TIMES and prospective modelling for urban planning

Study on the evaluation of urban transformation scenarios that respond to both energy, climate and socio-cultural issues.

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Cities are a key factor of **climate change mitigation**:

- increasingly concentrating *population*;
- responsible for a large part of *GHG emissions* and *energy consumption*;
- *complex systems*.
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French **urban planners** and stakeholders are not well equipped to face **long-term** issues:

- no *scientific* background (no idea of what is possible);
- no *money* for studies or scenarios;
- already *strong challenges*;
- *but* a high interest on *strategic* advices.
1 State of the art
   - Existing reviews
   - Topics

2 TIMES and urban modelling
   - Prospective modelling approach applied to cities
   - Issues already identified
   - TIMES city modelling

3 Conclusion and perspectives
Section 1

State of the art
Already a lot of works:

- because of the key role played by cities in climate change issues [OECD, 2010; UN, 2016; UN, 2017];
- because cities are gathering many people who want a certain quality of life;
- because of national or european funds (FP7\(^1\), ANR\(^2\));
- because of private interests (property developers, energy companies, software developers...);

\(^1\)European program.
\(^2\)ANR: French national agency for research.
<table>
<thead>
<tr>
<th>Source</th>
<th>Desc</th>
<th>Scale</th>
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<tr>
<td>Keirstead et al., 2012</td>
<td>comprehensive review on <strong>Urban Energy Systems</strong></td>
<td>Variable</td>
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<tr>
<td>Grimmond et al., 2010; Grimmond et al., 2011</td>
<td>on <strong>surface energy balance</strong></td>
<td>Building</td>
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<td>Alhamwi et al., 2017</td>
<td><strong>tools</strong> (GIS) oriented and review</td>
<td>City</td>
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<td>Shi et al., 2017</td>
<td>replace <strong>buildings shapes</strong> creation by computer-assisted tools</td>
<td>Building</td>
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<td>Allegrini et al., 2015</td>
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<td>Mendes et al., 2011</td>
<td><strong>ICES</strong> (Integrated Community Energy Systems)</td>
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<td>C. Kennedy et al., 2011</td>
<td><strong>metabolism</strong> approaches</td>
<td>City</td>
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<td>Geneletti et al., 2017</td>
<td>sustainable approach in <strong>periurban</strong> fringes</td>
<td>Peri-urban</td>
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<td>Swan et al., 2009</td>
<td><strong>energy consumption</strong> in residential</td>
<td>Sector</td>
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<td>Engel-Yan et al., 2005</td>
<td><strong>infrastructures</strong> and quality of life</td>
<td>District</td>
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<td>Connolly et al., 2010</td>
<td>integration of <strong>renewable energy</strong></td>
<td>Variable</td>
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<tr>
<td>Vreenegoor et al., 2004</td>
<td><strong>energy performance</strong></td>
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Topics I

- Cities operations, investment decision, location choice, e.g. Artelys software;
- Climate modelling, e.g. for renewable energy sources potential [Amado et al., 2012];
- Urban Heat Island mitigation, e.g. [Masson et al., 2014; Salvati et al., 2017];
- Pollution simulation, e.g. cf. CEREA (ENPC) work;
- Urban metabolism and flux, e.g. [Barles, 2015; Christopher Kennedy, 2012];
- Building and building energy consumptions optimisation, e.g. [Swan et al., 2009; Nouvel et al., 2017];
- Transport and mobility, e.g. [Arampatzis et al., 2004];
- Urban growth, e.g. [Angel et al., 2007];
- Representation of existing buildings in a city [Gadsden et al., 2003; Mutani et al., 2016; Kellett et al., 2013; Tornay et al., 2017];
- Inhabitants behaviors, e.g. [Le Gallic et al., 2016; Schwartz, 2006];
- Decision support, e.g. [Haurie, 2001; Fragniere et al., 1999; Assoumou et al., 2015].
Also legal or institutions inputs in France:

- Energy issues barely taken into account in planning legal documents;
- Climate change mitigation acknowledged but not prioritized of high importance;
- Fauna and flora more watched (obligation to preserve, compensate, etc.);
- Advices from government, national or regional agencies (e.g. ADEME) to include climate change issues into urban and regional planning documents.

Urban planners:

- Contextual approaches;
- Attracting elements in the territory;
- Respect of existing buildings.
Figure: Set of similar projects or models
Conclusions

On research:

- No study from urban planning point of view;
- Not many studies on long-term (e.g. Masson et al., 2014);
- Often on a too detailed scale (building) or too large (aggregate at city level) for urban planners;
Conclusions

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From research:
- Data availability at studied level is a key issue;
- Cities are highly dependent of their environment and close regions;
Section 2

TIMES and urban modelling
Interest and goals

**Current approaches** from urban planners met in France:

- *Intuitive*, experience-based;
- Respect of the *territory logics*;
- *Ideas* on ecology, energy and social;
- Slowly using *data science* potential (through technical consultants).

Need from urban planners:

- Data increasingly available;
- Insert sciences in the process of urban creation;
- Careful: not replace urban planners but provide decision support;
- Evaluate if their ideas do respect their intentions;
- “Think before drawing”;
- Give insight of long-term data concerning scenarios of development;
- Apply prospective modelling to town planning.
Interest and goals

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Issues already identified

Data:
- Often not available at wanted scale;
- Confidentiality issue (local authorities not willing to give away their data);
- Coherence, ambiguity, reliability.

