SIMULATION APPROACH FOR PREDICTING THE ENVIRONMENTAL FOOTPRINT OF CONNECTED AND AUTONOMOUS MOBILITY

SYMPOSIUM ECAV (ELECTRIC, CONNECTED AND AUTONOMOUS VEHICLE FOR SMART MOBILITY)

Samir Anbri

IFP Energies nouvelles, Solaize, France

November 24, 2020

SÉCURITÉ ACCEPTABILITÉ MOBILITÉ AUTONOME

IFP Energies nouvelles

IFP SCHOOL

INSTITUT CARNOT IFPEN Transports Energie

AGENDA

I. Context

II. Modeling the impact of the car's connecting system in terms of energy consumption for traction and associated emissions

   a. Emissions analysis methodology of the connected vehicle
   b. Case study: A comparative analysis of emissions between a non-connected and a connected vehicle

III. Large scale emissions analysis of autonomous transport service

   a. Environmental impact assessment methodology of autonomous transport service
   b. Case study: Modeling the current emissions map of the city of Lyon

AGENDA

I. Context

II. Modeling the impact of the car's connecting system in terms of energy consumption for traction and associated emissions

   a. Emissions analysis methodology of the connected vehicle

   b. Case study: A comparative analysis of emissions between a non-connected and a connected vehicle

III. Large scale emissions analysis of autonomous transport service

   a. Environmental impact assessment methodology of autonomous transport service

   b. Case study: Modeling the current emissions map of the city of Lyon

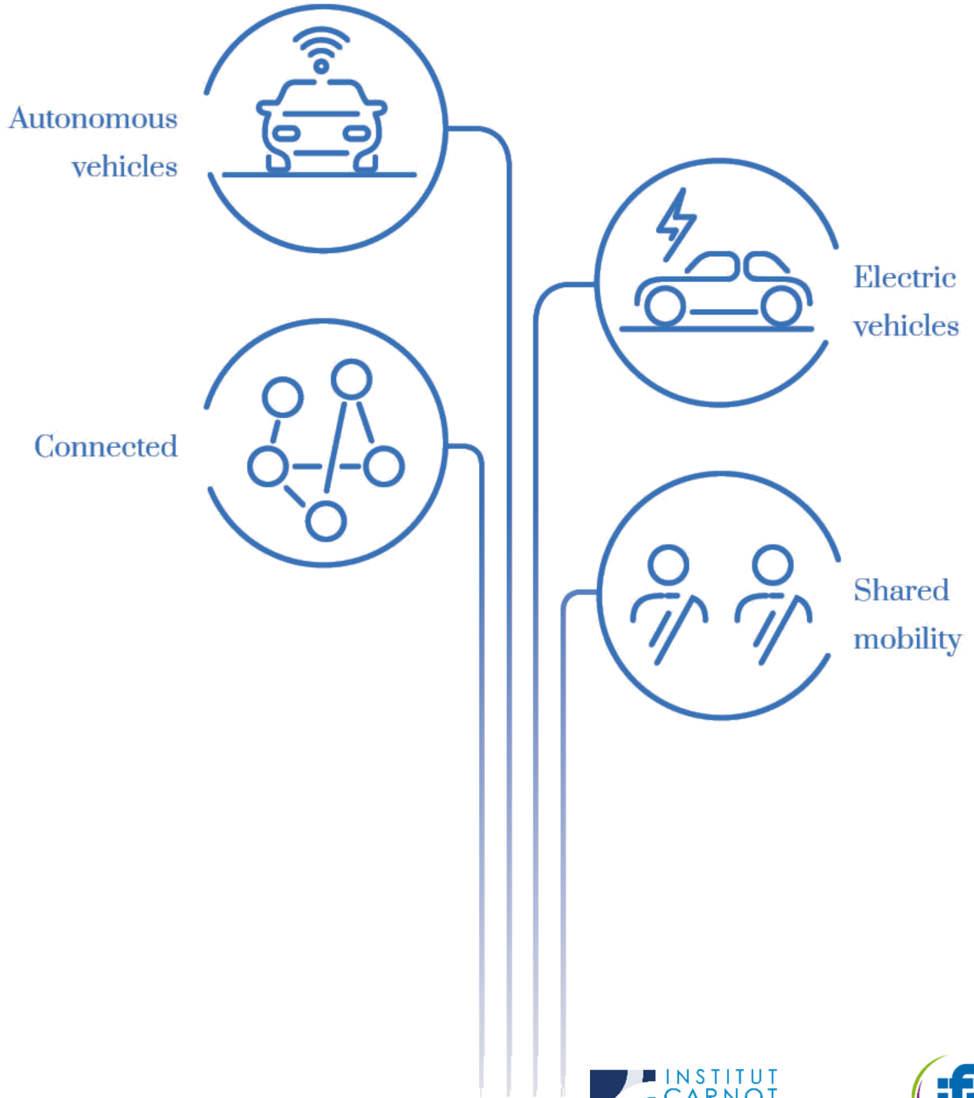
CONTEXT

The reduction of transport emissions is a significant challenge:

- The transport sector is the largest emitter of CO_2 in France (more than 30%).
- The transport sector represents more than 50% of NOx emissions and more than 15% of PM emissions in France.

New technology solutions are also emerging:

1. New engine technology
2. New exhaust gas aftertreatment technology
3. Electric mobility
4. Hydrogen mobility
5. Shared mobility
6. Smart mobility



