FORECASTING OF TRAFFIC JAMS CAUSED BY ADVERSE WEATHER

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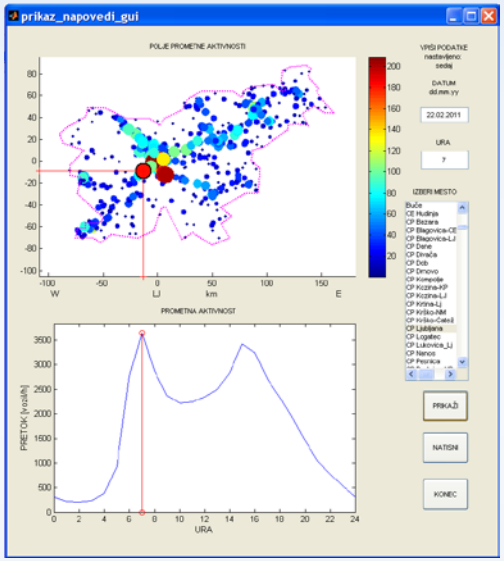
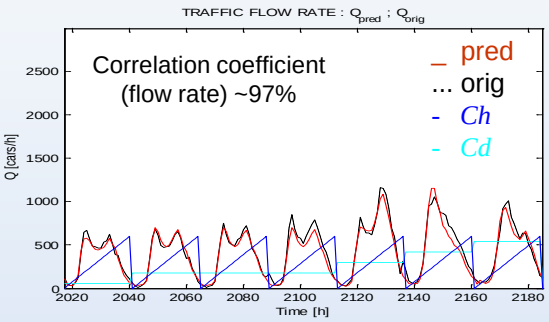
Objectives

- **Problem:** How to forecast formation and characteristics of traffic jams caused by adverse weather?
- **Example:** Evolution of traffic jam on road section with increased slipperiness or fog.
- **Source of information:** Forecasted traffic flow at critical road sector and appropriate speed limit determined from road weather conditions.
- **Mathematical tool:** Hybrid system comprised of: input traffic flow, road capacity and jam estimators.
- **Goal:** To develop an intelligent unit for traffic information providers and road operators.

Prediction of traffic flow rate (normal driving conditions)

Basis: Prediction is performed by a non-parametric statistical model using previously recorded time series of flow rate.





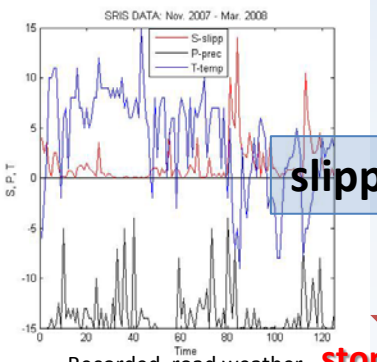
Prediction of traffic jam

Intelligent unit

Basis: Hybrid system comprised of: input traffic flow, road capacity and jam estimators

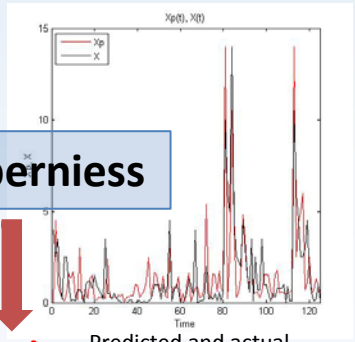
Prediction of road weather conditions

Basis: Prediction is performed by a non-parametric statistical model using previously recorded road weather data.



