Fundamentals of Traffic Operations and Control

Exercise 5 (November 15, 2017)

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

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, $n_m$ and (ii) vehicles searching-for-parking $n_s$:

$$n = n_s + n_m$$

The trip completion rate of family $i$:

$$o_i = P_i / l_i$$

Note that $o_s$ is the trip completion rate of the whole system, and of family (ii). While $o_m$ is the trip completion rate of family (i) and the input to family (ii).

$P_i = (n_i / n^*) P$, $l_i$ is the average trip length of the family, $l_s$, cruising distance before finding a parking spot, is dynamic depending on parking availability. Calculation of $l_s$ can be found in next page.

a. Write down discretized dynamic equations of the system with the consideration of parking (for example, simplify and discretize equations 10a, 10b in the next page for $n_s, n_m$).

b. Simulate the system with 1min-interval. Use $P_{\text{max}} = 50$ [veh-kms/min], $l_m = 1$ [km], $d_f = 20$ [m]. If at 7am, there are already $n_0 = 500$ [veh] (consider $n_{m0} = 500, n_{s0} = 0$) and the available parking $a_{p0} = 450$, when will all the on-street parking be filled ($a_p = 0$)?

c. Compare to 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 $L$ (equation 12b)?

d. Discuss possible policies that can help reduce the delay caused by cruising-for-parking.
Calculation of $l_s$

Denote by $n_p$ the vehicles parked on street (families $p$) and by $N_p$ the total number of parking spots. Also, let $p = n_p/N_p$ be the percentage of available parking spots, and $d_i$ be the average distance traveled between two adjacent spots (from $N_p$). We assume that $p$ and $d_i$ do not vary drastically in the dimension of space. When a vehicle reaches its destination, it is assumed that it does Bernoulli trials with probability of success $p$, until finding an available spot. The number of trials until the 1st success follows a geometric distribution with mean $1/p$. In each trial a vehicle travels, on average, distance $d_i$ and the average distance traveled while searching for parking is $l_s = d_i/p$. To model the effect of parking, the reservoir $R$ is divided in three sub-reservoirs:

Example dynamic equations

$$\frac{dn_{m}}{dt} = q_{R \rightarrow R} + q_{R \rightarrow R} - O_{m}(n_{m}, n) \quad (10a)$$

$$\frac{dn_{s}}{dt} = O_{m}(n_{m}, n) - O_{s}(n_{s}, n) \quad (10b)$$

$$\frac{1}{l_s} = \left(1 - \frac{n_s}{n}\right) \frac{1}{l_m} \quad (12b)$$

More details can be found on page 9, 10 and 11 of the document “Parking notes” on moodle.