Intelligent Road and Infrastructure data for automated driving

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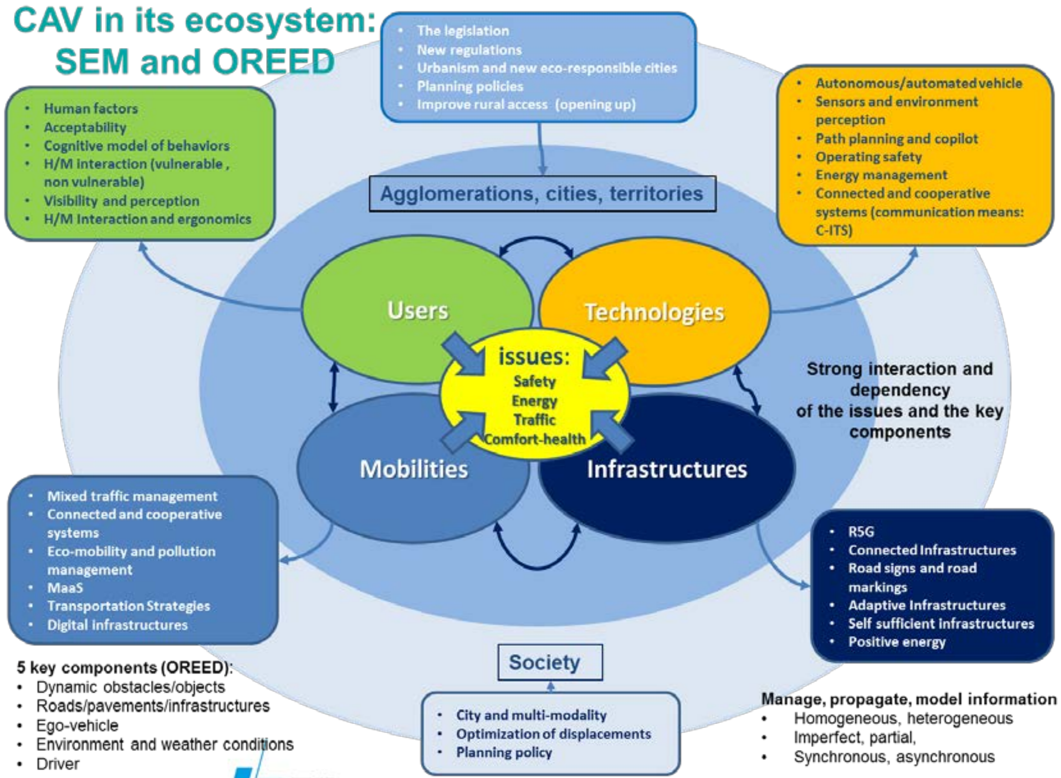
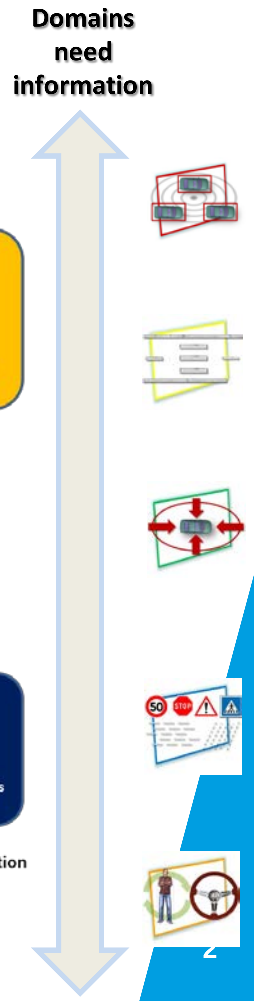
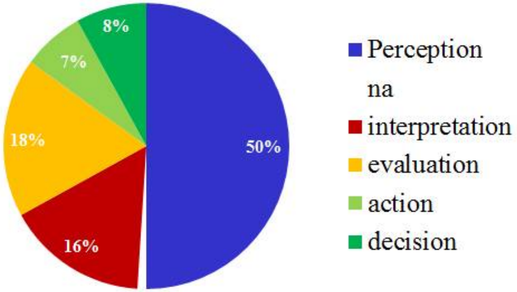
Road ecosystem for mobility
Key components and domains

- The **humans/users** who
- **Use/interact/cooperate** with
- **Technologies and mobility means** on
- **Dedicated and adapted infrastructures** to
- **Move efficiently** and **optimally** according to
- 4 main **criteria** (safety/energy/mobility/comfort and health) for
- **Personal** or **economic** goals

