Exercise 4 (October 25, 2017)

**Note:** In this exercise, “optimal metering rate” means the least restrictive rate required to prevent congestion in the mainline.

**Question 1: Ramp metering**

Consider a ramp with two lanes, one for single passenger vehicles (SPVs) which may wait at the ramp meter, and an HOV (high occupancy vehicle) bypass lane where vehicles enter mainline without stopping at the meter. Vehicles arrive at the ramp at a rate of 300 veh/h during the whole day, except one peak hour where the rate is 1000 veh/h. 20% of all vehicles are HOVs with 2 passengers each. Mainline capacity is 6000 veh/h and mainline demand is 5400 veh/h for the whole day. The ramp queue can hold as many vehicles as needed.

a) Determine the optimal metering rate for the SVP lane.
b) What will be the total delay (in vehicle hours travelled) for SVP users?
c) What will be the time saving (in passenger hours travelled) compared to a scenario where all vehicles are treated the same?
d) Determine the maximum queue length that will occur during the day.

**Question 2: Coordinated ramp metering**

Consider the freeway sketch below. Vehicles arrive at the first ramp with a rate of \( r_1 = 800 \) veh/h and at the second with \( r_2 = 1000 \) veh/h. The arrival rate \( q_0 \) is equal to 4000 veh/h for one hour (off-peak) and 4600 veh/h for another hour (peak). Both ramps have a maximum storage capacity of 100 queued vehicles and the mainline capacity is 6000 veh/h.

![Freeway Sketch](image)

a) Based on these demands where and at what time will the bottleneck of the freeway be created?
b) Which ramp should start metering first and what is the optimal metering rate for that ramp?
c) At what time will the ramp reach the maximum storage capacity? What happens after this point? What are the optimal metering rates for the two ramps in this situation? (Hint: Ramp-metering strategy is feedforward for both ramps.)
d) At what time will both ramp queues reach their storage capacities? Do you have any suggestion about the ramp metering policy after this point?