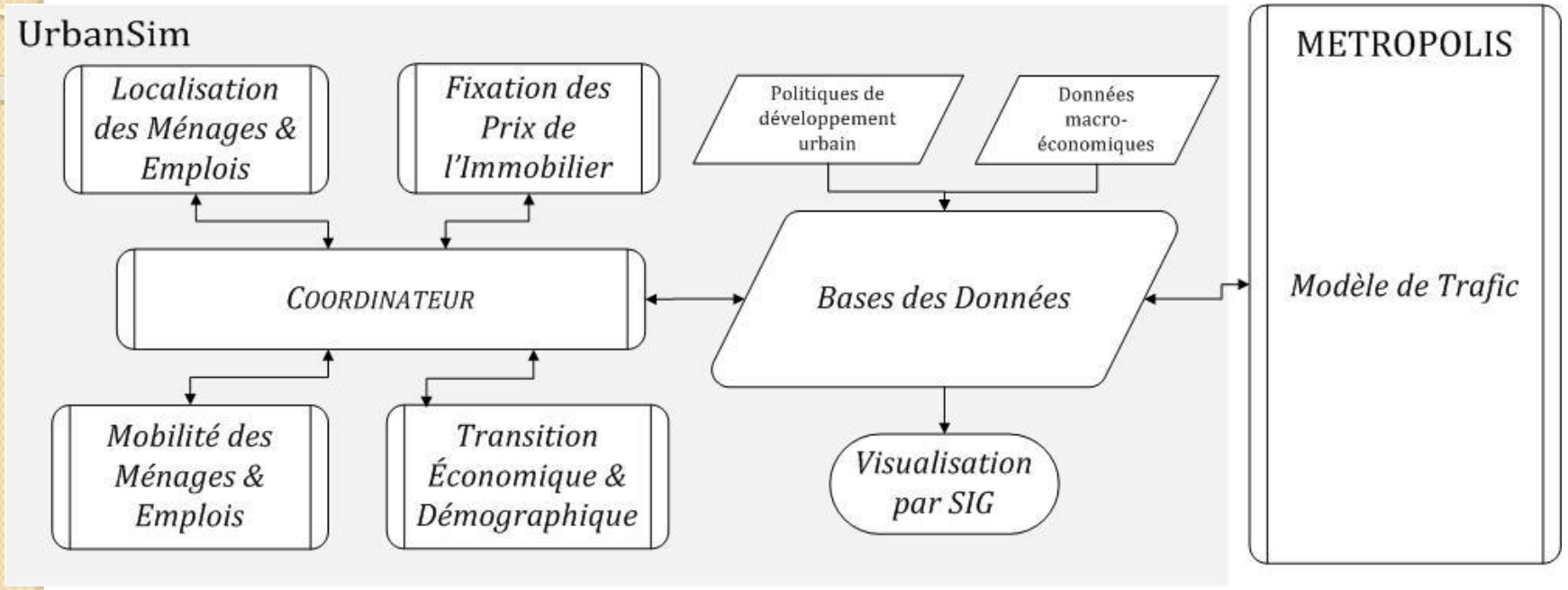
- Very difficult to take into account in a GE model because increases
  - number of equations (linear) and
  - number of parameters to calibrate (quadratic)
  - ➔ limited heterogeneity in GE models
    - A few income classes (2-3)
    - A few classes describing household composition (2-3)
    - A few activity sectors (3-5)
    - A few qualification levels (2-3)
- No real limit to heterogeneity in disequilibrium models
  - Gender (2), age (3-10 or continuous), nationality (2+), education (3-5), profession (5) of HH head and each active HH member
  - Activity sector (10), qualification (4-6)
  - Household composition (10), number of children by age group
- Individuals versus households
  - Either, not both in GE models
  - Disequilibrium models can manage both: a household is made of several members

Required data (past and future)

- Demographic model (fertility, mortality, household formation, immigration, emigration)
  - Distribution of households by age of household head, number of children, income, activity, etc.: evolution over time in the region
  - "Control totals" endogenous (predicted by demographic module) or exogenous at regional level; specific location within region endogenous
- Input-output matrices
  - Sector-specific economic activity
  - Usually endogenous in general equilibrium models, exogenous or omitted in disequilibrium models
- Land use
  - Large public/private projects, regulation
- Transport
  - Infrastructure, capacity, congestion laws on PC network
  - Infrastructure, supply on PT network

