Young Researchers Seminar 2009

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Integrating the effects of adverse weather conditions on traffic:

Methodology, empirical analysis and simulation

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Outline

I. Problem Statement

II. Methodology

III. Results from real world data

IV. Online traffic state estimation

V. Concluding remarks

I. Problem Statement

- Proactive real-time traffic management systems involve a comprehensive knowledge of all elements impacting traffic conditions.
- Adverse weather conditions are well recognized as one important event which can severely impact traffic in terms of traffic operations and safety
- What are adverse weather conditions ? The presented work focuses only on the effects of rain on traffic.

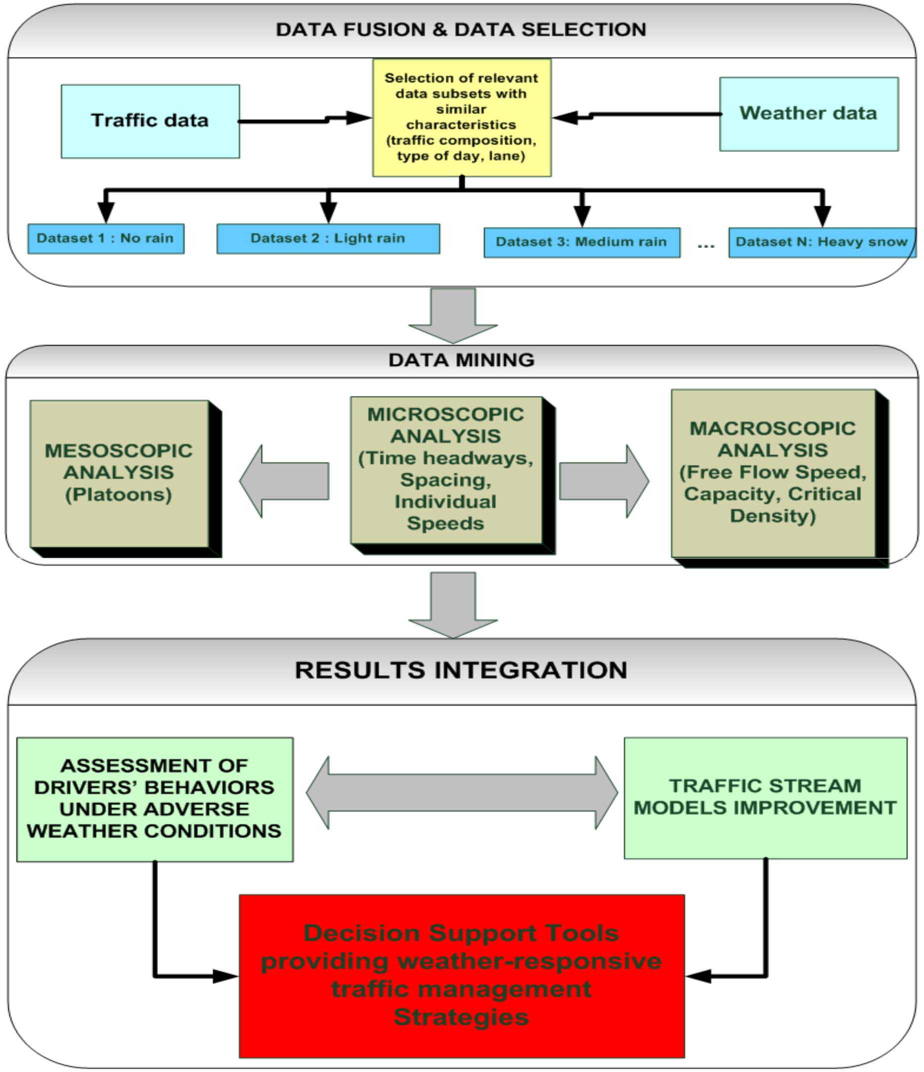
How does adverse weather impact traffic ?

DRIVERS' BEHAVIOUR	Speed and acceleration	↘
	Time Headways	↗
	Spacing	↗
	Lane Changing	
	Platooning ?	
TRAFFIC OPERATIONS	Capacity	↘
	Traffic Volume	↘
	Speed	↘
	Speed Variation	↗
	Congestion Severity	↗

How does adverse weather impact safety ?

