FORECASTING DEVELOPMENT OF TRAFFIC JAM AT A HIGH-WAY BOTTLENECK

Igor Grabec and Franc Švegl

Amanova – Intelligtent systems, sensors and new materials, Ltd,
Technology Park Ljubljana, Slovenia

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AMANOVA d.o.o.
Intelligent systems, sensors
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Objectives

- **Problem:** How to forecast development of a traffic jam at a bottleneck of high-way?
- **Source of information:** Predicted traffic flow rate at a selected road section.
- **Mathematical tool:** Coupled fundamental traffic flow diagram and continuity equation.
- **Goal:** To develop a new tool for traffic information center.

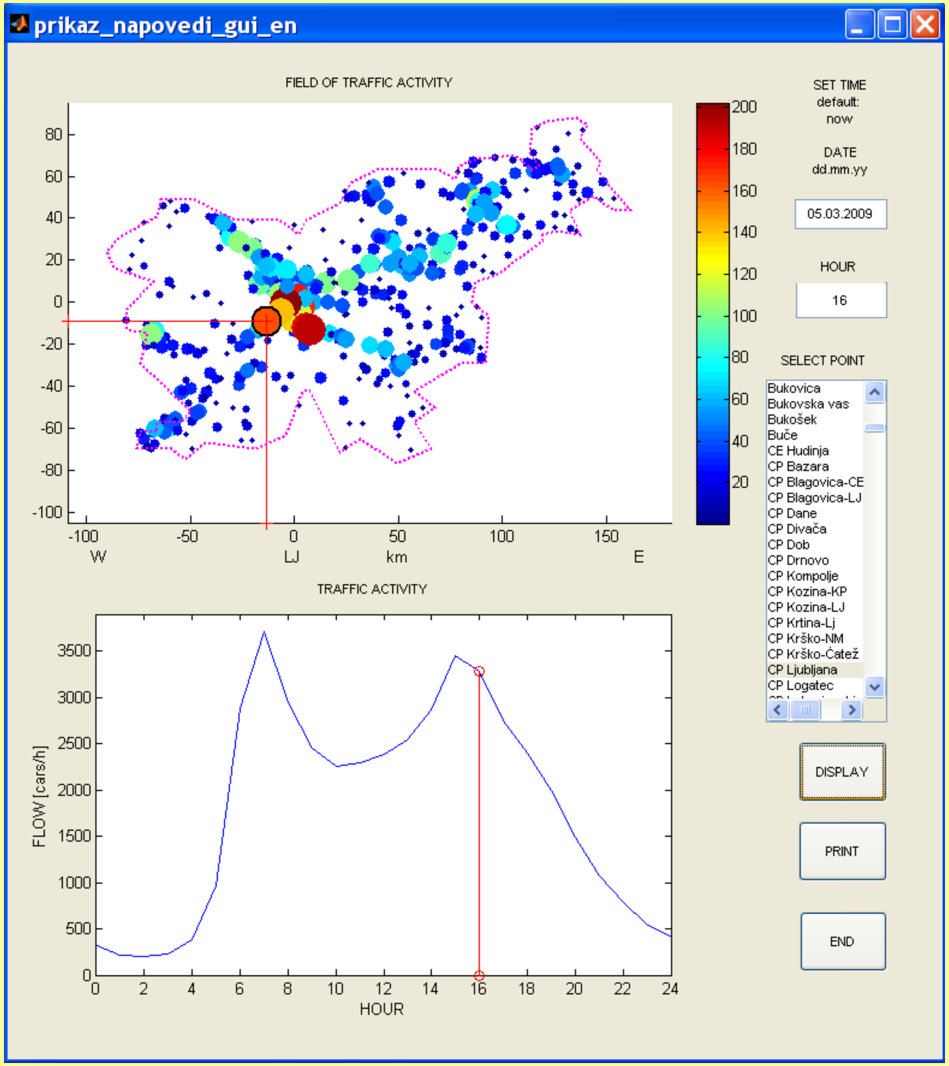
Prediction of traffic flow rate

- **Basis:** Prediction of traffic activity on high-ways of Slovenia is performed by a non-parametric statistical model using previously recorded time series of flow rate.

- **Applicable tool:** The model operates in the graphic user interface that yields time series of the predicted flow rate at a selected time interval and road sector.