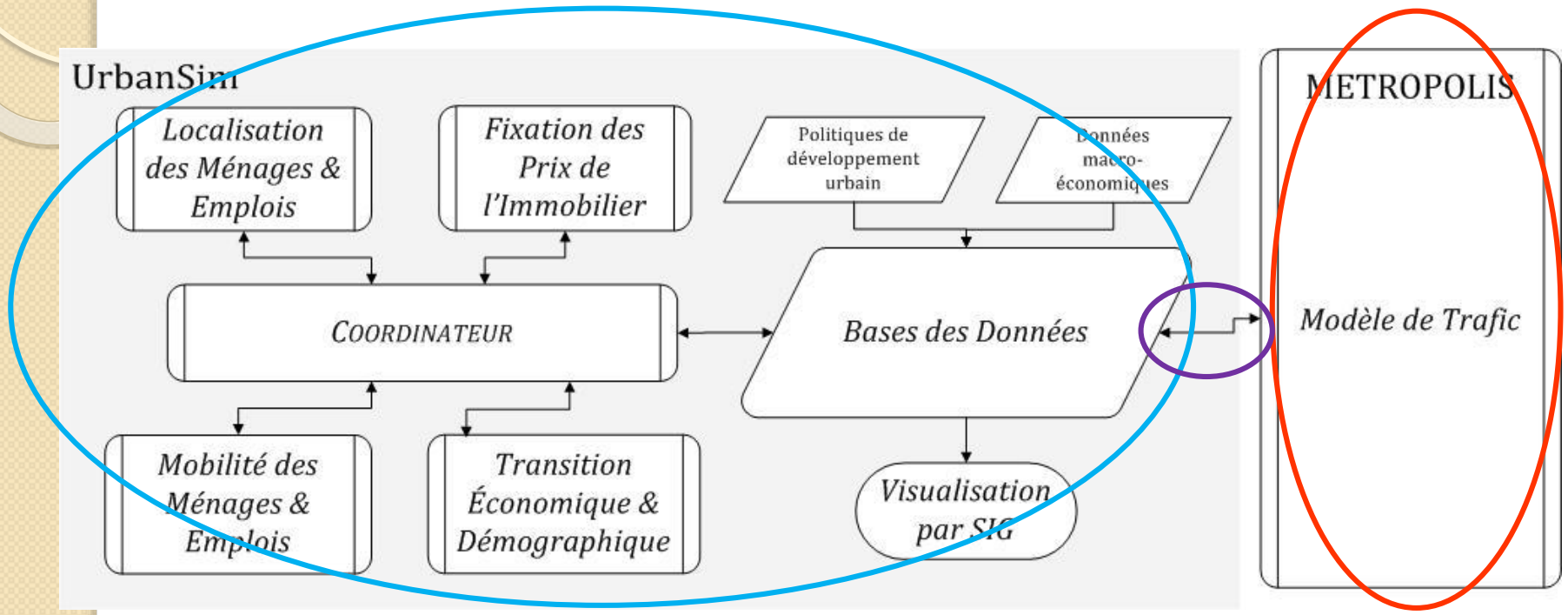
ZOOM ON EURBANSIMM

How EUrbanSimM runs



- Modular structure: one module represents one agent decision / one process
- Interactions loops: arrows