INSTITUT CARNOT IFPEN Transports Energie

IFP Energies nouvelles

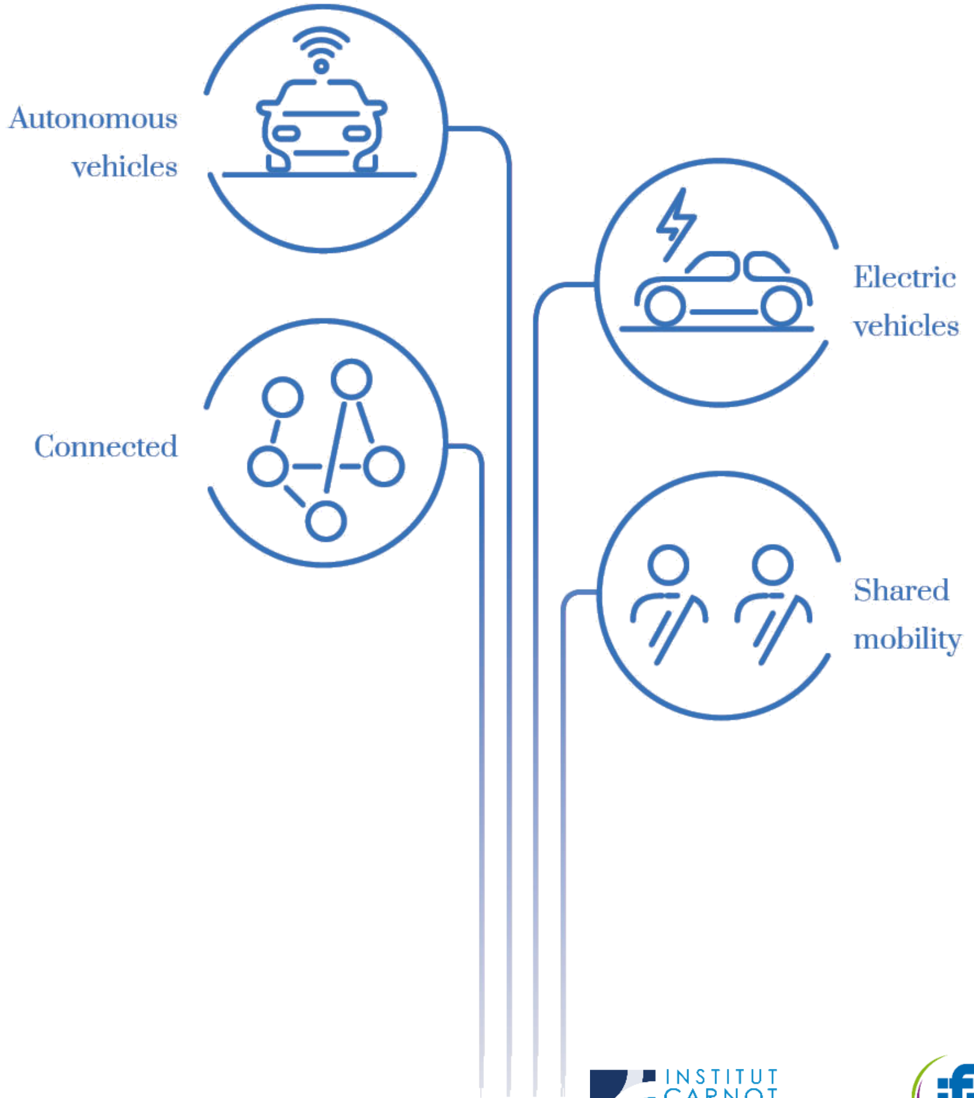
CONTEXT

The reduction of transport emissions is a significant challenge:

- The transport sector is the largest emitter of CO_2 in France (more than 30%).
- The transport sector represents more than 50% of NOx emissions and more than 15% of PM emissions in France.

New technology solutions are also emerging:

1. New engine technology
2. New exhaust gas aftertreatment technology
3. Electric mobility
4. Hydrogen mobility
5. Shared mobility
6. Smart mobility



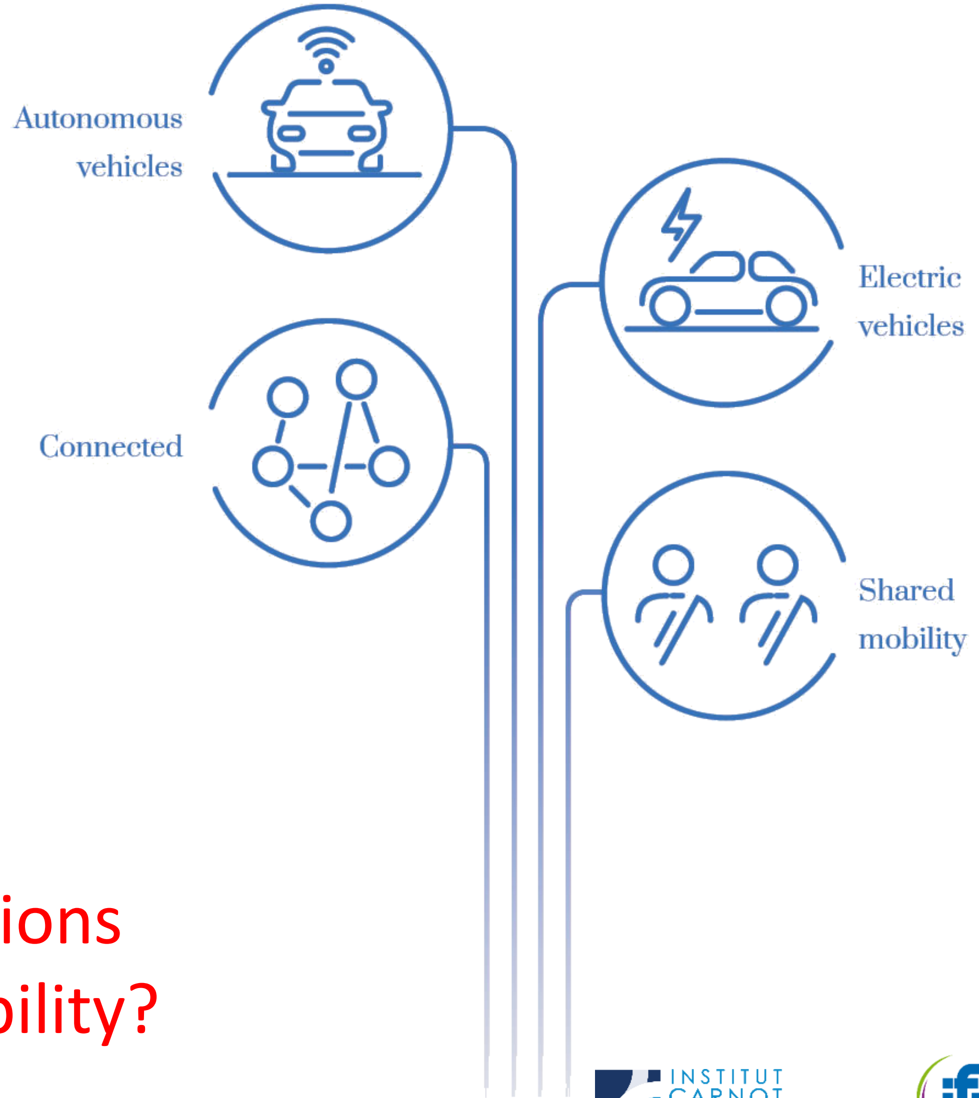
INSTITUT CARNOT IFPEN Transports Energie

IFP Energies nouvelles

CONTEXT

- Connected and intelligent mobilities have been identified as key technologies for reducing emissions and increasing transport efficiency:

  1. Route choice optimization (Eco-Routing)
  2. Driving behaviors optimization (Eco-Driving)
  3. Choice of the charge stations (Eco-Charging)
  4. Traffic control
  5. Fleet management
  6. Mobility management
  7. MaaS (Mobility as a Service)



How can we also predict the emissions reduction enabled by intelligent mobility?