Recorded road weather data - www.sris.nu

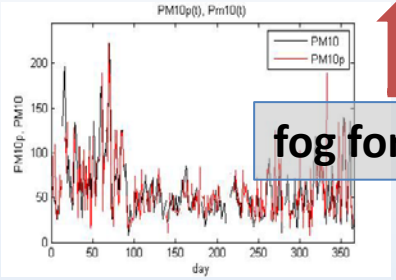
slipperiness



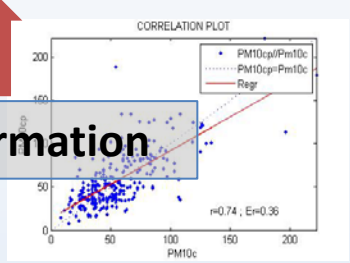
Predicted and actual slipperiness *X*

stopping distance

$$X_{st} = x_{react} + x_{break}$$



fog formation



The fog formation is predicted from previous records of: concentration of particulate matter *PM10* , wind velocity *W*, humidity *H* and temperature *T*

Estimation of speed limit

- A proper speed limit on wet road is obtained by equalizing stopping distances at normal and wet conditions:

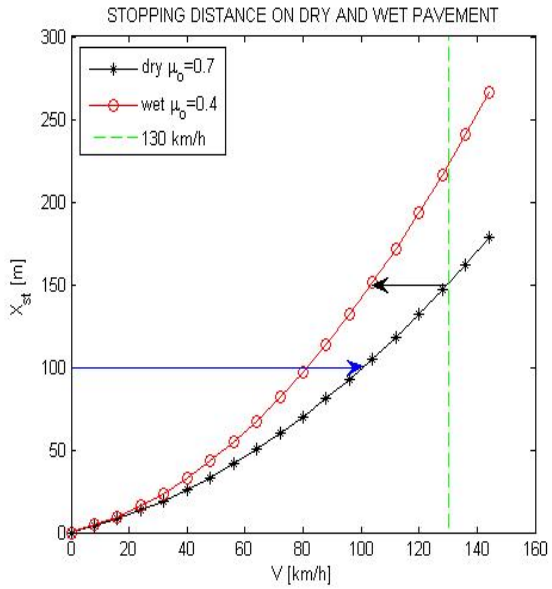
  $x_{st1} = x_{st2}$ - **black arrow**

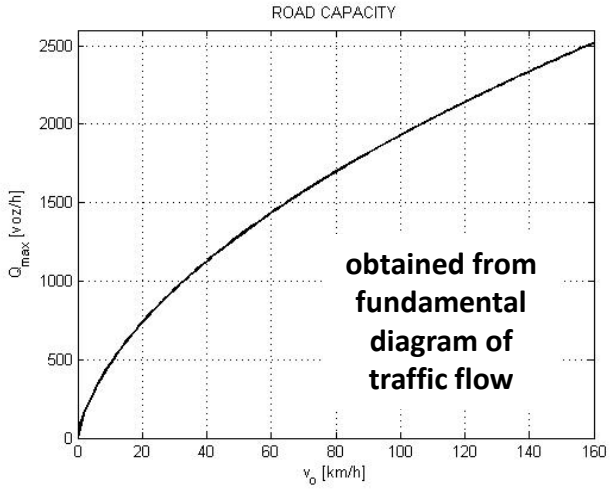
Due to decay of $\mu(v)$ the stopping distance is increased:
$x_{st} = x_{react} + x_{break} \approx \tau v + \exp(0.7v/c)\, v^2/2\, \mu_o\, g$

- A proper speed limit at decreased visibility is obtained by equalizing stopping and visibility distance:

  $x_{st2} = x_{vis}$ - **blue arrow**

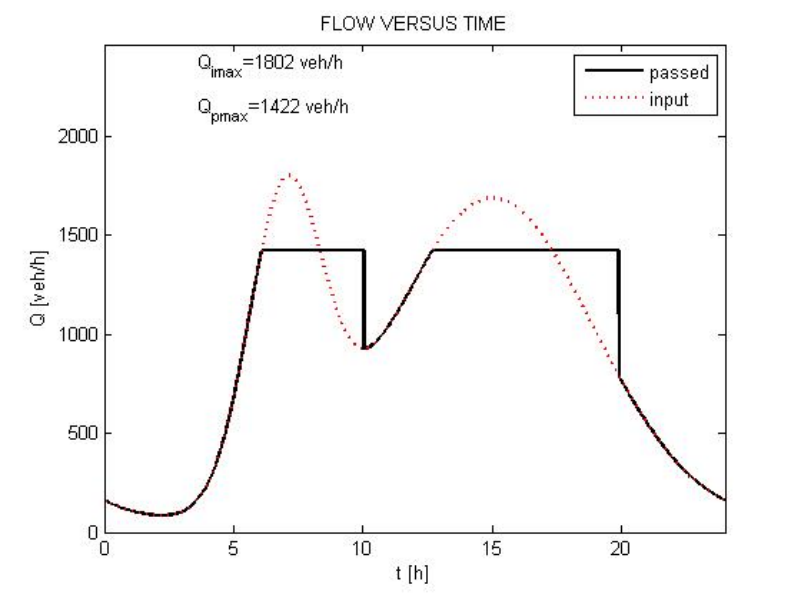
Speed limit determines the road capacity Q_{max}.

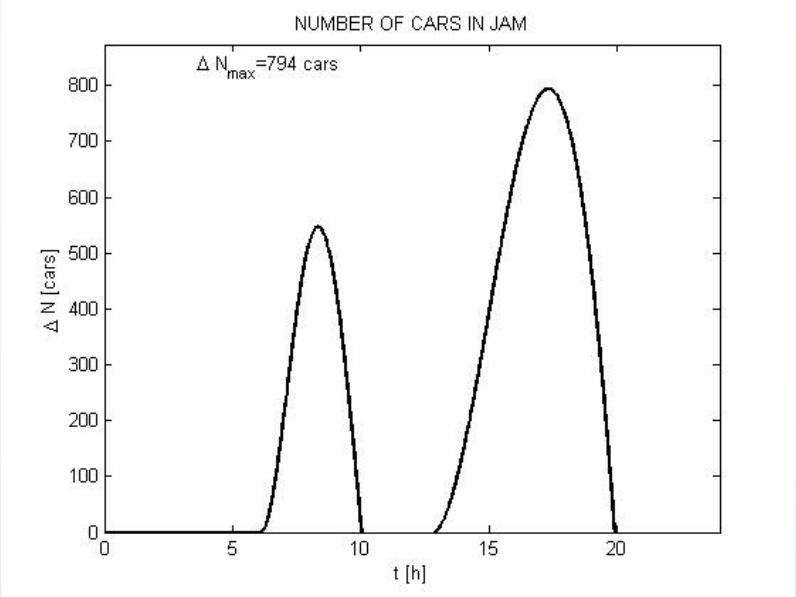




Estimation of jam length

- When the input flow surpasses the road capacity: *Qin>Qmax*, a jam starts to evolve.
- The number of cars in jam is estimated by the integral: $\Delta N = \int (Q_{in} - Q_{max})dt$.
- The time that a car coming to the jam spends to pass it is estimated by: $T_J = \Delta N / Q_{max}$.
- The jam length can be estimated by this time and velocity of the car: $L = T_J * v_c$





Determination of taffic jam characteristics

Description by field equations

- Velocity adaptation law:
- $\frac{\partial v}{\partial t} + v\frac{\partial v}{\partial x} = \frac{v_e(\rho) - v}{T}$;
- Relaxation time: $T \cong 3\tau$
- Continuity equation:
- $\frac{\partial \rho}{\partial t} + \frac{\partial \rho v}{\partial x} = I(x,t)$
- Traffic source term:
- $I(x,t) = Q(t)\delta(x,t)$; $Q(t)$ is forecast

