FIG Working Week
May 18-22 2011

Urban modeling vs. actual cities: towards an operational assessment of mismatches

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Introduction

Urban growth models to forecast land-use change are currently the subject of **intense research activities**.

One of the challenges is **to assess to what extent models reproduce reality**. Each model is a simplified version of the actual world. Some aspects of the city may be simulated in a schematic way, while some others may be represented with an in-depth analysis.

For a given model, this leads to a **great robustness** along some dimensions, and to **unreliable results** along others: it is necessary to measure these strengths and weaknesses.

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Steps of the analysis

This study aims to **assess the validity of urban change models.**

The methodology described in this analysis is applied on the **dynamic economic land-use/transportation interaction model NEDUM2**, which predicts scenarios of urban growth in the Paris area.

We conduct the **calibration** of the model. Then we perform model validation by comparing actual **rents, population density and housing sizes** curves to curves obtained from the model.

In the second phase, we look into more scientifically founded indicators and we use **two methodologies** proposed in Pontius and Schneider (2001) and Pontius et al. (2004).

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Model calibration

Firstly, it is crucial to **distinguish between calibration and validation**. Separation between data used for the two procedures must be maintained.

In literature, we found several **definitions of calibration**.

Verburg et al. (2006): "the process of creating a model such that it is **consistent** with the data used to create the model".

Parker (2002): the "derivation of **best-fit model parameters** from real world data".

Rykiel (1996): "the estimation and adjustment of model parameters to improve the **agreement between model output and a data set**, as a demonstration that a model possesses a satisfactory **range of accuracy**, consistent with the intended application of the model".

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Model validation

Model validation:

– is the process of measuring the **agreement between the model prediction and independent data**. If there is a "good" match, then the method used to make the prediction is said to be valid (Verburg et al., 2006).

– **compares model outputs with real-world observations** or the product of another model that is assumed to adequately characterize reality (Parker et al., 2002).

– describes a test on which to base an opinion of **how well a model performs** so that a user can decide whether the model is acceptable for its intended purpose (Rykiel, 1996).

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Assessing the performance of land-use models

Manson (2003) raises a question about goals of validation: "It is not particularly useful to try to define a model as valid or as invalid. It is more useful to state carefully the **degree** to which a model is valid".

Models are able to provide insights regarding **some questions**. As a consequence, a validation process cannot be designed independently of the questions the model is supposed to tackle.

The majority of the existing land use models **lack a proper validation**.

The most common problem is failure to state what the **validation criteria** are. The only way to resolve disagreements over the meaning of validation could be the **establishing of a convention** (Rykiel, 1996).

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NEDUM

The Non Equilibrium Dynamic Urban Model (**NEDUM**), developed in CIRED, is conceived to address the stylized evolutions of urban systems through **time and space**.

NEDUM is based on **standard urban economics approached** (Von Thuenen, Alonso, Mills and Muth). Its approach allows to represent non-stationary states, taking into account inertia in households' relocation, in apartments' sizes, housing service production, and stickiness in housing rents.

NEDUM represented **transport costs** as a function of the distance to the city centre. The two-dimensional version (NEDUM2) introduces realistic transport infrastructure and thus reflects spatial heterogeneity in the agglomeration.

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Model hypotheses

The model relies on several **simplifying assumptions**.

- Firstly, there is a **unique city center**, and worker daily commuting is by one daily round-way trip to the center.
- Second, the trade-off between **transportation costs and accommodation size** as the major factor explaining **housing prices.**
- A third supposition is that the city structure is freely driven by **market forces**. Some constraints have been introduced, such as a limited building height.
- Finally, all households are supposed to have the **same income**.