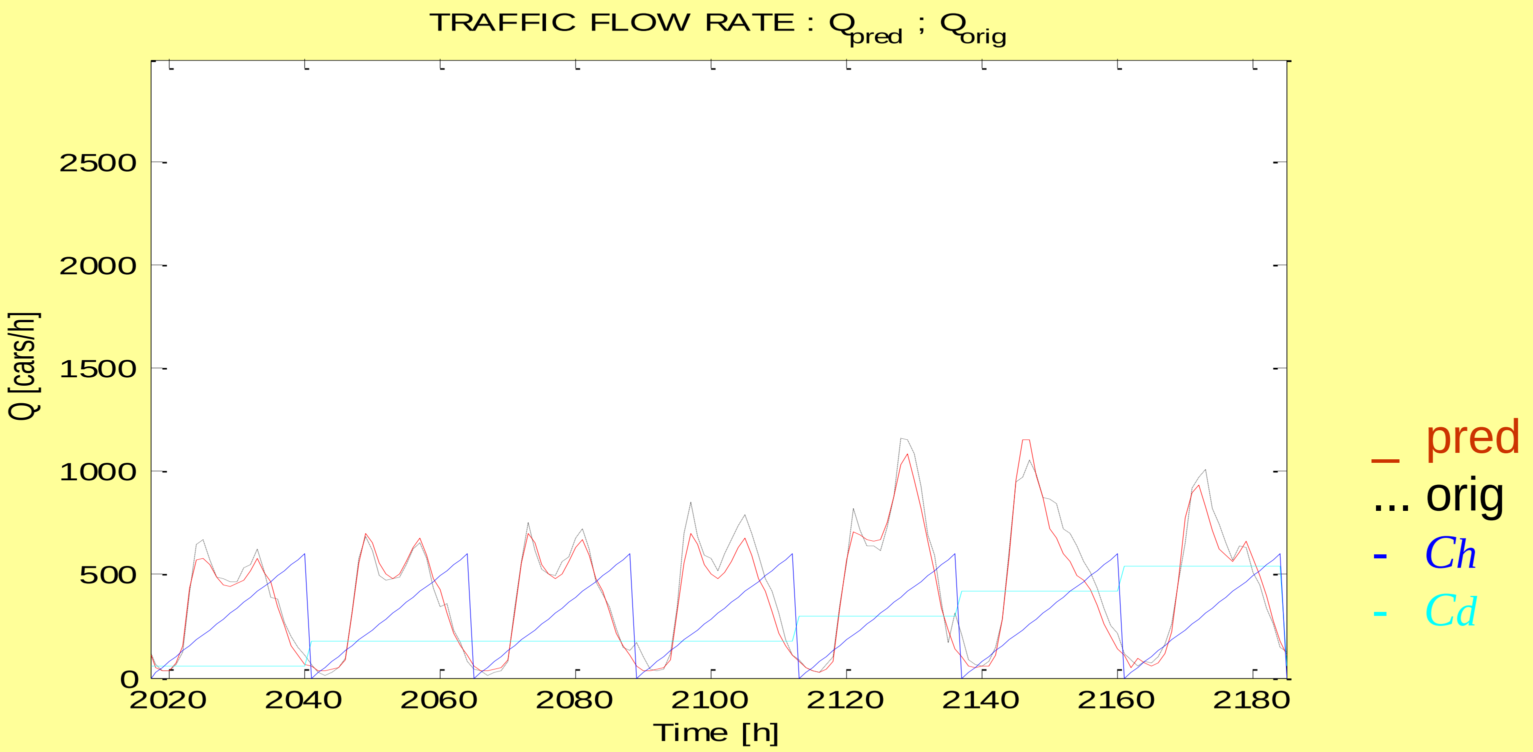
- **Goal of the next step:** To develop a model for mapping of the forecast traffic flow into predictor of the traffic jam length at the bottleneck.

Graphic user interface for prediction of traffic flow rate



- For a prediction the user sets:
- day, hour, and point
- The interface displays:
- Top: field of traffic activity
- Bottom: traffic flow rate
- Lines: selected place and hour

