Welcome to the Workshop on Mathematical Foundations of Traffic

Alexandre Bayen, Rinaldo Colombo, Paola Goatin, Benedetto Piccoli

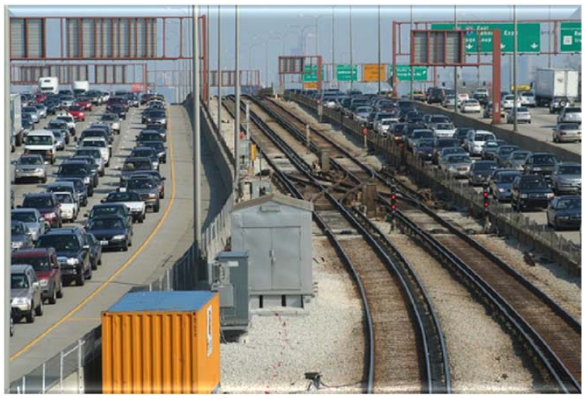
INRIA, Sophia Antipolis, March 2013

Large scale infrastructure systems

Physical systems integrate dynamical processes in which spatial variations play an integral role in their evolution. Multiple challenges

- **Large scale data analytics on streaming data**
- **Control of non fully automated systems (human in the loop)**



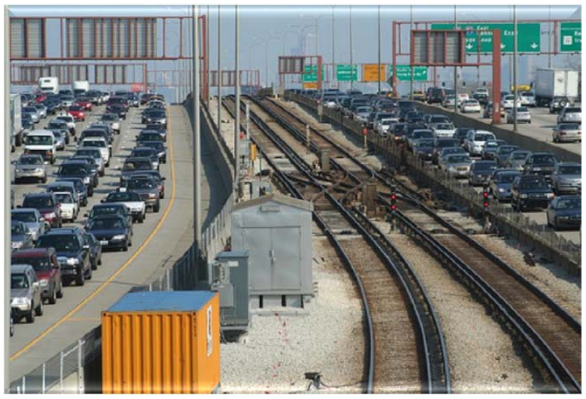


Large scale infrastructure systems

Physical systems integrate dynamical processes in which spatial variations play an integral role in their evolution. Multiple challenges

- **Large scale data analytics on streaming data**
- **Control of non fully automated systems (human in the loop)**





“Classical” source of traffic information

Dedicated traffic monitoring infrastructure:

- **Self inductive loops**
- **Wireless pavement sensors**
- **FasTrak, EZ-pass transponders**
- **Cameras**
- **Radars**
- **License plate readers**

Issues of today’s dedicated infrastructure

- **Installation costs**
- **Maintenance costs**
- **Reliability**
- **Coverage**

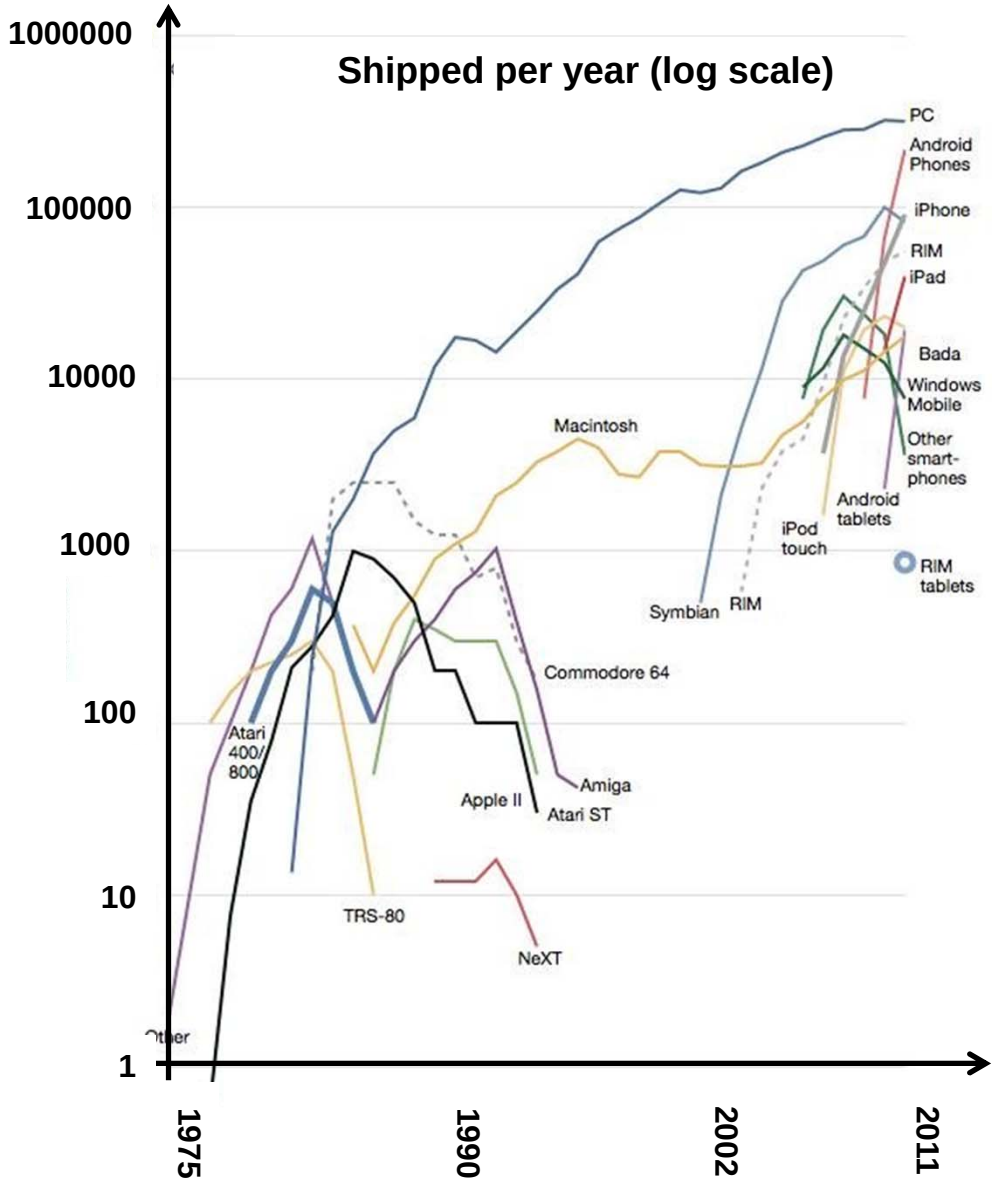
2008 → 2012: web 2.0 on wheels

Emergence of the mobile internet

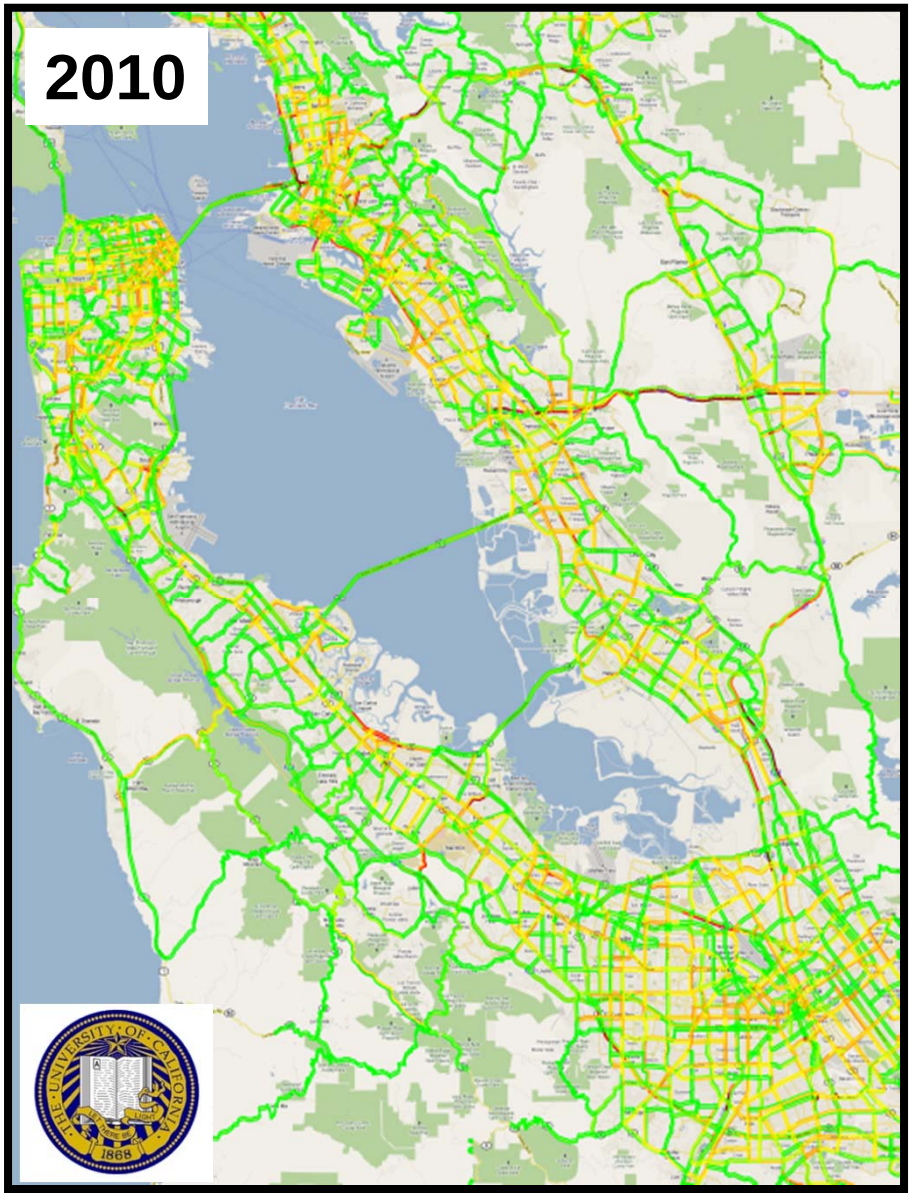
- Internet accesses from mobile devices skyrocketing
- More than 4 billion phones on earth
- More than 1 billion smartphones on earth
- More than 1 million android phones activated every day