II. MODELING THE IMPACT OF THE CAR’S CONNECTING SYSTEM IN TERMS OF ENERGY CONSUMPTION FOR TRACTION AND ASSOCIATED EMISSIONS

AGENDA

INSTITUT CARNOT IFPEN Transports Energie

IFP Energies nouvelles

EMISSIONS ANALYSIS METHODOLOGY OF THE CONNECTED VEHICLE

Objectives

- *Realistically simulate the behavior of the connected vehicle.*
- *Quantify the impact of the car's connecting system in terms of energy consumption for traction and associated emissions.*
- *Provide a comparative analysis between a non-connected and a connected car.*

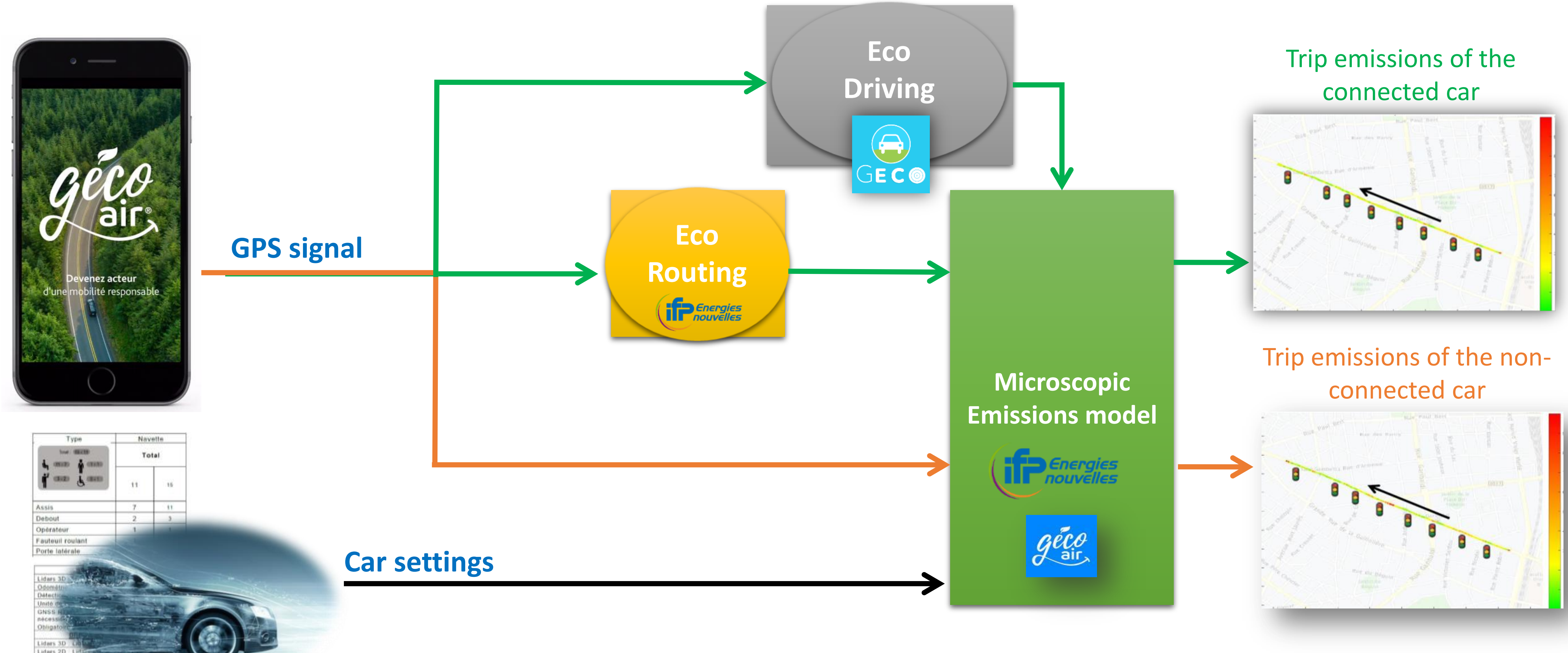
Definition of the connected vehicle used for simulation

a. Technical improvement of engines are considered (downsizing, vehicle hybridization, etc.)

b. Optimization of the speed profiles to reduce the consumption (eco-driving assumption)

c. Optimization of the route choice (eco-routing assumption)

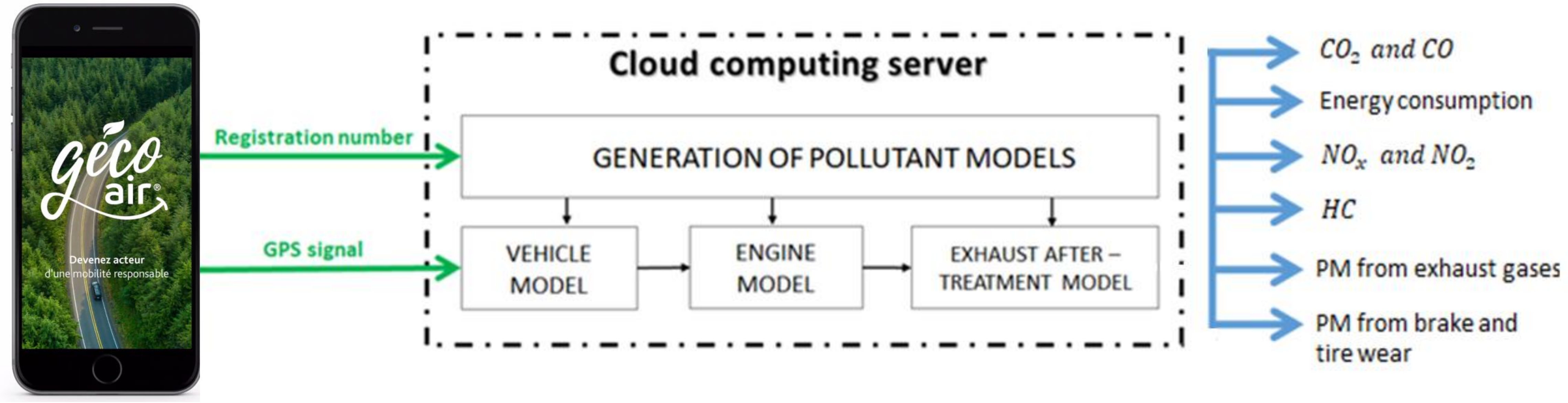
EMISSIONS ANALYSIS METHODOLOGY OF THE CONNECTED VEHICLE



- Geco air data → real-world connected data (1Hz vehicle speed, acceleration, road slope, external temperature)

EMISSIONS ANALYSIS METHODOLOGY OF THE CONNECTED VEHICLE

SUSTAINABLE MOBILITY



The model was validated on a total of 265 vehicles including all technologies and all European emission standards.