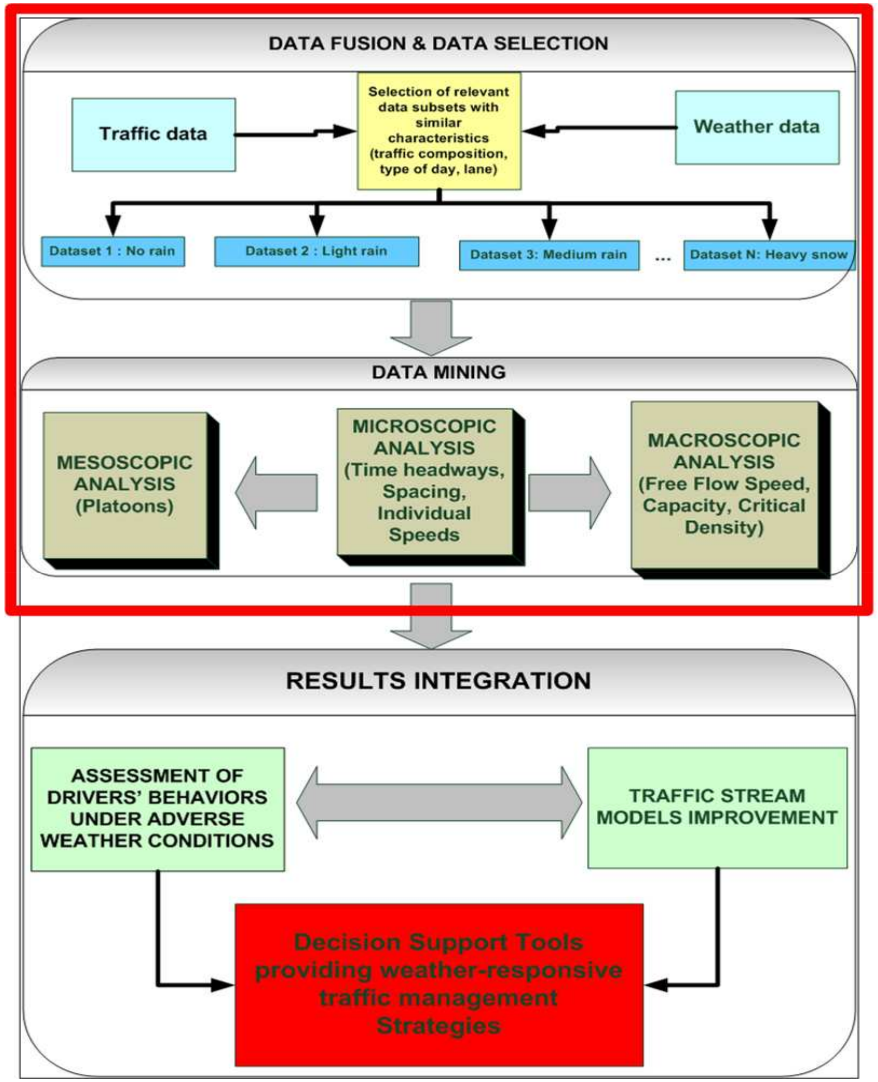
- Precipitation impacts the driver's safety by degrading the state of the pavement, reducing the visibility as well as light,
- Increase of the crash frequencies and above all crash severity,
- Lagged effect of precipitations across days : the effect of rain is higher if many days have passed since the last precipitation.

II. Methodology



- Relevant datasets
- Multi-level assessment
- Integration of weather effects into traffic models
- Online weather-responsive decision support systems (DSS)

