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VEHICLES TRAJECTORY ANALYSIS : AN INNOVATIVE APPROACH OF ROAD SAFETY

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Outline

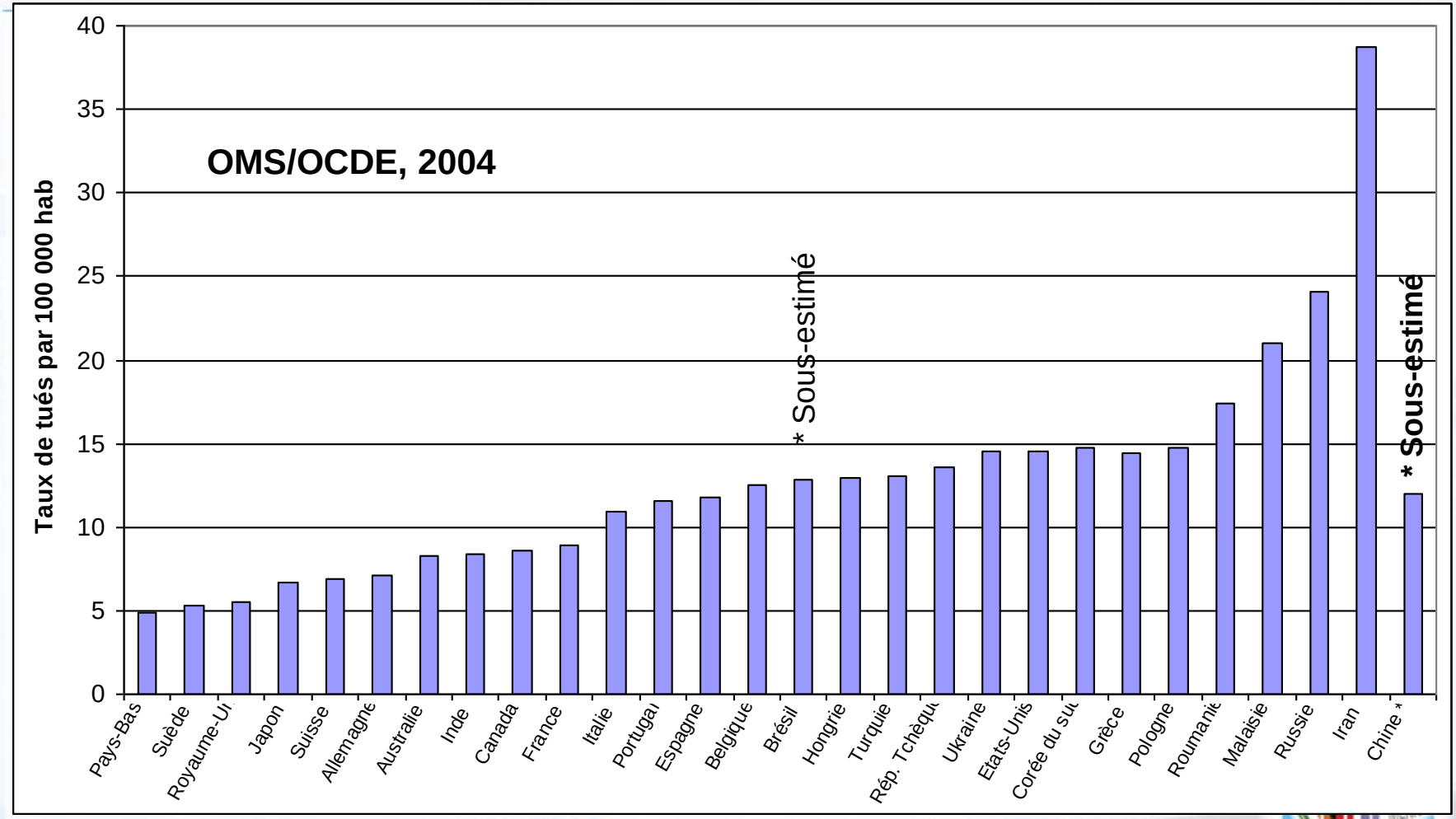
- Challenges
- Trajectories and accident mitigation
- Trajectory observatories
- Trajectory modeling and limit states
- Data, measurement methods and calibration
- Diagnosis tools
- Warning in bends
- Risk mitigation in intersections
- Automated speed enforcement impact on speeds
- Conclusions