Principles of LUTI modeling

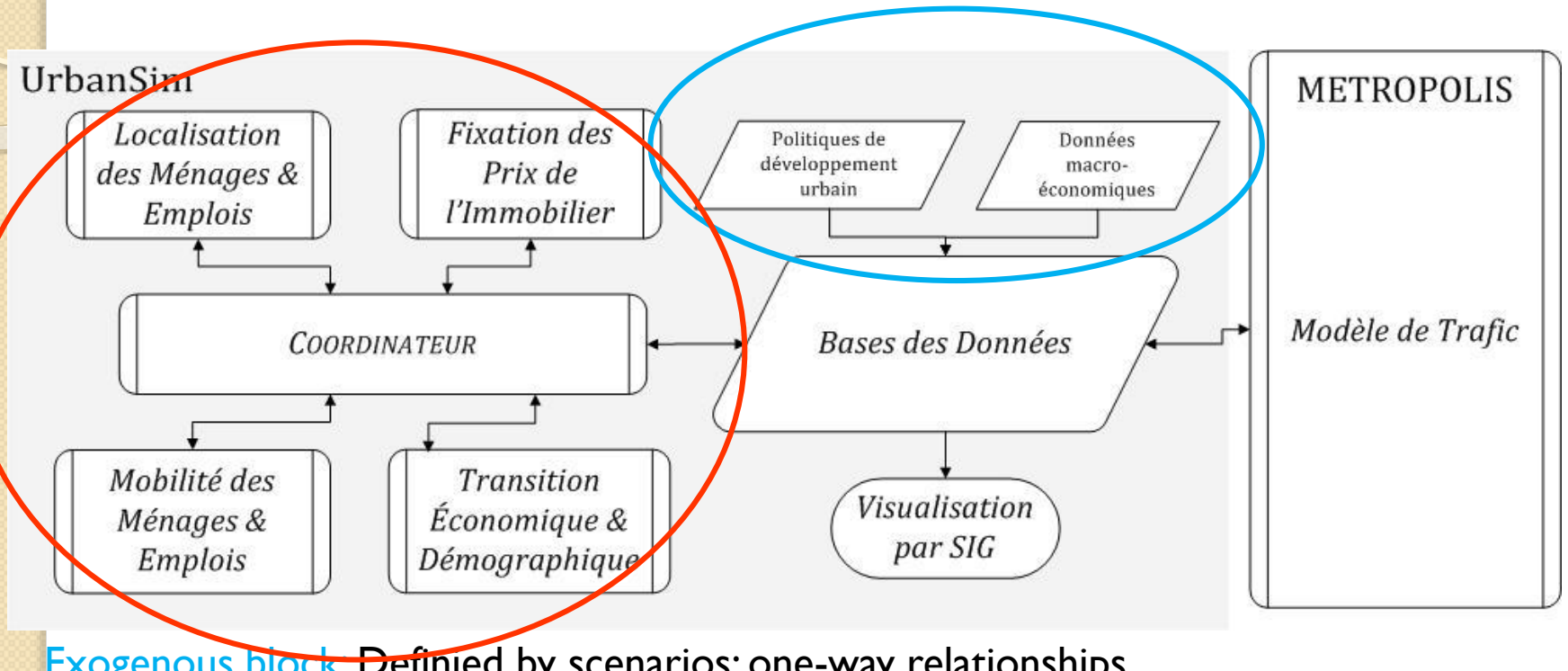


Land Use Part: Yearly interaction loops between modules within EUrbanSim

Transport Part: See André de Palma's lectures on Metropolis

Interaction Part: Interaction loops each 3 years between EUrbanSim & Metropolis

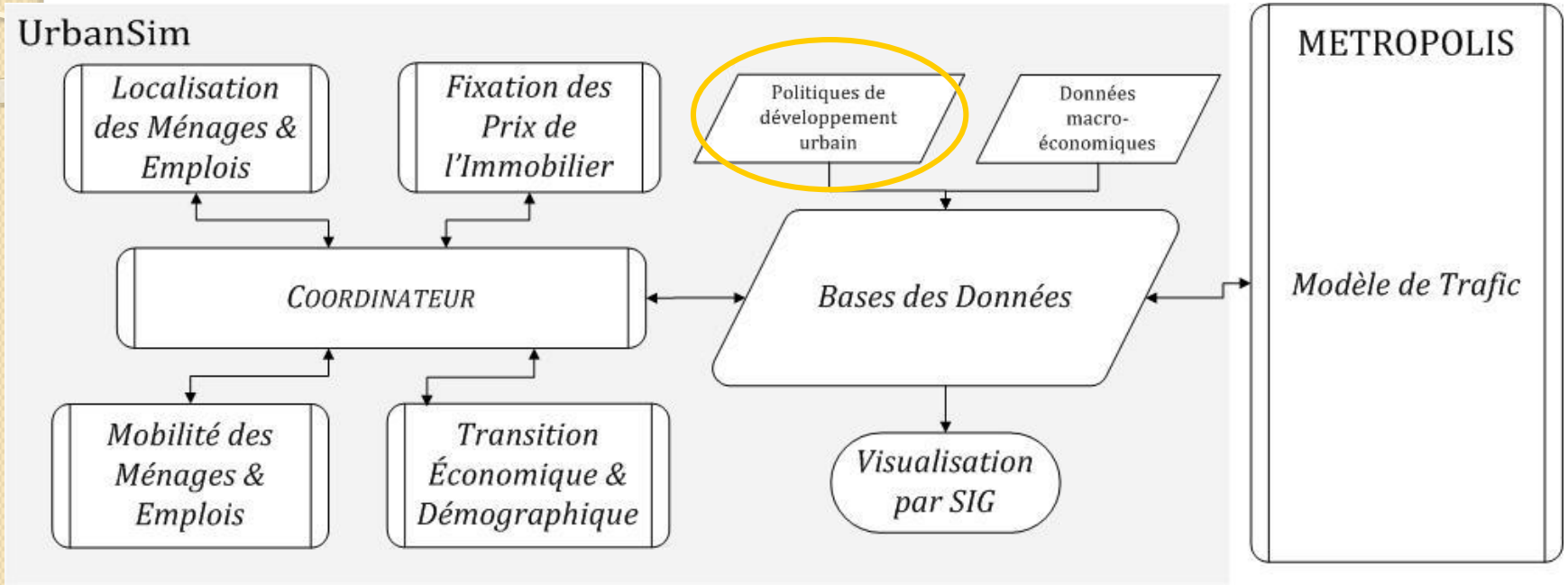
UrbanSim modules



Exogenous block: Defined by scenarios: one-way relationships