EMISSIONS ANALYSIS METHODOLOGY OF THE CONNECTED VEHICLE

SUSTAINABLE MOBILITY

- Why do we use a microscopic emissions model?

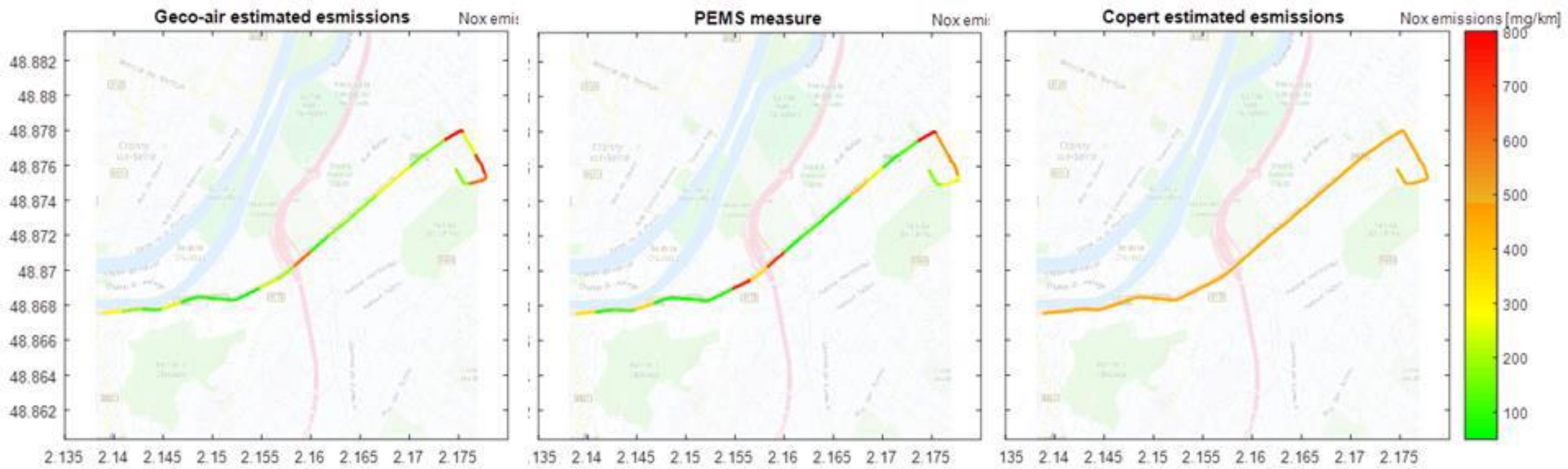
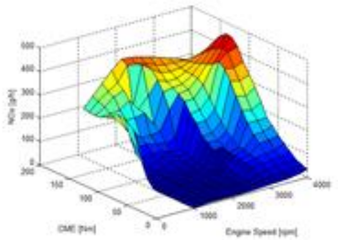


Figure 1: Comparison of NOx emissions for a Euro 5 Diesel vehicle on a RDE



- High spatio-temporal resolution
- Driver behaviour included

The microscopic model suggests a significant evolution by accounting for the acceleration and the slopes.

INSTITUT CARNOT IFPEN Transports Energie

IFP Energies nouvelles

EMISSIONS ANALYSIS METHODOLOGY OF THE CONNECTED VEHICLE

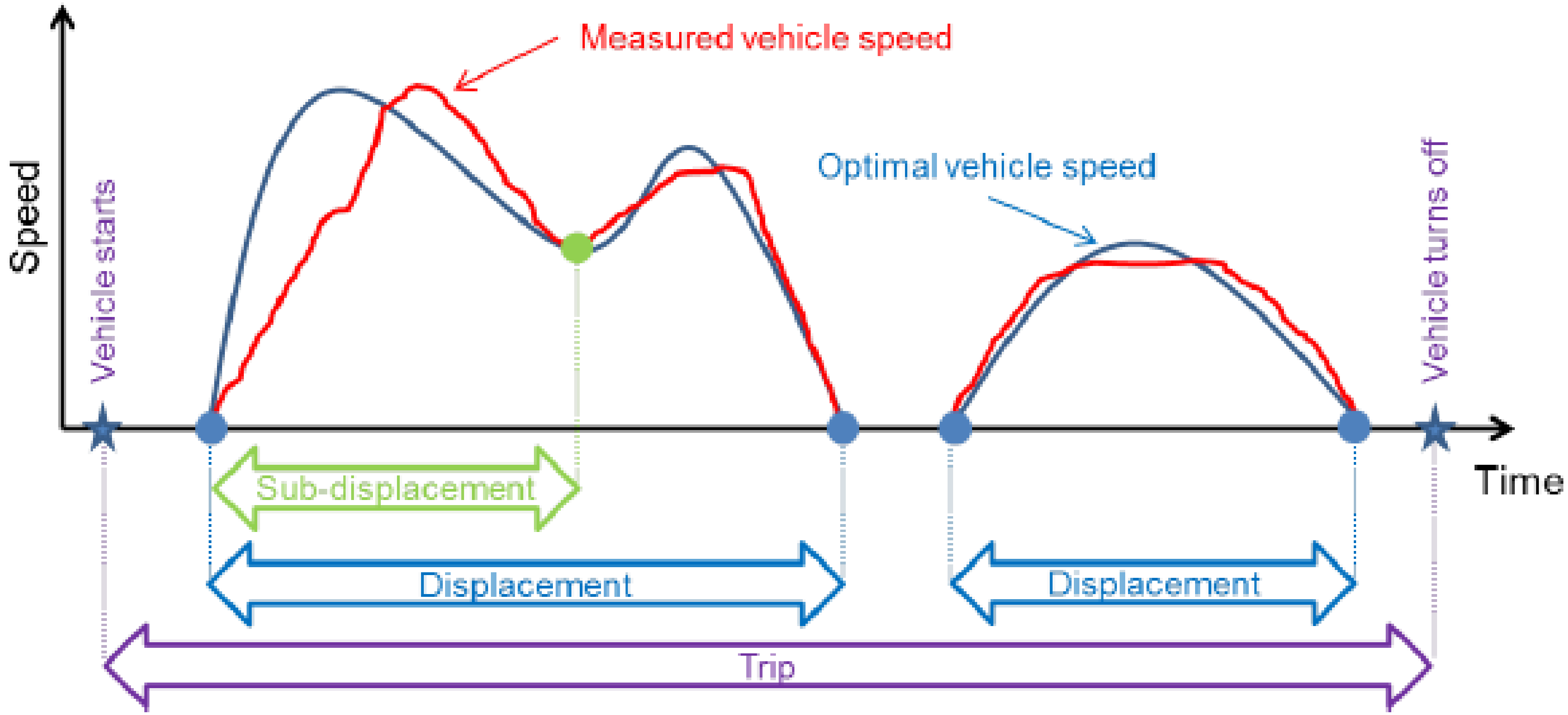


Figure 2 :
Different phases of a trip

- Optimal vehicle speed computation is the core of the eco-driving strategy:

1. The trip is divided into displacements and each displacement is divided into sub-displacements.
2. An optimal velocity trajectory is calculated for each sub-displacement using an optimal control algorithm.
3. A complete vehicle powertrain model is used to give an accurate estimation of the consumption.