Challenges
Trajectories and road safety

Challenges

- 1,3 million fatalities/yr on the roads (worldwide)
- Not uniformly distributed:
  - OECD: 120 000, BRIC: 260-300 000, others: 900 000
- 50 millions injuries/yr, 90% in developing countries
- Childs, pedestrians, cyclists, elder persons
- 65 to 100 bn $/yr, or 0.5 to 3% of GNP
- Figure reliability: OECD, WHO, WB, IRF, polices
- OECD: - 20 to 40%, developing countries: +20 - 25% in 10 yrs

Fatalities on roads per country



Trajectories and risk mitigation

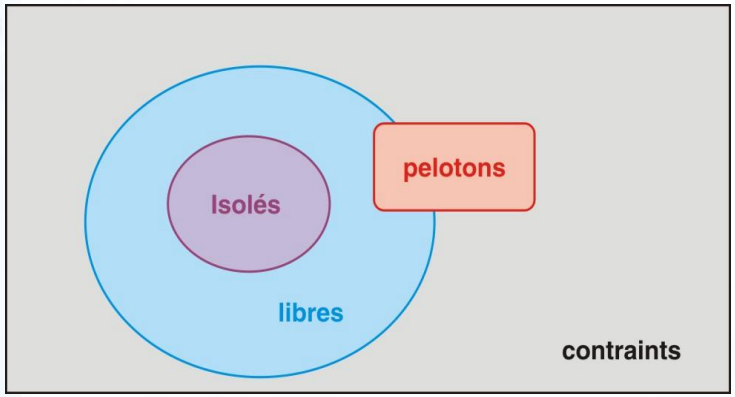
- EU: 0.6 fatality/100 millions pass.km - 8 fatality/1000 km/yr
  accidents → statistics of rare events (Prob 10^{-4}-10^{-8}), main causes solved, combination of complex causes
- IFSTTAR (2003): study "quasi-accidents" or "near missed" → risk indicator, appropriate driver behavior /vehicle - ext. conditions
- "Extended" Trajectory: time function (X,V,Γ,J):
  vehicle + infrastructure + driver (+ ext. conditions)
- Failure trajectory analysis: Prob 10^{-1}-10^{-3}
  incidents, statistics OK

Trajectory observatory
Models – measurements –
Limit states - data

Trajectory observatories

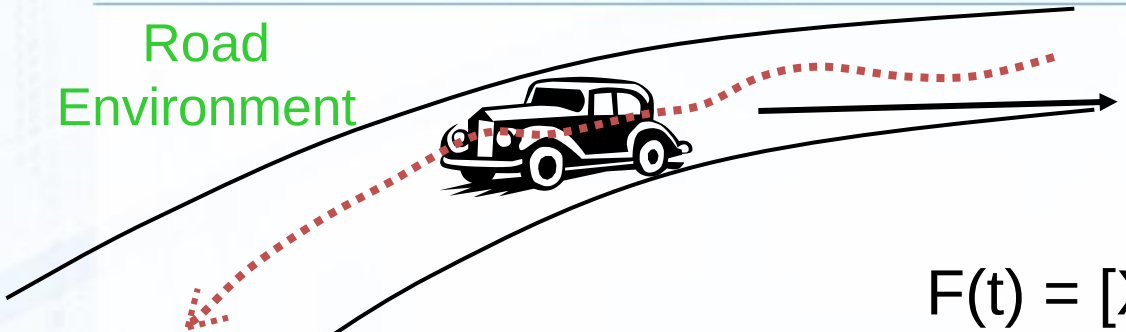
- Tools, devices + softwares, data collection + processing + analysis / databases

	On-board measurements	Road side measurements
Local Trajectories < 100m	MITL	METL
Global Trajectories > 100 m	MITG	METG
Reference Trajectories	MRT	



- Vehicle types (cars, HGV…)
- Conditions and external parameters (traffic, weather…)

Trajectories : model & measurement



Road Environment

Trajectory models and measurements

$F(t) = [X(t), Y(t), Z(t)]$

Other measures

Other road data (weather, traffic…)

Sample of trajectories

$F(t) = \{f_i(t)\}$

Trajectory modeling:
- reference trajectory
- acceptable trajectory
-safe/unsafe trajectory