Example of a prediction

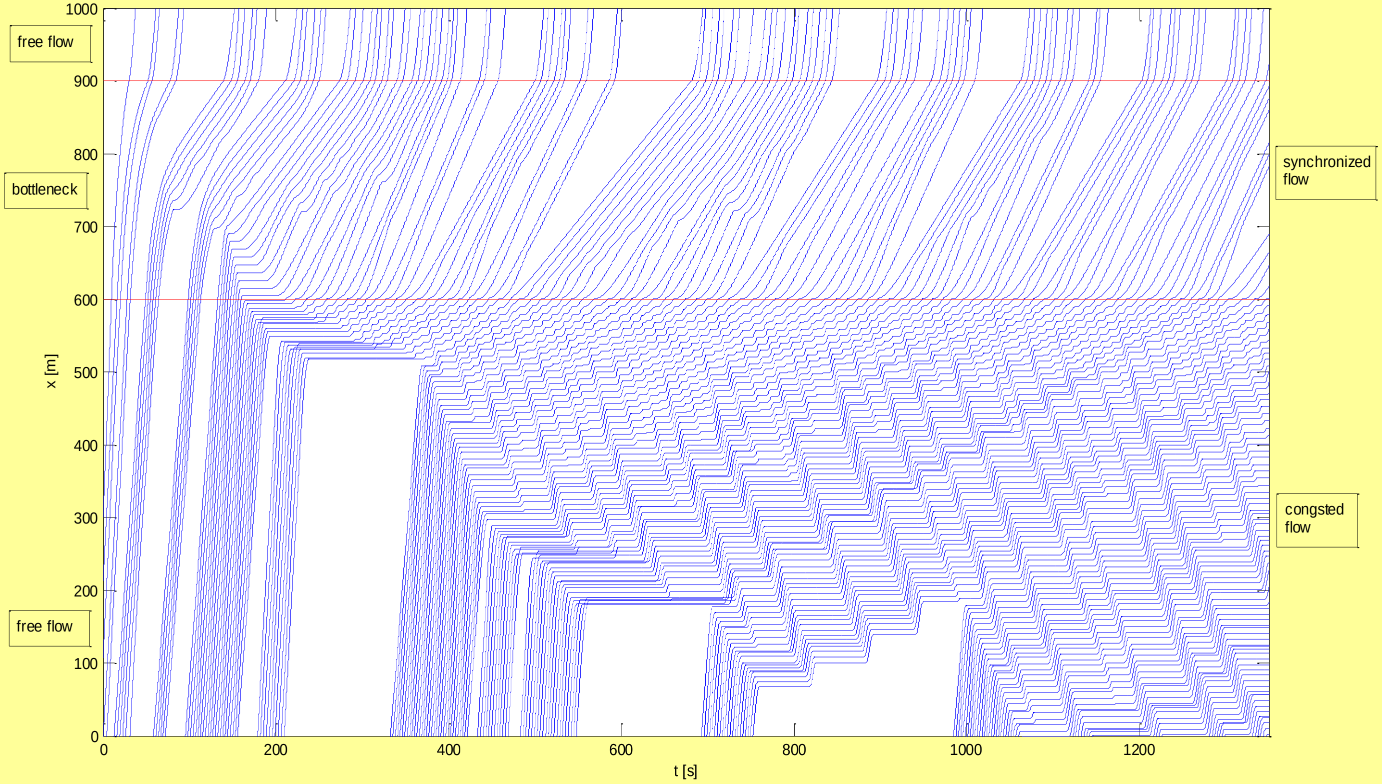


Correlation coefficient of predicted and observed flow rate is ~97%

Micro-dynamic modelling of jam evolution at a bottleneck

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

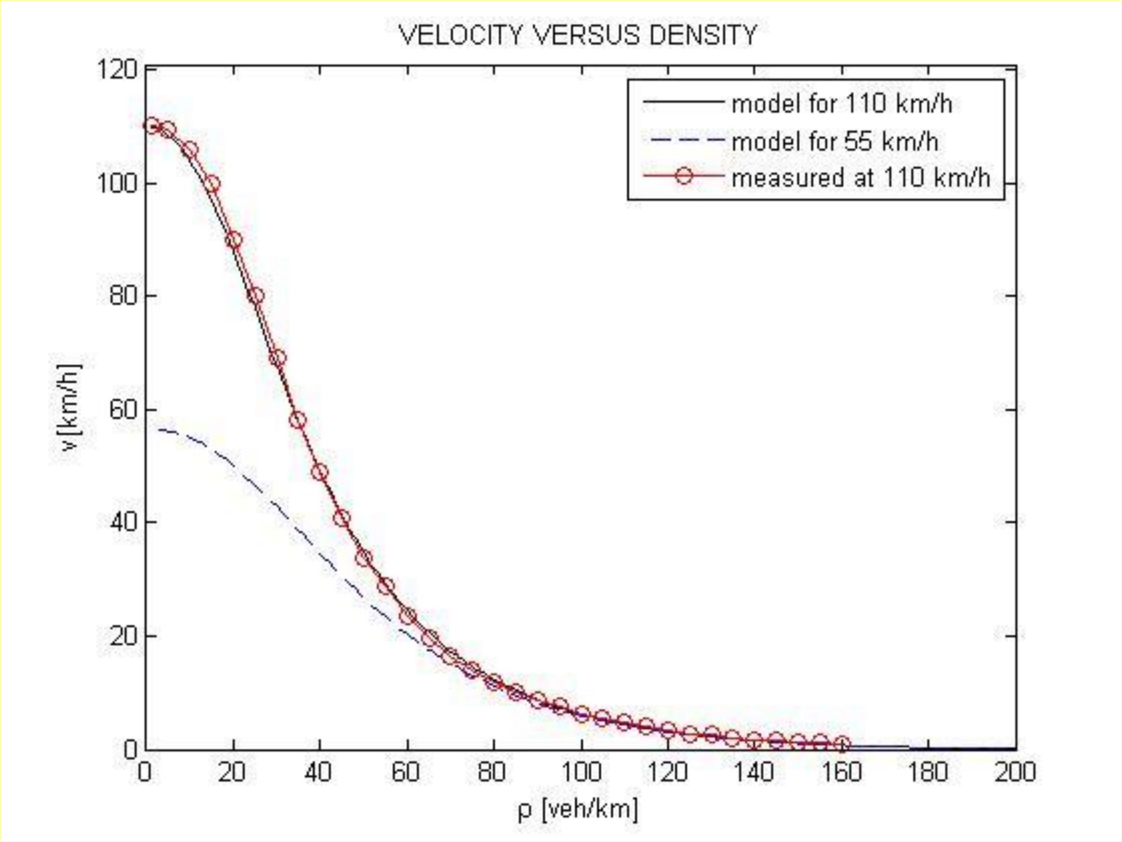
Variables

- 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
  - $u = C\,\lambda/\tau$: characteristric velocity; C~3
  - $r = \lambda + \tau w$: proper distance
  - $w = (r - \lambda)\,/\,\tau$: proper velocity

