An Overview of Multimodal Transport Design and Challenges Underlined by a Carsharing Case-study

Lionel SCREMIN, MIC project manager

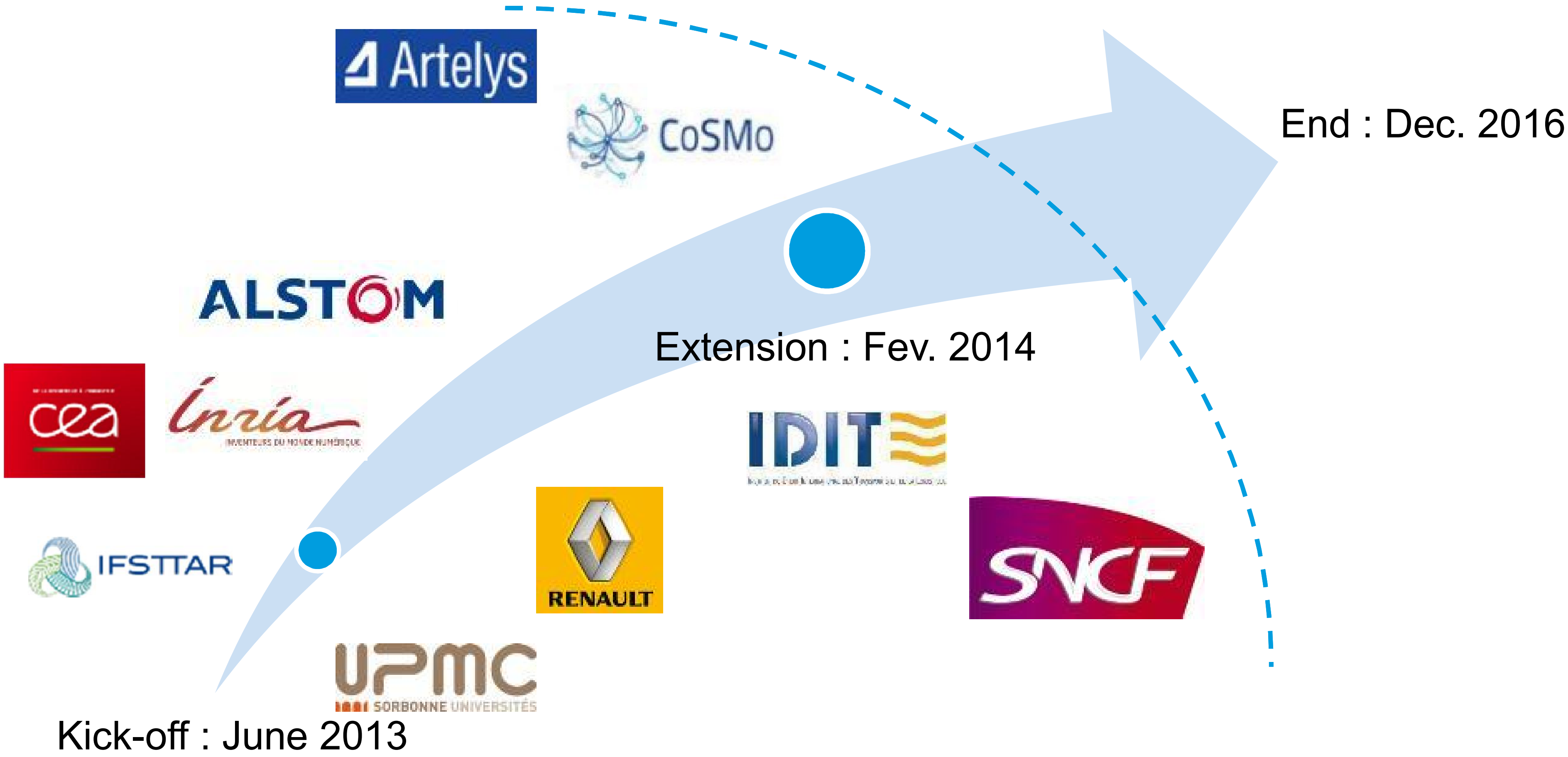
Aurélien CARLIER, Ph.D. student

November 14th, 2014

- A brief introduction to MIC project
- Multimodality foreword
- Modeling challenges
- Simulation
- Decision aid for planning
- Decision aid for Supervision
- Business outlook
- Case-study : carsharing
- Conclusion