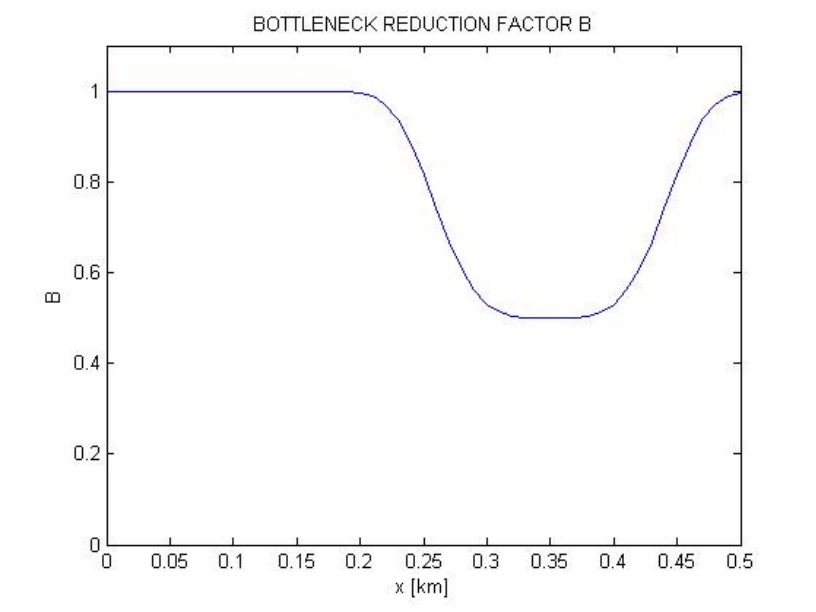
Numerical treatment

- Cell dimensions: $\Delta x = \lambda$; $\Delta t = 0.1\tau$
- Intervals: $0 < x < 0.5\text{km}$; $0 < t < 1\text{h}$
- Initial and boundary conditions: $\rho = 0$; $v = 0$.
- Source term specified by the predicted flow rate Q centered at rush hour: $t = 0.5\text{h}$.
- Transition to non-dimensional variables: t/τ ; x/λ ; $v\,\tau/\lambda$; $\rho\,\lambda$; $Q\tau$

Macro-modeling based on fundamental diagram of flow and continuity equation. Boundary condition is determined by the predicted flow.

Example of the disturbed region

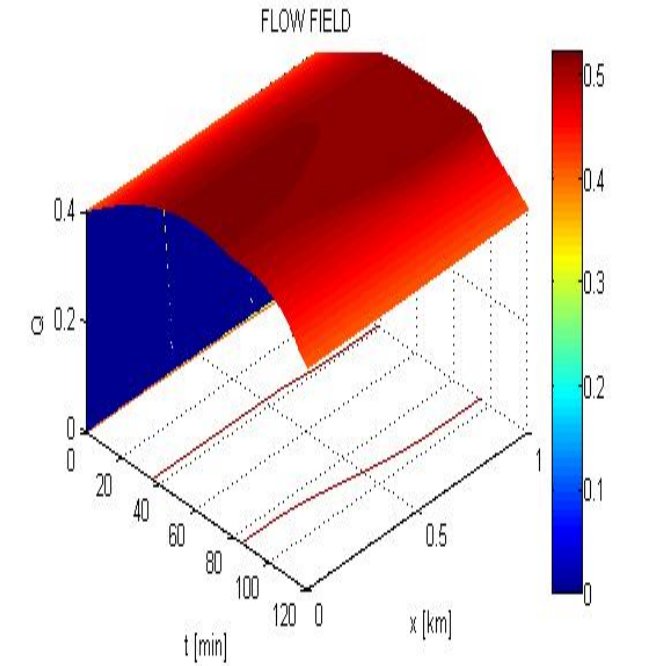
- Position: $0.2\text{km} < x < 0.4\text{km}$
- Reduced speed: $0.5\ v_o$



Dependence of the velocity reduction factor *B* on *x*.