Endogenous block: Determined by EUrbanSim : two-way relationships : each module influences other modules and depends on other modules

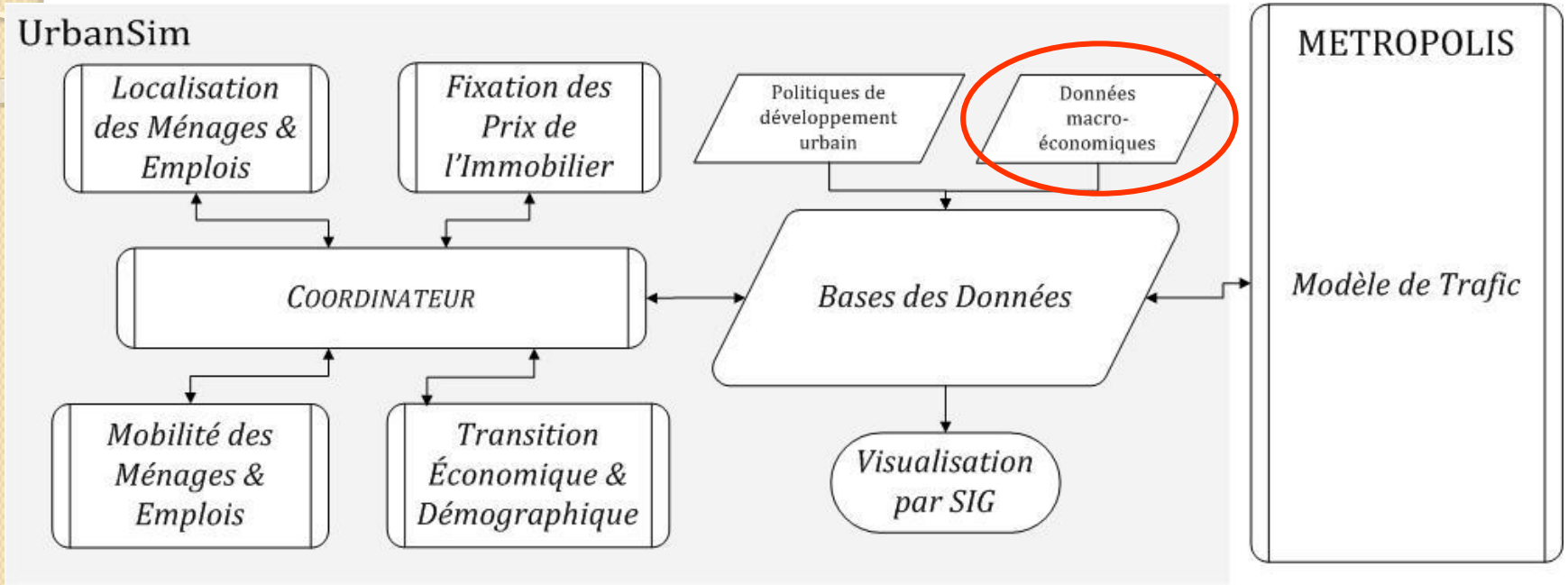
UrbanSimM modules



Opportunities for urban development

Local regulation and restrictions/constraints on land use and urban development.
Translates urban development policies (social housing, etc.)