Equilibrium velocity

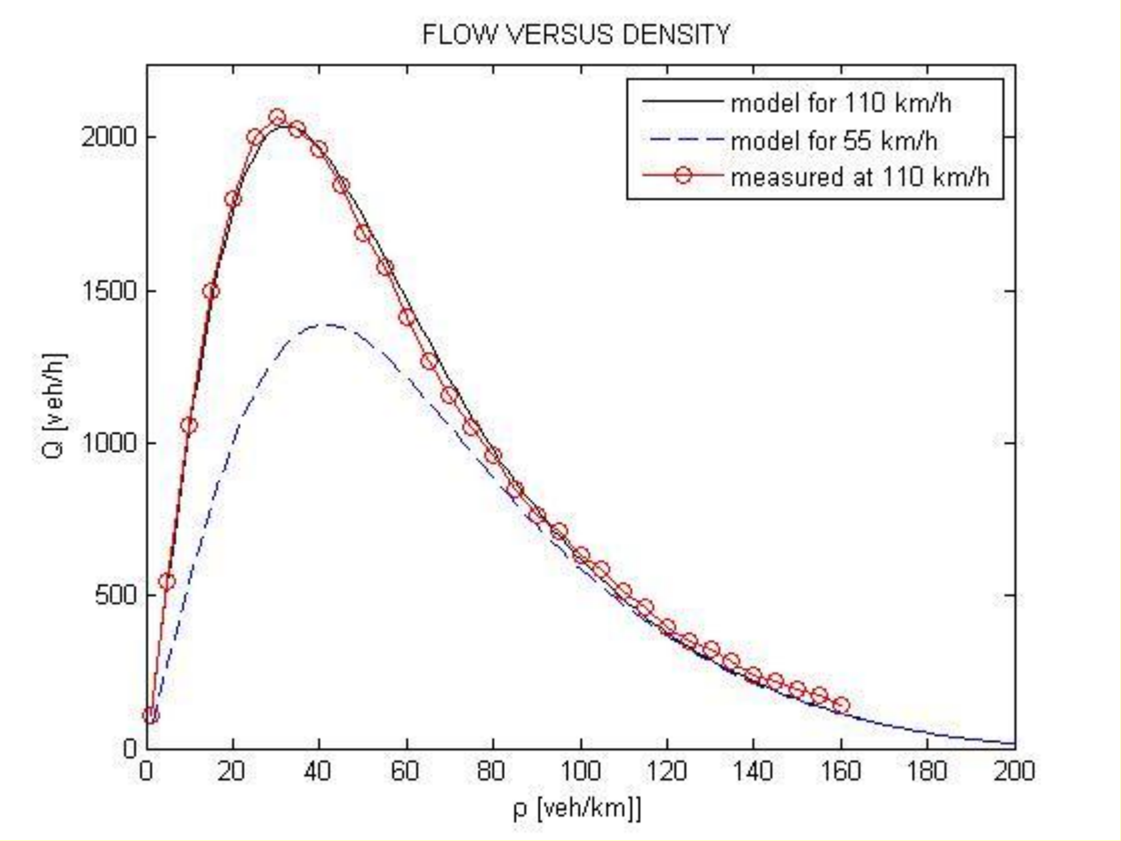
- Equilibrium velocity v_e is determined by the velocity limit v_o and the proper velocity w. Constraints: $v_e \leq v_o$ and $v_e \leq w$ lead to
- Joint constraint: $\frac{1}{v_e} = \frac{1}{v_o} + \frac{A}{w}$
- The proper weight: $A = \frac{3\lambda}{r-\lambda} = \frac{u}{w}$ yields
- The fundamental law: $v_e = \frac{v_o}{1+\frac{uv_o}{w^2}}$

Fundamental diagram $v_e(\rho)$



Dependence of equilibrium velocity v_e on the density ρ.
Measured data from: D. Helbing: Verkehrsdynamik

Fundamental diagram $Q(\rho)$



Dependence of the flow rate Q on the density ρ.