Sensing and communication

- GSM, GPRS, WiFi, bluetooth, infrared, radio,
- GPS, accelerometer, light sensor, camera, microphone



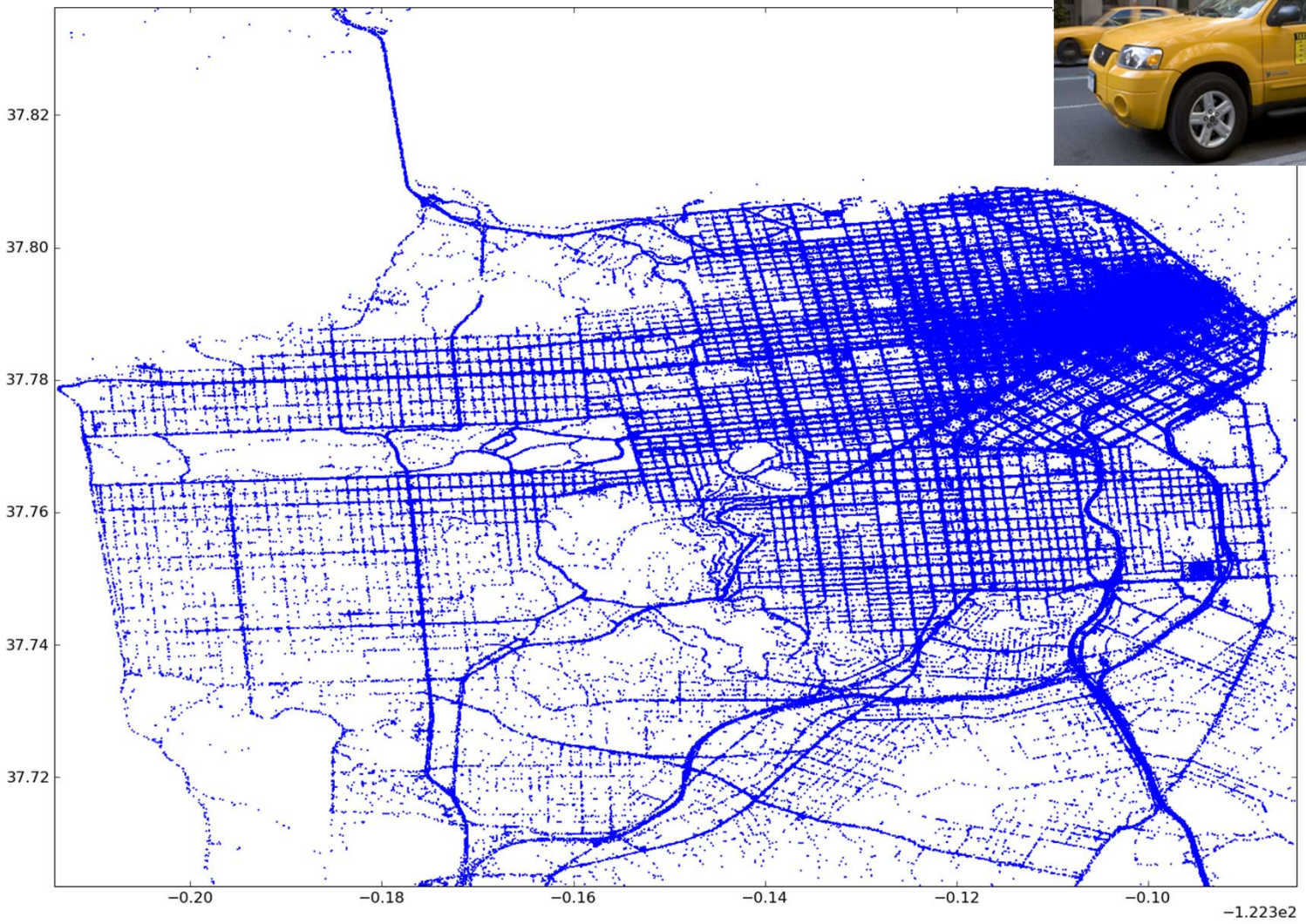
First historical indirect beneficiary: transportation



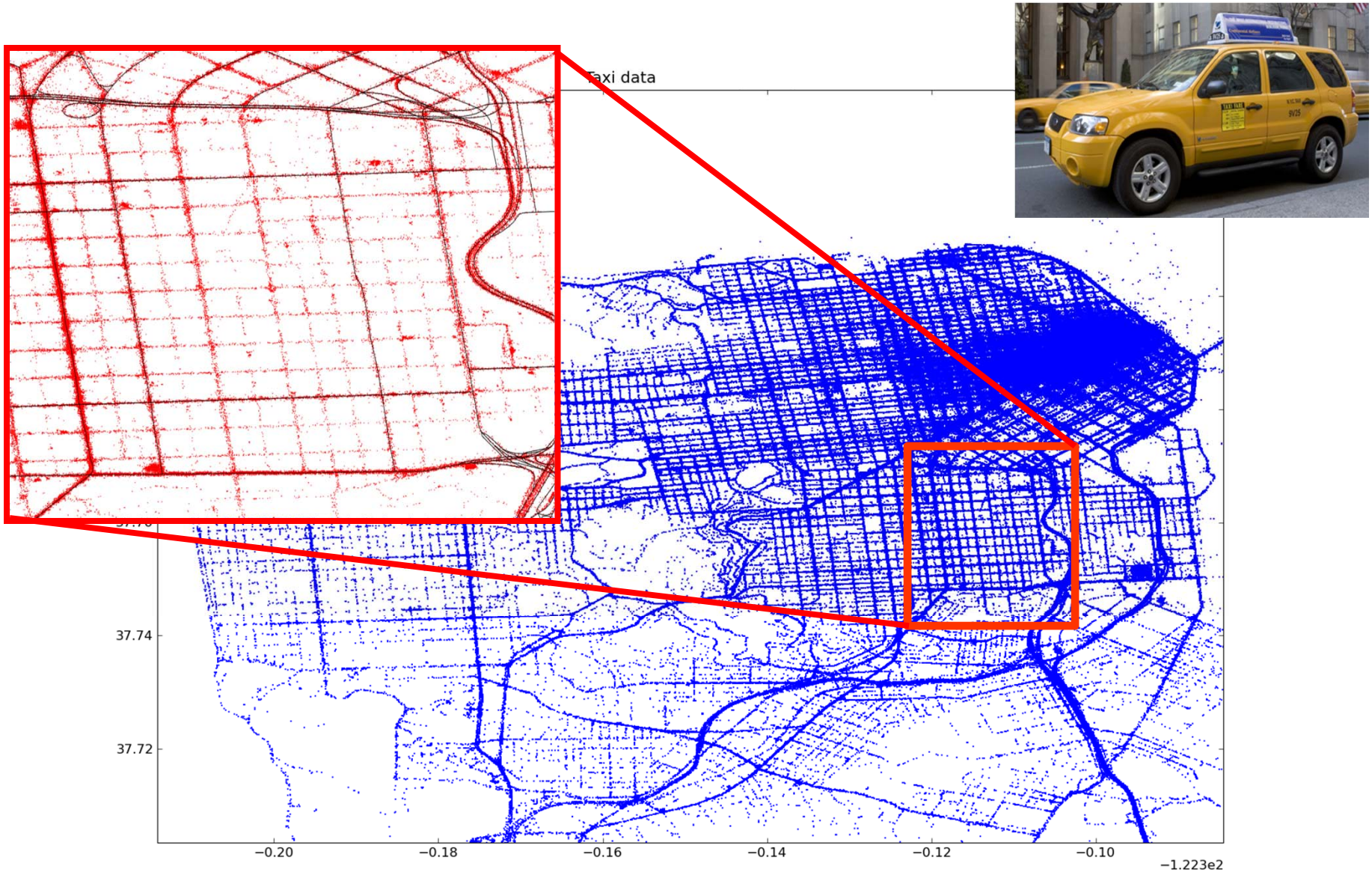
Example: 0.5% of Mobile Millennium data (one day)