Methodology



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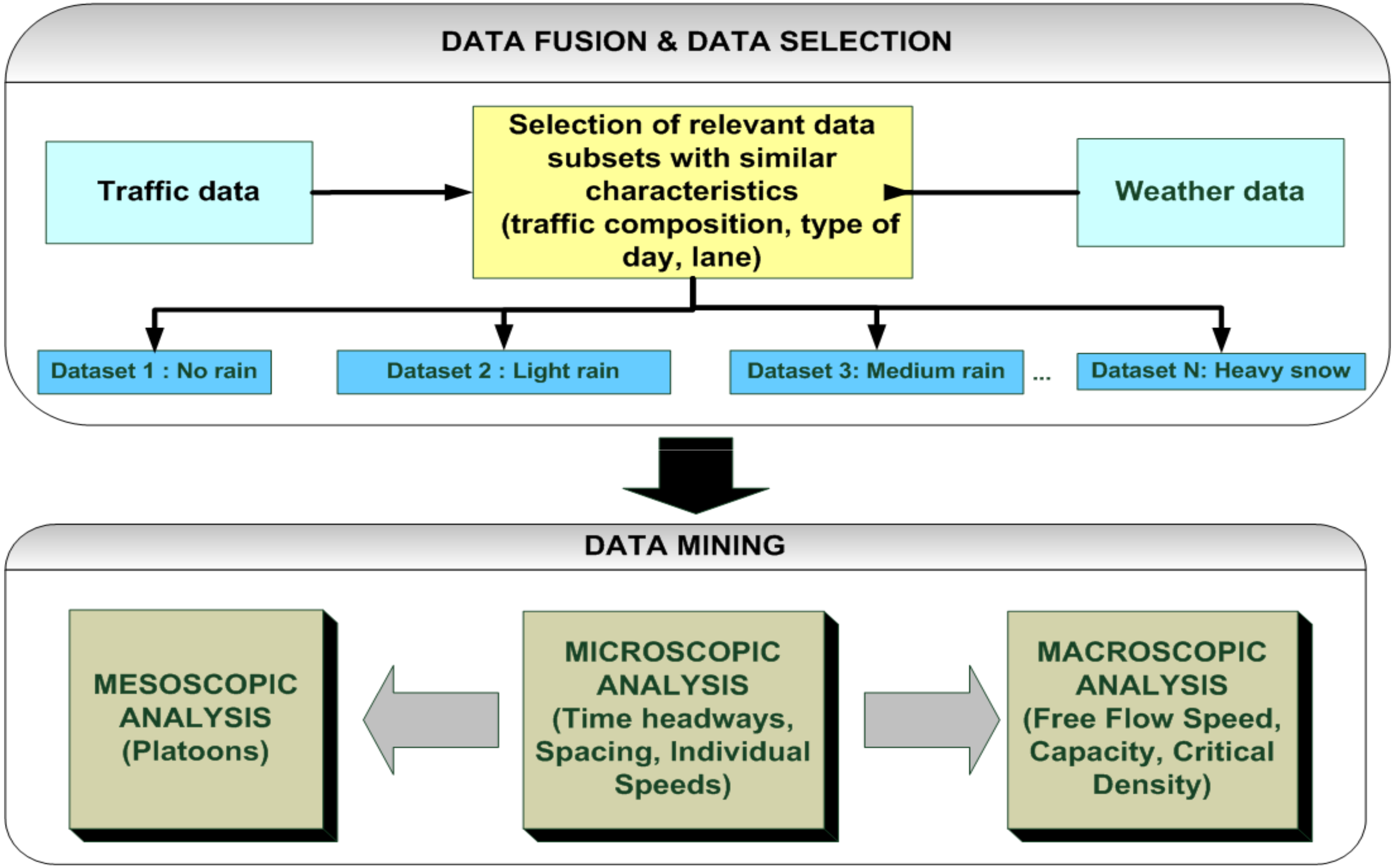
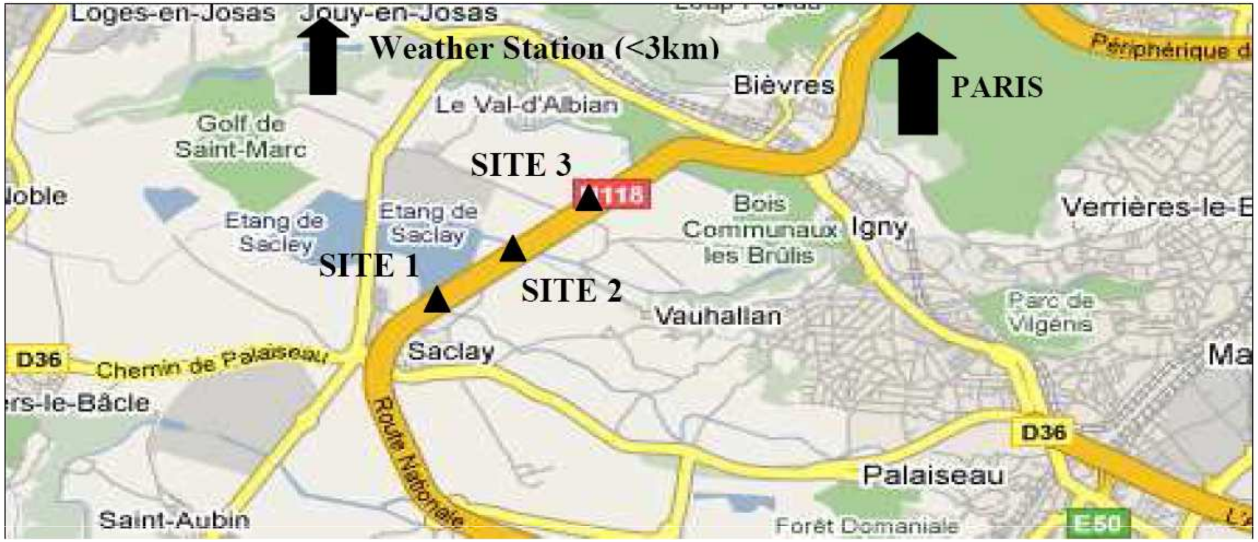
Methodology (II): data selection & data mining