AGENDA

I. Context

II. Modeling the impact of the car's connecting system in terms of energy consumption for traction and associated emissions

   a. Emissions analysis methodology of the connected vehicle
   b. Case study: A comparative analysis of emissions between a non-connected and a connected vehicle

III. Large scale emissions analysis of autonomous transport service

   a. Environmental impact assessment methodology of autonomous transport service
   b. Case study: Modeling the current emissions map of the city of Lyon

CASE STUDY: A COMPARATIVE ANALYSIS OF EMISSIONS BETWEEN A NON-CONNECTED AND A CONNECTED VEHICLE

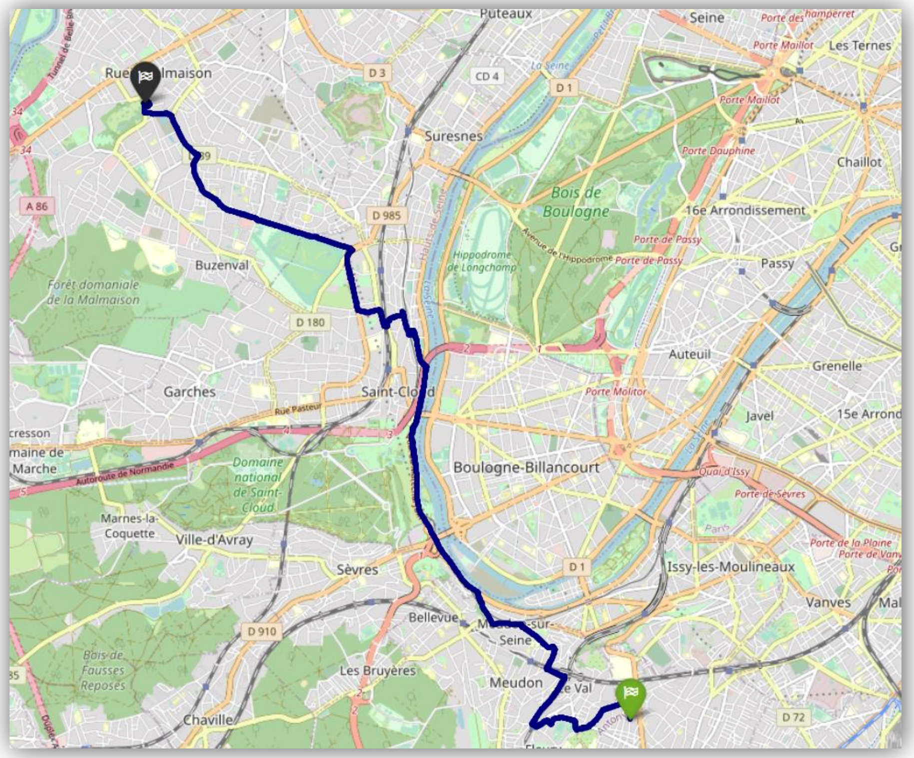


Figure 3: Example of an urban trip

Vehicle and engine parameters:

- 1.5 TSI EVO
- ICE Power : 131 Hp
- Car mass : 1269 kg

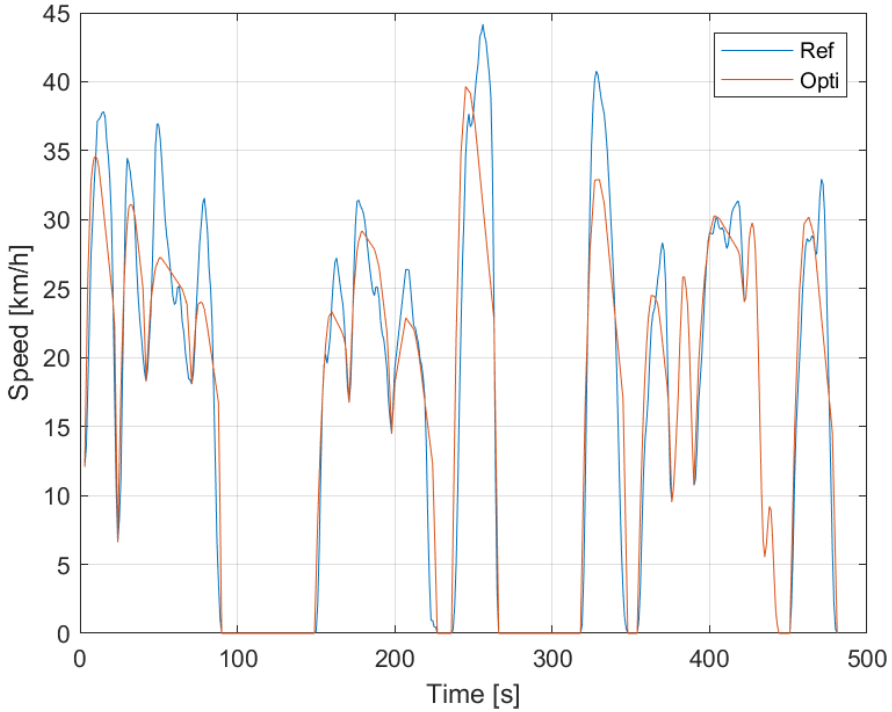


Figure 4: Optimal velocity trajectory of a sub-displacement (ICE powertrain)

	Non-connected car	Connected car	Reduction
Consumption (gCO_2/km)	198	171	14%
CO (mg/km)	398	259	35%
PM10 Brake & Tire (mg/km)	16	9	44%

INSTITUT CARNOT IFPEN Transports Energie
IFP Energies nouvelles

III. LARGE SCALE EMISSIONS ANALYSIS OF AUTONOMOUS PUBLIC TRANSPORT SERVICE

AGENDA

INSTITUT CARNOT IFPEN Transports Energie

IFP Energies nouvelles

LARGE SCALE EMISSIONS ANALYSIS OF AUTONOMOUS PUBLIC TRANSPORT SERVICE

Objectives

1. Produce current emissions/consumption maps with high temporal and spatial resolution.
2. Produce the predicted emissions/consumption map on a future scenario. This scenario considers the large-scale deployment of an autonomous public transport service.