One day of Yellow Cab data: 2010-03-29 04:00:02.0

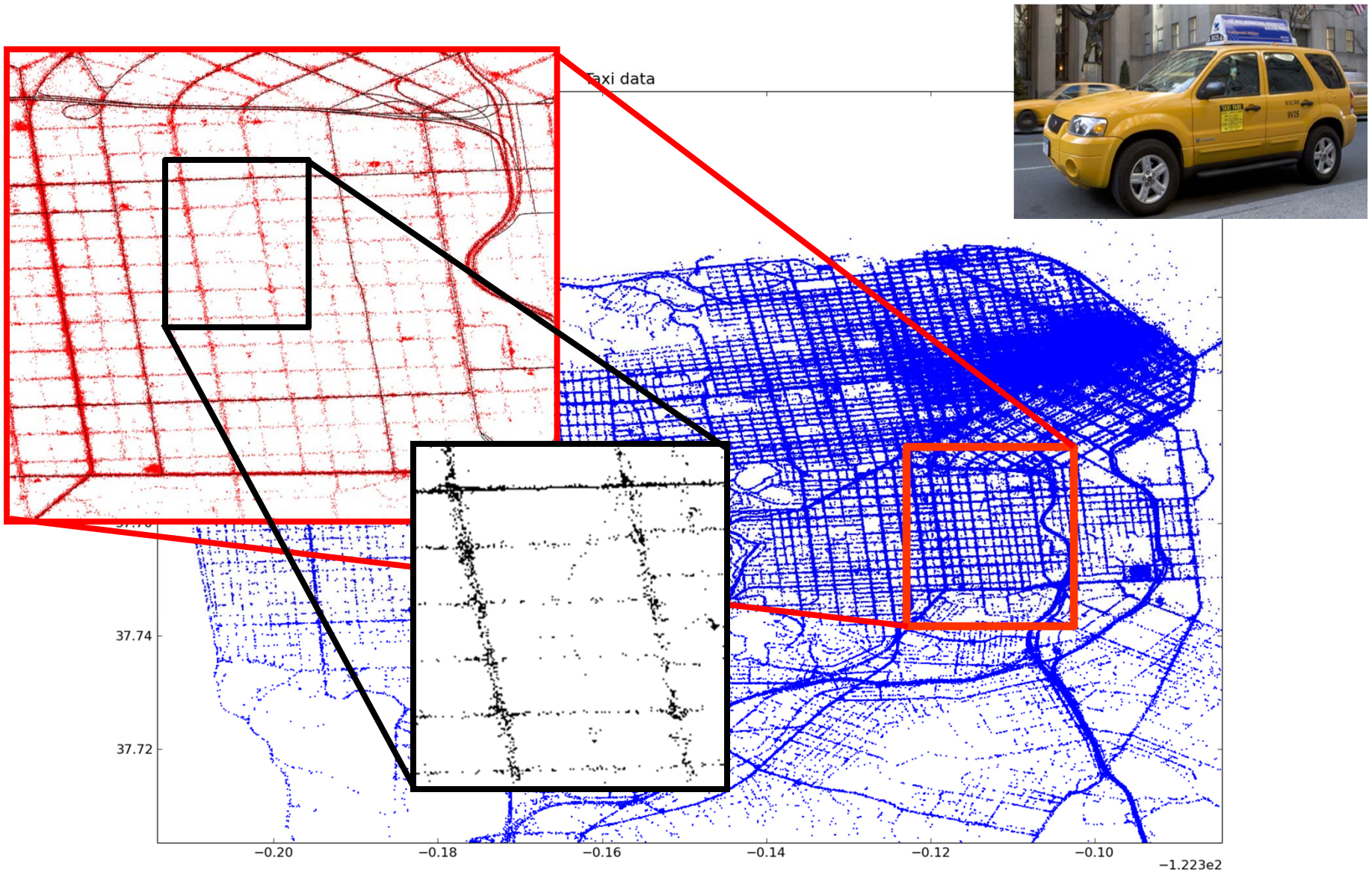
Example: 0.5% of Mobile Millennium data (one day)



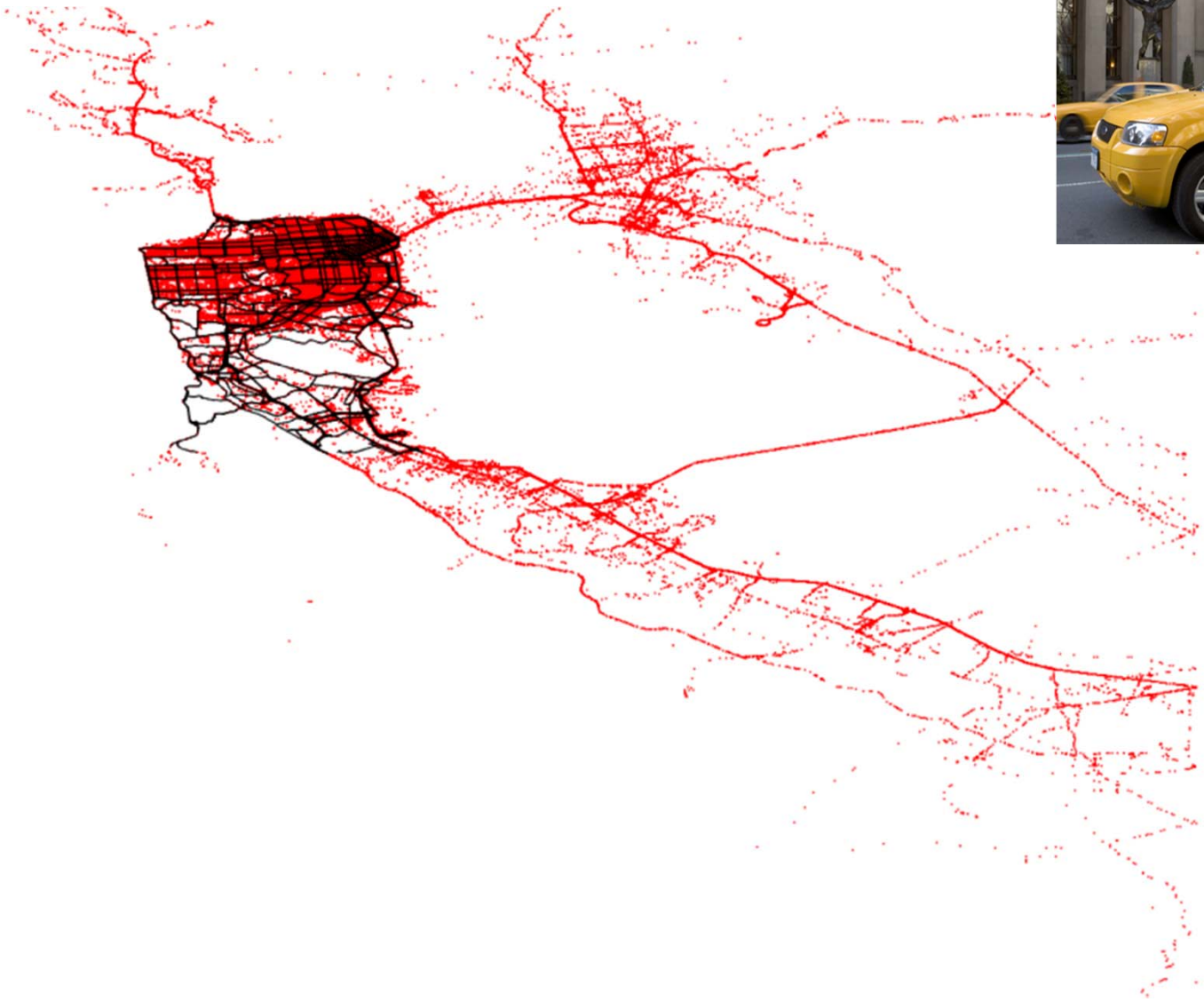
Example: 0.5% of Mobile Millennium data (one day)