Introduction to MIC project

Scope : Build tools for modeling, planning, optimizing and decision making



- **Multimodality exists from the moment on one transition is made from one transport medium to another**
  - Dense urban zone
  - Passenger ground transit

- **Multimodal transport is usually made of several systems :**
  - Operated independently
  - Managed independently
  - Distributed spatially
  - Evolving with different development process
  - Yet, fostering emerging behavior all together

- **Transport governance over a specific territory is usually ensured by a city agency, a transport authority or a public organization**

- **Strong case for Modeling and Simulating for sake of decision aid**

- **No such model as “one size fits all”**
  - Public or private ?
  - Micro or macro ?
  - Multimodal : rail and road ?
- **Road traffic hydrodynamics**
  - First order : demand and supply equilibrium
  - Second order : speed expression as differential equations
  - Multi-class : driving behavior, vehicles and destinations
- **Rail traffic**
  - Usually more microscopic and discrete event-based
  - Max-plus algebra (time-tables), Petri nets (triggers)
  - Empirical regulation approach (headway, end point, time tables…)
- **Passenger centric modeling**
  - Passenger interaction is a key input
  - Modal shift and demand estimation

- **Scale 1:1 replication is hardly possible :**
  - The SoS is too wide
  - Sometimes it does not exist in real life
  - Yet, transportation is very data intensive
- **Hoping to fetch all data is utopia :**
  - Personal privacy
  - Conservatism vs Open data
  - Some data just don’t exist
- **Simulations pros :**
  - Scenario-based
  - Stochasticity
  - True challenge lies in finding observable data to calibrate models

- **Planning activity :**
  - in advance, extended time frame (months…)
  - Dimensioning & positioning resources of a transport authority
  - For sake of optimization upon distinctive criteria
- **Example of Carsharing :**
  - Fleet dimensions
  - Vehicle charging stations locations
  - Unbalance problems

- **Supervision activity**
  - In operation, with time constraints (minutes…)
  - System regulation of the organized transport service to achieve the desired planning
  - Predictive inputs for an operator
- **Example of traffic supervision :**
  - Historically performed on a per mode basis
  - Multimodal supervision smoothens operations and provides better quality end to end from the passenger point of view (example : passenger information)
  - Upon an exploitation profile supervision can help maximize connections transfers (ex : peak hours) or save energy (ex : reduce speed)

- **Governance**
  - Transport is key for sustainability, yet its governance is very complex
  - Regions in France are responsible for multimodal mobility since 2014
  - Regulation cannot keep the pace with new usages
- **Business approach**
  - Traditionally organized in silos (ex : car vs train)
  - Global optimization can be performed transversally (cost/passenger, time/km, CO_2/km)
  - " Google is our main competitor" – SNCF CEO

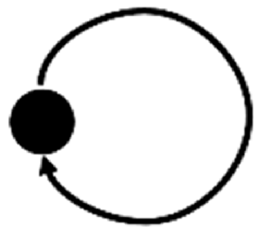
Definition:

System involving a small to medium fleet of **vehicles**, available at several **stations**, to be used by a relatively large group of **members**.[1]

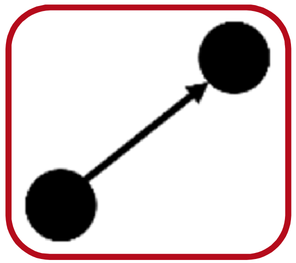
Relieve the user from ownership responsibilities:

- Insurance
- Fuel or electricity
- Maintenance
- Amortization
- Taxes
- Parking places, etc.

Round-trip



One-way



[1] S. A. Shaheen, D. Sperling, et C. Wagner, "A short history of carsharing in the 90's", *Institute of Transportation Studies*, Sept. 1999.

