A generic and modular simulation model for suburban densification

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Session: Simulating Social and Spatial Processes

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Context: the SUBDENSE project

The SubDense European project studies the dynamics of suburban densification by:

SUB DENSE

Understanding polyrationalities of space, actors and policies on suburban densification

- exploring how diverse strategies of land policy interact with landowners' and local stakeholders' interest and agency to shape suburban densification and their impact on suburbia across different planning systems (France, Germany, UK);
- combining quantitative approaches (geodata analysis and geosimulation) with qualitative approaches (social and policy science and planning).

A collaborative dashboard for mediation

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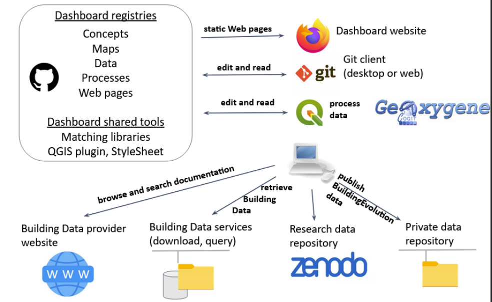


→ git-based architecture to share in a reproducible, transparent, and traceable way informations between experts on data products, metadata, code for processing data, etc. [Bucher et al., 2024]

→ matching algorithms for building change detection [Guardiola et al., 2024] (cf presentation in session on Change Detection)

Research objective

WP3 of the Subdense project: *"How do land policies respond to the interests and agency of stakeholders in an effective and efficient way?"*

→ simulation as a tool to explore "what-if" scenarios for policies

→ as for qualitative analysis and geospatial data analysis, a generic and transferable approach must be proposed

Research question:

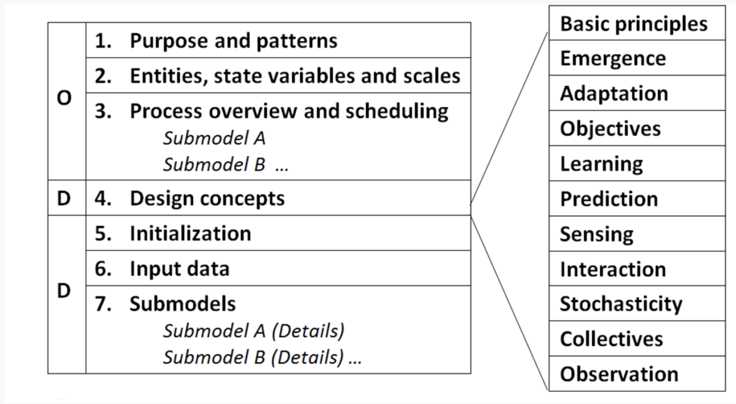
Which simulation model for densification processes to ensure comparability across countries and the exploration of policies?

Simulating urban densification

- [Burke et al., 2024]: Agent-based Model simulating the behavior of residents, developers, landowners, and the local zoning authority
- [Leao et al., 2018]: parcels and buildings as autonomous agents
- [Curie et al., 2010]: simulation at the block level
- [Pawar and Jha, 2023]: data driven abm of household relocation and its impact on density
- [Chakraborty et al., 2022]: Cellular Automaton models to model and predict urban densification
- [Chakraborty et al., 2025]: spatial statistics and machine learning

Model description following the ODD protocol

Overview, Design, Details: a protocol to describe ABMs in a standardised way [Grimm et al., 2020]



Overview

1. Purpose and patterns: spatial patterns of densification linked to driver variables and sustainability indicators, to explore and optimise policies linked to densification.