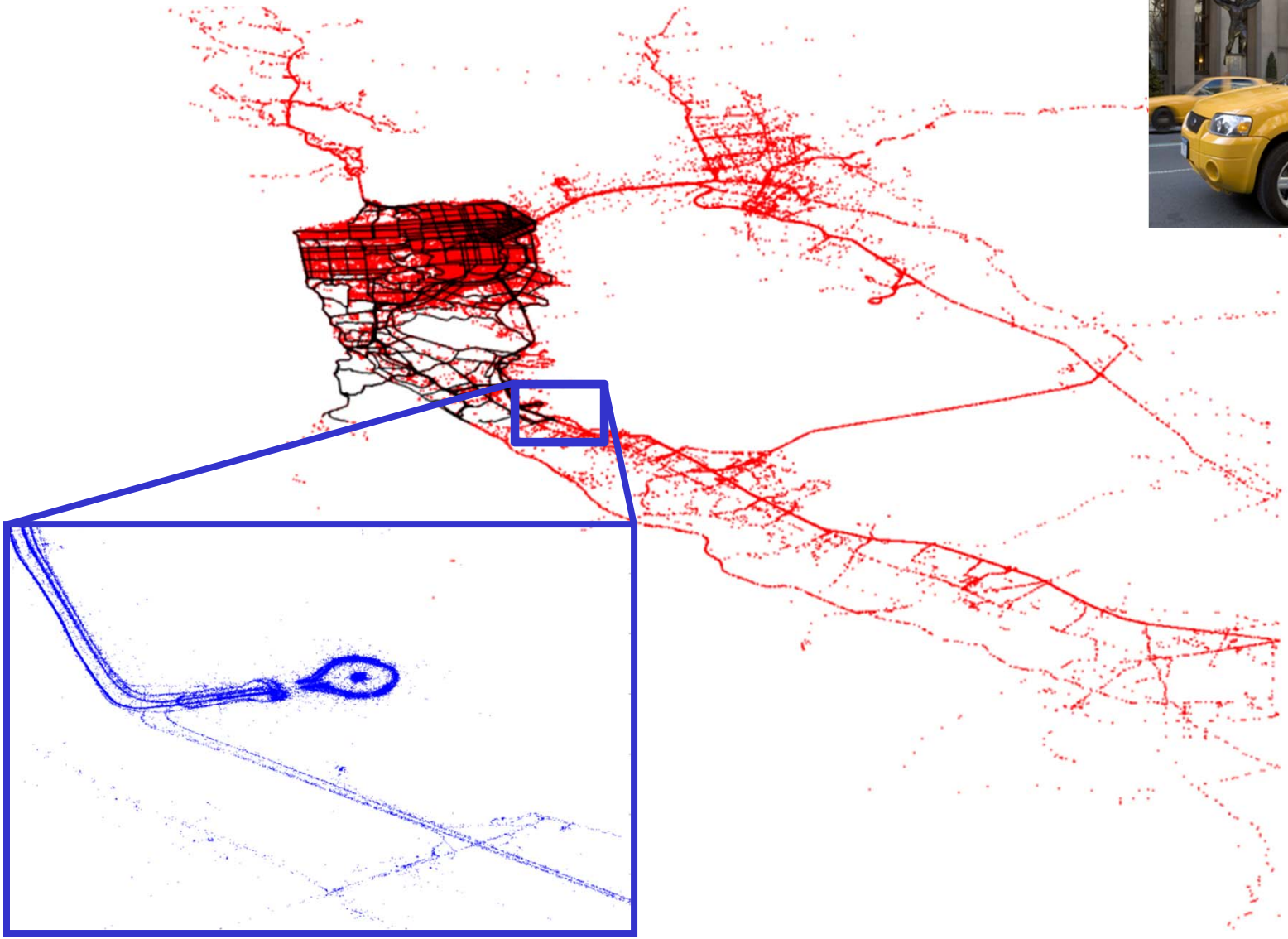
Example: 0.5% of Mobile Millennium data (one day)



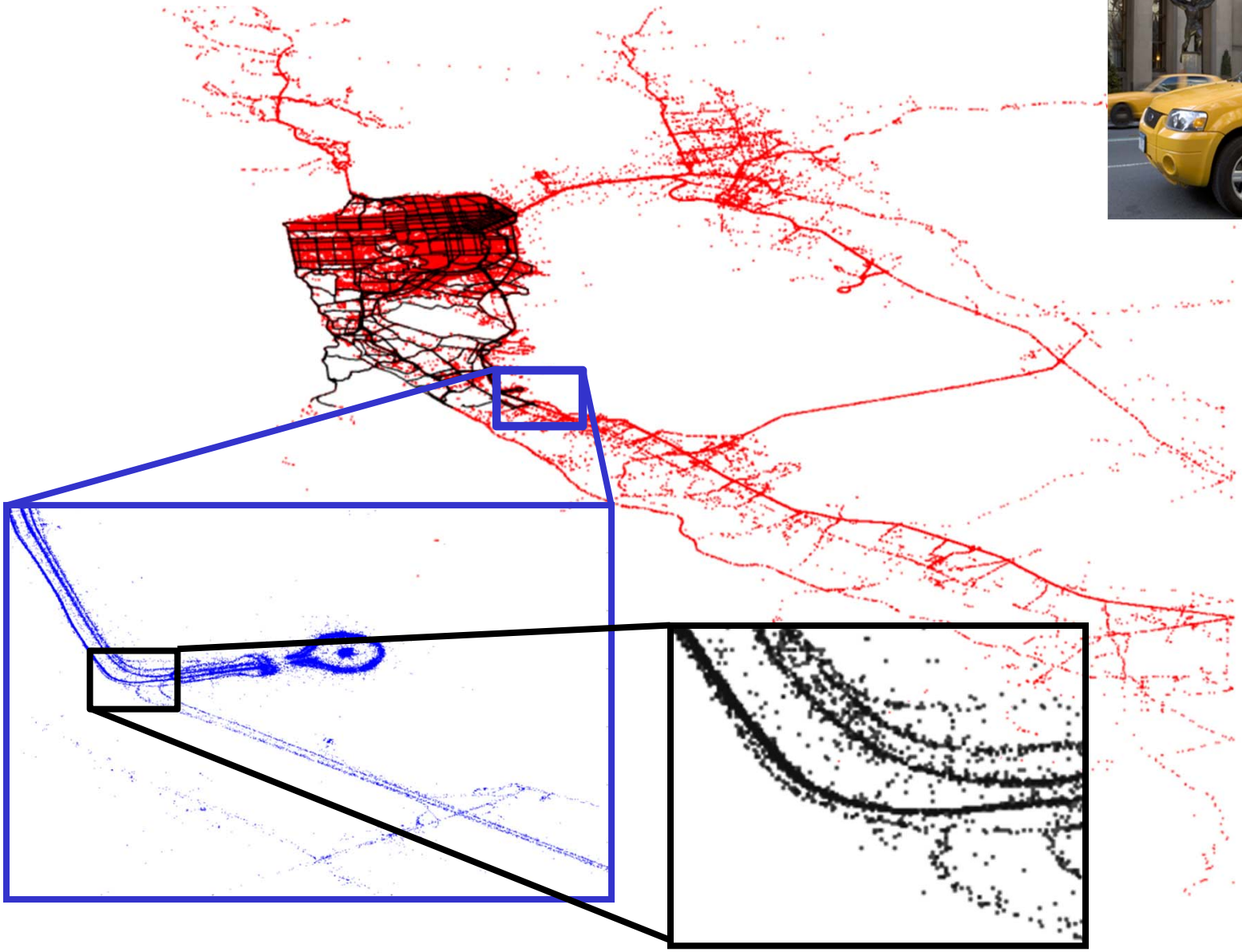
Example: 0.5% of Mobile Millennium data (one day)



Example: 0.5% of Mobile Millennium data (one day)



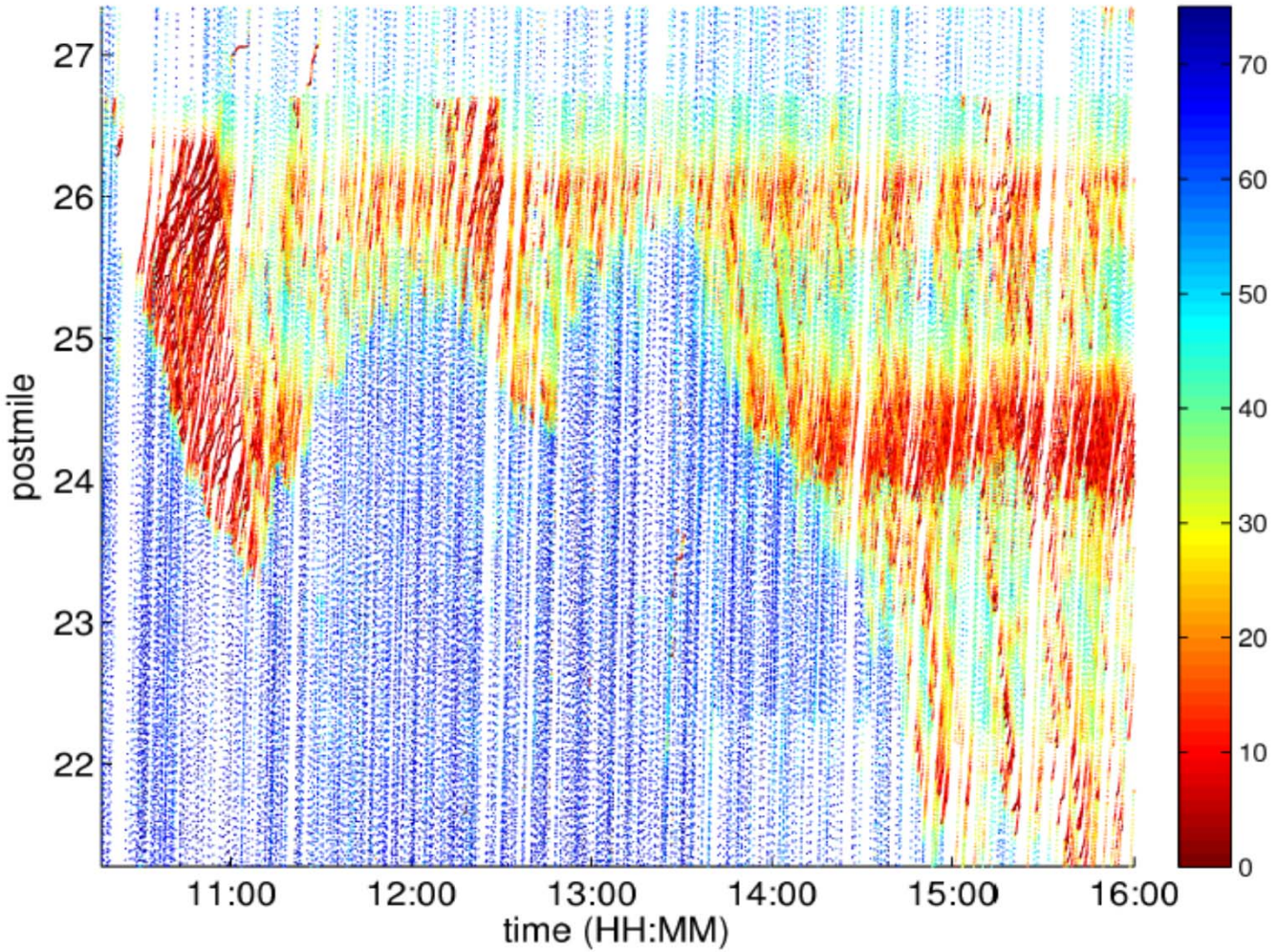
Example: 0.5% of Mobile Millennium data (one day)