Road characteristics and environment

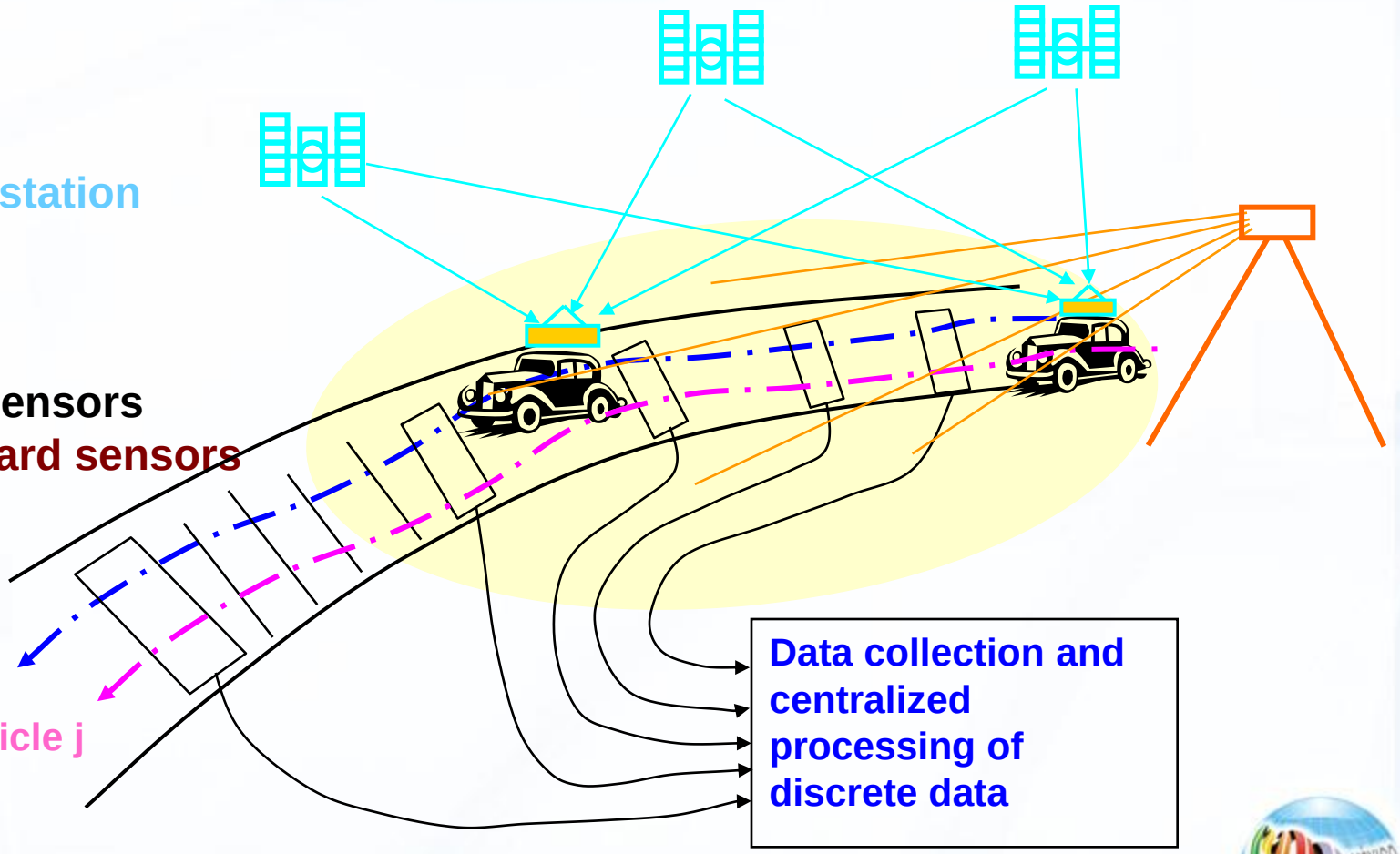
Processing and analysis

Relationship between trajectory and road characteristics ➔ "risk level" road / environment

Trajectory measurement tools

- GPS
- Inertia station
- Video
- Radar
- Lidar
- Road sensors

+ On-board sensors



Trajectories and limit states

- Trajectory = (random) process in R^n
  location & derivates, location time function = path
- Distance between trajectories (Mahalanobis)
  to distinguish traj. with same path & ≠ time functions
- Safety domain - $g(X,V,\Gamma)\geq 0$:
  - Ultimate limit states: accident, irreversibility
  - Serviceability limit states: quasi-accident, reversibility
- Link (correlation) failures- infra characteristics, vehicles, driver commands, situations