Field equations

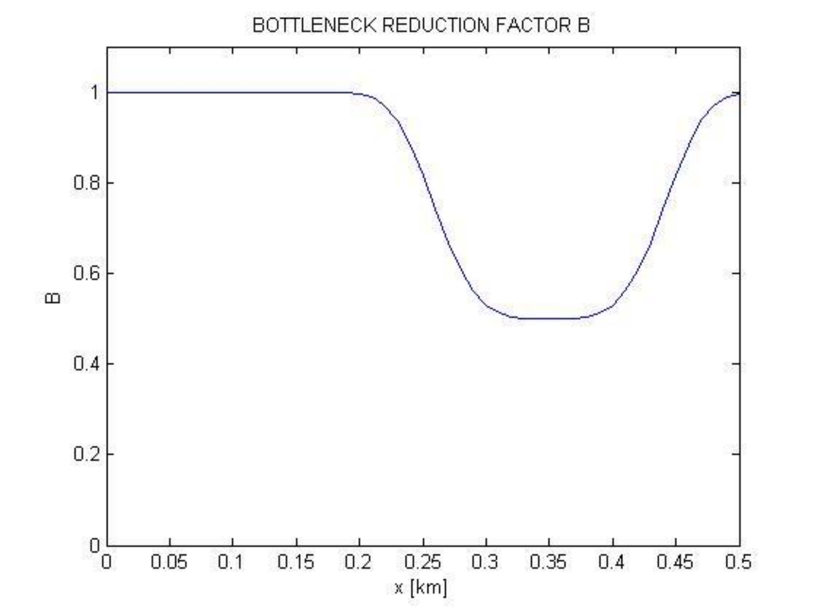
- Velocity adaptation law:
- $\frac{\partial v}{\partial t} + v\frac{\partial v}{\partial x} = \frac{v_e(\rho) - v}{T}$;
- Relaxation time: $T \cong 3\tau$
- Continuity equation:
- $\frac{\partial \rho}{\partial t} + \frac{\partial \rho v}{\partial x} = I(x,t)$
- Traffic source term:
- $I(x,t) = Q(t)\delta(x,t)$;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