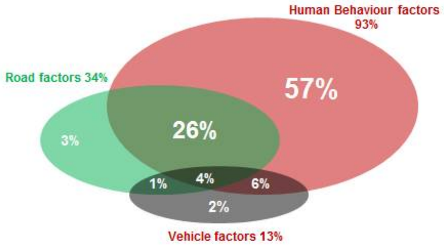


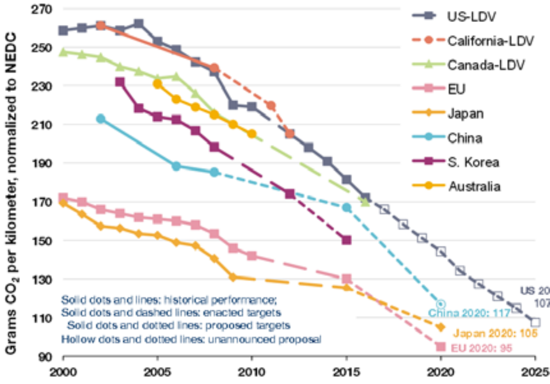


Context: why we need to deploy Cooperative and Automated Vehicle?



- **Safety issues**
  - More than 70,000 fatalities, injured and disabled people
  - Causes of the majority of accidents: the human
  - Remark: minimize the impact of human failures
    - Need to help the driver and the users: development of **Perception**, **Interpretation**, **Decision**, **Action functions**
    - Development of **active** and **informative** embedded **applications** (ADAS-PADAS-ADCOS)
    - Development of **monitoring** service from **infrastructure** in **hazardous areas**
    - Development of autonomous, automated, connected vehicles (cooperative systems).
    - **Human centered design application** for CAV levels 3 and 4
- **Energy and pollution issues**
  - USA: Transport represents 67% of CO2 emissions and the light vehicles 61%
  - France: The light vehicles represent 55% of CO2 emissions
  - 2000 to 2015: strong reduction of CO2 emissions accepted from [270; 170] to [190; 130], with a convergence toward values < 130.
- **Mobility and congestion issues**
  - Significant increase in vehicles density:
    - **More frequent congestion**
    - **Infrastructure** difficult to adapt in order to manage congestions
    - **Impact** on the consumption and the safety
    - **Economic impact**: transport of goods
  - Remark: find new ways to manage traffic with CAV
- **ADAS are one of the solutions to answer the interdependent issues: safety, energy, mobility**
  - Need to estimate and understand the key components and the involved domains in the road ecosystem
    - **Obstacles, Road, Ego-vehicle, Environment, Driver (system OREED)**



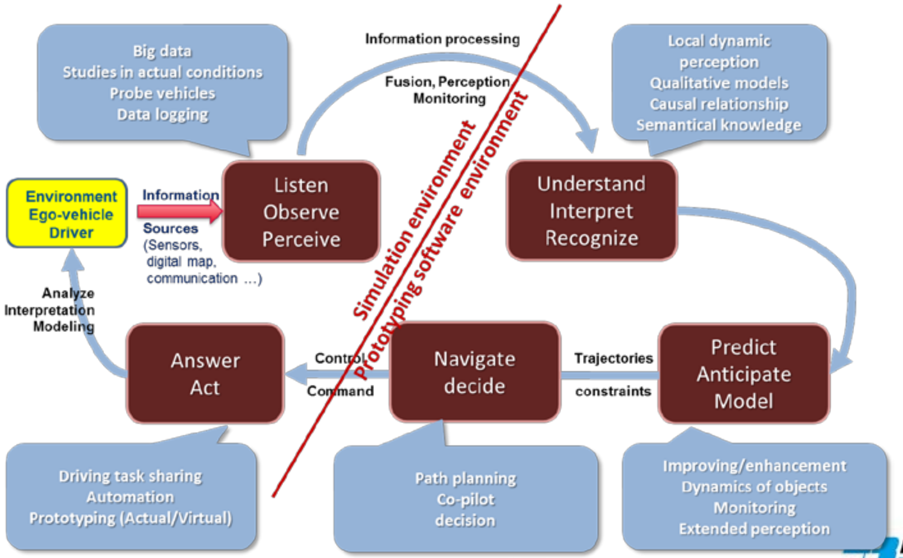


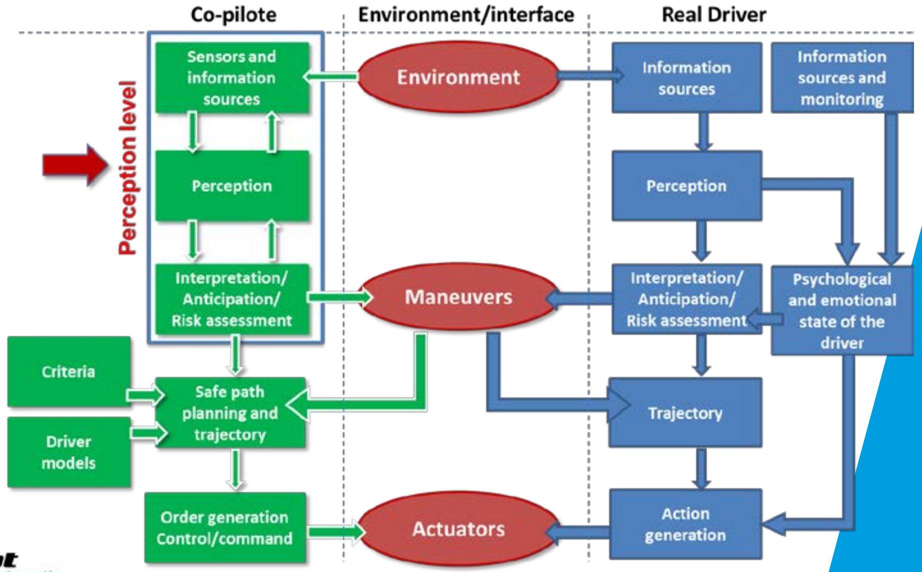
[1] China's target reflects gasoline fleet scenario. If including other fuel types, the target will be lower.
[2] US and Canada light-duty vehicles include light-commercial vehicles.