Location →
Date, time →
Mobility data →

IFPEN methodology (géco air, IFP Energies nouvelles, MATSim Multi-Agent Transport Simulation, PTV VISUM)

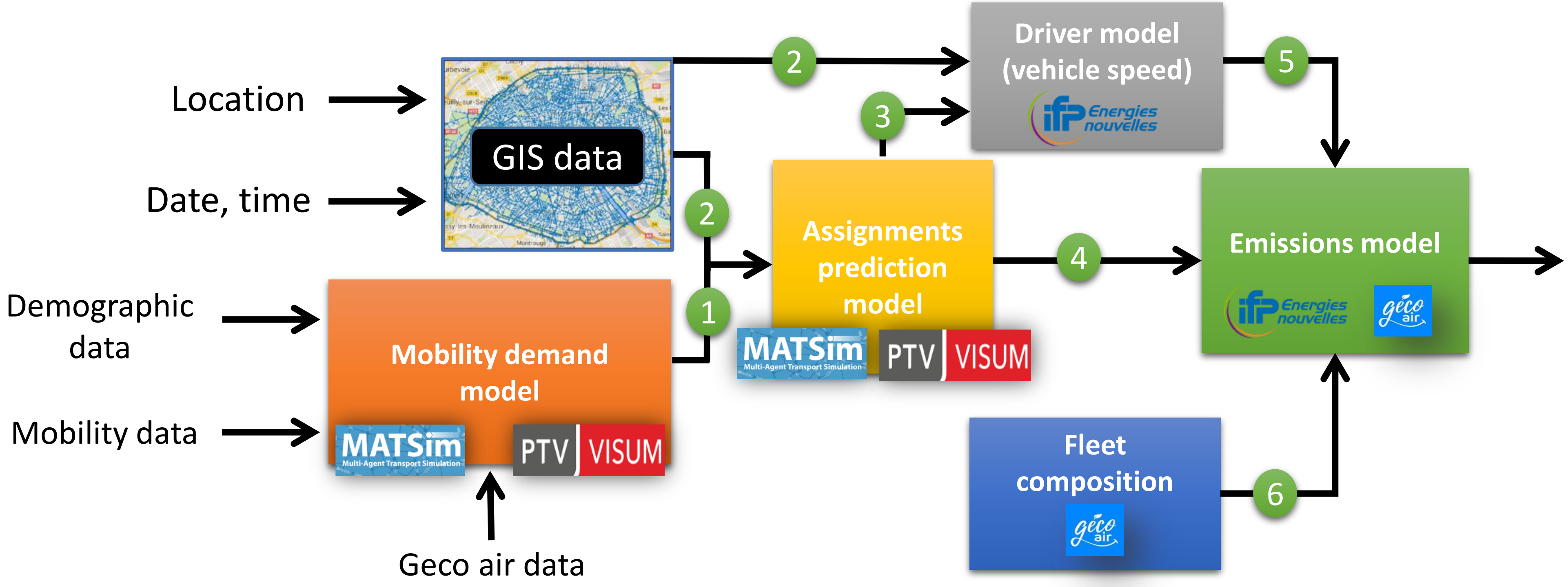
→ Reference emissions/consumption map
→ Predicted emissions/consumption map

comparison

↑ Addition of an autonomous/connected on-demand public transport service

LARGE SCALE EMISSIONS ANALYSIS OF AUTONOMOUS PUBLIC TRANSPORT SERVICE

1. Produce current emissions and consumption maps with high temporal and spatial resolution



Reference emissions/consumption map

1 Modal choice → the number of trips for each mode of transport

2 GIS Data → road signs, network topography, etc.

3 Traffic flow, speed and traffic density for each road segment of the network

4 Traffic flow

5 The velocity profiles for each road segment

6 Fleet distribution

2. Produce the predicted emissions/consumption map on a future scenario

Figure 5 : Autonomous on-demand shuttle operating on the university campus of Saclay (SAM project – Experiment 7).

Assumption

An autonomous on-demand public transport service is introduced in the study area. A large-scale deployment is expected by 2030.

How to adapt the previous methodology to map the situation to 2030?

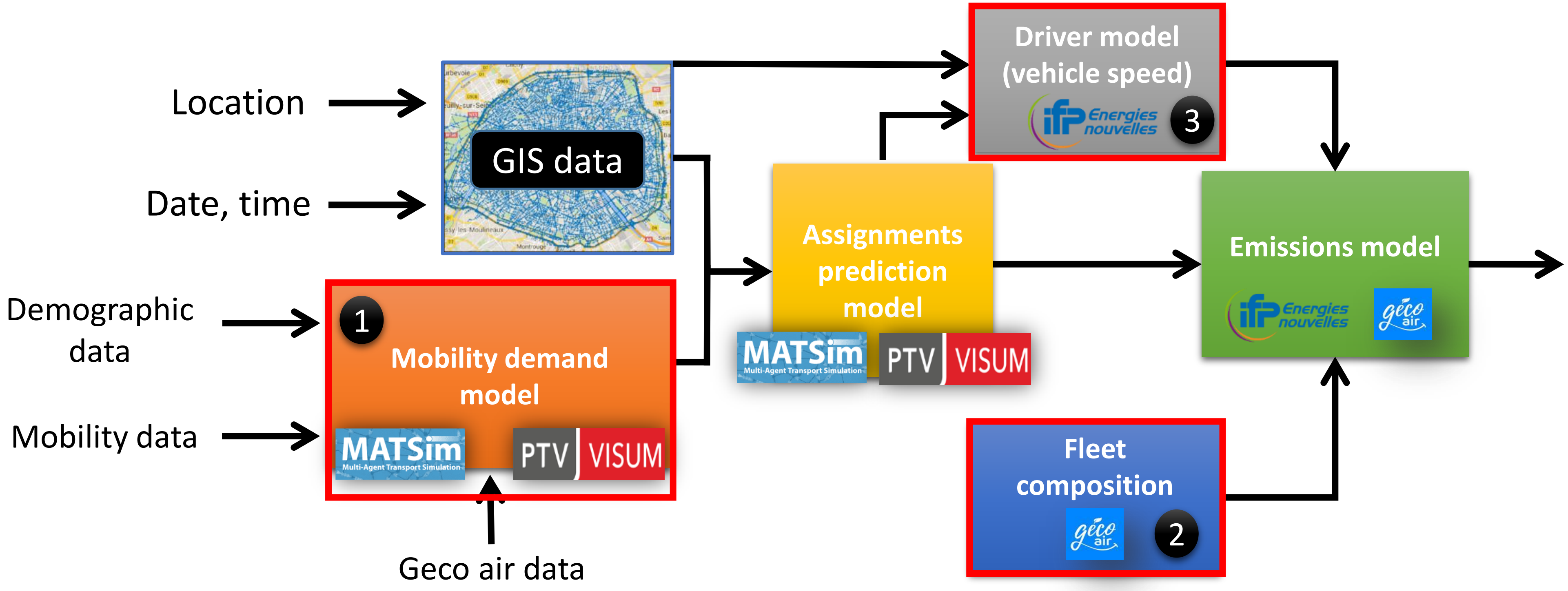
INSTITUT CARNOT IFPEN Transports Energie