Numerical treatment

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

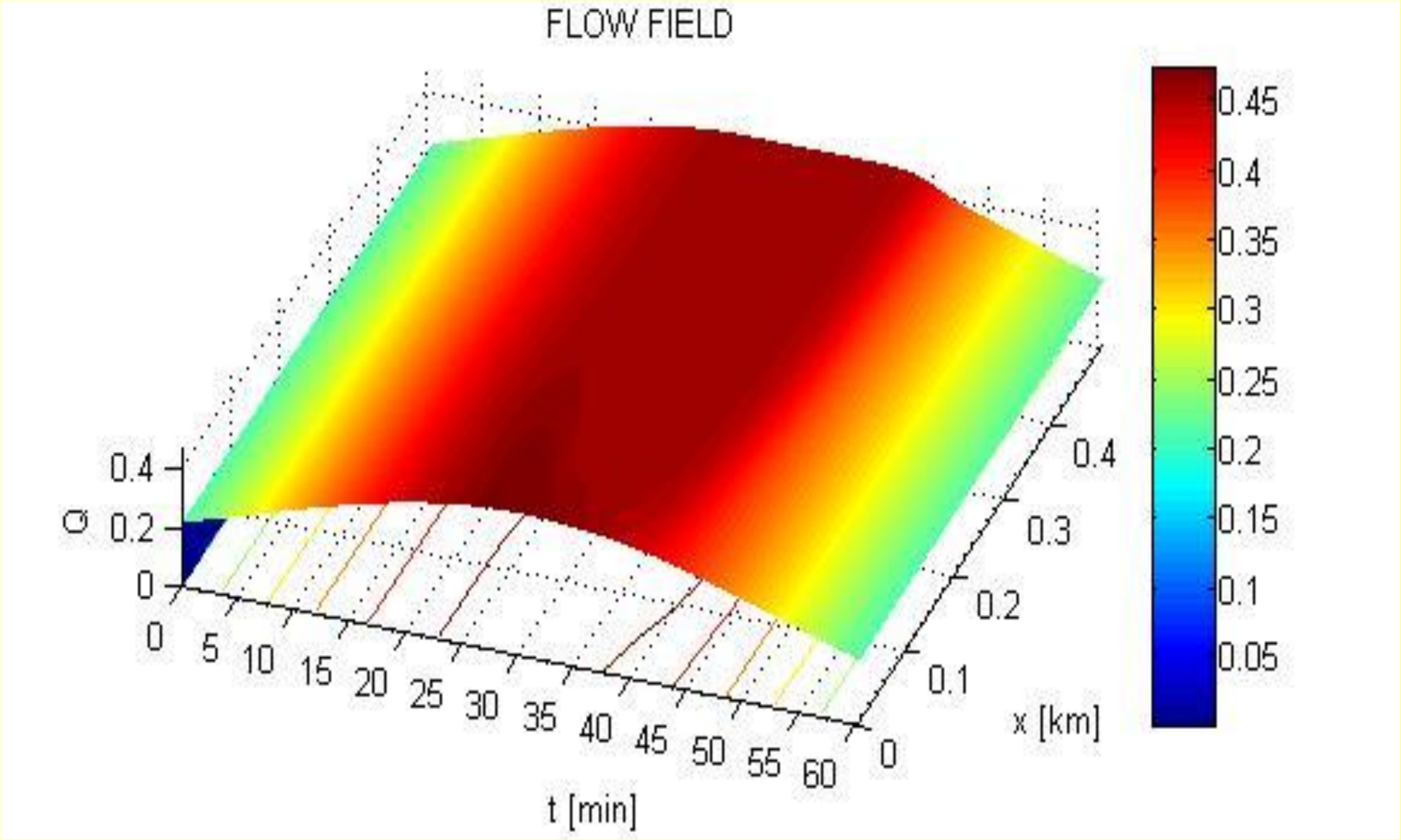
Specification of the bottleneck

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



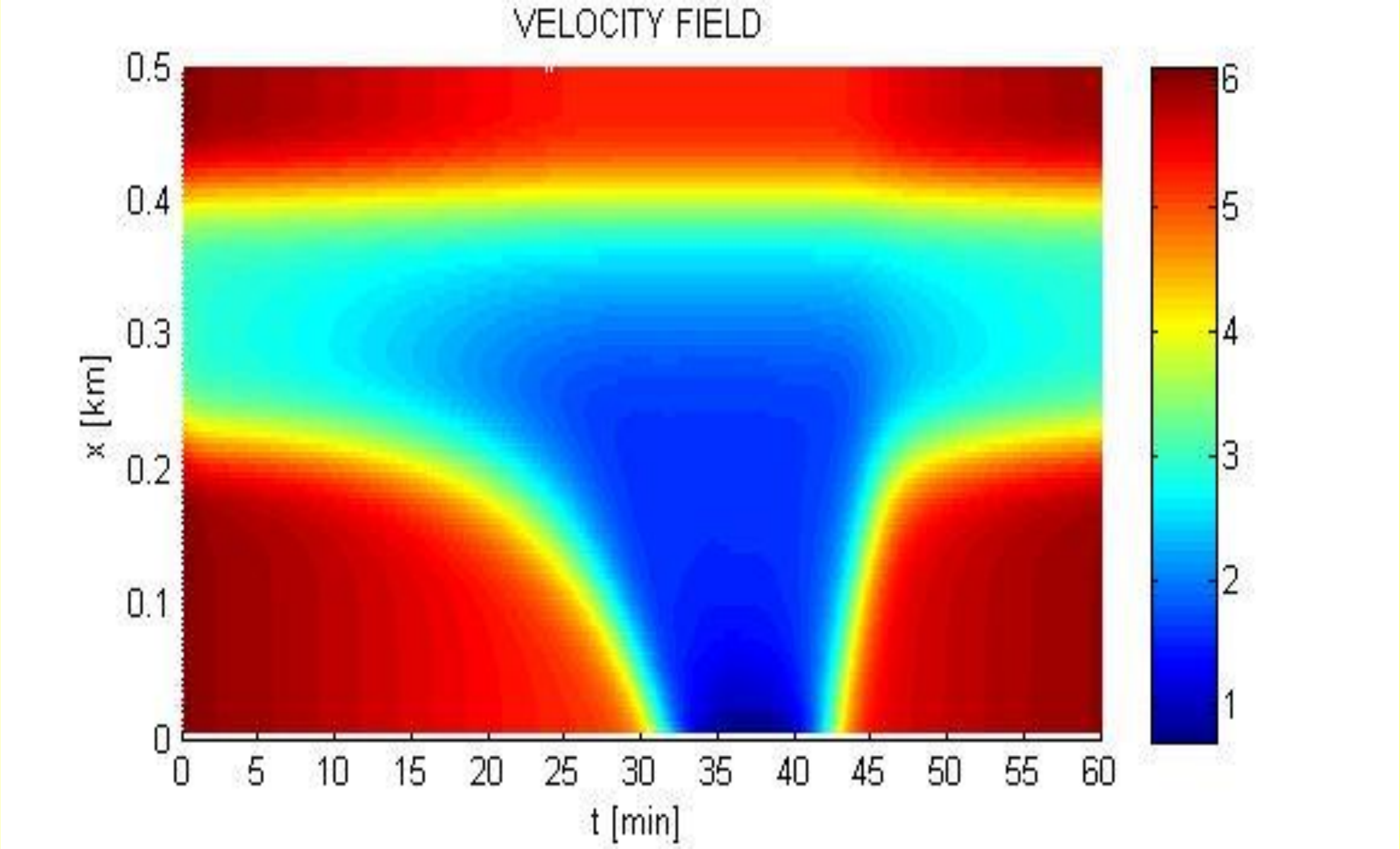
Dependence of the velocity reduction factor *B* on *x.*