III. Results from real world data: 118 national road



- Two-lane freeway section near Paris with high traffic volume
- Traffic data collected from 2005 to 2007 from 9 double-trap loop sensors.
- First traffic data selection from 3 out of 9 sensors located on a homogeneous section (same topography)

Datasets construction

TRAFFIC DATA

• Same day category (regular weekday) and same time periods (morning/evening peak hours)

• Similar traffic composition & significant amount of vehicles (>10 000 vehicles per lane).

• Speed limit = 110 km/h (68.3 mph). Only the southbound direction towards Paris is considered.

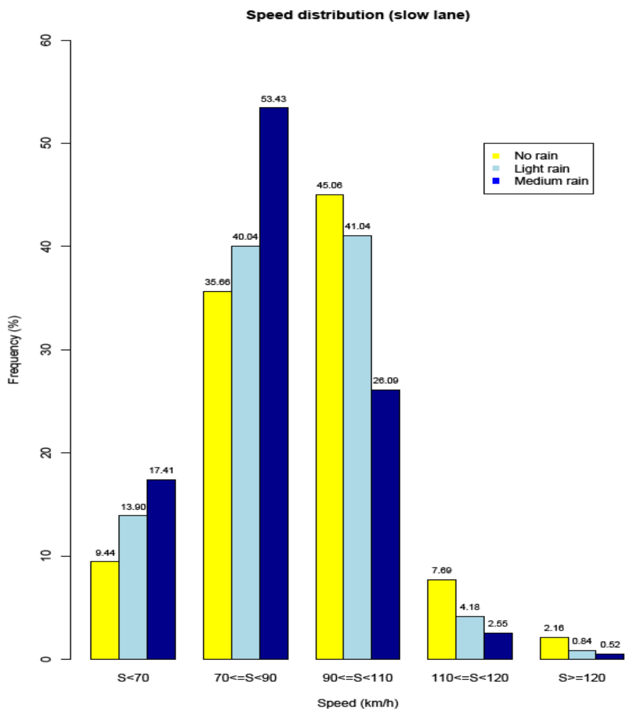