What it means to have GPS data at 2% penetration

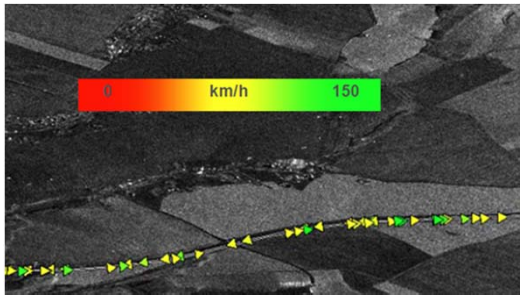
Paradise for data assimilation starts at 2% penetration rate

- **However, it is rare to have such penetration uniformly (spatio temporally): thus algorithms need to work on decimated data**

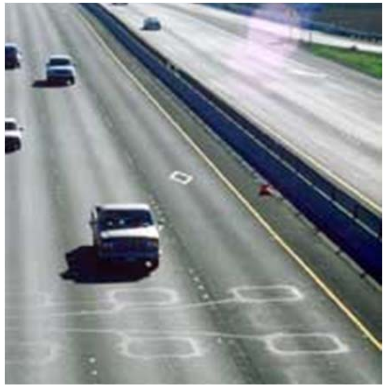


Data fusion at very large scale

The future lies in integration, mining and analytics of BIG DATA



From the sky or space



From the ground

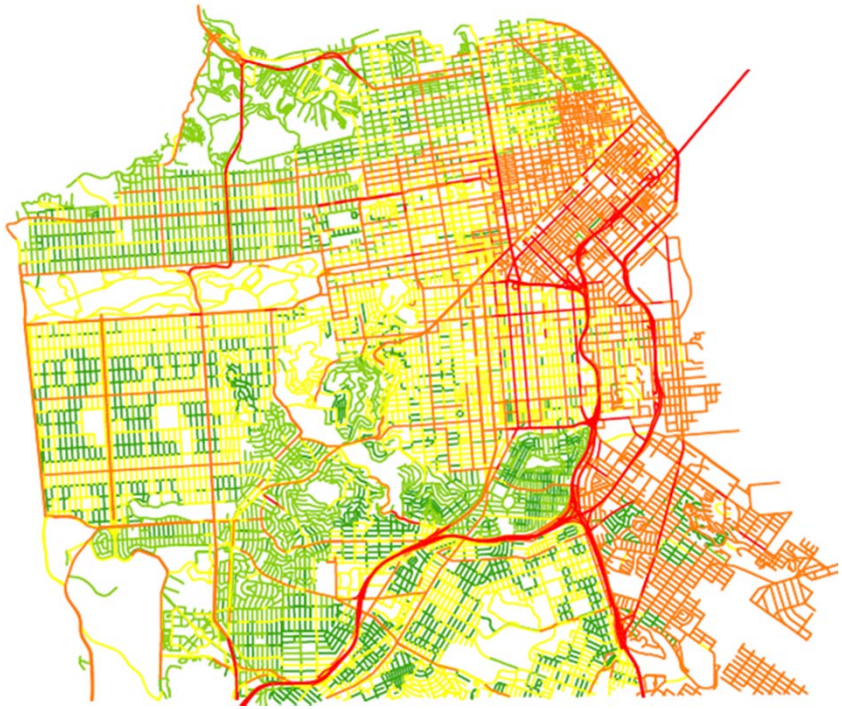
From the vehicles

Traffic tomorrow: beyond traffic

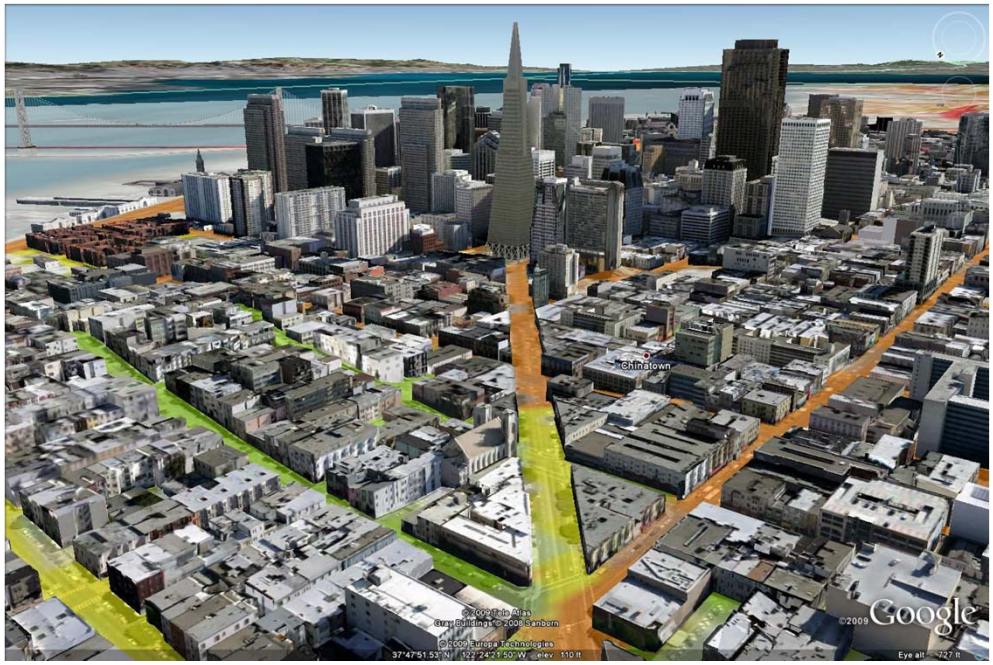
e-Wellness project (E. Seto)

- **Noise levels inferred from traffic: moving beyond the “average number of vehicles / year” paradigm: hour by hour noise levels.**

Today: noise map (static)



Tomorrow: hourly noise map

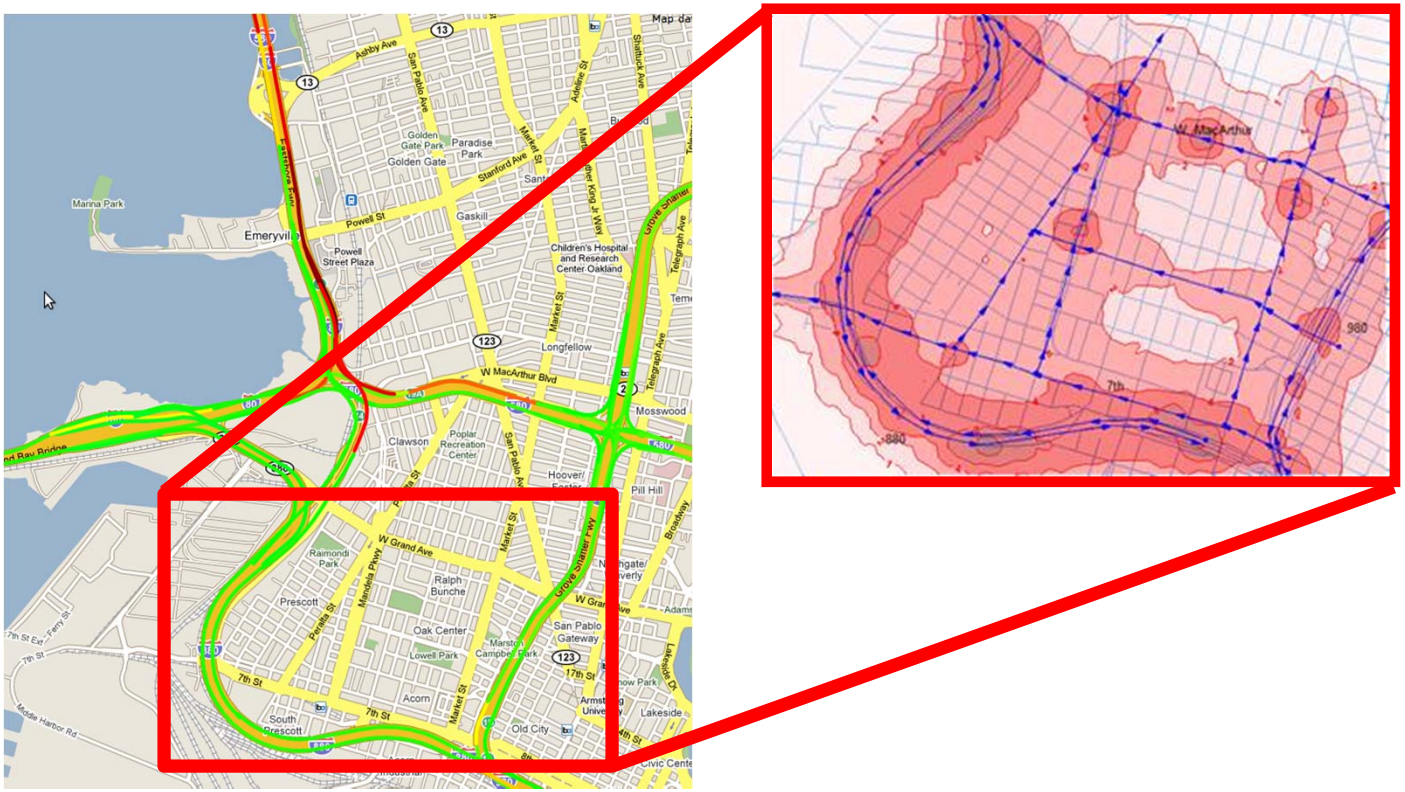


Traffic tomorrow: beyond traffic

e-Wellness project (E. Seto)