Information processing and propagation

A complex multiple layers system

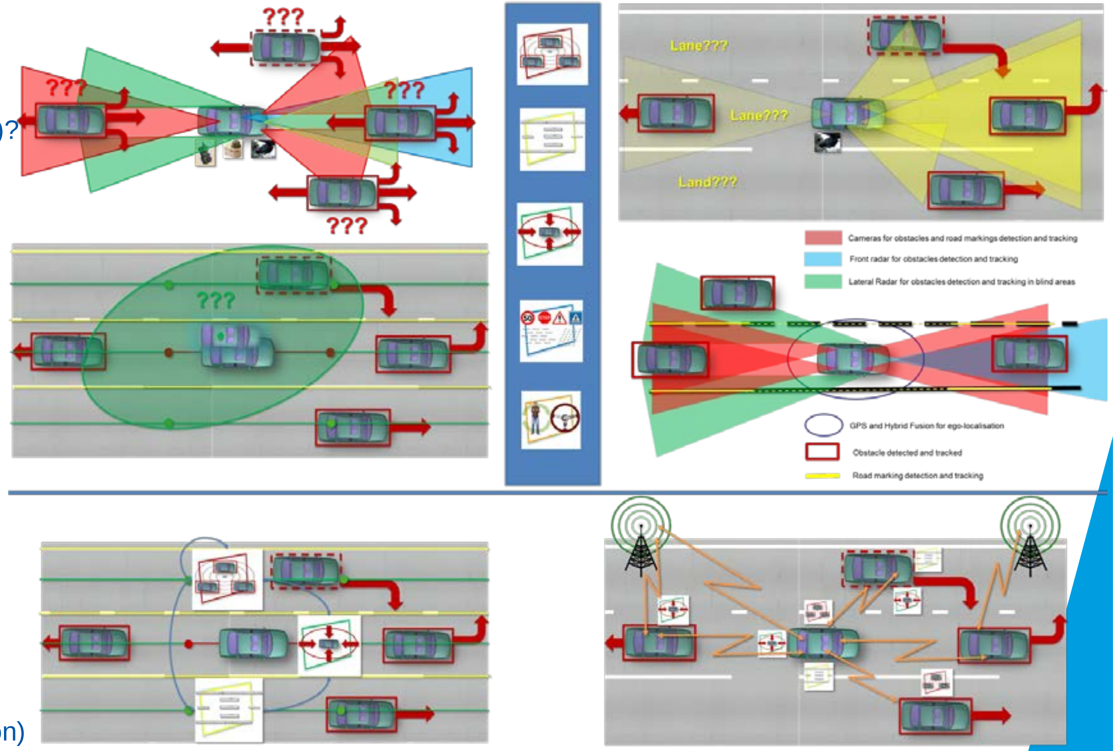
- Critical information come from the embedded sensors → vehicle's surrounding perception
- Bad perception capabilities and/or bad environment readability → potential failure, drawbacks, faults
- In order to guarantee "High Level of Quality" for CAV services → guarantee information quality and perception performances → Infrastructure must help perception layer with well Adapted and "High level of Quality" information