Key numbers about carsharing

4,94 M members[1]

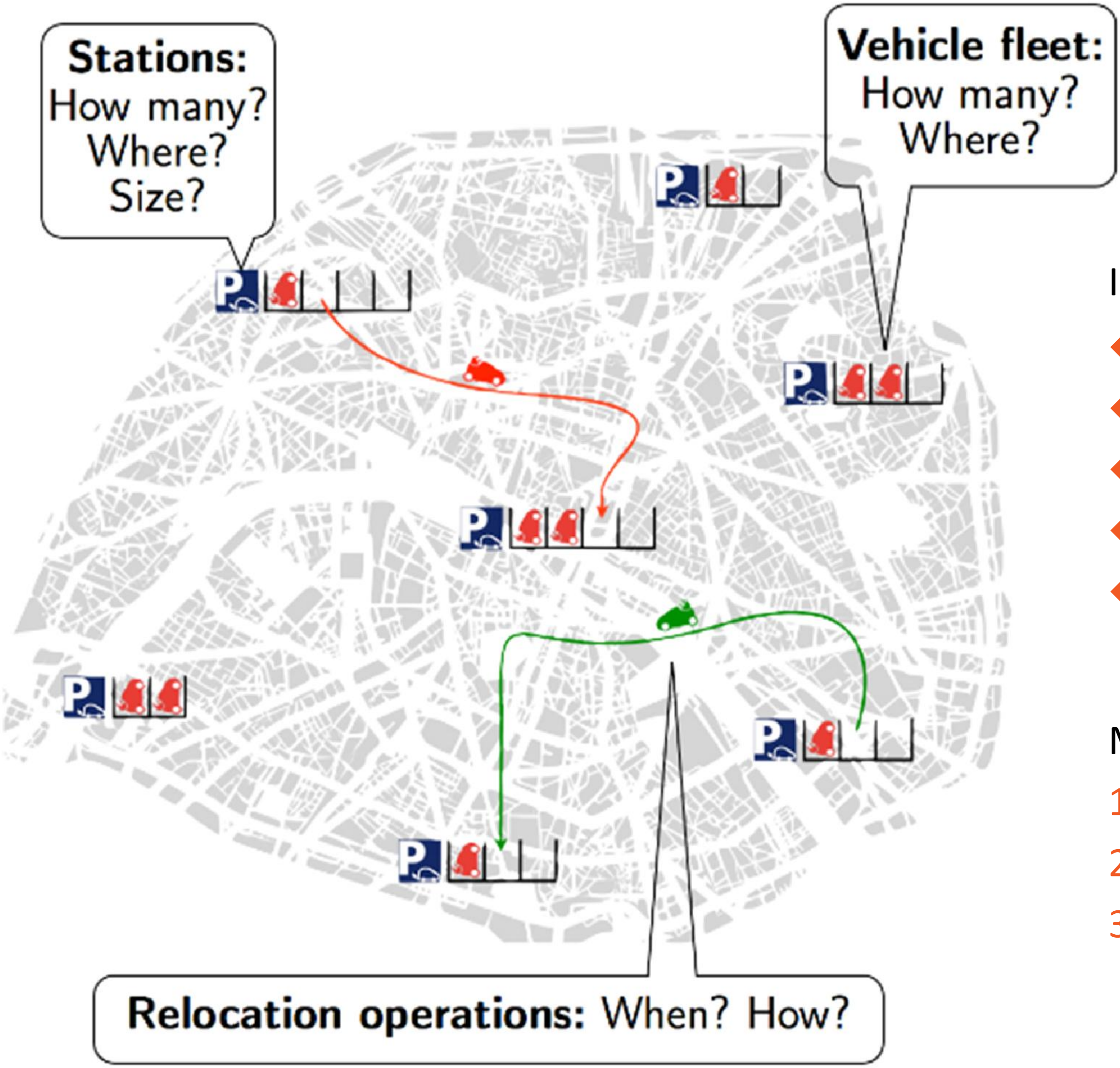
92 000 vehicles[1]

41% of annual market growth rate until 2018[2]

zipcar

Sources: [1] Frost and Sullivan (2014) Strategic Insight of the global Carsharing Market Report #ND90-18, June 2014.