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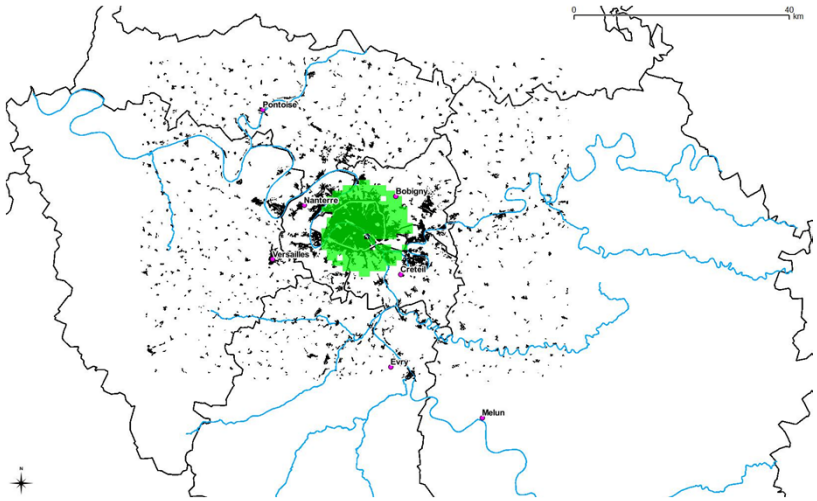
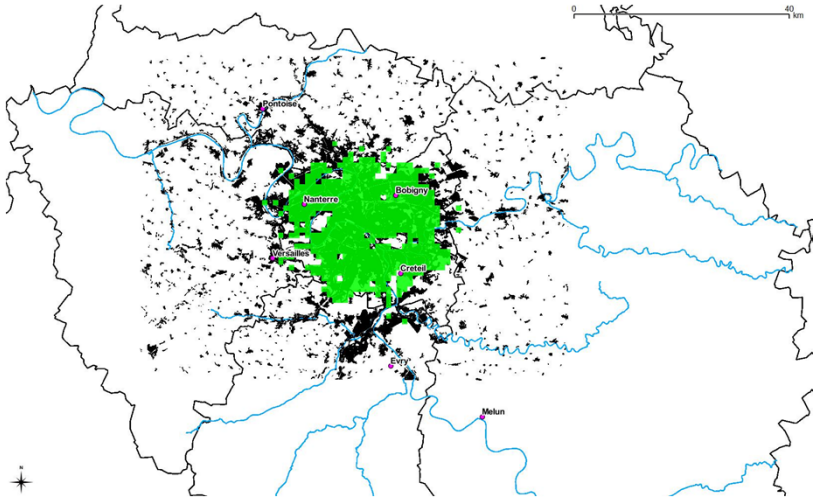
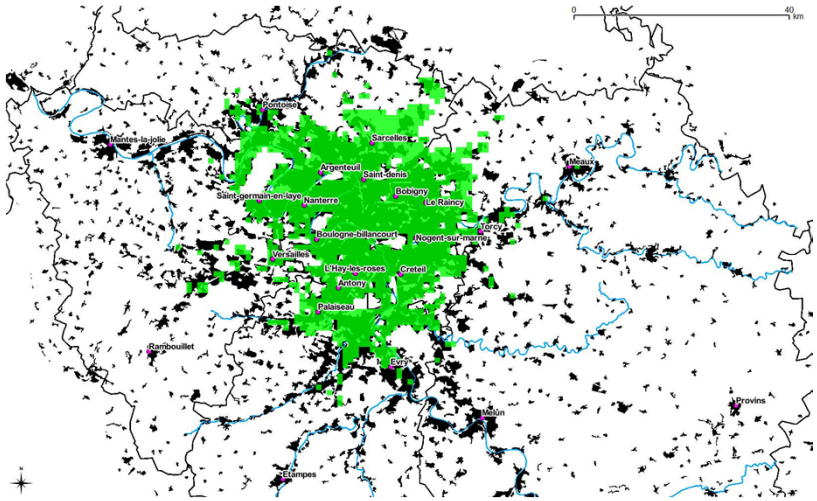
Paris urban area in 1900