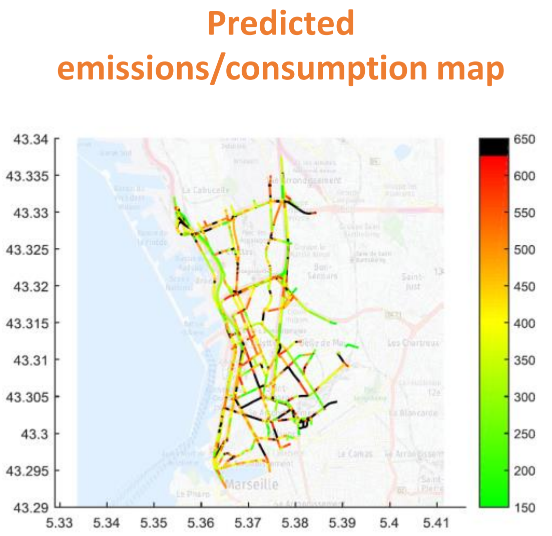
IFP Energies nouvelles

LARGE SCALE EMISSIONS ANALYSIS OF AUTONOMOUS PUBLIC TRANSPORT SERVICE

SUSTAINABLE MOBILITY

2. Produce the predicted emissions/consumption map on a future scenario





1 **Update of the distribution model** → Areas served by the new transport service can become more attractive.

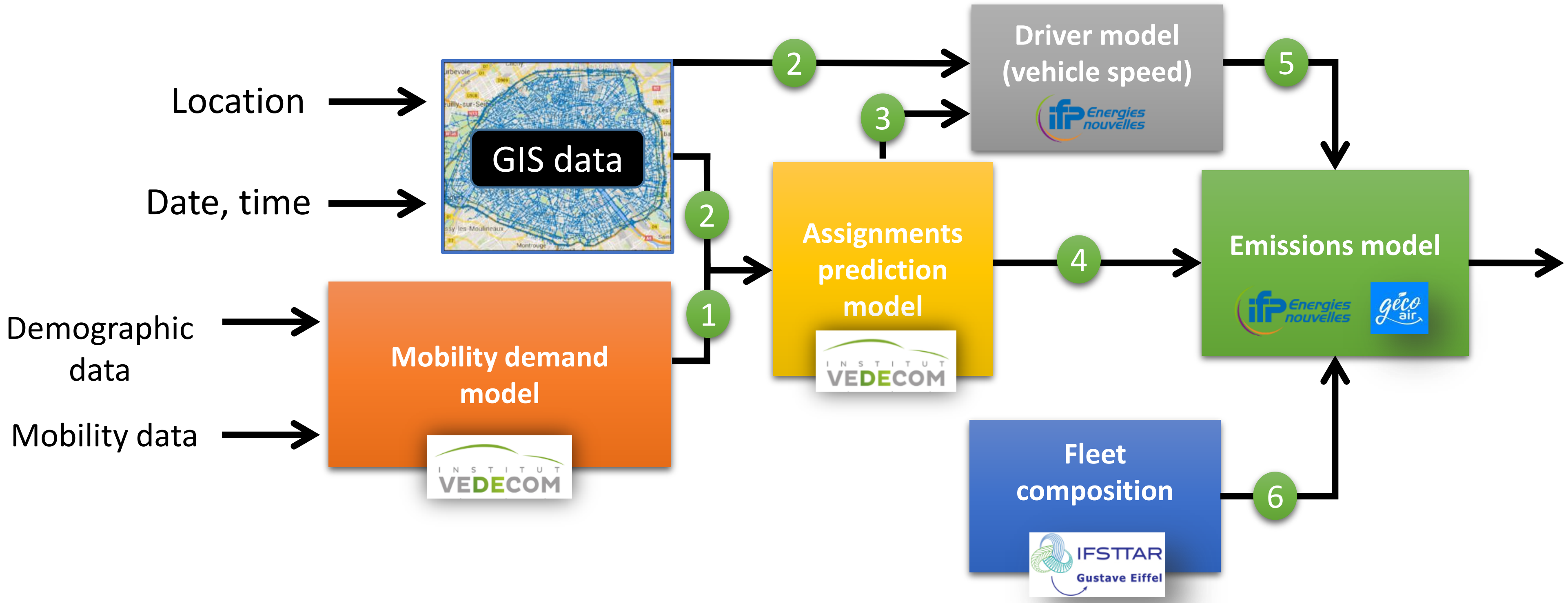
1 **Update of the modal choice model** → The creation of a new public transport line may reduce the use of individual transport.

2 **Update the fleet composition model**→ We must use a fleet composition of the 2030 horizon (IFSTTAR data).

3 **Update of the driver model (speed profiles prediction model)** → Speed profiles of autonomous/connected vehicles must be added (eco-driving). We have to update the speed profiles of vehicles that interact with the new service.

LARGE SCALE EMISSIONS ANALYSIS OF AUTONOMOUS PUBLIC TRANSPORT SERVICE

- SAM PROJECT: Environmental evaluation of experiments 7 and 8 (Saclay and Rouen)



Reference and Predicted emissions/consumption map

SÉCURITÉ ACCEPTABILITÉ MOBILITÉ AUTONOME

Opération réalisée avec le concours des Investissements d'avenir de l'Etat confiés à l'ADEME

AGENDA

I. Context

II. Modeling the impact of the car's connecting system in terms of energy consumption for traction and associated emissions

   a. Emissions analysis methodology of the connected vehicle
   b. Case study: A comparative analysis of emissions between a non-connected and a connected vehicle

III. Large scale emissions analysis of autonomous transport service

   a. Environmental impact assessment methodology of autonomous transport service
   b. Case study: Modeling the current emissions map of the city of Lyon