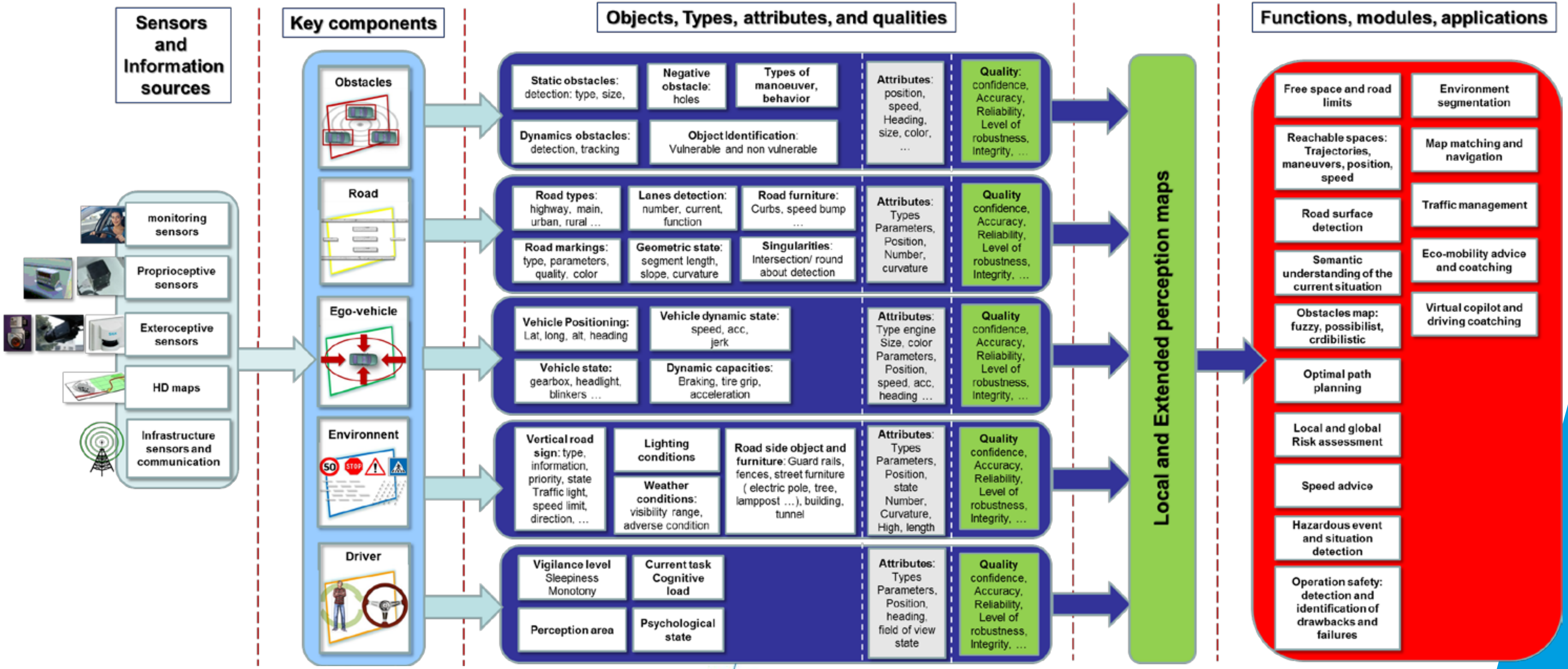
Perception of the road environment:
5 key components in order to model and understand

- Which **sensors** (passive vs active)?
- **How many**?
- Which **topology**?
- Which **configuration** and **performances** (intrinsic, extrinsic)?
- What is the **dynamic** of each **obstacle**?
- Is the obstacle **tracked** for a **long time**?
- Are we able to **predict** its **future state**?
- Can we **quantify** the level of **confidence**?
- What is the **roadway configuration**?
- What is the **number of lane**?
- What is the type, quality and meaning of **road marking**?
- What is the current **traffic lane configuration** (ego-lane)?
- What is the **dynamic state** of the ego-vehicle?
- What is its **configuration** on the **roadway**?
- What is the **future configuration** of the **roadway**?
- What is the **level of visibility** (weather and road configuration)
- What is the current **driver state**?
- …



Information processing and propagation

Key concept: a complex multiple layers information system



How automated vehicles can drive safely ?

- **To drive safely, key functions must be ensured with a high level of reliability**
  - Reliable trajectory control
  - Anticipation of simple or complex situation
- **As the level of automation will increase (level 1 to 5) vehicle dependence to infrastructure is growing**
  – The infrastructure must provide an increasing level of quality of information and service (HQoI and HQoS)

Key function	V2V interaction	V2I interaction
Lane keeping	NO	YES
Curve overshooting prevention	NO	YES
Distance headway control	YES	NO
Collision avoidance or mitigation	YES	NO
Speed control according to road geometry, road surface, weather condition and legal speed limits	NO	YES
Safe overtaking	YES	YES
Safe crossroad and roundabout crossing	YES	YES

Which infrastructure key features and data?