WEATHER DATA

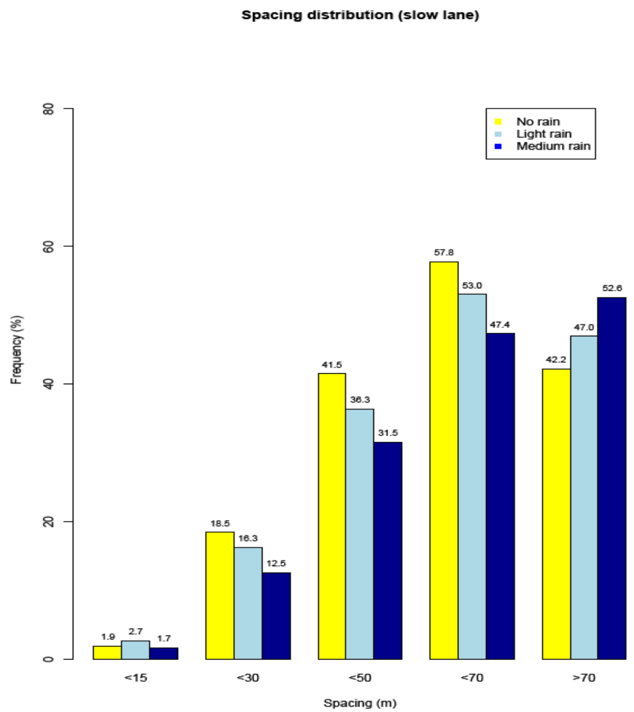
• Hourly weather data provided by a consistent weather station located near the section.

• Then, traffic data were divided into 3 datasets according to the rain intensity:

  • No rain: rainfall= 0 mm/h
  • Light: up to 2 mm/h
  • Medium: from 2 to 3 mm/h

Results: speed and spacing distributions

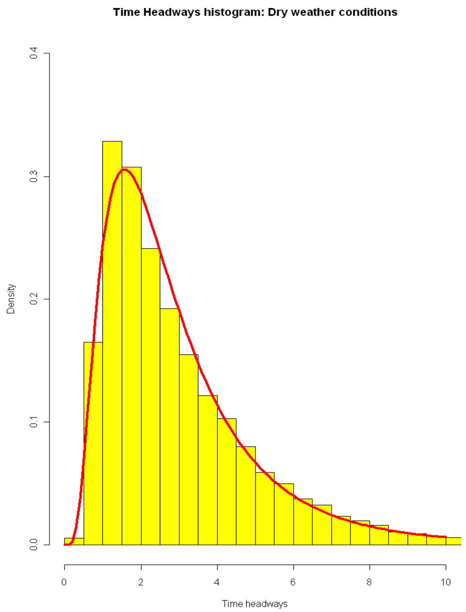


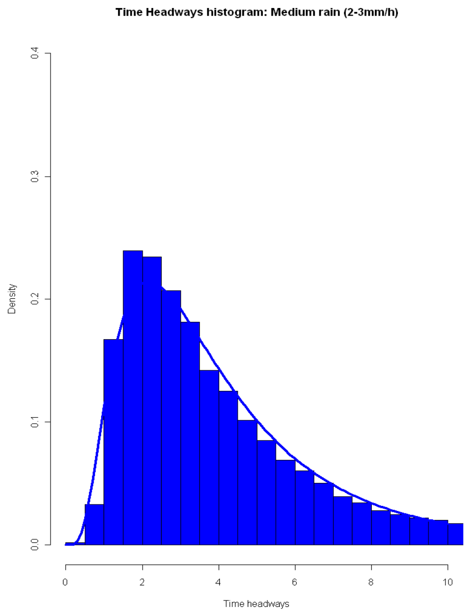


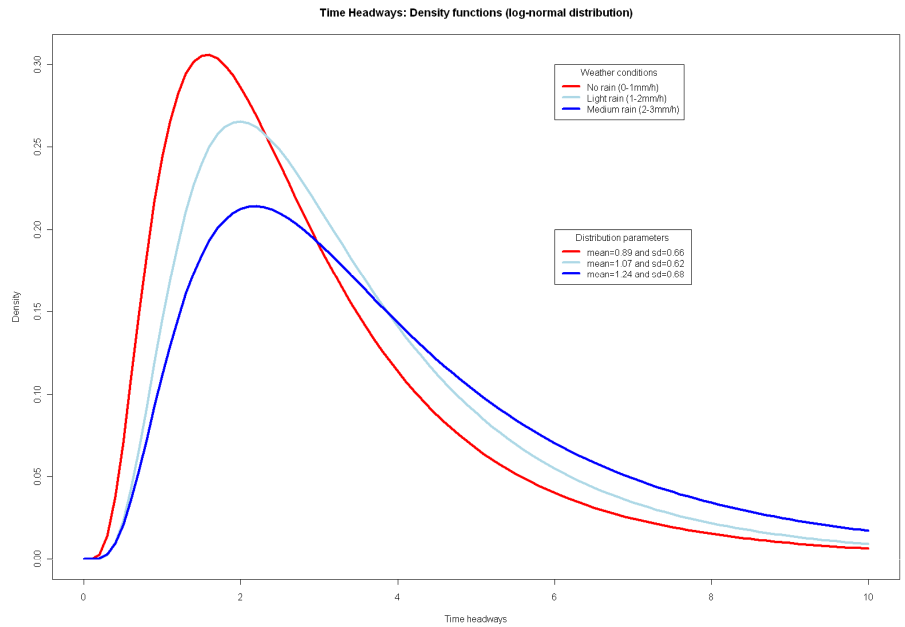
• Clear decrease for the slow lane of the frequencies of speeds > 90 km/h under rainy conditions. Primary adaptation to rain = speed reduction.