2. Entities, state variables and scales: all agents at the microscopic scale (intra-urban) within an urban area extent (mesoscopic scale) [Pumain, 2008]:

- City authority (monitoring indicators to adapt regulations: density threshold, financial incentives, ZAN, ZAC, ...)
- Developers (optimising constructed floor space: develop empty plots or densify/refurbish existing buildings; competition between developers?)
- Individual owners (move out, densify their houses, split their plots)
- **Buildings and Plots** are basic geographical entities without autonomous behavior

3. Process overview and scheduling:

1. If time step is a multiple of t_P, authority updates the regulation (strategy parameters: "limit sprawl" (increase density threshold), "maximise accessibility" (subsidised development projects), ...
2. Developers with a fixed budget:
   - Evaluate a set of areas for potential projects (SimPLU3D model for building potential [Brasebin et al., 2017])
   - Construct the more profitable development with a price signal $p = floor \times f(density, accessibility, \ldots)$
3. Landowners (randomly selected) need more space and either move out, densify, or split their plot (ParcelManager model [Colomb et al., 2022])

Design concepts

4. **Design concepts:**

Basic principles: highly simplified "economic behavior" of agents, with an accurate spatialisation

Emergence: densification dynamics

Adaptation: locations of agent choices depend on the situation

Objectives: contradictory objectives across agents

Learning: no learning, stationary behavior

Prediction: no prediction, react to the current situation

Sensing: price signal spatially known with noise

Interaction: between agents through the environment (regulations, buildings and plots, prices)

Stochasticity: randomness in choices (type "discrete choices")

Collectives: no endogeneity, strong emergence postulated with the authority

Observation: spatio-temporal distribution of density and prices

Details

5. Initialisation: plots and buildings (single-family houses and multi-storeys), one authority, a few developers, landowners a fixed proportion of dwellings

6. Input data:

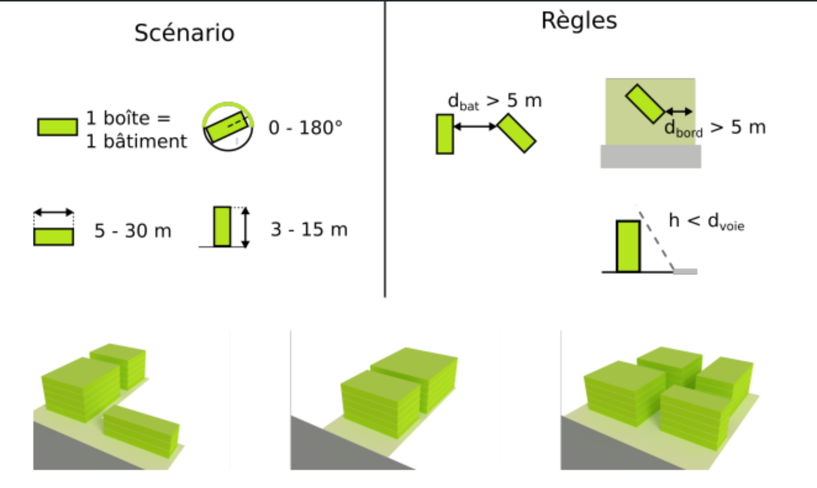
- synthetic data to remove geographical contingencies [Raimbault et al., 2019]: from a density landscape [Raimbault, 2018] or directly buildings [Raimbault and Perret, 2019]
- real plots and buildings from an urban area, filled with a synthetic population of landowners [Colomb et al., 2024]

7. Submodels:

- SimPLU3D to evaluate densification potential [Brasebin et al., 2017]
- ParcelManager for splitting plots [Colomb et al., 2022]
- Economic models for prices, developers behavior and utility, landowners discrete choices and utility

→ submodels can be included or not in a multi-modeling approach, to have a **modular** and **transferable** simulation model [Raimbault and Batty, 2021]

The SimPLU3D models optimises buildable envelopes given the *Plan Local d'Urbanisme* regulations [Brasebin et al., 2017]



The ParcelManager model to split parcels

The ParcelManager model provides several algorithms for a realistic splitting of parcels with road network access [Colomb et al., 2022]

Open issues and next steps

Open issues to sort out before continuing the model:

- Application of SimPLU3D to the German (explicit plan regulations) and UK (case by case regulations) contexts (already applied to the US)
- Which level of economic processes (price and market model, behavior of agents)?
- Genericity of developers and authorities across countries?

Next steps:

- Discussion with qualitative researchers and insights from fieldwork surveys in the three countries
- Systematic review of potential processes to be included, first version to be implemented
- Exploration on synthetic data to explore stylised policies [Kang and Raimbault, 2023]
- Application to case studies of the Subdense project
- Calibration on observed densification dynamics

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