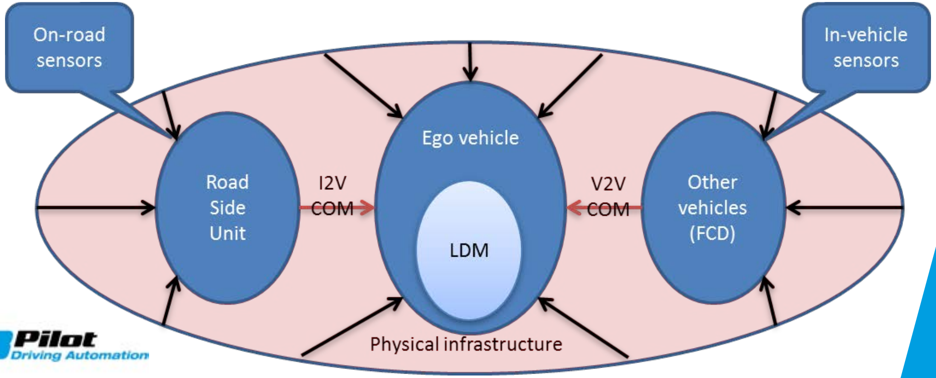
Infrastructure Features	Role/Impact	Variability ov. the time
Lane marking readability	Vehicle guidance for lateral control	Static
Road curvature and cant	Vehicle stability, curve overshooting prevention	Static
Road slope	Collision avoidance during overtaking manoeuvre.	Static
Road skid resistance	Vehicle stability in straight-right and curve situation	Static, temporary
Ruts, potholes, ruptures, cracks	Vehicle stability in all situation	Temporary
Geometric visibility	Collision avoidance during overtaking manoeuvre	Static
Traffic light status readability	Safe crossroad crossing	Dynamic
Road sign readability	Driving with respect to highway code (e.g. speed limit)	Static
Weather condition	Vehicle stability, vehicle headway, safe overtaking	Dynamic

Feature metrics for infrastructure as a smart sensor

- **Depending on the automation level, vehicles will expect from infrastructure a given level of HQoI and HQoS**
  - Example : ruts and potholes impact is negligible on safety at 50 km/h but is critical at 130 km/h
- **HQoI and HQoS must be quantized : need a feature metric**
  - 1st approach (today) : crash data base analysis
    - correlation between accident and key features presence or absence
  - 2nd approach (open research) : probabilistic approach aiming at estimating a crash probability given some feature values and conversely to set the threshold for a given safety level. Refer to study on curvatures failures.
  - Up to now : automated vehicle crash database does not exit : necessity to combine real-world database and physics-based simulation
- **Depending on the HQoI and HQoS levels, vehicle will decide to move into an automated (level 3 to 5) mode or into a manual mode (level 0 to 2).**

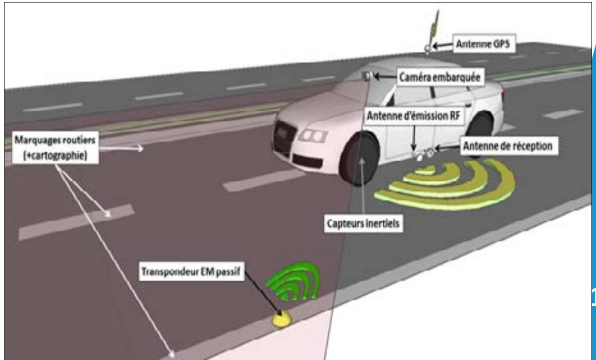
Secured itinerary, digital and physical architecture

- **Secured itinerary (or HQoSH)**
  - A road (or physical infrastructure) of which features values are enclosed within some limits such as automated vehicle can move on it safely
  - Modeled by the digital infrastructure
- **Digital infrastructure : a numeric representation of the physical infrastructure**
  - Modeled onboard by the Local Dynamic Perception Map (LDPM)
  - Must be continuously updated such as to reflect the physical infrastructure status
  - Supplied with data from road side equipment and **other automated vehicle acting as probe vehicles (FCD)**



Robustness, accuracy, reliability, confidence, integrity of data
The multi-sensor and multi-source data fusion

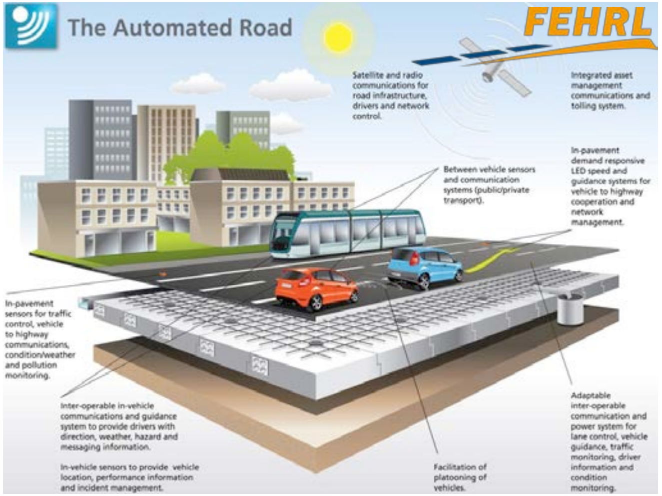
- **Example : lateral control → need to estimate accurately lateral position**
  - Level 1 : GPS and dead reckoning (Gyro, Odometer)
    - ➢ Inaccurate and sensitive to masking in urban canyon or tunnel ,
  - Level 2 : lane marking detection
    - ➢ Accurate but sensitive to lane marking degradation, adverse weather condition and camera glare
  - – Level 3 : on-road (embedded) electromagnetic tags
    - ➢ Accurate, expensive and sensitive to magnetic masses
- **Reliability and robustness is ensured by merging various level of information even is each of them have weaknesses**
  - ➢ Thanks to filtering methods like EKF, UKF, IMM



