Fundamentals of Traffic Operations and Control
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Exercise
Parking management

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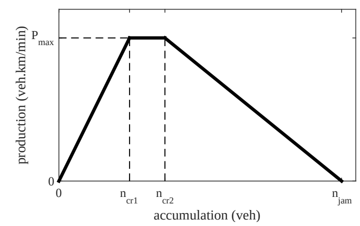

Figure 1: Macroscopic fundamental diagram.

Consider a city center where the traffic conditions are described by an MFD of production (veh-kms traveled) vs. accumulation (veh) with a trapezoidal shape (see fig. 1). The parameters are: (1) trip production $P_{\max}$, with $P_{\max} = O_{\max} \cdot L$, where $O_{\max}$ is the maximum outflow and L is the average trip length; (2) critical accumulations $n_{\text{cr1}} = 1000$ veh, $n_{\text{cr2}} = 1500$ veh, and jam accumulation $n_{\text{jam}} = 4000$ veh. The city has a constant demand rate $q = 150$ veh/min, and a limited on-street parking availability, $N_p = 500$ veh, with N_p expressing the total amount of parking spots. Vehicles have to cruise for parking before reaching their destinations.

Recall what you have learned about the MFD. Now the system has two families of vehicles: (i) vehicles moving towards their destination but not yet searching for parking (family m), modeled via n_m, and (ii) vehicles searching for parking (family s), modeled via n_s, with $n = n_m + n_s$, where n is the total accumulation. The trip completion rates of the two families are:

$$o_m = \frac{P_m}{l_m} = \frac{n_m}{n} \cdot P \cdot \frac{1}{l_m} \qquad o_s = \frac{P_s}{l_s} = \frac{n_s}{n} \cdot P \cdot \frac{1}{l_s},$$

where o_s is the trip completion rate of the whole system, and of family s, o_m is the trip completion rate of family m and the input to family s, l_m and l_s are the average trip lengths of the two families, with l_s denoting the cruising distance before finding a parking spot, which depends dynamically on parking availability as $l_s = d_1 \cdot N_p / a_p(t)$, where d_1 is the average distance traveled between two adjacent spots and $a_p(t)$ is the number of available parking spots.

a) Write down the time-discretized dynamic equations of the system with the consideration of parking.

b) Simulate the system with a time step of 1 min. Use $P_{\max} = 50$ veh.km/min, $l_m = 1$ km, $d_1 = 20$ m. If at 7 am, there are already $n(t = 0) = 500$ veh (consider $n_m(t = 0) = 500$ veh and $n_s(t = 0) = 0$ veh) and the available parking $a_p(t = 0) = 450$ veh, when will all the on-street parking be filled (i.e., what is t for which $a_p(t) = 0$ veh?)

c) Consider the scenario where N_p is infinite. How much is the extra delay due to the limitation of parking space? What about the average trip length l (with $l = \frac{l_m \cdot n}{n - n_s}$)?

d) Discuss possible policies that can help reduce the delay caused by cruising-for-parking.