• Frequency of short spacing decreases during inclement weather conditions -> Drop of about 10% of the spacing <50m under medium rain conditions.

Results: Time headways (TH) distributions

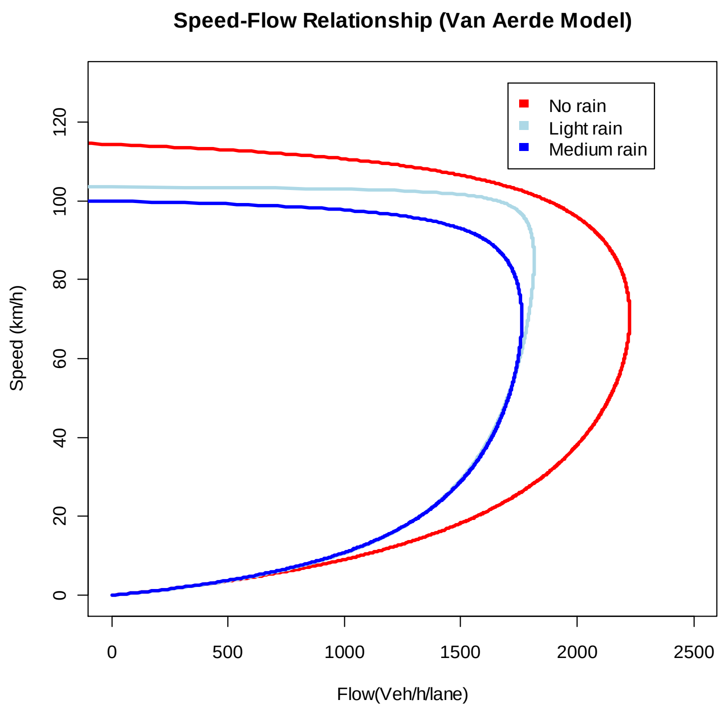


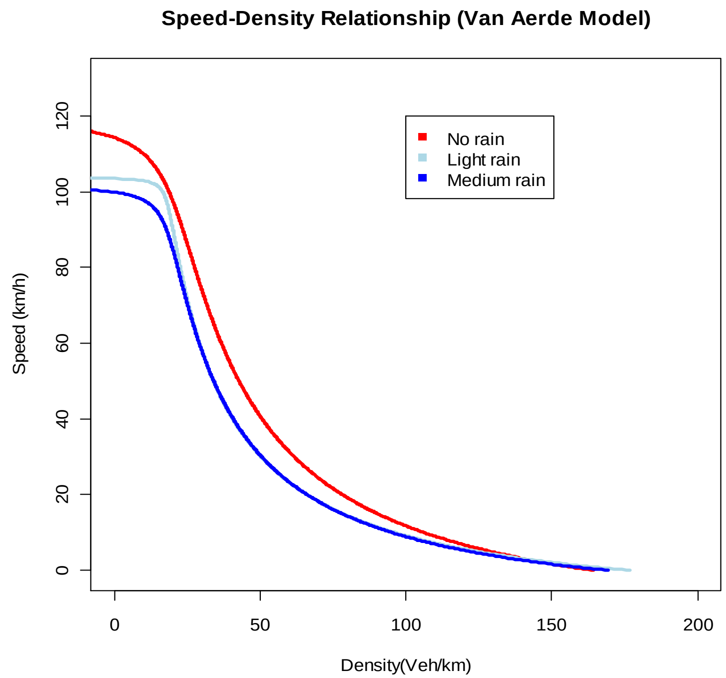




- Frequency of TH <3s higher under dry conditions.
- Good fit of the log normal distribution with our TH distribution.
- The higher the intensity of rain is, the lower the density of short TH is.