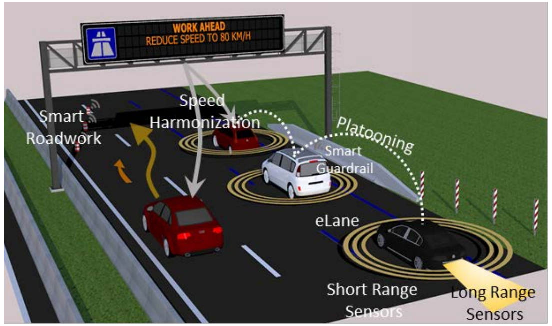
From Automated vehicles to automated roads

Key concept : Towards Hybrid Infrastructures

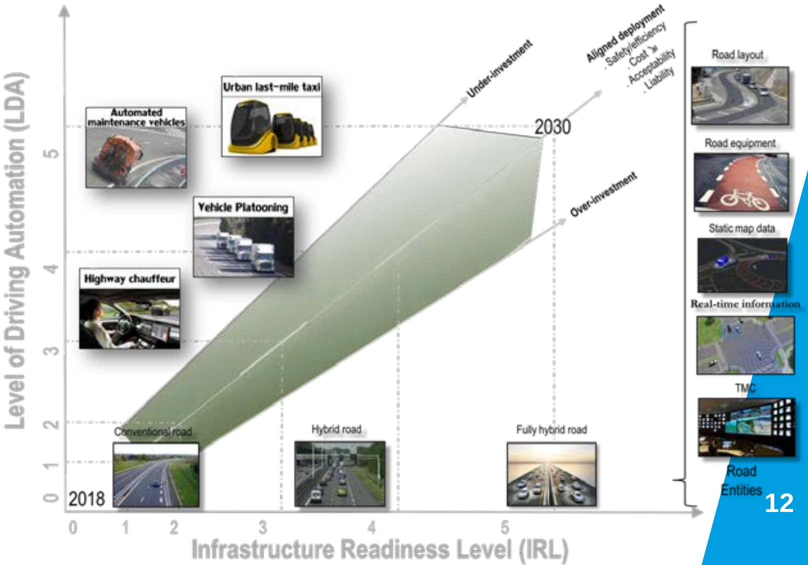
- **Fully integrated with the user, vehicle and operations:**
  - The **automated road** will incorporate a fully **integrated information**, **monitoring** and **control system**; **communicating** between **road users**, **vehicles** and **operators**.
  - It will support a **cooperative vehicle-road system** that will manage travel demand and traffic movements.
  - It will **measure**, report and respond to its own condition, providing instant **information** on **weather**, **incidents** and **travel information**.