Data and measuring tools

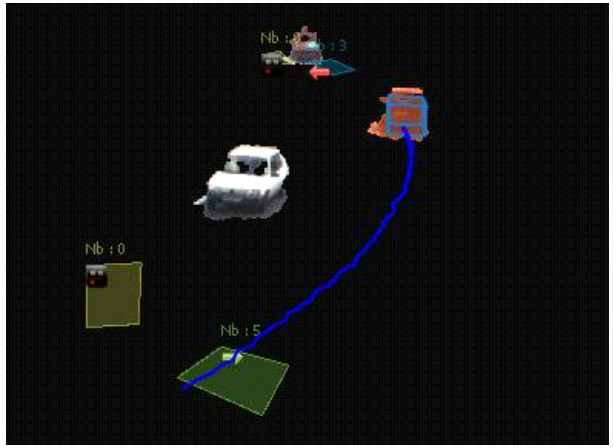
Parameter	Technology	GPS	Inertia	Camera	Radar	Lidar
Position (plane)	On-board	+++	++	++	+	+
	Road side	-	-	++	+	++
Angle de cap	On-board	+	+++	+	-	-
	Road side			+	+	+
Speed (long.)	On-board	++	+++	-	+	+
	Road side	-	-	+	++	+
Accelerations (long. + transv.)	On-board	-	+++	-	-	-
	Road side	-	-	-	+	-

Calibration: MRT (vehicle Ifsttar: VERT)
Cinematic bi-frequency GPS_& inertia station, accuracy: a few cm

Applications

Diagnosis tools (1)

- Black holes
  - Bends, intersections…
  - Local observatory, road side
  - Cameras + lidar
  - All vehicles
  - Data fusion: *filtrage particulaire + bicycle model*
  - Range > 100 m
  - Transv. location: RMS 0.2-0.3 m
  - Long. speed: RMS 1.3 km/h

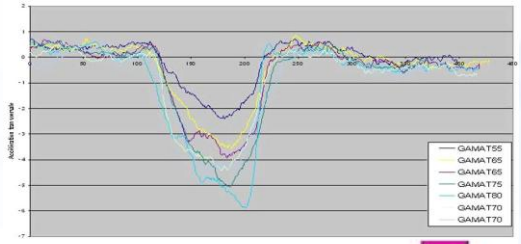


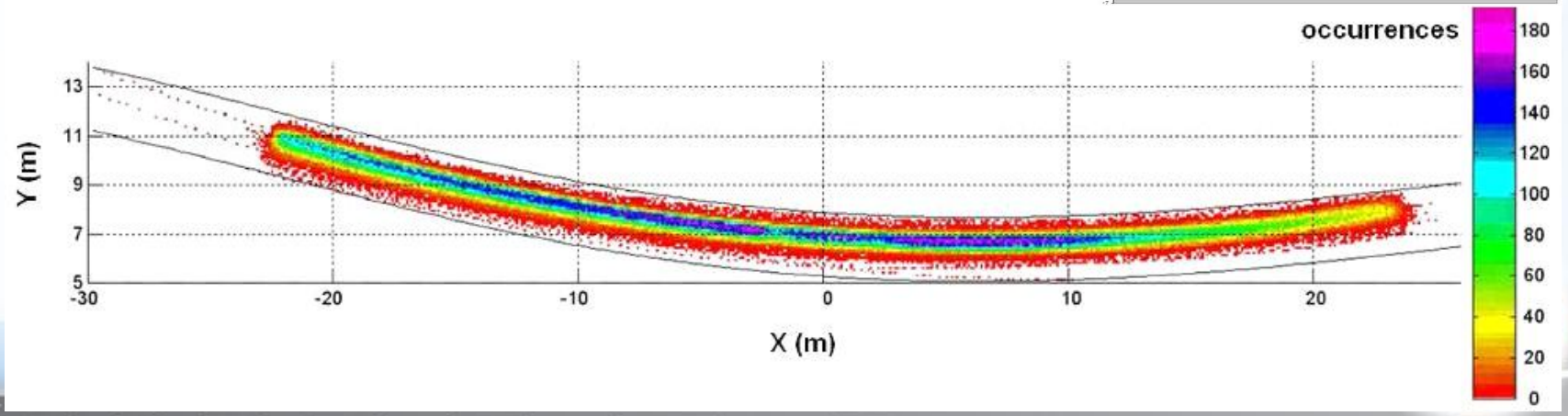
Diagnosis tools (2)