[2] reportsnreports.com



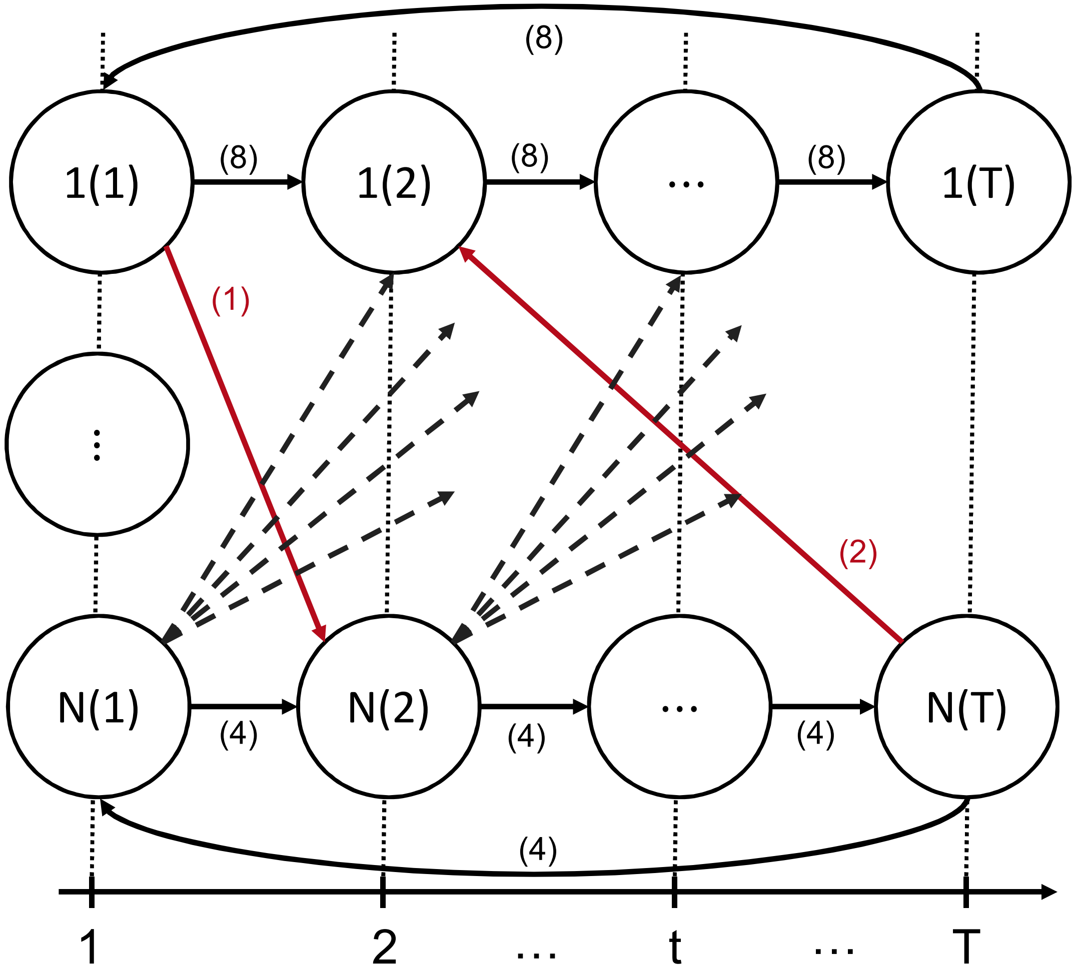
Inputs:

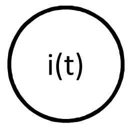
- Set of **stations**
- **Time scale**
- Maximum **size** of stations
- **Demands** between stations
- **Travel times**

Multi-objective optimization:

1. Maximize the total demand
2. Minimize the number of vehicles
3. Minimize the number of relocation operations

Modeling Approach: Time Extended Graph[2] (TEG) using flows





Station *i* at time *t*

Stock arcs

Demand arcs

Relocation arcs

(·) Capacities on arcs

Graph densiy:
Nodes: $|\mathcal{N}| = N \times T$
Arcs: $|\mathcal{A}| = N^2 \cdot T + M = \Theta(N^2 \cdot T)$

[2] Ahuja, Magnanti, and Orlin, Network flows: theory, algorithms, and applications. Englewood Cliffs, N.J.: Prentice Hall, 1993.