UrbanSimM modules

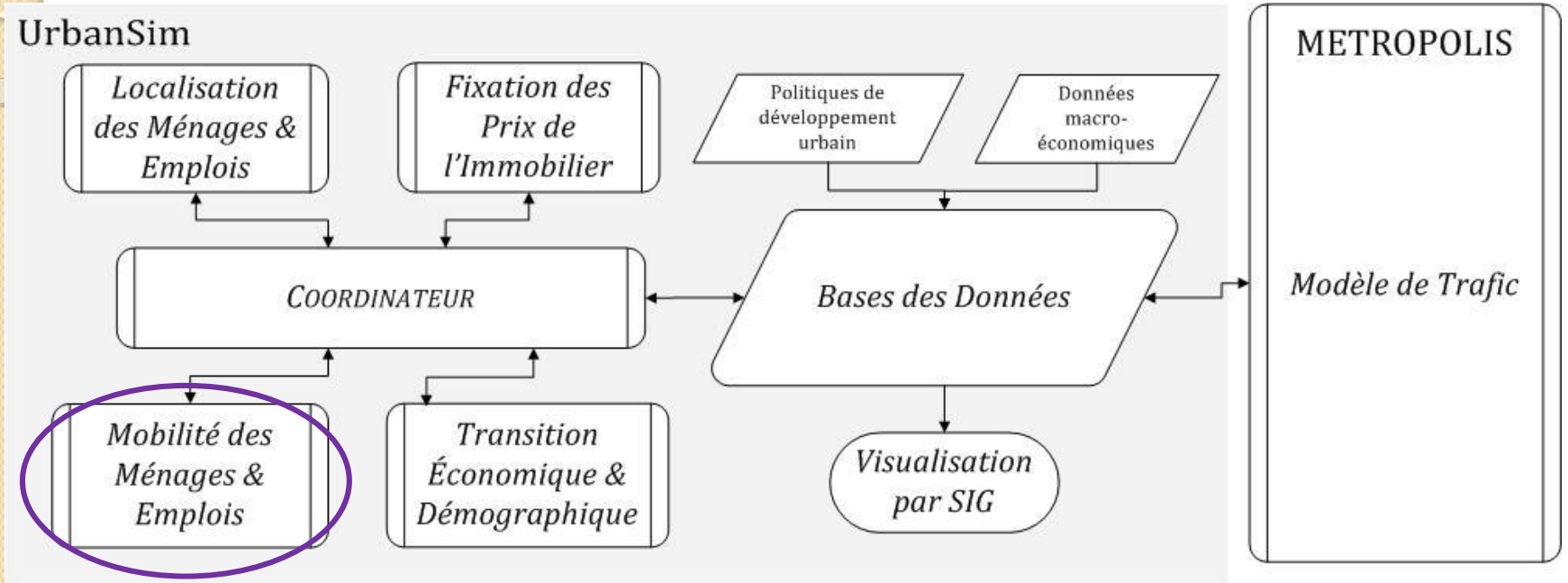


Macroeconomic data: Scenarios for economic development

Exogenous "P+E" Hypotheses on long-term evolutions aggregated at regional level

Could be endogenized using demographic module

UrbanSimM modules

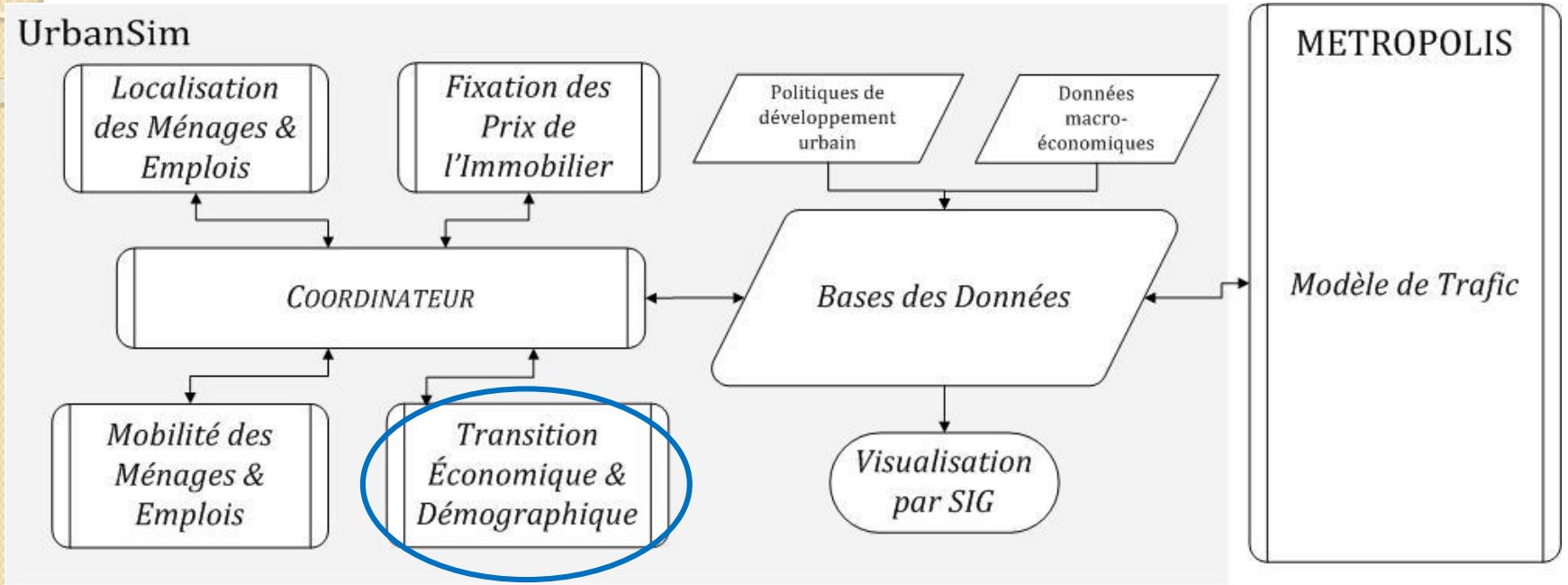


Mobility modules

Employment: death or relocation of firms

Households: relocation within/outside Ile-de-France region

UrbanSimM modules



Transition modules

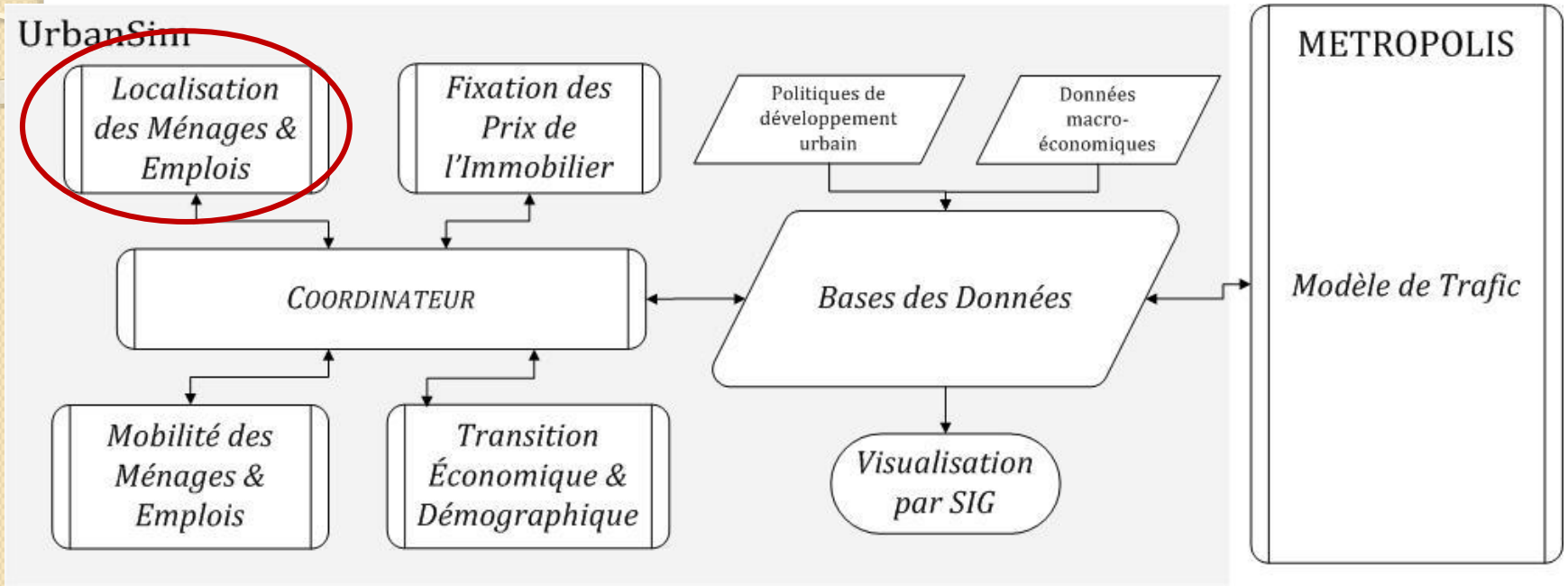
Economic transition: evolution of number and size of firms