Highway Environment

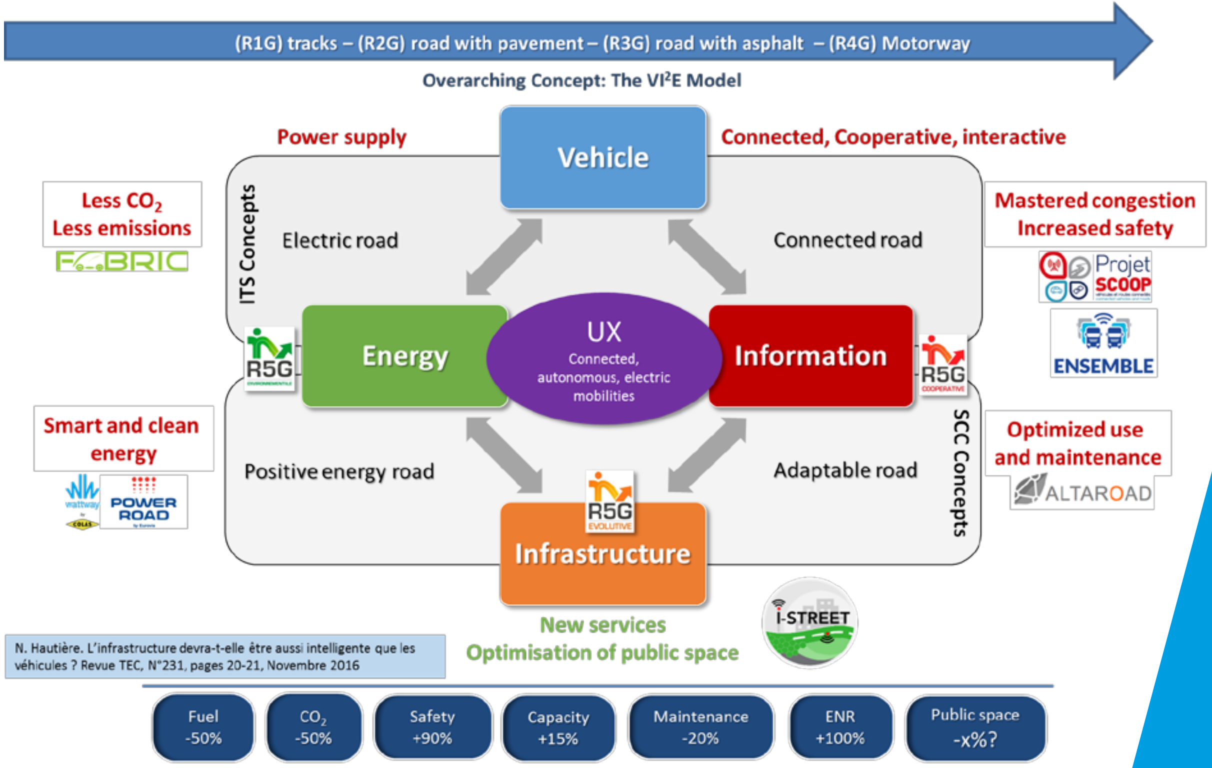


Urban Environment



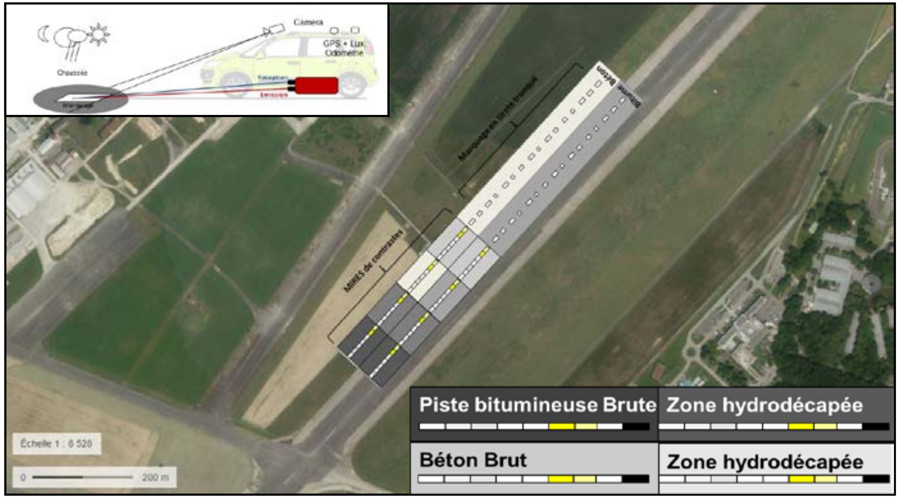
Several ways in order to address the R5G issue involving CAV

- **The "intelligence" is embedded in the vehicle**
  - Problem with degraded weather and visibility conditions: limited perception range
- **The "intelligence" is mainly put on the infrastructure**
  - Control from road side control center
  - Problem if a cyber attack occurs
  - Without information from infrastructure the vehicle become almost blind.
- **The "intelligence" is shared between both vehicles and infrastructure**
  - More clever and efficient in case of failure on one of the 2 parts. Better from a operating safety point of view.
  - The vehicle could be a probe in order to check the readability and the access of the infrastructure information
  - Better to detect external attack
  - Guarantee a higher level of perception quality

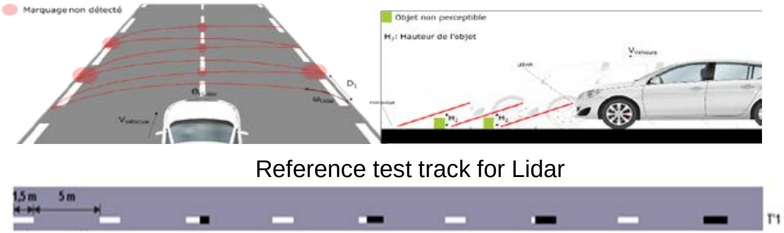


How to design new generation of road signs
Highly automated driving

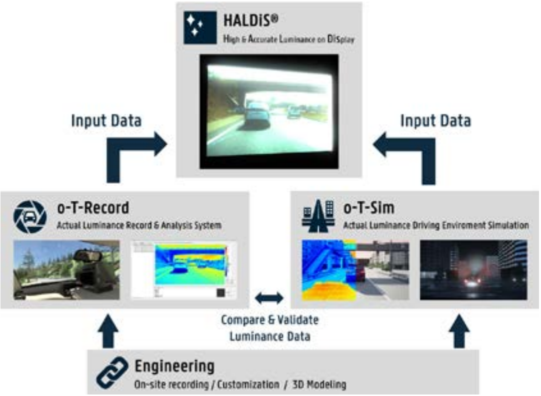
- **Objectives: cross evaluation protocol of in-vehicle sensors and road signs**
  - Establish a correlation between detection of signaling by a vehicle sensor and measurements by a reference device
  - Develop a HIL bench to test a AV sensor for a given road sign and vice versa.