Field distributions

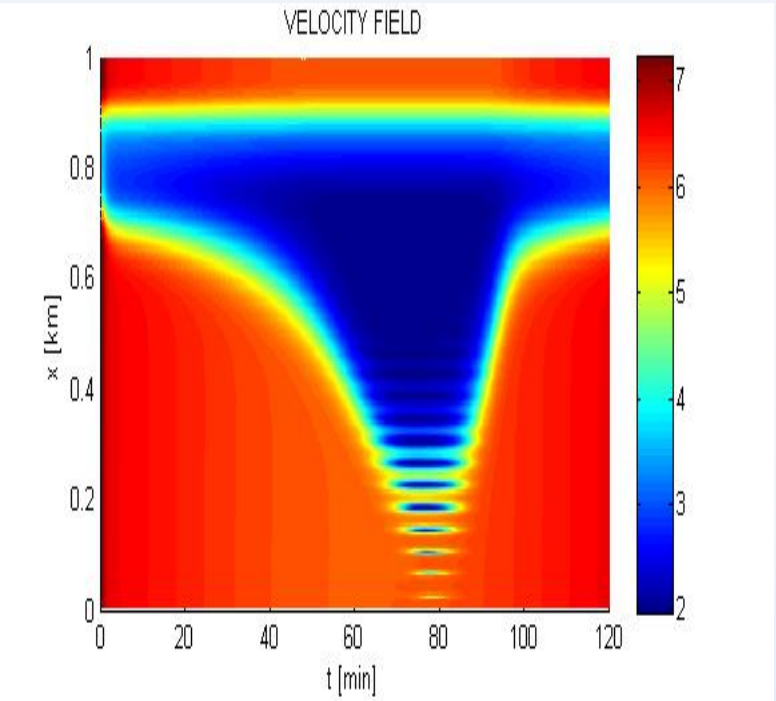
Traffic flow field

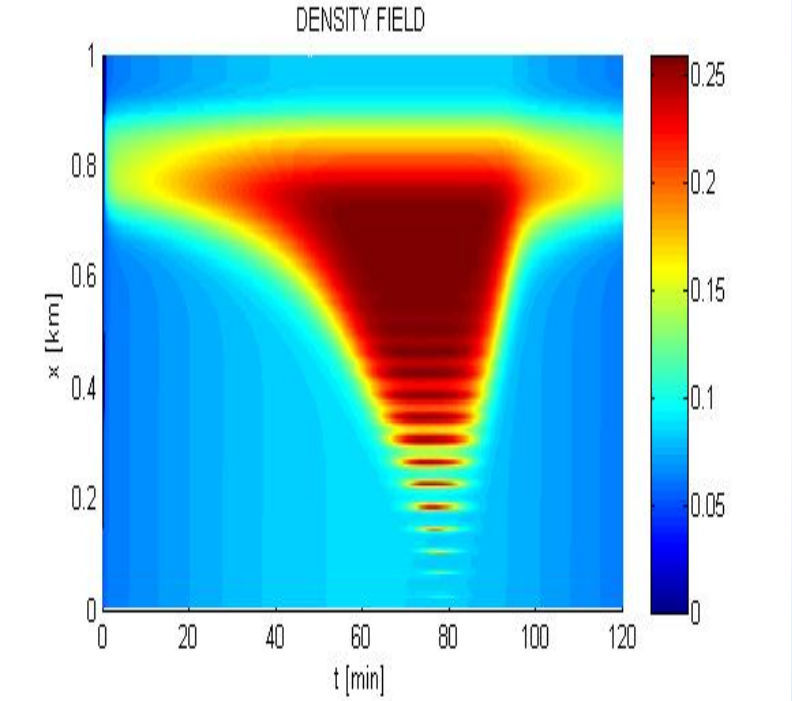


Parameters: v_o=130 km/h ; Q_{max}=1875 veh/h

Example of the disturbed region

Field distributions





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Coclusions

- Information on traffic jams is vital for road users.
- Forecasting of traffic jams provides support for traffic information center and road services.
- We have shown that in spite of rather complex, non-linear, and stochastic character of traffic flow, it is possible to model the evolution of traffic jam at a disturbed region based upon the forecasted input flow and the proper speed limit that corresponds to driving conditions in severe weather.
- The next step is to transfer predicted data directly to drivers (e.g. over mobile phones).