Demographic transition: evolution of number and structure of households

Both at regional (aggregate) level

Building of dwellings and offices to ensure a minimum vacancy rate

UrbanSimM modules

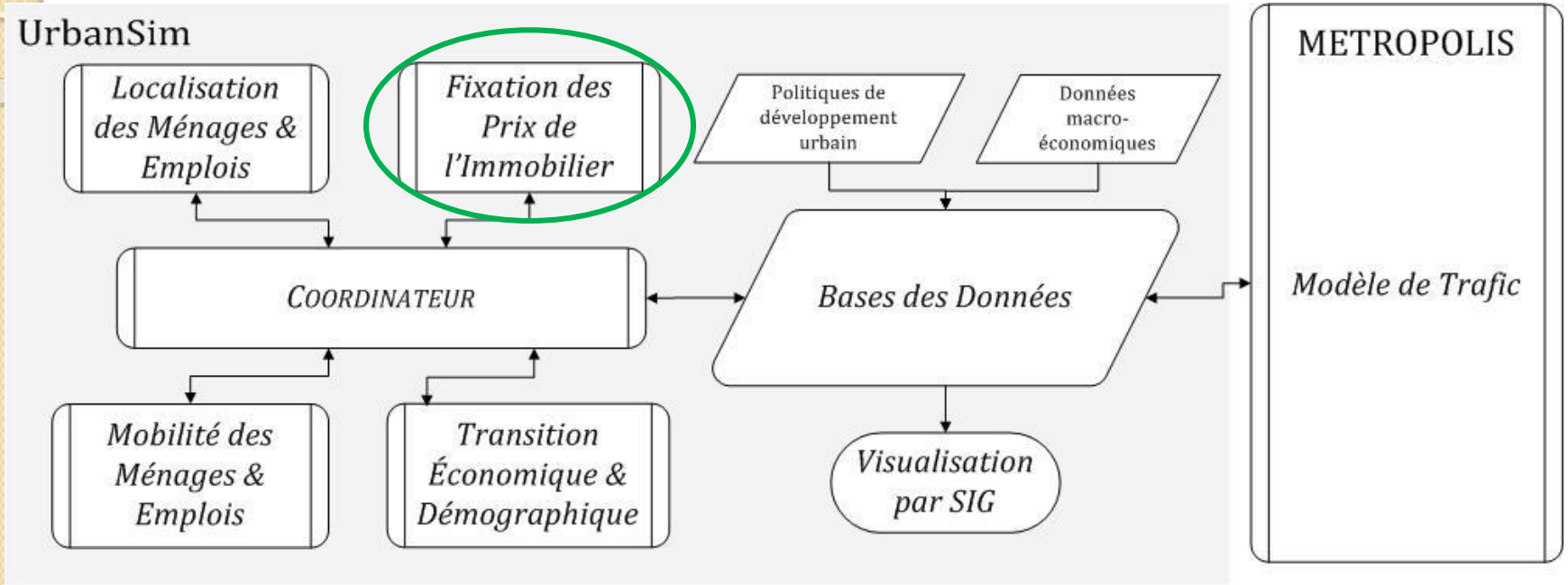


Location modules of:

firms by size and activity sector

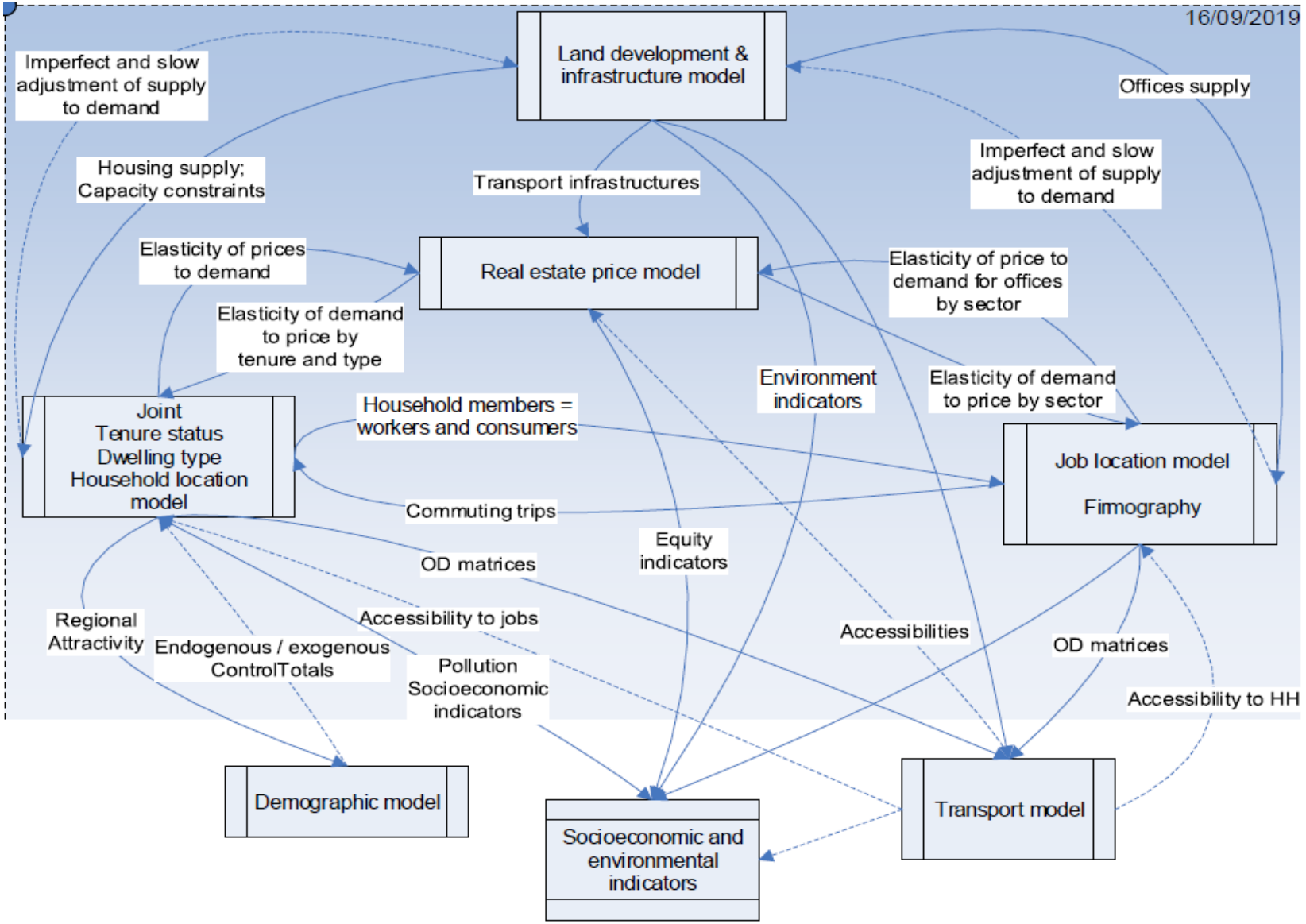
households by tenure status and dwelling type

