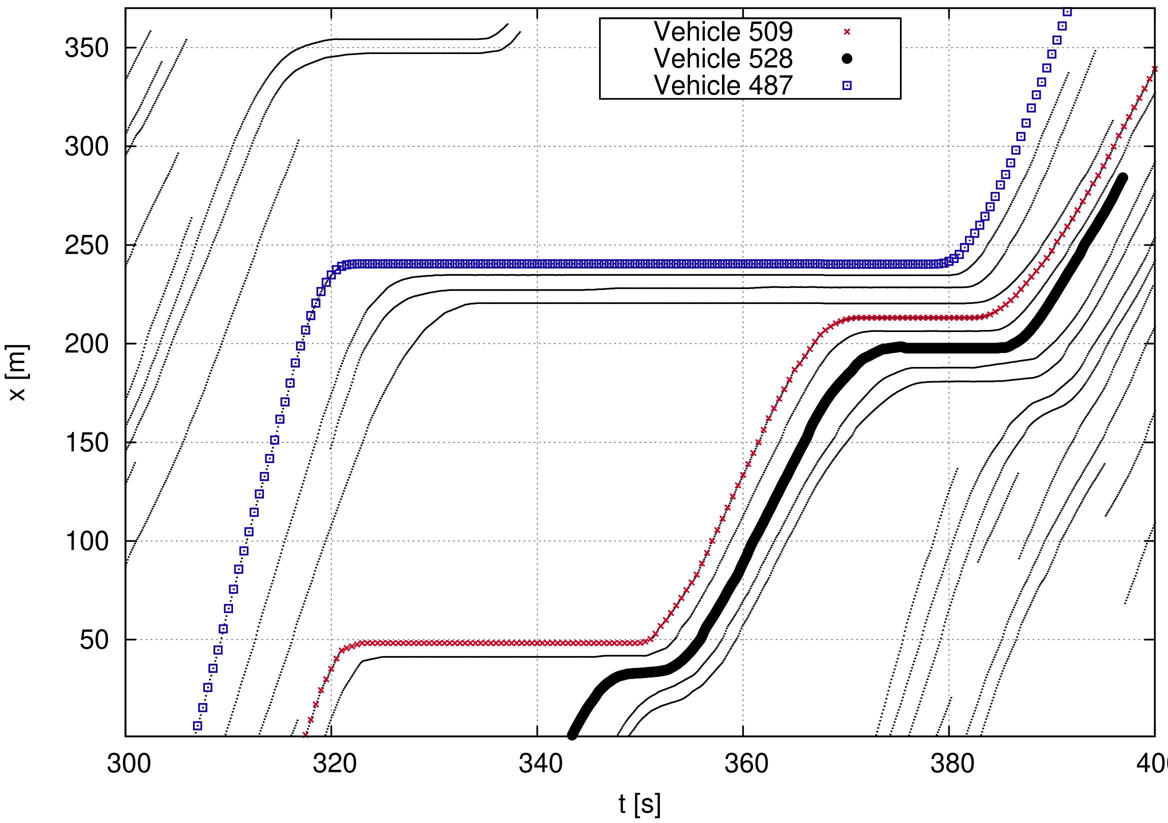
Name:	First name:	Matrikel number:

Exam to the Lecture
Traffic Dynamics and Simulation
SS 2024

Total 120 points

Problem 1 (40 points)

Given are trajectories of the second lane of a four-lane directional road in a city:



(a) At which locations do you expect signalized intersections? Also estimate the red phases of each traffic light for vehicles in the direction of the trajectories.

(b) Some trajectories begin and end inside the displayed spatiotemporal window, and this is not a data error. Give two possible reasons for each of the following:

- beginning trajectories,
- ending trajectories.

(c) The data is now used to calibrate the Intelligent-Driver Model (IDM). Argue that, for the thick solid trajectory (Vehicle 528), it is possible to estimate the time gap T, the minimum gap (provided that the vehicle lengths are known), and the comfortable deceleration b, but neither the acceleration parameter a nor the desired speed v_0.

(d) Indicate one named trajectory (Vehicle 509, 528, and 487), each, where it is possible to estimate

- the desired speed v_0,
- the acceleration a.

(e) Estimate the parameters $\rho_{\max}$, w, and $Q_{\max}$ of the triangular fundamental diagram from the diagram

Problem 2 (40 points)

(a) Describe the differences between macroscopic traffic flow models of first and second order. Give the main dynamical variables of each model class.

(b) Is it possible for models of (i) first, (ii) second order to describe traffic flow instabilities? Justify your answer.

(c) Show that, for continuous densities and speeds and in the limit of the speed adaptation time $\tau \to 0$, the second-order Kerner-Konhäuser model becomes a first-order LWR model. Give the fundamental flow-density relation $Q_e(\rho)$ of this model.