Results: Macroscopic level





- Calibration of Van Aerde Model.

- Drop in free-flow speed: 8% under light rain conditions and of about 12.6% under medium rain conditions.

- Roadway capacity decreases by 18.5% vs 21% under light & medium rain conditions.

Consistency with other studies

Light rain conditions: reductions coefficient of two key parameters on freeways: free-flow speed and capacity:

Country	Road type	Free-flow speed	Capacity	Reference
France	interurban area	8% – 12.5%	18.5% – 21%	Previous study
France	urban ring road	9%	15.5%	Billot et al. (2008)
Canada	urban freeway	10%		Andrey et al. (2006)
USA	3 metropolitan areas	6% – 9%	10% – 11%	Rakha et al. (2008)
Japan	metropolitan expressway	5%	6 – 9%	Chung et al. (2006)

- Results are context-dependent (urban/interurban area).
- Regarding other world-wide studies, traffic parameters reductions are slightly higher.
- Regional differences need to be analyzed.

IV. Toward online weather-responsive estimation

• Goal: to show how the new knowledge about the rain effects would be useful from a simulation point of view.

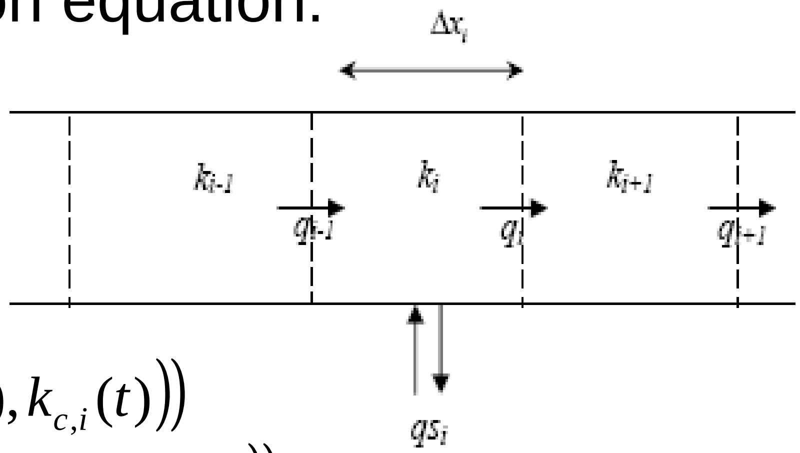
• Tools: Bayesian framework with the use of Monte Carlo observer-based traffic flow estimations.

• Simulation case from real world data: eastern part of lyon's ring road (urban motorway)

Macroscopic traffic model

- Discretized version of conservation equation:

$$k_i(t+\Delta t_N)=k_i(t)+\frac{\Delta t_N}{\Delta x_i}\left(q_{i-1}(t)-q_i(t)\right)$$



- Gudunov balance equation:

$$\begin{cases} \text{Cell } i \text{ demand}: \Gamma_i(t)=Q_{e,i,t}\left(\min\left(k_i(t),k_{c,i}(t)\right)\right) \\ \text{Cell } i+1 \text{ supply}: \Omega_{i+1}(t)=Q_{e,i+1,t}\left(\max\left(k_{i+1}(t),k_{c,i+1}(t)\right)\right) \\ \text{Resulting flow}: q_i(t)=\min\left(\Gamma_i(t),\Omega_{i+1}(t)\right) \end{cases}$$

- State Vector:

$$x_t=\left(k_1(t),k_2(t),\cdots,k_n(t),q_0(t),q_1(t),\cdots,q_n(t)\right)^T$$

2*n*+1

$$x_{t+1}=f(x_t)$$

Observation equation and state estimation

- The measured quantities (vector y_t) are flows and densities in certain cells, i.e. components of the state vector x_t:

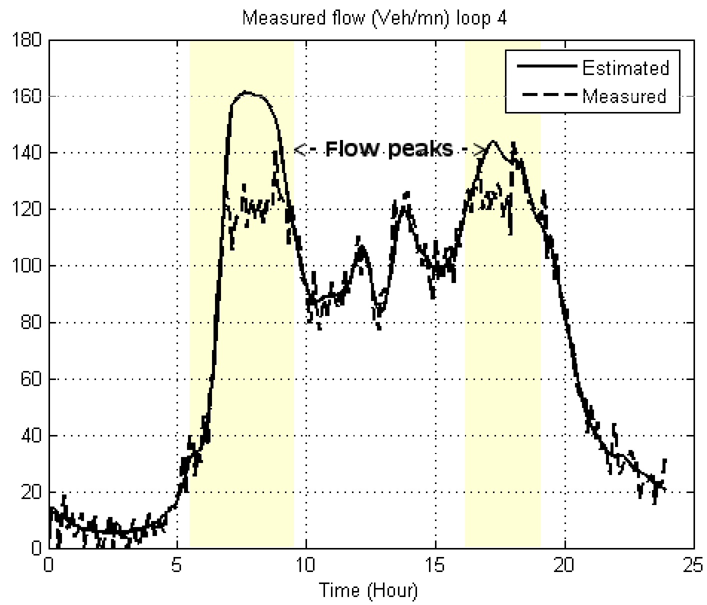
$$y_t = Cx_t$$

- Bayesian framework: the dynamic state estimation is carried out through the construction of the posterior probability density of the state.
- Tools: sequential Monte Carlo (SMC) State Estimation

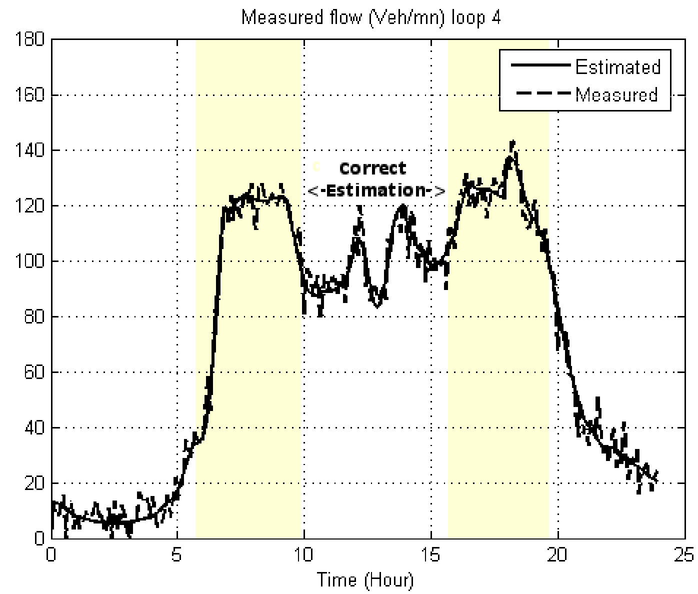
deriving an estimate of: $P\left(x_t \middle| x_{t-1}, u_{t-1}, y_t\right)$

Integration of weather in a observer-based model

- A day-long scenario under adverse weather conditions is created.
- Without any knowledge about rain effects => overestimation of traffic volume during peaks hours
- By introducing the new knowledge about rain impacts into the fundamental diagram => new simulation leads to correct estimations



Switch to an adverse weather fundamental diagram



Perspectives & current works

• Analysis of weather impact on platooning: does a platooning phenomenon raise more often under adverse weather conditions ?

• Wider range of rain and snow intensities -> analysis of swiss and japanese data enabling also comparison of regional differences.

• Effect of weather on travel times: french regional project TPTEO with road operator AREA

• **Adaptative traffic modelling according to prevailing weather conditions.**

• **Vlasov Fokker Planck traffic modelling taking into account platooning and the weather parameter**

Conclusion

• Standardized methodology for weather impact integration into DSS.

• Work undertaken within an european project enabling data and knowledge sharing:

COST ACTION TU0702 (http://tu0702.inrets.fr)

• Goal: Provide the road operators with weather-sensitive management tools (DSS)

Thank you for your attention !

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