References

- I. Grabec, F. Švegl, *Modeling and Forecasting of Traffic Flow*, ISEP 2010, Ljubljana, SI
- F. Švegl, I. Grabec, *Prediction of winter driving conditions*, Proc. SIRWEC – 15th, Quebec, CA, 2010
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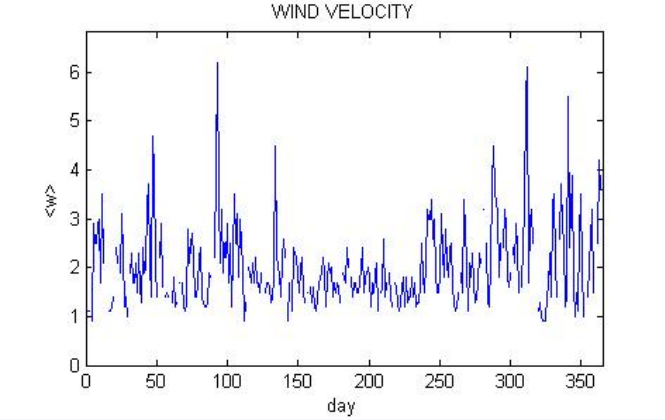
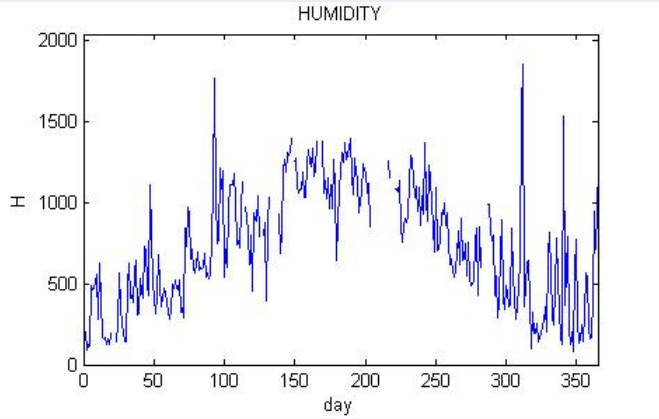
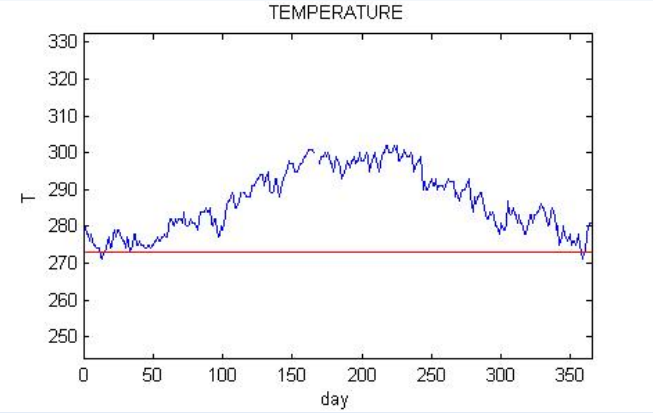
Thank you for your attention!

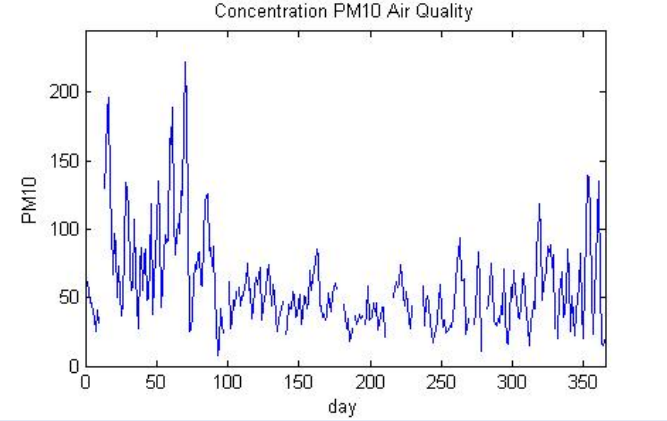
Kiitos mielenkiinnosta!

