Impacts of urban spatial structure on air quality

an integrated modeling approach

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Work in progress!

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Urban forms matter for greenhouse gas emissions...

The Built-up Area of Atlanta and Barcelona Represented at the Same Scale

Lower emissions in Barcelona because of:

1 - Shorter travel distance;

2 – Easier use of public transport:

Barcelona has 99 km of metro line.

To provide the same accessibility to metro in Atlanta, 3400 km would be necessary.

Source: Alain Bertaud
Urban Heat Island effect

Temperatures are higher in cities than in rural areas, especially at night.

Example of the 2003 heat wave.

Source: CNRM, Météo-France (V. Masson, G. Pigeon, A. Lemonsu, C. Marchadier)
Cities and climate change

- **Urban forms matter for greenhouse gas emissions**
  - Transport, housing, ...

- **Urban forms matter for climate-change vulnerability**
  - Urban heat island
  - Urbanization in flooding prone areas...

- **Urban forms matter for many other policy objectives, e.g., related to social and spatial inequalities, competitiveness...**

- **Urban forms cannot change rapidly, so we already need to take into account current and future constraints**
  - Unprecedented need to anticipate future constraints and objectives and to act with no delay
State of urban air quality in France / Europe

- **A European issue**
  - Air pollution levels remain a concern in many parts of Europe
  - Transportation is a major contributor to NOx (55%) and fine PM (30%) emissions. It also generates very close proximity to emissions.

Evolution of hourly concentrations at all stations of the AIRPARIF air quality network for a week of summer 2007

*Source: I. Coll*
State of urban air quality in France / Europe

- A European issue
  - Air pollution levels remain a concern in many parts of Europe
  - Transportation is a major contributor to NOx (55%) and fine PM (30%) emissions. It also generates very close proximity to emissions.

- Always a key political issue in the agenda
  - Epidemiological research confirms the significant long-term impact on human health
  - Increasing expectations of urban populations confronted with environmental and public health issues
  - ... but
  - Uncertainties about the evolution of pollutant background concentrations
  - Incomplete implementation of existing air quality policies
  - Such trends remain incompatible with sustainable development
Research question

- What are the impacts of the form of urban growth on air quality?
  - Go beyond the only consideration of emission control
  - Identify urban growth scenarios leading to low pollution levels

- A confrontation of several mechanisms
  1. In a compact urban form, pollutant emissions can be lower than in a sprawled city (*higher public transport/non-motorized travel modal share*)
  2. In a compact urban form, pollutant emissions can be higher than in a sprawled city (*increased congestion*)
  3. In a compact urban form, everybody leaves closer to emission sources...
Project goals

- Several works have investigated into this issue
  - E.g. Borrego et al. 2006, De Ridder et al. 2008, Martins 2012, Schindler et Caruso 2014...
  - The result of the confrontation of the 2 mechanisms depends on the type of pollutant, and on the city
  - Also depends on the type of vehicles → technological change can have an important impact

- Many questions still need to be addressed
  - What result for the case of Paris?
  - To what extent can mitigation policies (e.g. vehicle efficiency increases, electric vehicles...) influence this issue?
  - To what extent can adaptation policies (e.g. city greening) influence this issue?
  - Are there thresholds? Non-linear relationships?
  - Is there an optimal density/urban form when considering both CO2 emissions and air pollution?
  - Is the link between urban shape and air quality significant enough to play a role in the public debate?
  - ...

Vincent Viguié

29/07/2015
Proposed approach

- Integrated city modelling

- Build an integrated modeling chain from existing proven models
  - Based on existing expertise rather than reinventing state-of-the-art models
  - Designed to provide new type of analyses, through thematic transversality

- Challenges:
  - Heterogeneity of philosophies
  - Heterogeneity of refinement degrees for a given parameter / urban component
  - Uncertainty cascade
Better model the interactions urban activities - Environment

Physical parameters, choice of urbanization, transport ...

Environmental policies (urban forms, economics, energy)

MODUS / GREEN models
Model for modal allocation and traffic simulation
Construction of traffic flows
Calculating associated emissions

NEDUM 2D: Socio-economic model / interaction transport–landuse
Rearrangement of urban space
Transport costs
Rent cost

Urban consequences of policy choices
→ Location of new employment centers and residential areas
→ New landuse

City structure & urban fabric

Emissions linked with road traffic
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CHIMERE model: air quality / concentration fields
CHIMERE TOOL: Chemistry Transport Model

- Internal modules for calculation
  - Chemical scheme
  - Thermodynamics
  - Transport scheme
  - Solver

- Meteorological Parameters (model)
  - Gridded concentration fields
  - All calculated species

- Chemical fields
  - (large scale models)

- Emissions
  - (database – emission models)

Species:
- \(O_3\)
- \(NO\)
- \(NO_2\)
- \(PM10\)
- ...
First results (work in progress)

- We compare 2 scenarios
  - Paris today *(reference case)*
  - **Compact scenario**: Paris, as if strong land-use policies had been implemented since 1960 to promote a compact city development
First results (work in progress)

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- Paris today (reference case)
- Compact scenario: Paris, as if strong land-use policies had been implemented since 1960 to promote a compact city development

2008: REAL SITUATION

2008: DENSIFYING ONLY 1960 EXISTING URBAN AREAS
First results (work in progress)

- **We compare 2 scenarios**
  - Paris today *(reference case)*
  - **Compact scenario**: Paris, as if strong land-use policies had been implemented since 1960 to promote a compact city development

- **Apart from transport related emissions, all emissions are the same**

- **Simulation for the weather of the first week of January 2009**
  - NB: we only simulate emissions due to commuting trips
  - We make here no difference between week days and weekend
First results (work in progress)

- NO concentration in the \textit{reference} scenario

7 a.m. at the end of a week corresponding to the first week of January 2009
First results (work in progress)

- NO concentration in the *compact* scenario

7 a.m. at the end of a week corresponding to the first week of January 2009
First results (work in progress)

- In the middle of the city, NO concentration appears higher, in average, in the compact scenario

- But the difference is very small...

- Work in progress! (issue with congestion ?...)

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