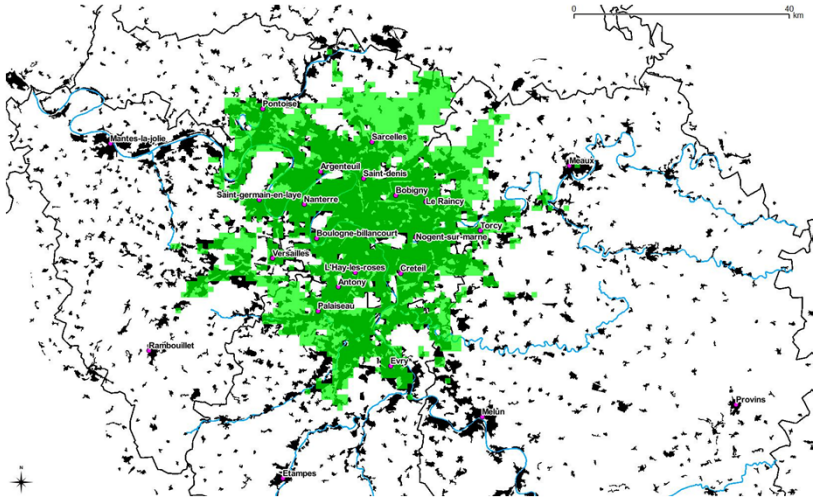
Paris urban area in 1960



Paris urban area in 1990



Paris urban area in 2006



Calibration and validation data

We conducted the model **calibration** in order to obtain an equilibrium as close as possible to the current profile of Paris area.

The table presents a summary of (i) the data that are used as a **direct input to the model** or as a model parameter; (ii) the **unobservable parameters** that need to be calibrated; (iii) the **data that are used to validate** the model.

First, we perform model validation by comparing **actual rents, population density and housing sizes** curves to curves obtained from the model.

Data used as model input	Calibration data	Validation data
Urban area population	Travel time cost as a function travel duration	Population density
Households average size	Rent determining city border	Rents and real estate prices across the city
Households average income	Households utility function parameters	Accommodation size (only at 3 points across the city)
Transport prices	The 2 coefficients determining construction costs	*Indications over construction costs*
Transport times		*Indications over travel time cost*

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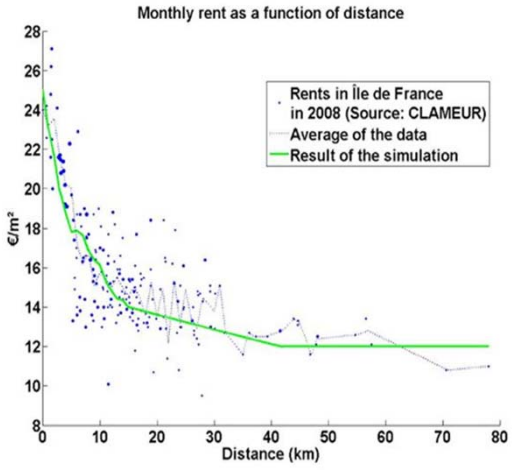
Actual rent (2008) and rents computed by the model



The model describes the evolution of rents across the city quite satisfactorily. There`s just a modest bent to underestimate the rents.

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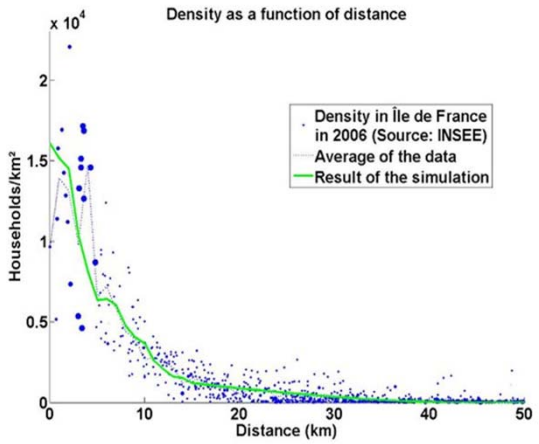
Actual population density (2006) and density computed by the model



The model gives as a result a growing density when getting close to the city centre. This is probably one of the limits of the monocentric model. However, the agreement between the model and the data seems satisfying.

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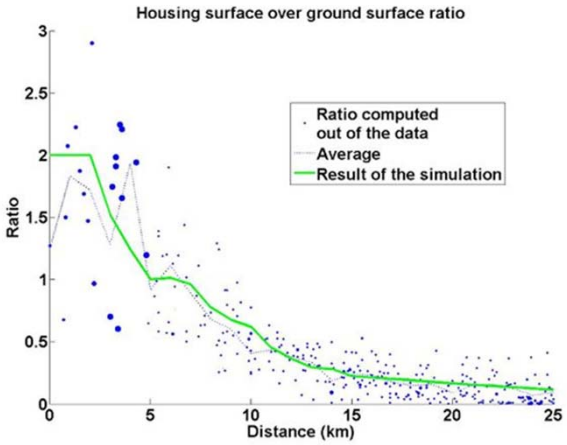
Actual dwelling density (2006) and computed by the model



The figure compares the ratio of actual inhabited surface and inhabited surface calculated by NEDUM2 . The agreement between the model and data seems here very satisfactory.