- Itinerary diagnosis
  - a few km to more than 100 km
  - global observatory, on-board
  - samples of vehicle and trajectories (instrumented *fleet, naturalistic driving*)
  - mono-frequency GPS + gyro meter + odometer + B&W camera *(road signs)* + context record
  - data fusion: *Kalman filtering + bicycle model*
  - unlimited range
  - transv. location : RMS 0.1-0.2 m with road signs
  - long. speed: RMS 1.5 km/h

Warning in bend (1)

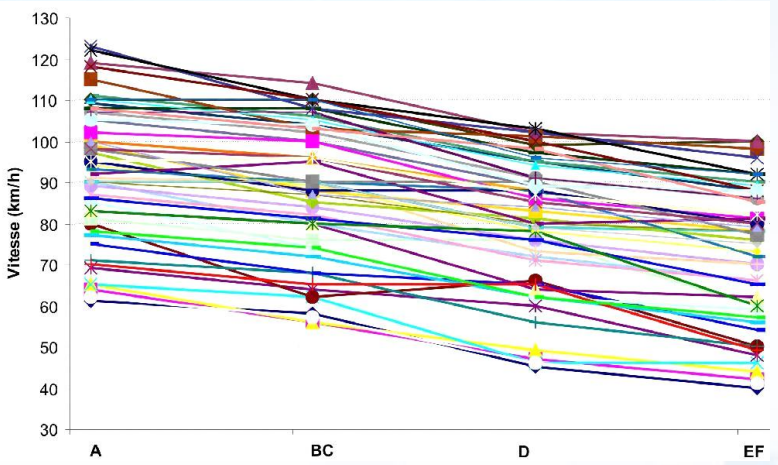
- France, 2009: 32% accidents, 36% fatalities
- Trajectory survey to analyze road signing and driver behaviors
- Y, V_X, Γ_X, Γ_Y: functions of x, thresholds (limit states), e.g. $\Gamma_{X,Y} \leq 5$ m/s².
- MITL → measuring spots & light signal in the bend approach (if $V_X > V_{85}$).

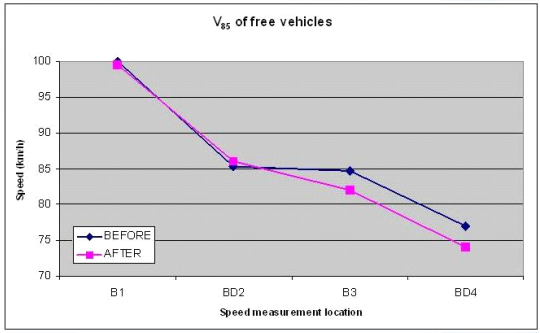


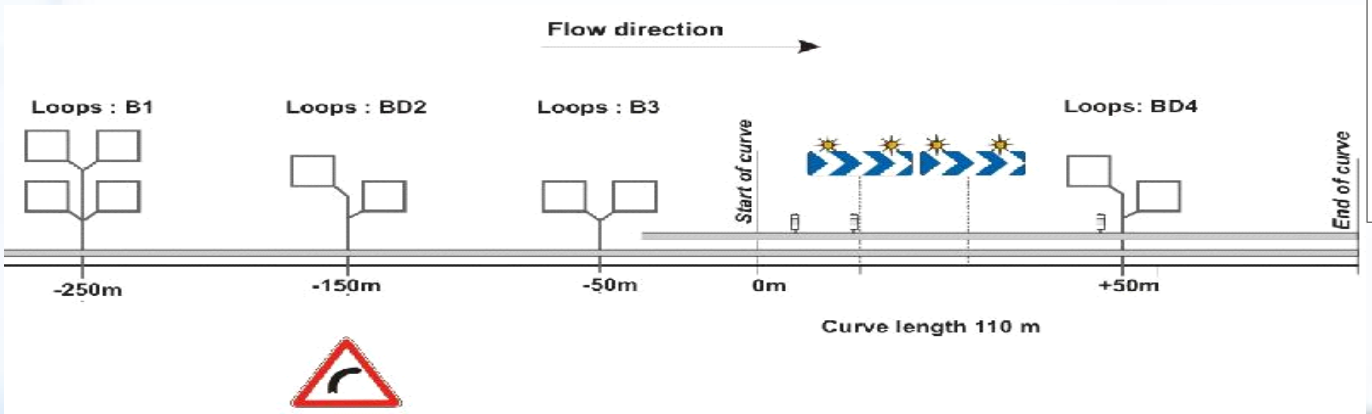


Warning in bend(2)