- **Noise levels inferred from traffic: moving beyond the "average number of vehicles / year" paradigm: hour by hour noise levels.**
- **Emission levels inferred from traffic, using emission and atmospheric dispersion models. Next gen: sensor based.**

Today: pollution map



Tomorrow: sensor based data

Courtesy NASA/DHS

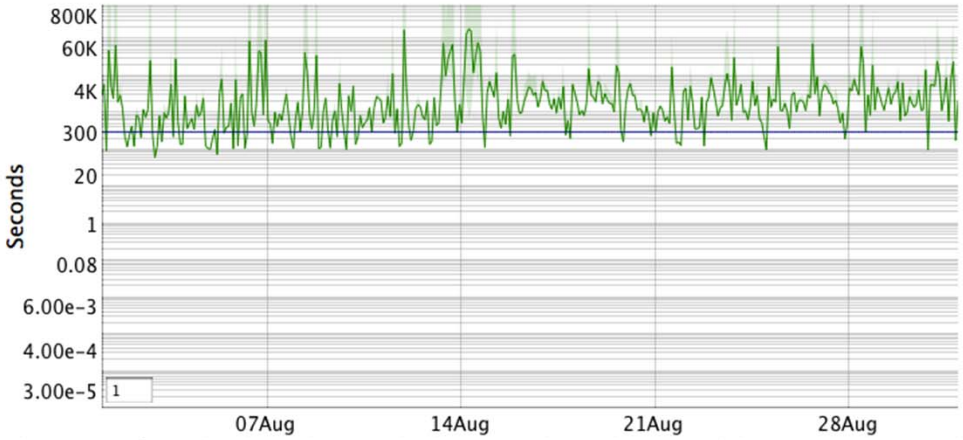
Leveraging Hybrid Traffic Data

The public agencies will use novel types of data

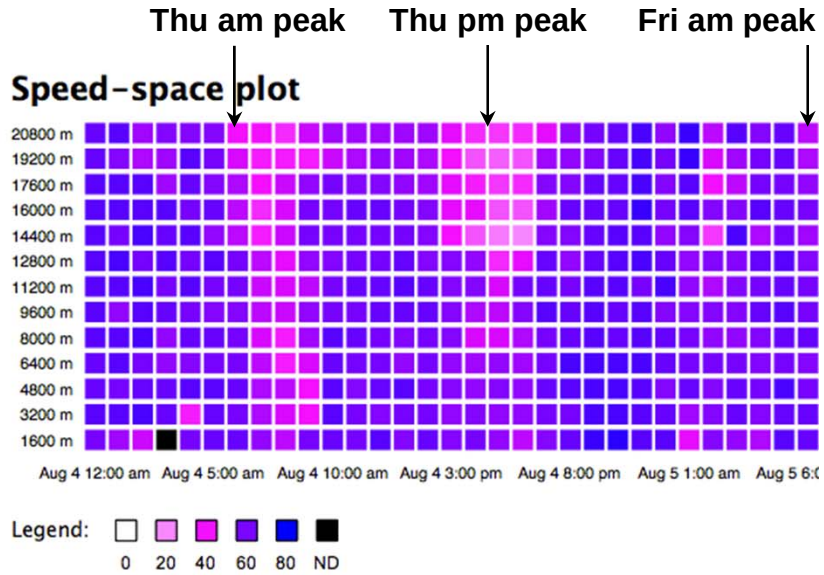
- **Unprocessed data (“dust”, “raw”) probe data**
- **Data can be used to enhance traffic information and management**
- **Procurement procedures unknown until 2010 in California**
- **Pricing schemes unknown until 2010 in California**

Hybrid Traffic Data – Data Quality Metrics

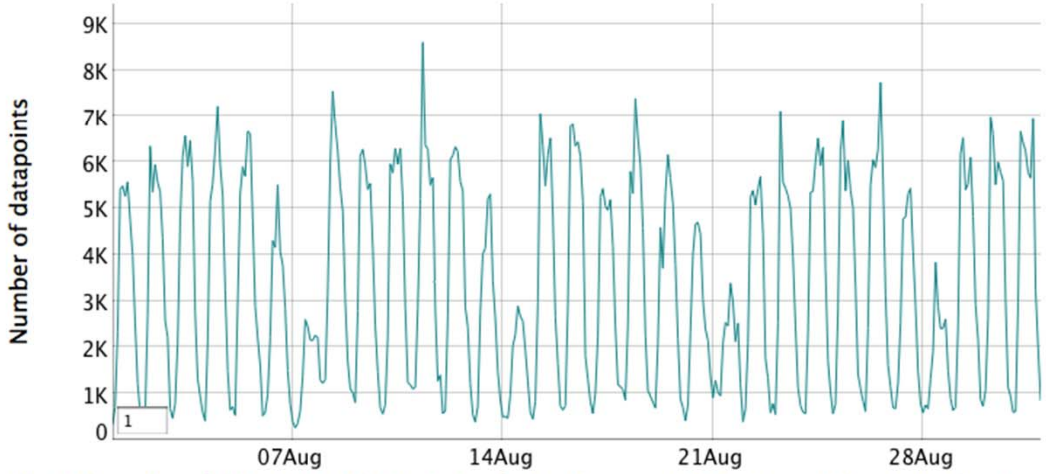
Transmission delay



The amount of time that elapses between the device recording its location and the corresponding record being inserted into the database, in seconds. Line is the average; shaded area represents a standard deviation on either side of the average. Data aggregated every two hours.



Time coverage



The total number of data points at the time specified on the *x*-axis. Data aggregated every two hours.

Provide public agencies with quality metrics, including:

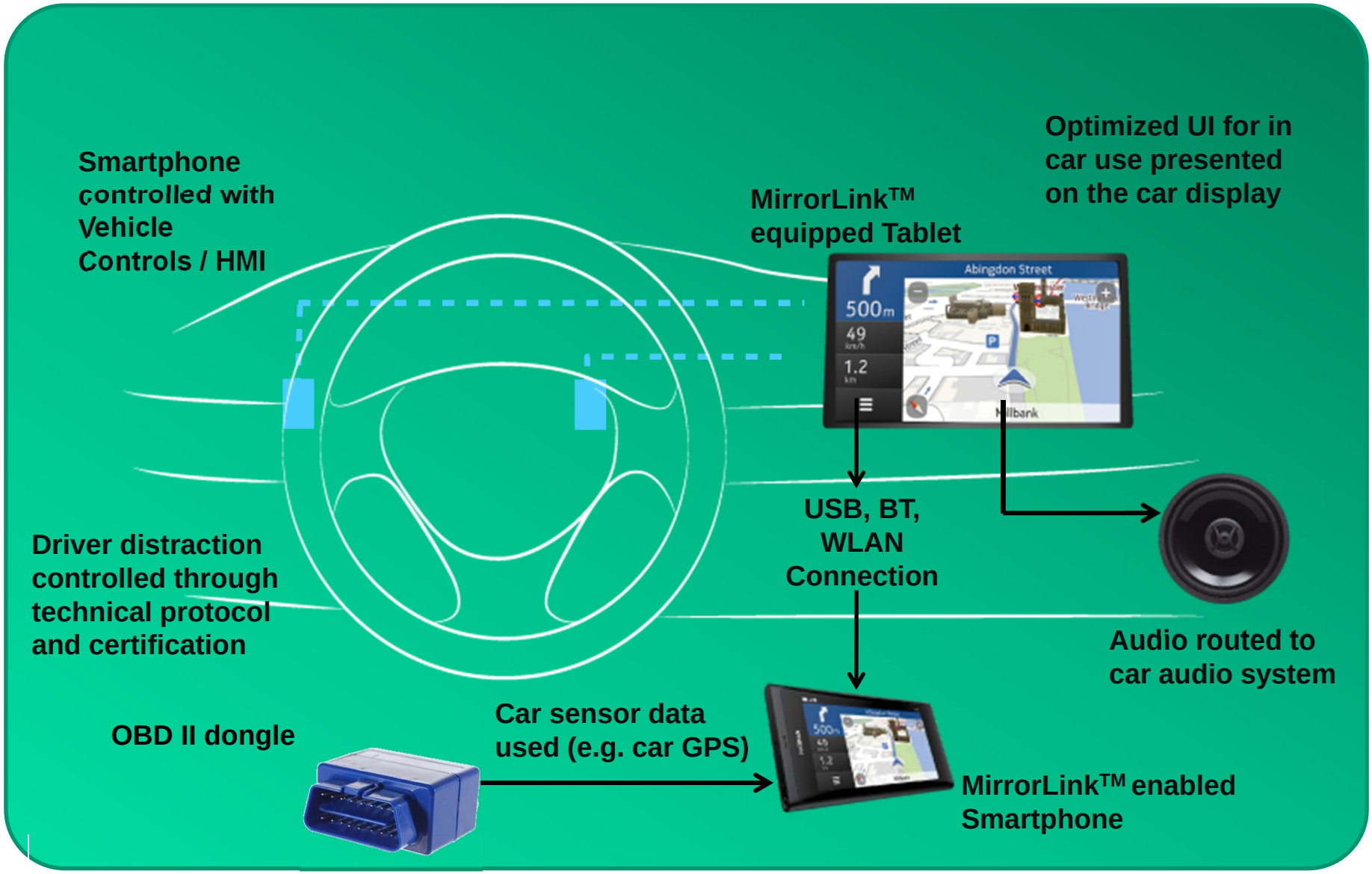
- **Latency**
- **Coverage**
- **Accuracy of tracks**
- **Volumes**
- **Etc.**