UrbanSimM modules



Real estate prices module
by tenure status and dwelling type

Interactions modeled in UrbanSim

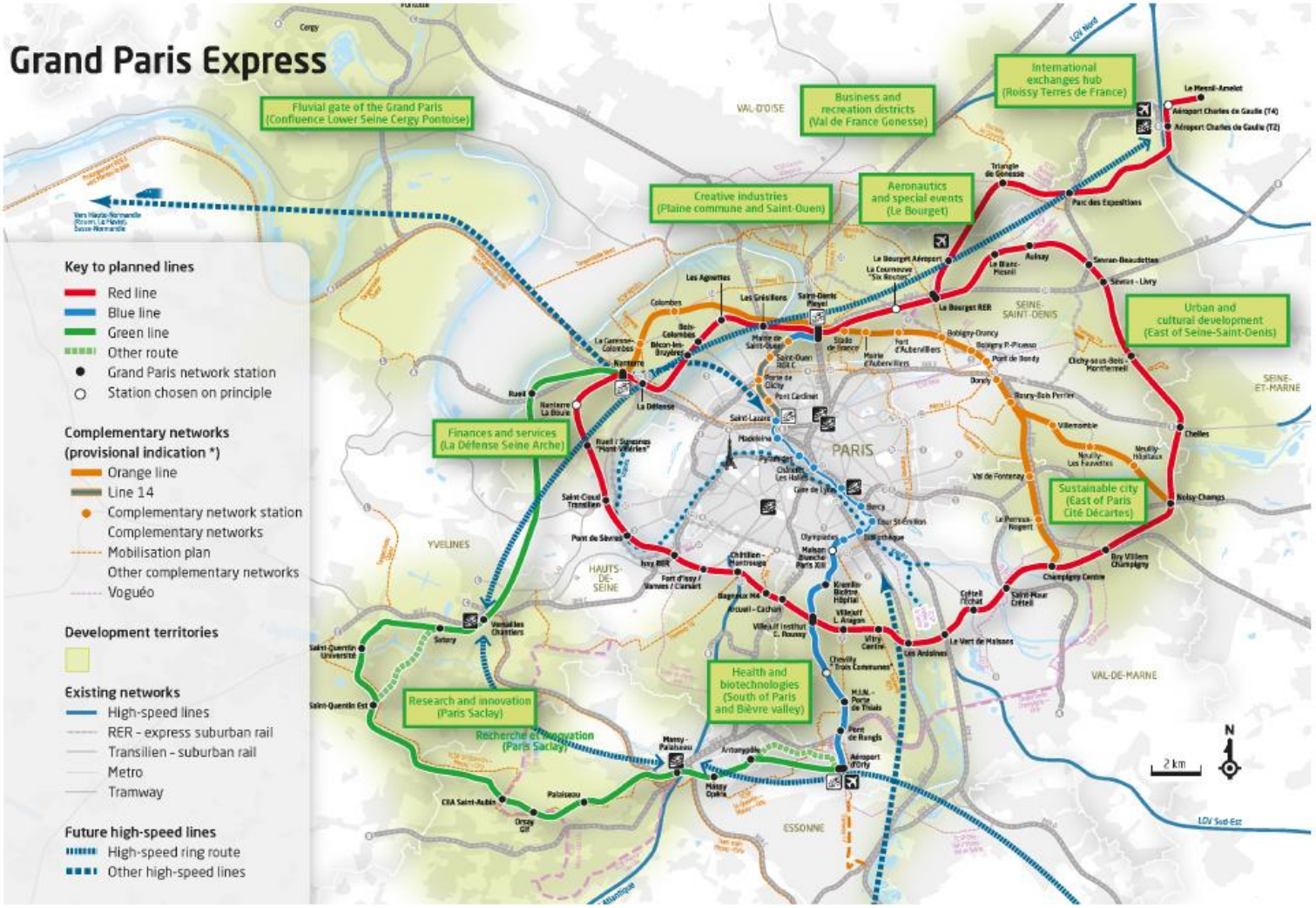


APPLICATION IN ILE-DE-FRANCE : GRAND PARIS EXPRESS

Grand Paris Express network

- « Transformational » infrastructure
- Largest project of PT network development since metro was built at the beginning of XXth century
- Progressive extension until 2035
- 4 automatic metro lines connected to existing network
- 160 km additional lines (50% of existing metro network)
- Nearly 100 new stations accessible to more than 100 communes, spread over a dozen of « CDT » (Contrat de Développement Territorial) or « hubs »
- 30 to 50 billion € budget

The Grand Paris Express network



Hubs around Paris → polycentric city

- Biotechnologies
- Clichy-Montfermeil
- Confluence (river transportation)
- Descartes
- La Défense (Finance)
- Le Bourget
- Pleyel
- Roissy-Pôle
- Saclay (« French Silicon Valley »)
- Val de France - Gonnesse

Scenarios modeled (in 2030)

- Reference Scenario (REF)
  - without Grand Paris Express projet
  - 1,348 million inhabitants more than in 2006
  - 0.685 million jobs more than in 2006
- Reference Scenario + GPE (S0)
  - Assumes that GPE will not attract additional population or jobs
- Low impact scenario (S1)
  - 1,406 million inhabitants more than in 2006
  - 0.8 million jobs more than in 2006
- Large impact scenario (S2)
  - Significant regional attractiviy induced by the project
  - 1.5 million inhabitants more than in 2006
  - 1 million jobs more than in 2006