Variables used in PM10 modeling





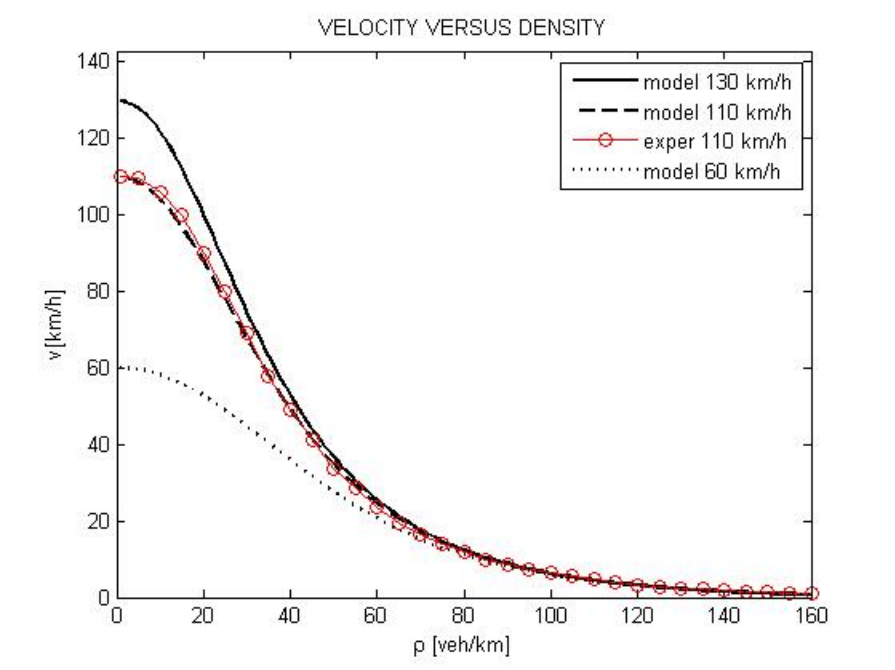


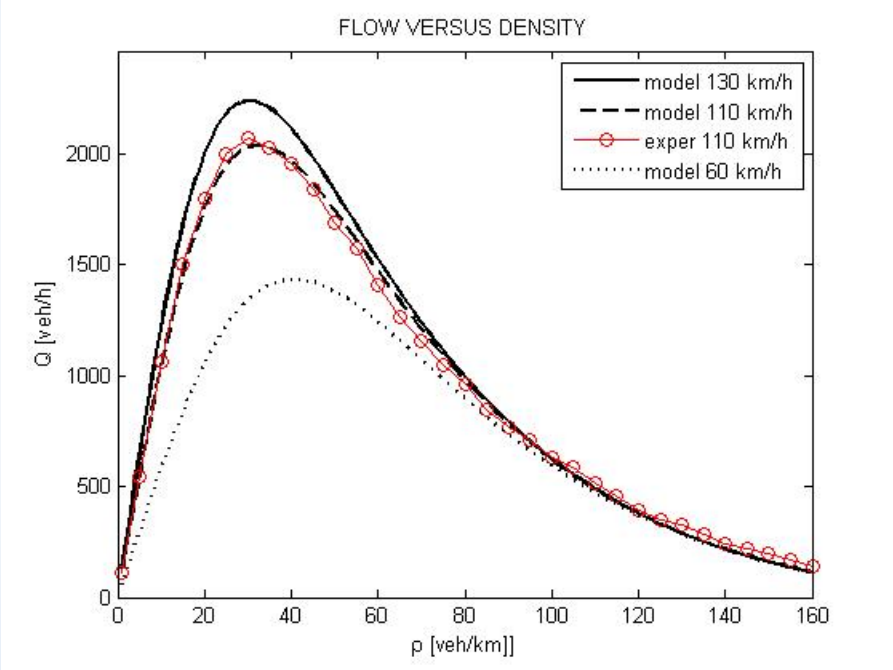


Statistical variables

- Basic variables:
  - r : distance between cars, $\rho=1/r$: density of cars
  - v : mean velocity,
  - $ve(\rho)$: equilibrium velocity
  - $Q=\rho v$: flow rate
- Parameters and reference variables:
  - λ~5m : car length, $r - \lambda$: clear spacing
  - $\tau \sim 1s$: reaction time
  - $u = C\,\lambda/\tau$: characteristic velocity; C~3