Flow field – $Q(x,t)$



Parameters: v_o=110km/h ; Q_{max}=1700 veh/h

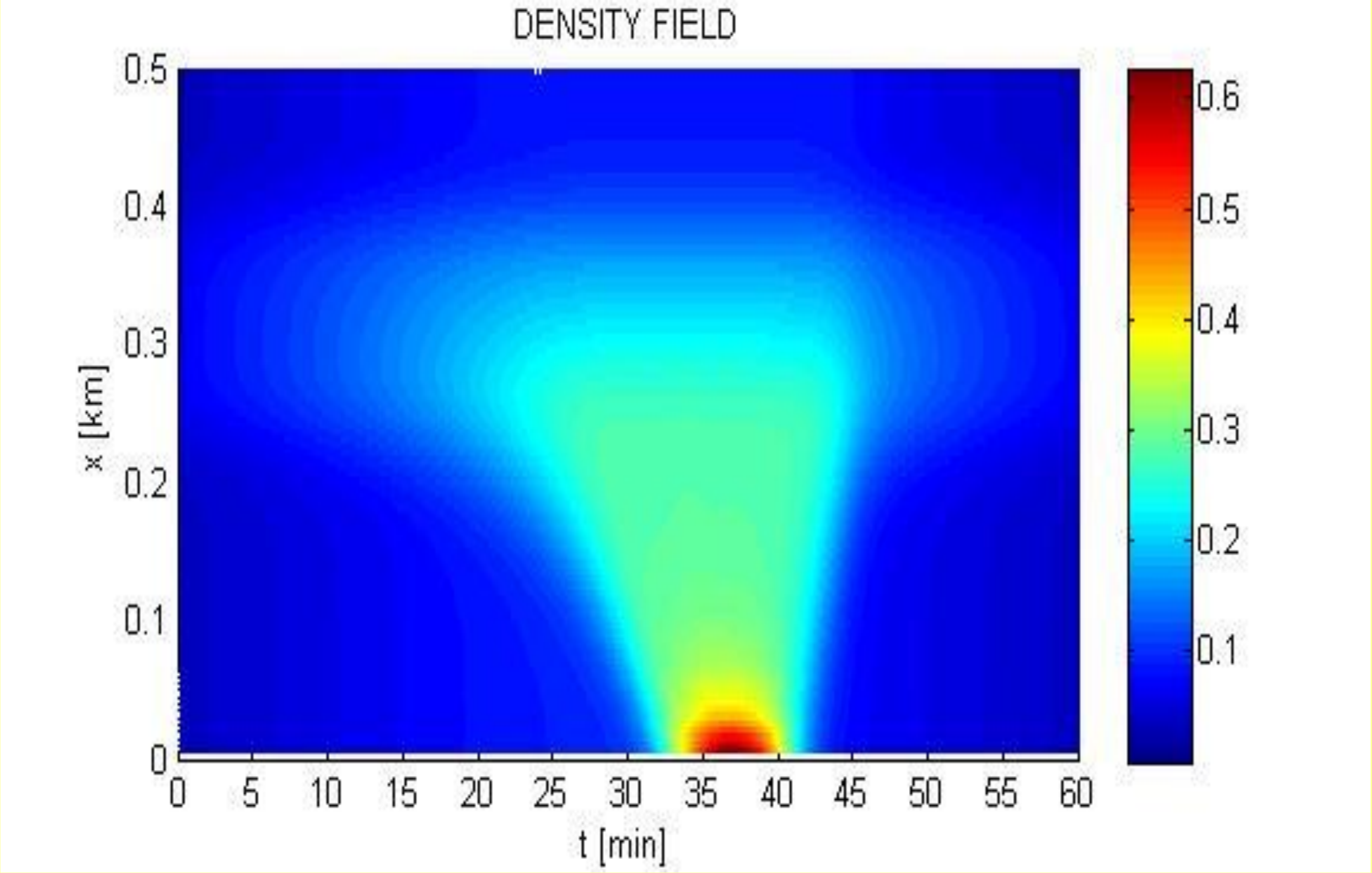
Velocity field – $v(x,t)$



Parameters: v_o=110km/h ; Q_{max}=1700 veh/h

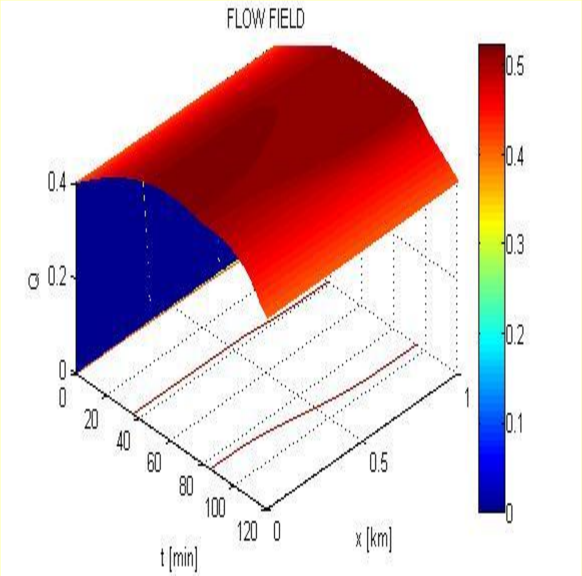
Backward jam propagation velocity: $v_{jam} \sim -0.2 km/10 min$