Reference test track for camera

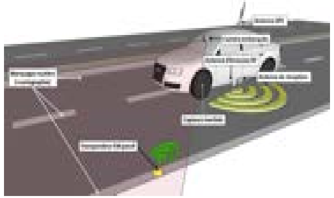


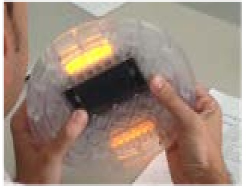
Reference test track for Lidar

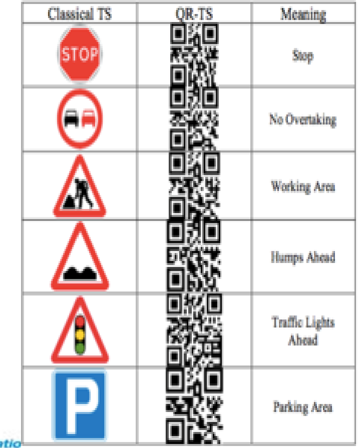


A few L3-4 infrastructure components

- Smart roadwork signaling
- Smart lane marking (e.g. transponders)
- Connected safety barrier
- Road side unit
- Hybrid road signage
- More contrasted lane marking







Classical TS	QR-TS	Meaning
STOP		Stop
		No Overtaking
		Working Area
		Humps Ahead
		Traffic Lights Ahead
P		Parking Area

Conclusion: Impact of automation on road infrastructure

- To be able to circulate, the automated vehicles require infrastructures of which one is able to establish permanently the level of service (concept of HQoI for HQoS)
- This HQoS can be established by connecting on-board and off-board sensors, and building associated models and indicators.
- Depending on the level of connectivity and automation of the fleet, it will be possible to automate traffic and improve the efficiency of traffic management (concept of IRL).
- Depending on the regulations that will be put in place, the impact of this deployment will be virtuous or not, and must necessarily be accompanied by the deployment of cleaner and more shared mobility.
- Therefore, in addition to their automation, infrastructures must integrate the issues of digital transition, energy transition and ecological transition.
- Question: Will the new generation of infrastructure be a well maintained, hybrid, connected infrastructure? What should be the embedded sensor capability? What will be the road side sensor and perception infrastructure? Will the same road infrastructure for human drivers and virtual copilot (embedded system)?

Issue to take into account: the Cyber Safety and Cyber Attacks communication, perception, system state

- **Cyber attacks could be a serious issue: data theft, intentional failure, takeover. It requires the implementation of increasingly complex security strategies and protocols. The most dangerous attacks are those that target information availability.**
- **Five categories of cyber attacks for VAC using VANETs, : (1) availability, (2) data integrity, (3) confidentiality, (4) authenticity and (5) non-repudiation.**
  - The “*Black hole*” and “*Grey hole*” attacks: the compromised communication node stops relaying messages to neighboring nodes. The distribution of information on the network is then blocked. The "Black hole" consists of deleting all messages, while the “Grey hole” only deletes certain messages.
  - The “*flooding attack*” which consists in sending an enormous volume of messages to saturate the communication node which then becomes unavailable. The VANET is very sensitive and vulnerable to this type of attack.
  - The « *Jamming attack* »: Broadcasting signals to corrupt data or jam the transmission channel. Currently no effective solution exists to prevent this type of attack
  - The « *Coalition and platooning attacks* »: A set of compromised communication nodes will collaborate to carry out malicious and harmful actions such as blocking information or isolating network vehicles. This attack can combine and make several types of attacks in same time.

Issue to take into account: the Cyber Safety and Cyber Attacks communication, perception, system state

- **Threats to data integrity (sensors, environment, comm) are also a sensitive issue for VACs: We need to be able to guarantee the readability, the accuracy and the consistency of the data that propagates over the network:**
  - The modification, degradation, and alteration of data as well as the injection of false messages which will induce malfunctions in the systems on board the vehicle.
  - Replay / repeat attacks which involve replaying messages received at a different time to look like those sent by the original sender. One defense strategy is to use the storage of recently received messages (cache memory) to compare the content of new messages and to reject temporally erroneous messages. In VANETs, a time stamp, one-time tagging information, and a short message lifetime provide some resilience to these attacks.
  - GPS data spoofing attacks consist of transmitting false GPS data (false location of the transmitter) or delaying their transmission thereby rendering them erroneous.

Thank you for your kind attention.

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Colours

Primary colours

R 0 G 158 B 255	R 109 G 207 B 246	R 199 G 234 B 251
R 0 G 0 B 0	R 109 G 110 B 113	R 230 G 231 B 232

Secondary colours

R 0 G 105 B 145
R 198 G 63 B 57

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