Scale:
- Too detailed (520 regions?): makes it incalculable; blurs the interpretation; diminishes the effects of urban transformations; makes it impossible to find relevant and precise data.
- Too general (only cities? whole metropolitan?): how to take into account local changes; how to respect the geography and existing artificial elements; needs another model between both scales; not relevant.

How to represent non energetic, social, aesthetic issues?
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How to represent non energetic, social, aesthetic issues?
Choose a city;
How?

- Choose a city;
- Define the **smallest scale** depending on available data (IRIS for France);

![Diagram illustrating the process with nodes labeled City, Data, and TIMES.]

- From data;
- From urban planners experience;
- From imagined scenarios.

Assemble each small element (IRIS) with archetypes;

- Separate the city territory in zones:
  - Following districts or cities boundaries;
  - Because of urban logic;
  - Similar from a data perspective;

- Add constraints, scenarios (TIMES);

Apply solutions to the territory [Nouvel et al., 2015].

City

Data

TIMES
How?

- Choose a city;
- Define the **smallest scale** depending on available data (IRIS for France);
- Create technologies for each different "way of living in cities", for each **archetype** [Christen et al., 2012; Kellett et al., 2018; Gadsden et al., 2003; Mutani et al., 2016]:
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- Add constraints, scenarios (TIMES);
- Apply solutions to the territory [Nouvel et al., 2015].
Results on Bordeaux (France)

Figure: Examples of data for Bordeaux metropolitan territory

**Pluridisciplinary** by Gonçalves et al., 2017; **Urban ecosystems** by Larondelle et al., 2013; **Sociology, migration and agriculture** by laquinta et al., 2000; **Statistics** by Danielaini et al., 2017; **Land-use and satellites pictures** analysis by Huang et al., 2016.
Results on Bordeaux (France)

Figure: Examples of result for Bordeaux metropolitan territory
Zones

Figure: Zones (5) and archetypes (30) fusion: each zone has $X$ times each archetype.
Section 3

Conclusion and perspectives
Real need from *urban planners* for scientific validation and means of comparison. Real need for *energy* issues for long-term modelling.
Work in progress

First step done:
- Choice of a specific city (Bordeaux in France);
- Data collection;
- Representation and clustering of small areas of the city.

Next steps:
- More data needed (unavailable online);
- TIMES modelling.
Thanks

Thank you for your attention!
Open to any suggestion!

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Context of the PhD

PhD, Center for Applied Mathematics (MINES ParisTech)
Supervised by Nadia Maïzi

Collaboration with Agence Nicolas Michelin & Associés (french architecture and urban planning agency located in Paris):
- That instigated the project;
- To think of a way to help urban planners and not replace them;
- To discover how this unknown domain works;
- To have applications opportunities;
- To have information from the inside of town planning companies.

Supervised by Mélusine Hucault
<table>
<thead>
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<th>Source</th>
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<td>BDX</td>
<td>woods</td>
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<tr>
<td></td>
<td>group #**</td>
<td>21 groups according to activities zones of local land-use plan</td>
<td>/</td>
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<tr>
<td></td>
<td>flood zone**</td>
<td>groups according to flood risk prevention plan</td>
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<tr>
<td></td>
<td>forest fires**</td>
<td>groups according to natural risk prevention plan</td>
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<td></td>
<td>flu trans***</td>
<td>motorized flows between zones [CUB et al., 2009]</td>
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<tr>
<td>Urban atlas (Copernicus)</td>
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<td>Green spaces area</td>
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<td>cop moy trees</td>
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<td>cop build area</td>
<td>Built land area</td>
<td>%</td>
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<td>Enedis</td>
<td>enedis cons resid</td>
<td>Residential sector electricity consumption</td>
<td>MWh</td>
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<td>Services sector electricity consumption</td>
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<td>PV electricity production</td>
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### Data used (uptil now) II

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<tr>
<td>IGN</td>
<td>ign built area</td>
<td>Built land area</td>
<td>%</td>
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<td></td>
<td>road length perc****</td>
<td>Road length</td>
<td>m/m²</td>
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<tr>
<td></td>
<td>road area perc****</td>
<td>Road area</td>
<td>m²/m²</td>
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<td></td>
<td>pop density</td>
<td>Population density</td>
<td>inhab/m²</td>
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<tr>
<td></td>
<td>duration moving</td>
<td>Average duration since move-in</td>
<td>year</td>
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<tr>
<td>INSEE</td>
<td>housing aver area</td>
<td>Average area of housing</td>
<td>m²</td>
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<tr>
<td></td>
<td>nb flats</td>
<td>Number of flats</td>
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<td></td>
<td>nb housing</td>
<td>Number of housing</td>
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<td>nb houses</td>
<td>Number of houses</td>
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<tr>
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<tr>
<td></td>
<td>distance center</td>
<td>Distance to metropolitan center</td>
<td>m</td>
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</tbody>
</table>

* only recommandations from local authority.
** not usable like that (very specific to some IRIS).
*** data from CUB et al., 2009.
**** separates IRIS between high density, around the center and the others, with a low density, mostly in periphery.