Effect of GPE

- Reduce congestion in CBD (Paris city) by allowing direct suburbs-suburbs trips
- Concentrate jobs in the core of the region (Paris+ CDTs)
- Concentrate population in the core of the region, later and to a less extent
- Ile-de-France becomes a polycentric city

APPLICATION IN GRAND EST: STRASBOURG EUROMETROPOLE

Strasbourg metropole

- Specificities of International dimension
  - International commuting
  - Country-specific preferences and regulations
  - Households/workers choose their country of residence /work
    - International competition on labor and real estate markets
    - Fiscal optimization
    - Firms choose the location country of each establishment and recruit acroiss borders
- Huge data requirement

EXERCISE SESSION

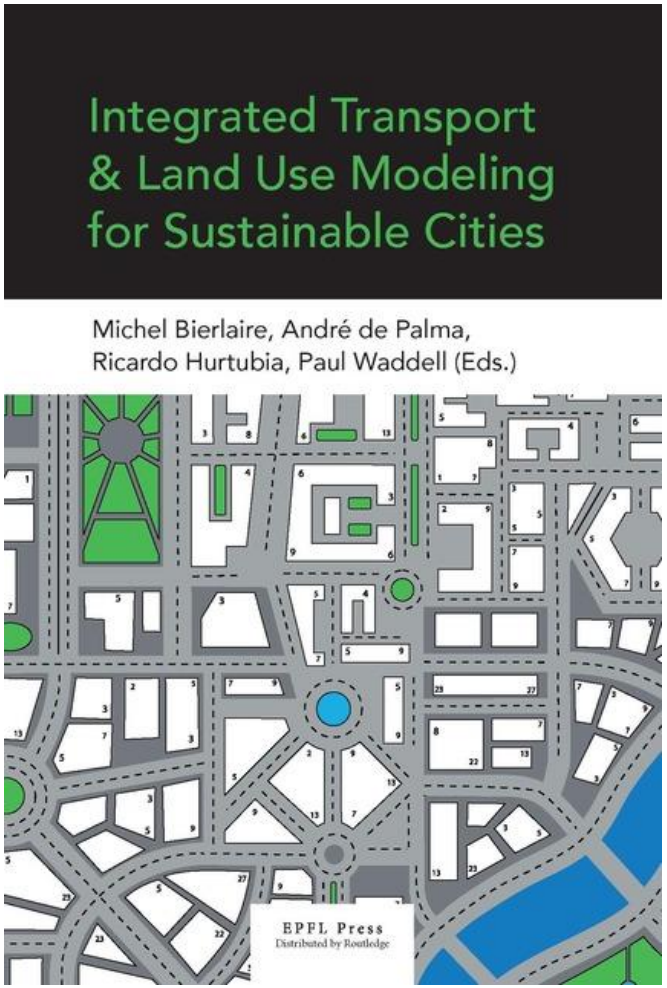
Global exercise on LUTI models Discussed interactively at the end

1. What are the main families of LUTI models?
2. Briefly describe their main principles and hypotheses, and their objectives (what they can be used for)
3. Discuss their respective advantages and drawbacks
4. Briefly develop an example of (existing or hypothetical) public policy, which can be evaluated using a LUTI model of your choice
5. Briefly describe an example of (planned or already implemented) transport project which can be evaluated using a LUTI model
6. What are the drawbacks of considering only either households or individuals residential location decisions?
7. What are the drawbacks of considering only either jobs or establishments or firms location decisions?

Some references

- de Palma A., K. Motamedi, N. Picard et P. Waddell (2005). "A Model of Residential Location Choice with Endogenous Housing Prices and Traffic for the Paris Region", *European Transport*, 31, 67-82
- de Palma A., K. Motamedi, N. Picard, P. Waddell (2007). "Accessibility and environmental quality: inequality in the Paris housing market", *European Transport*, 36, 47-74
- de Palma A., N. Picard, P. Waddell (2007). "Discrete choice models with capacity constraints: an empirical analysis of the housing market of the greater Paris region", *Journal of Urban Economics*, 62(2), 204-230
- Inoa, I., N. Picard, A. de Palma (2015). Effect of an Accessibility Measure in a Model for Choice of Residential Location, Workplace, and Type of employment, *Mathematical Population Studies*, 22(1), 4-36
- Picard, N. , A. de Palma (2019). Le modèle Urbansim, un outil d'analyse prévisionnelle de la localisation des emplois et de la population, in Les effets économiques du Grand Paris Express, Economica.
- http://www.sustaincity.org/

Further readings for those interested: Handbook on SustainCity project



- Ch. 7: Agent-based microsimulation of population dynamics (Turci, Pennec, Toulemon, Bringe, Baggio, Morand)
- Ch. 9: Intra-household Decision models of Residential and Job Location (Picard, de Palma, Inoa)
- Ch. 11: Modeling the life-cycle of firms and its effect on relocation choice (Bodenmann, Axhausen)
- Ch. 12: Econometric methods for land use microsimulation (Antoniou, Picard)
- Ch. 15: Indicators of sustainable development for microsimulation models (Proost, Van der Loo, Antoniou, Efthymiou)
- Ch. 16: Agile modeling: adapting UrbanSim to the European context using the Open Platform for Urban Simulation (Waddell, Wang, Sevcikova, Borning)
- Ch. 18: Integration of dynamic transport models and agent-based land use models (de Palma, Saifuzzaman, Motamedi)
- Ch. 20: Application of UrbanSim in Paris (Ile-de-France) Case study (de Palma, Picard, Motamedi)