  - $r = \lambda + \tau w$: proper distance
  - $w = (r - \lambda) / \tau$: proper velocity

Fundamental diagram of traffic

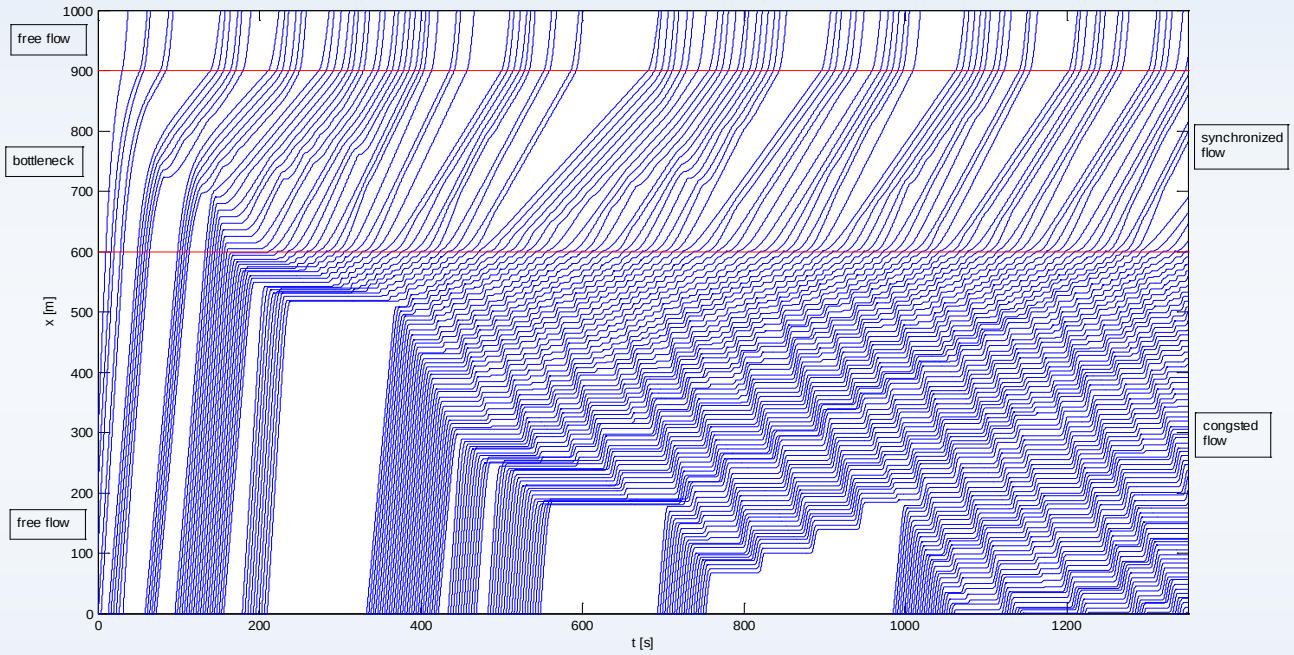




Micro-dynamic modeling of traffic jam evolution

Micro-dynamic model stems from driving rules and predictor of traffic flow.

Micro-model is not convenient for application.



The goal: Macro-modeling based on fundamental diagram of flow and continuity equation. Boundary condition is determined by the predicted flow