(d) Determine if, in following situations, (i) microscopic models, (ii) LWR models, or (iii) macroscopic models of second order are suited best. Justify your decisions in a few words.

  (i) Model the dynamics (including traffic breakdown) at an off-ramp bottleneck,
  (ii) determine if it is likely that on-ramp bottlenecks on a freeway will lead to traffic jams in the vacation season,
  (iii) model the effect of empty and full trucks at gradient sections,
  (iv) creating responsive surrounding traffic in driving simulators,
  (v) Determine instabilityies to traffic waves as a function of the density and the average driving style.

(e) Consider the full Gipps model. How would you parameterize it to model following driving style dimensions:

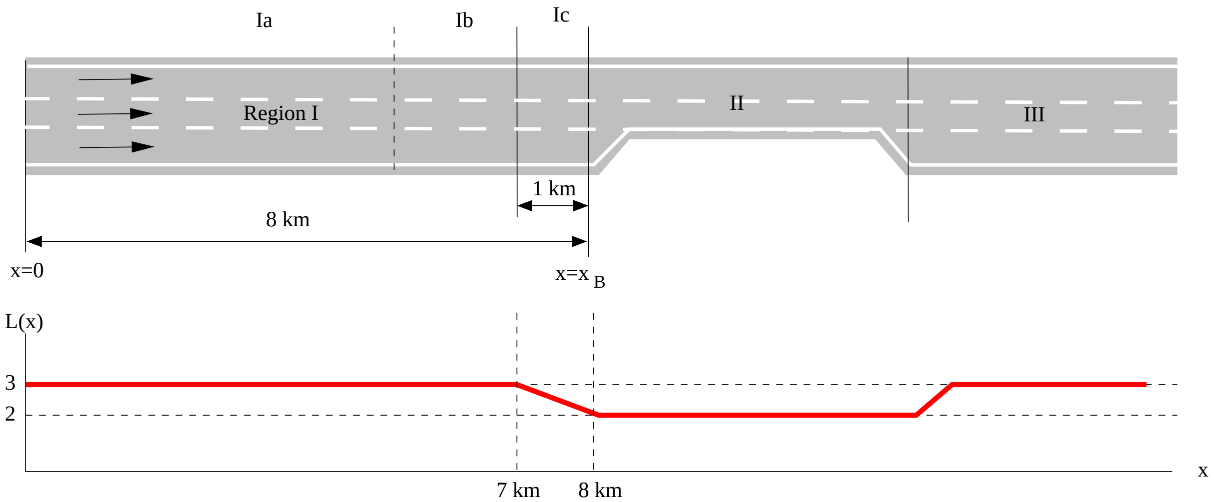
- fast vs slow,
- quickly vs slowly accelerating,
- aggressive vs relaxed,
- anticipative/experienced vs not experienced,
- safety oriented vs reckless [wagemutig].

Use the model parameters v_0, a, T, s_0, ϑ, b, and b_l and indicate if the parameters are to be chosen low, normal, or high for each of the above driving styles.

Hint: You need only indicate the values at one end of each dimension (i.e., fast, quickly accelerating, aggressive, anticipative, safety-oriented) implying that the values at the other end are opposite. Furthermore, indicate just the parameters with low and high values implying that all omitted parameter have normal values.

Problem 3 (40 points)

Given is following freeway road section with a lane-closing bottleneck and also the number of the real-valued effective number $L(x)$ of lanes as a function of the position x:



(a) Describe the motivation for introducing a non-integer location dependent effective number of lanes.

(b) The flow per lane is described by a LWR model with a triangular fundamental diagram with the parameters desired speed $V_0 = 90\,\text{km/h}$, wave speed $w = -18\,\text{km/h}$, and maximum flow $Q_{\text{max}} = 1\,800\,\text{veh/h}$. Calculate the density per lane "at capacity", the maximum density per lane, and the time gap T at the congested branch.

(c) For $t < 0$, assume a stationary (time independent) situation for a constant inflow $Q^{\text{tot}}(0,t) = Q_{\text{in}} = 2\,700\,\text{veh/h}$. Show that this does not lead to a traffic breakdown and calculate, as a function of x, (i) the total flow and density, (ii) the flow and density per lane.

(d) At $t = 0$, the flow suddenly increases to $4\,500\,\text{veh/h} = 2.5\,Q_{\text{max}}$. Show that this will lead to congestions and determine the location and time of the initial traffic breakdown.

Hint: at this location, the demand is equal to the local capacity.

(e) After a short time, the transition congested → maximum-flow state establishes at $x = x_B$. Determine the flow per lane, the density per lane and the local speed in the congested regions Ib and Ic (assuming that the transition free → congested is at $x < 7\,\text{km}$).

Hint: The flow in the congested regions is determined by the minimum bottleneck capacity.

(f) Calculate the propagation velocity of the free → congested transition Ia-Ib.