Leveraging social networks

The Connected Corridor Consortium will rely on social networks

- **Partnerships with major players in the ecosystem (e.g. Waze)**
- **Use of novel types of data (contextual, text based)**
- **Use of incentivization (not only through information)**
- **Behavioral response analysis**

The future of connected cars (in the next 5 yrs)

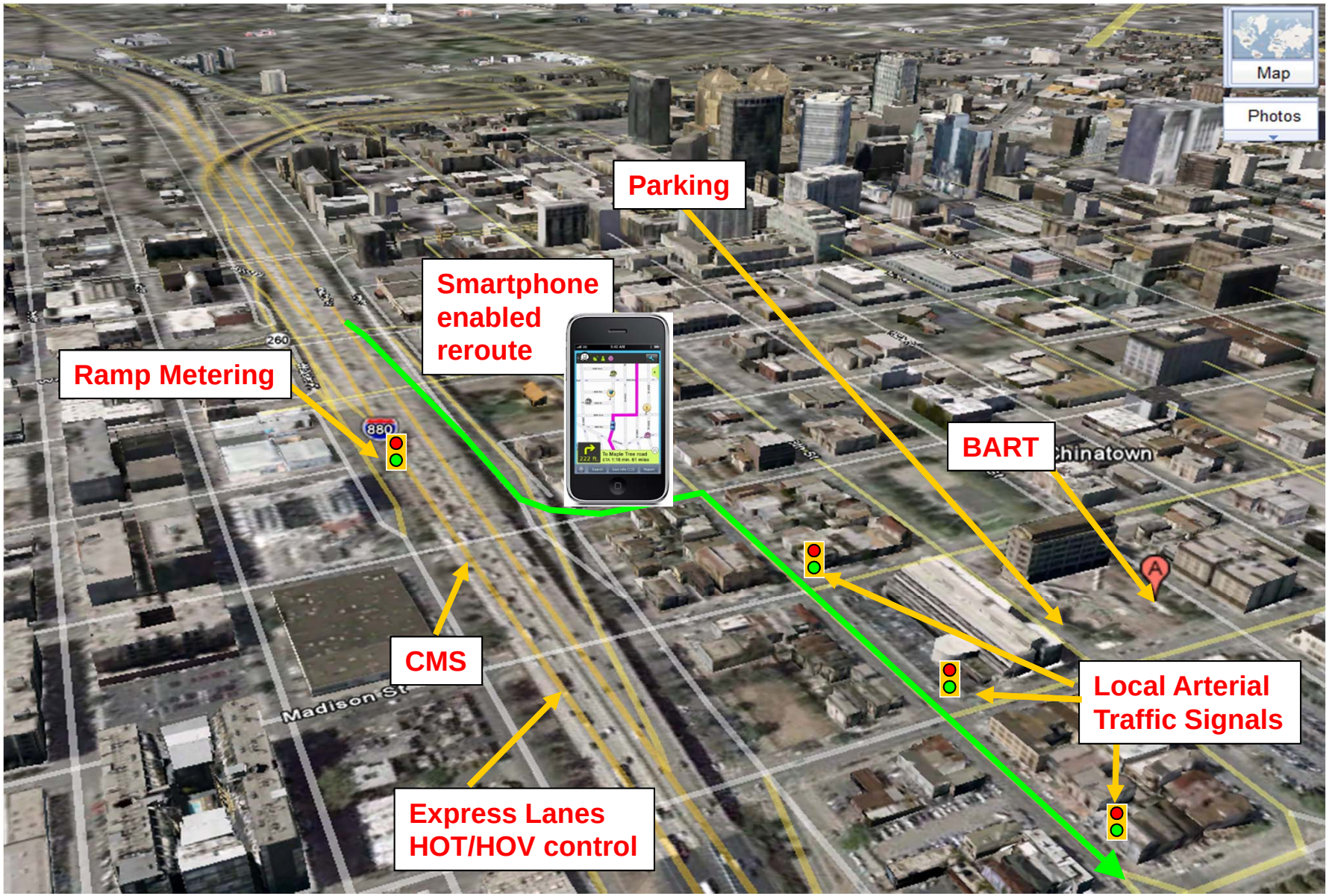


MirrorLink™: the Next Big Opportunity

The MirrorLink™ standard was introduced in 2010

- MirrorLink™ transforms the smartphone into a car app platform
- Managed by the Car Connectivity Consortium (69 members)
- All major car manufacturers
- All major Android and Windows phone manufacturers

The next big thing in California: ICM



Institutional architecture for connected corridors

Caltrans, TMC, MPO(s), Counties
actuation infrastructure
- **Metering**
- **CMS**
- **HOV/HOT**