Simulation process taking into account multimodal demand

Demand estimation

O/D matrix calculation

- Surveys
- Phone data

Multimodal simulation

Demand assignment

- Wardrop equilibrium
- Demand flows

Carsharing optimization

Data recovery for carsharing

- Station location
- System size

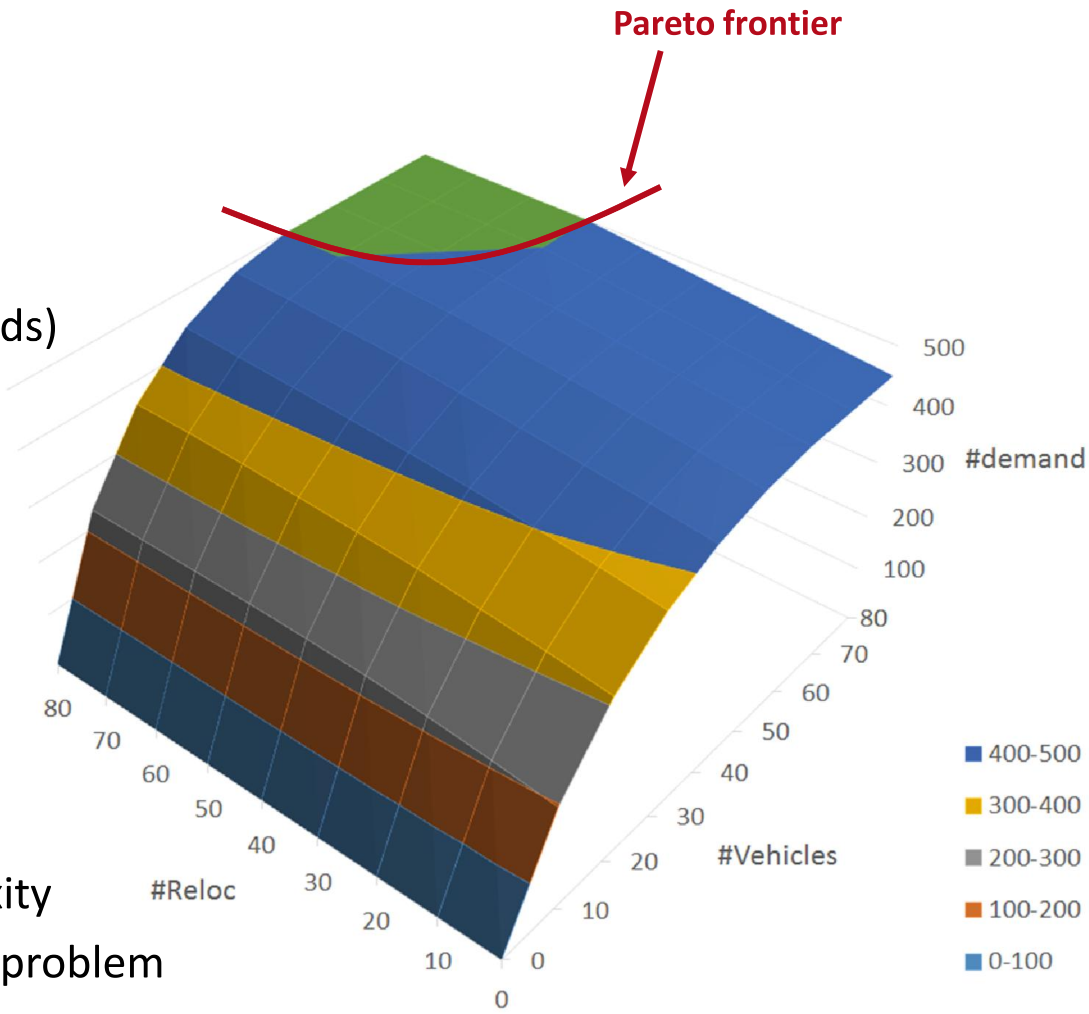
Random Data Generator

- Station positioning over an urban area;
- Station maximum sizes;
- Demands over time (24h period);
- Travel times during the period.

Pareto frontier for the optimal system dimensioning

Experimental context:

- $N = 10$ (number of stations)
- $T = 144$ (10 min time-step)
- $M = 500$ (number of demands)
- $R, C \in \{0, 10, \cdots, 80\}$ (range for the number of vehicles and relocation operations)



Future work:

- Include energy components
- State on the problem complexity
- Deal with the station location problem

- **Multimodal transportation as a SoS**
- **Design challenges to name a few :**
  - Models
  - Simulations and data
  - Governance
- **Source of optimization :**
  - Planning
  - Supervision
- **Carsharing as an illustration :**
  - Alternative mode
  - Some scientific and economic issues

Thanks !