- Instrumentation METL (loops & cameras)
- Statistics of trajectories → assessmer of warning threshold
  + impact of road sign
- V_X : -4% → -25% fatality risk

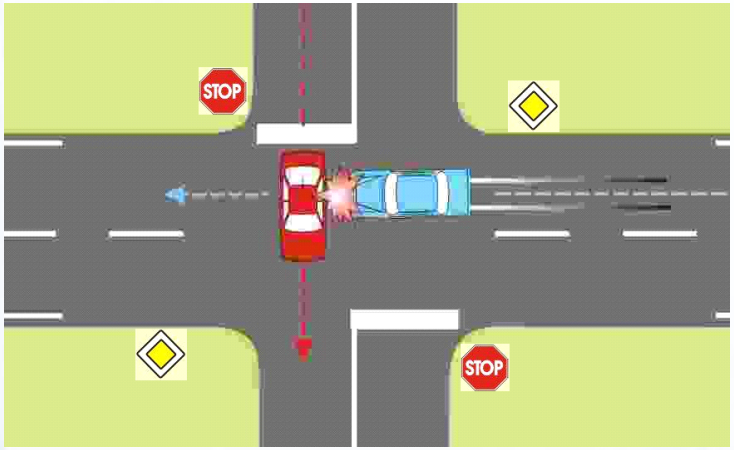






Risks in intersections

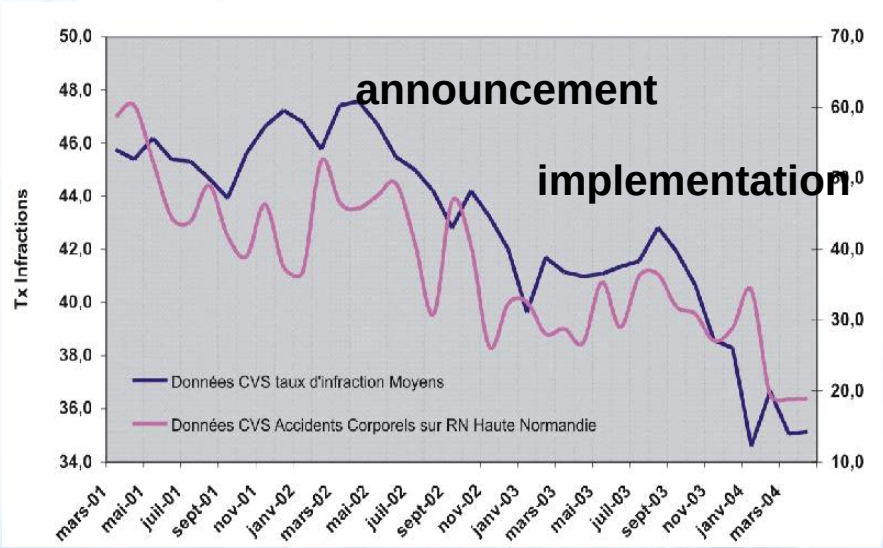
- Intersections in France: < 1% network 10% accidents, 13% fatalities
- Risk x10 in country side, overspeeding on priority roads, low visibility
- Low accident frequency → near-missed analysis (METL)



- Radar, loops, cameras
- Tc (time to collision) <> S (threshold)
  (e.g. 6 s for a 2 lane road)
- if Tc< S : video → cross risk
- Development assessment

Impact of automated speed enforcement and penalty

- 2003 → : speed AEP in France
- High reduction of unsafety
- Behavior and speed assessment: national, regional (METG), local (METL)



- 2000-2005 (Normandie) : speed and accident evolving
  60 stations, 400 000 cars/day
- Violations: 45% → 35%
  fatalities: -25% to -30%
- radar impact: ≈1 km + global mean speed reduction

Conclusions

- Trajectories = result of V-I-D interaction
- Development of observatories (IFSTTAR, SARI…)
  - road side, on-board, multi-sensor + data fusion
  - statistics with large trajectory samples, itineraries and black hole (bends, intersections…) diagnosis
  - Near-missed and risk studies, causes identification
- Mitigation and warnings (≠ curative) → human, money and environmental savings
- Perspectives : FOT + naturalistic driving, sensor improvement, DB, automated processing tools, instrumented vehicle fleets…