Transit agencies
- **BART**
- **Buses**
- **Carpool, zipcar, etc.**

Operational commands

CC system

Real-time access, data

Real-time access, data

Advisories
Commands
Travel info

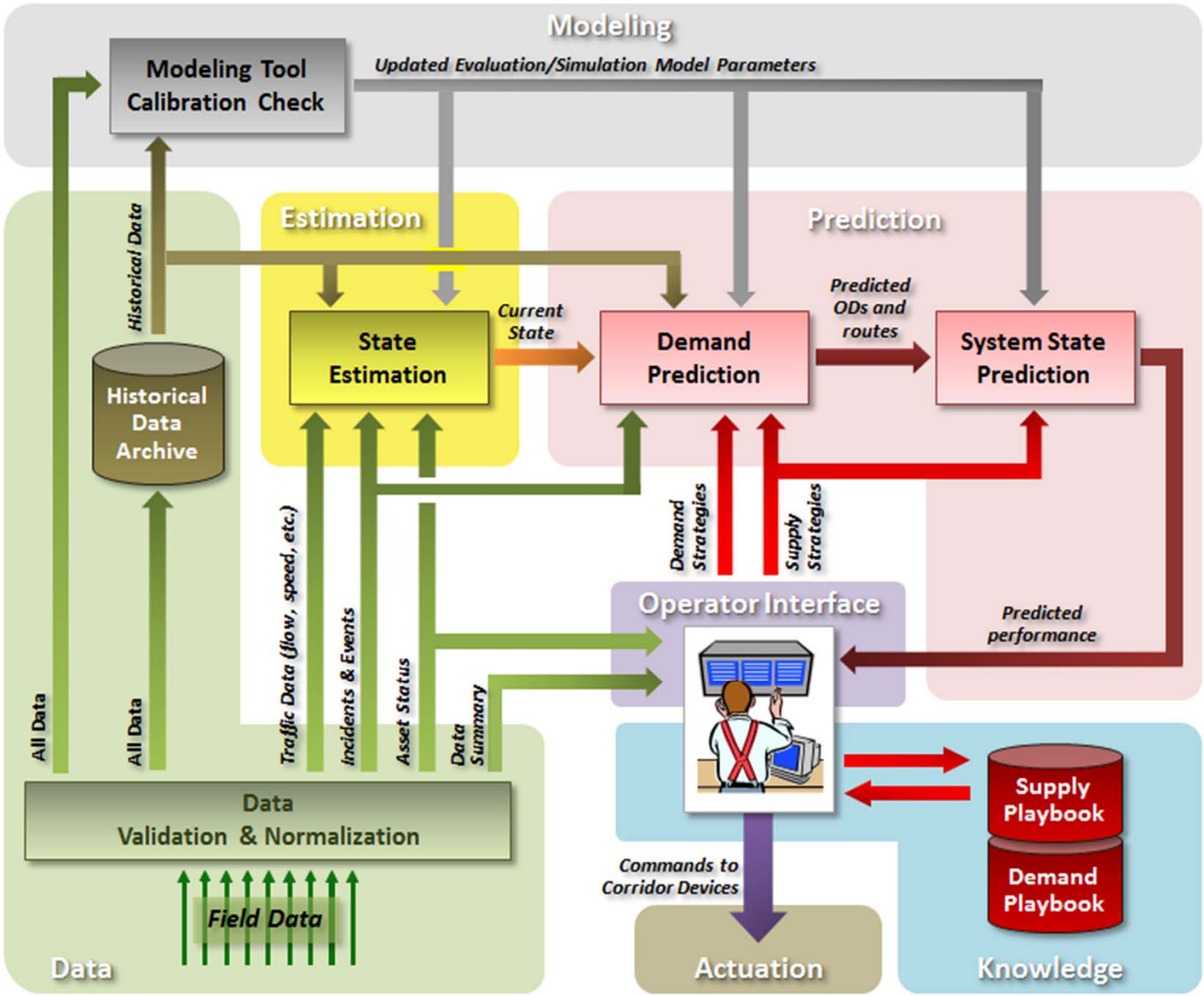
Services
Real-time
access
Data

Collaborative commuters
- **Web apps**
- **Mobile apps**

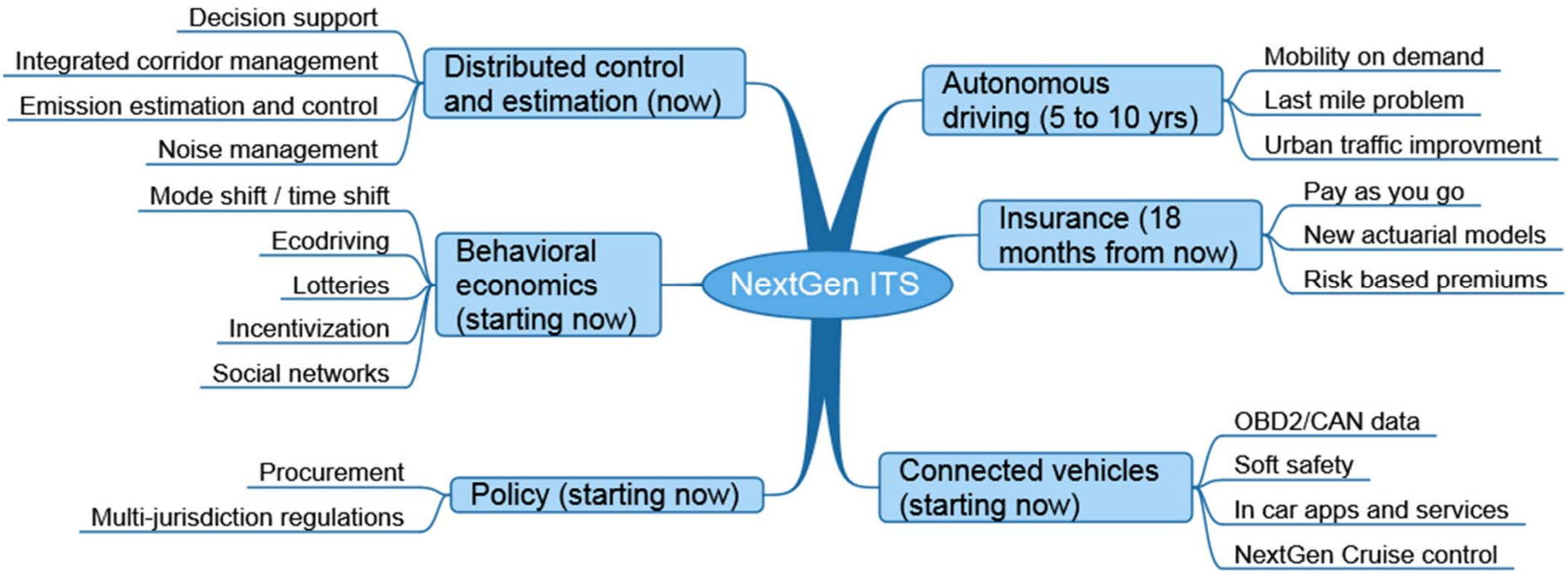
Sensing infrastructure
- **Loops (PeMS)**
- **FasTrak**

Industry partners
- **Data agreements**
- **Services (backend, front end)**

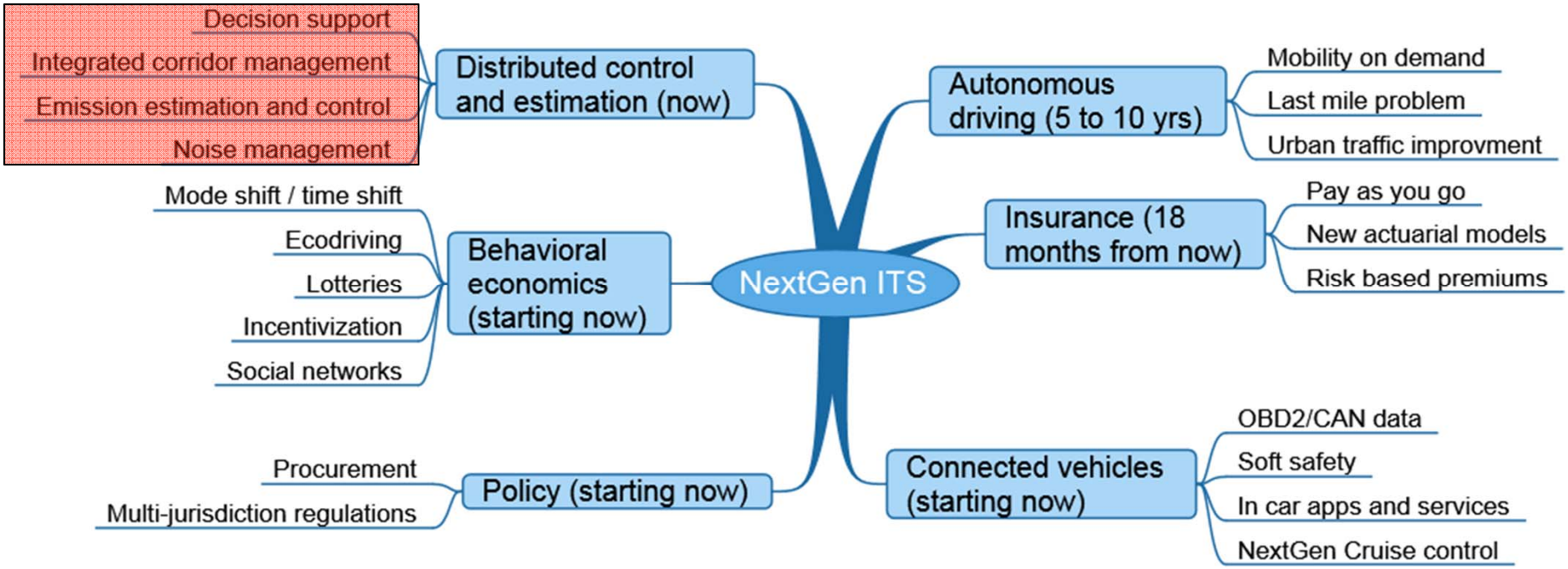
Building a decision support system



Next challenges of ITS



Next challenges of ITS



Themes covered in the workshop

Topics covered by the workshop

- **Bottlenecks (Gasser, Leclercq)**
- **Hamilton Jacobi (Claudel, Monneau, Costesque)**
- **Self organization (Christiani)**
- **PDE-ODE models, queuing (Della Monache, Arita, Tosin)**
- **Micro-macro (Rossi)**
- **Phase transition models, two phases (Blandin, Marcellini)**
- **Fundamental diagram (Zhang)**
- **Riemann solvers, junctions (Garavello, Cividini)**
- **Simulation (Briani)**
- **Second order models (Lebacque)**
- **Traffic monitoring (Work)**
- **Forecast and control (Canudas de Vit)**
- **Control (Canudas de Vit, Geroliminis, Hoogendoorn)**
- **Ramp metering (Gibbens)**
- **Traffic light control (Goettlich)**
- **Pedestrians (Borsche)**

Workshop schedule

March 2013	Wednesday 20	Thursday 21	Friday 22
8:30-9:00	Registration		
9:00-9:15		Goettlich	Zhang
9:15–9:45	Keynote Opening Bayen		
9:45-10:30	Lebacque	Work	Leclercq
10:30-11:00	coffee break		
11:00-11:45	Gasser	Canudas de Witt	Blandin
11:45-12:30	Gibbens	Geroliminis	Tosin Marcellini
12:30-14:30	lunch		
14:30-15:15	Monneau	Hoogendoorn	round table
15:15-16:00	Costeseque Cividini	Briani Rossi	
16:00-16:30	coffee break		
16:30-17:15	Claudel	Garavello	
17:15-18:00	Borsche Cristiani	Delle Monache Arita	

Workshop on Mathematical Foundations of Traffic

Successive workshops

- **Maiori, Italy, 2010**

Workshop on Mathematical Foundations of Traffic

Successive workshops

- **Maiori, Italy, 2010**
- **UCLA, USA, 2011**

Workshop on Mathematical Foundations of Traffic

Successive workshops

- **Maiori, Italy, 2010**
- **UCLA, USA, 2011**
- **KAUST University, Saudi Arabia, 2012**

Workshop on Mathematical Foundations of Traffic

Successive workshops

- **Maiori, Italy, 2010**
- **UCLA, USA, 2011**
- **KAUST University, Saudi Arabia, 2012**
- **INRIA Sophia Antipolis, 2013**

Workshop on Mathematical Foundations of Traffic

Successive workshops

- **Maiori, Italy, 2010**
- **UCLA, USA, 2011**
- **KAUST University, Saudi Arabia, 2012**
- **INRIA Sophia Antipolis, 2013**
- **KAUST University, Saudi 2014**

Workshop on Mathematical Foundations of Traffic

Successive workshops

- **Maiori, Italy, 2010**
- **UCLA, USA, 2011**
- **KAUST University, Saudi Arabia, 2012**
- **INRIA Sophia Antipolis, 2013**
- **KAUST University, Saudi 2014**
- **UCLA, USA 2015**