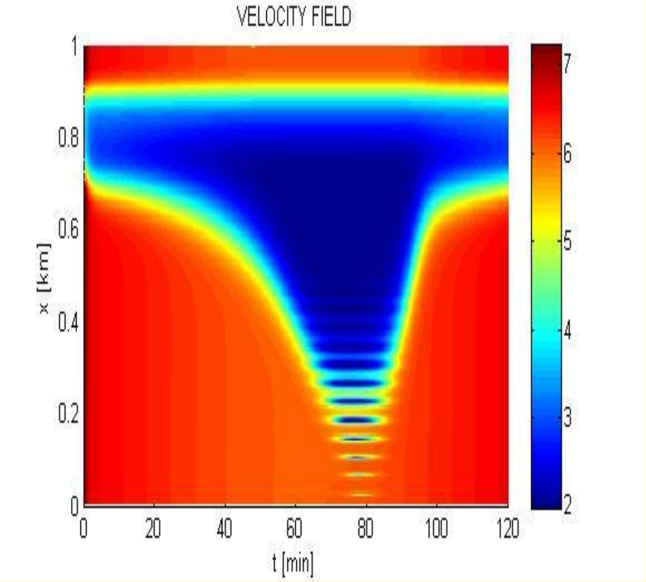
Density field – $\rho(x,t)$

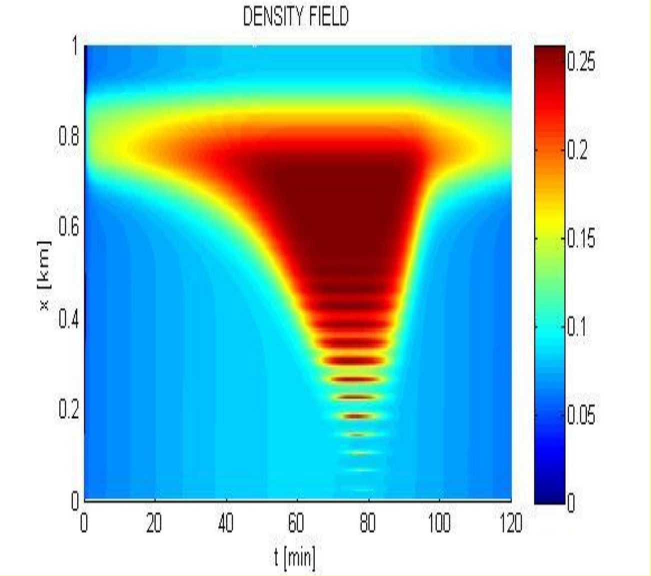


Parameters: v_o=110km/h ; Q_{max}=1700 veh/h

Field distributions







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

Application of jam forecasting

Observation: The evolution of traffic jam at the bottleneck critically depends on the input flow. Forecasting of its length is possible based upon the predicted flow.

Benefit: Before installing a bottleneck one can estimate its influence and diminish disturbances by a proper adaptation of the bottleneck structure.

Coclusions

- Fundamental traffic law and continuity equation describe the evolution of a jam at the bottleneck.
- Forecasting provides support for traffic information center and road services.
- The next step is to transfer predicted data to drivers over mobile telephones.

References

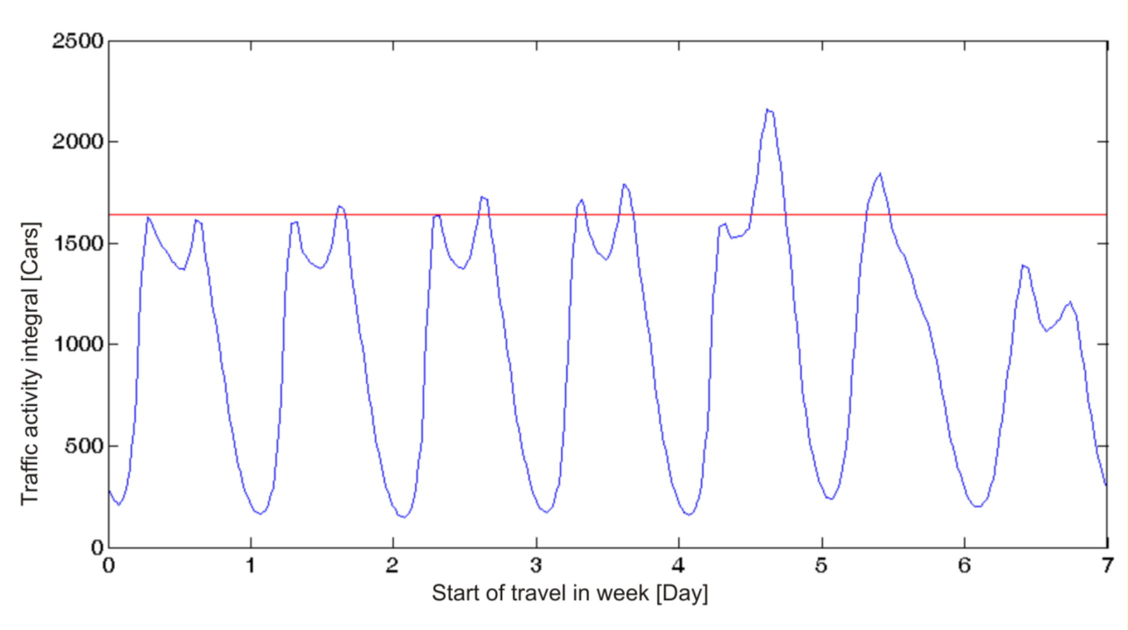
1. I. Grabec, F. Švegl, *Modeling and Forecasting of Traffic Flow*, Proc. ISEP 2010, Ljubljana, March 29-30, 2010

2. F. Švegl, I. Grabec, *Prediction of winter driving conditions*, Proc. of the International Road Weather Conference - SIRWEC – 15th, Quebec, CA, February 5-7, 2010

3. D.Helbing, *Verkehrsdynamik*, Springer (Berlin, 1997)

4. This research was supported by the company DARS

Forecasting of kritical traffic load on a way from KP to MB



Blue – integral of traffic flow from Koper to Maribor
Red – road capacity
Intersection – congestions start to develop