CASE STUDY : MODELING THE CURRENT EMISSIONS MAP OF THE CITY OF LYON

SUSTAINABLE MOBILITY

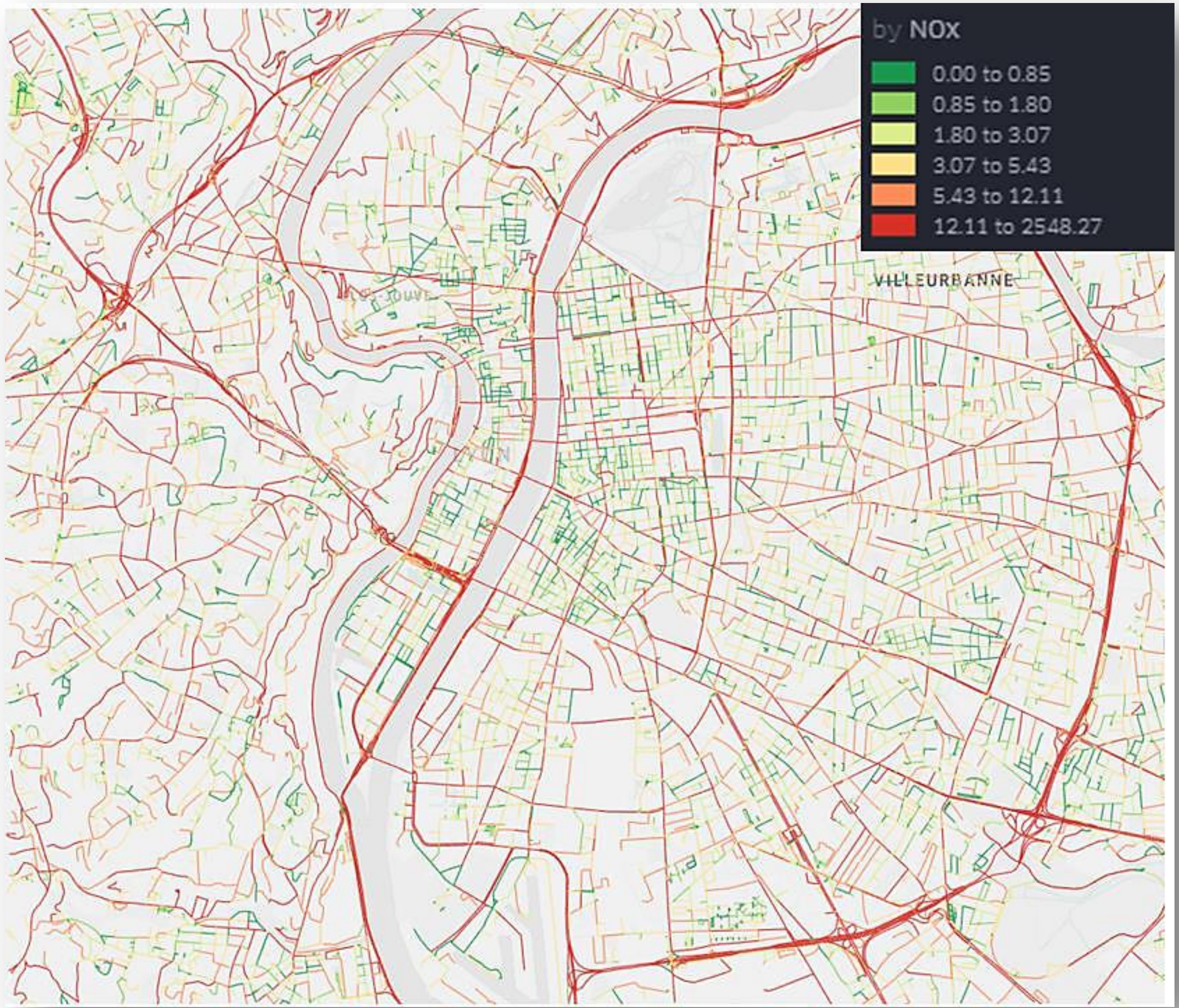


Figure 6: Actual NOx emissions levels map [mg/s]

- Location : Métropole de Lyon
- Time : 8 am → 9 am

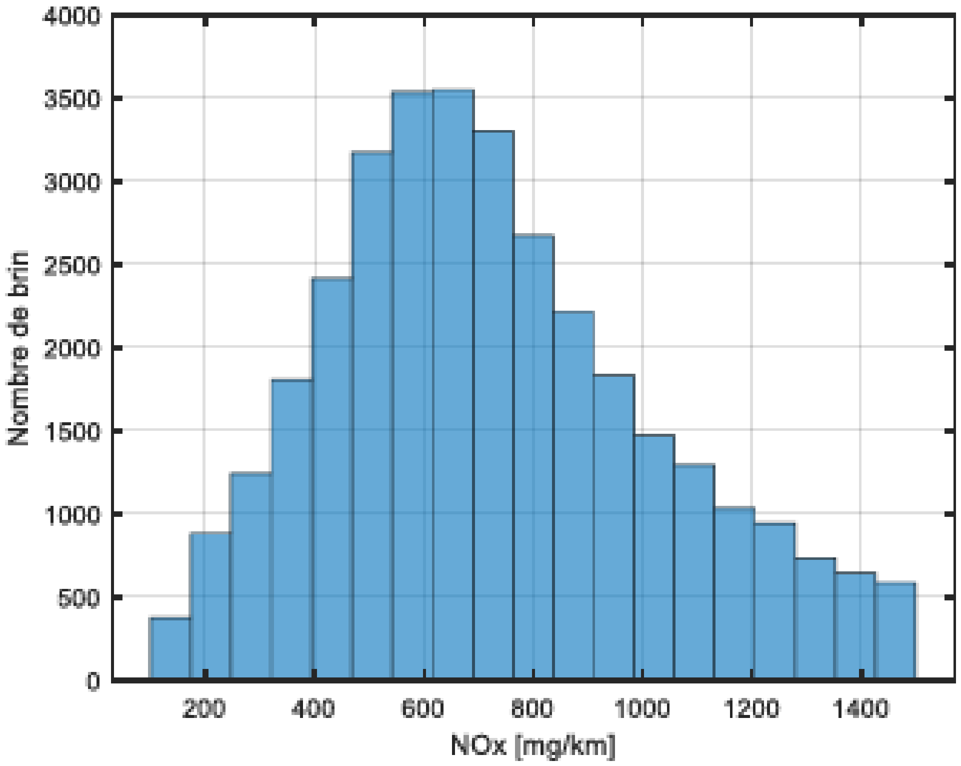


Figure 7: Histogram of the NOx emissions levels [mg/km]

CONCLUSIONS

- The developed method is a combination of our expertise in various fields:
  - Vehicle and engine modeling
  - Advanced optimization algorithms for Eco-Driving and Eco-Routing
  - Traffic modeling
- The overall approach is flexible and can take as input the mobility data (Geco air) for increased accuracy.
- A high spatial and temporal resolution emissions map can be obtained.
- Various mobility scenarios can be analyzed and compared at high precision.

Innover les énergies

Retrouvez-nous sur :

www.ifpenergiesnouvelles.fr

@IFPENinnovation