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Pontius and Schneider (2001) methodology

In 2001, Pontius and Schneider presented a method of validation that gives a quantitative measurement of the distance to perfect prediction called the Relative Operating Characteristic (**ROC**).

Pontius Jr R. G. and Schneider L. (2001). Land-cover change model validation by a ROC method for the Ipswich watershed, Massachusetts, USA. Agriculture, Ecosystems & Environment 85 (1-3) p.239-248.

The actual change map (the Corine Land-cover database) is given in terms of **"urbanized" or "non-urbanized" land**. We set the ratio **threshold** beyond which an area is considered urbanized.

The value of the floor area ratio that sets the limit of the city plays an important role in the accuracy of the model.

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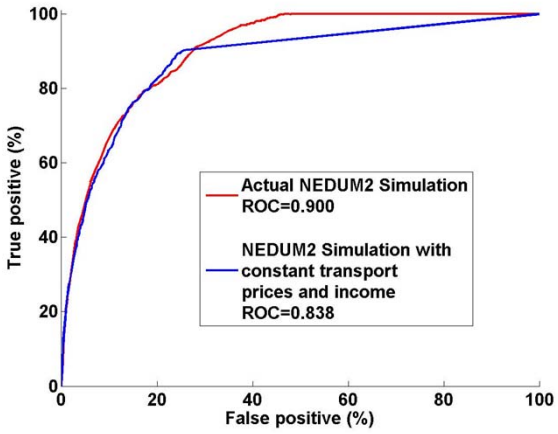
ROC curves



The simulation NEDUM2 gets a better result than the "special" simulation (blue line): this means that it is possible to improve the model and make our simulation more efficient than the "special" simulation by changing this marker.

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Pontius et al. (2004) methodology

We also tested the validation method described in Pontius et al. (2004). It budget **sources of agreement and disagreement** between the prediction map and the reference map.

It compares the predictive model to a **Null model** that predicts pure persistence.

Pontius Jr R. G., Huffaker D. and Denman K. (2004). Useful techniques of validation for spatially explicit land-change models. Ecological Modelling 179(4) p.445-461.

We compared the results of **different simulations**: NEDUM2 with constant transport prices and income, NEDUM2 with evolution of these values, city evolution proportional to population growth and the Null model (no city evolution).

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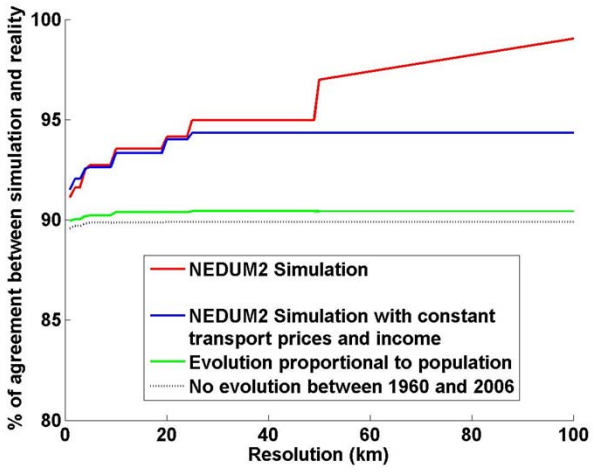
Simulations results



Comparison of the results of various simulations. The y axis specifies the resolution in square kilometers, in order to evaluate how the scale influences the assessment.

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Conclusions

This prior validation process yielded quite **satisfactory results**.

NEDUM2 reproduces fairly faithfully the available data on the Paris area and it is satisfactory in answering to specific questions.

In particular, when examining urban structure on a long term horizon and at the scale of an agglomeration, it is realistic to suppose that **real estate prices are fundamentally driven by transportation costs**.

To further improve the validation of NEDUM2, we have initiated a reflection on a set of other indicators.

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Thank you!

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