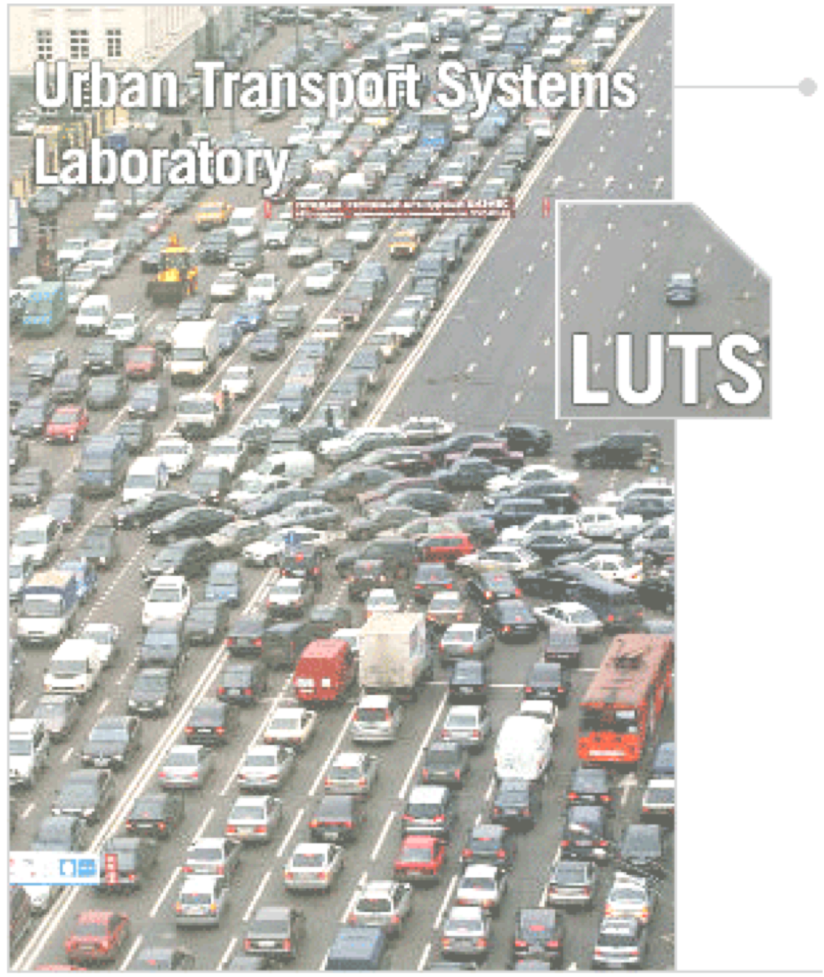
ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

Macroscopic Fundamental Diagram:
Existence, Physical Properties and Dynamic Modeling



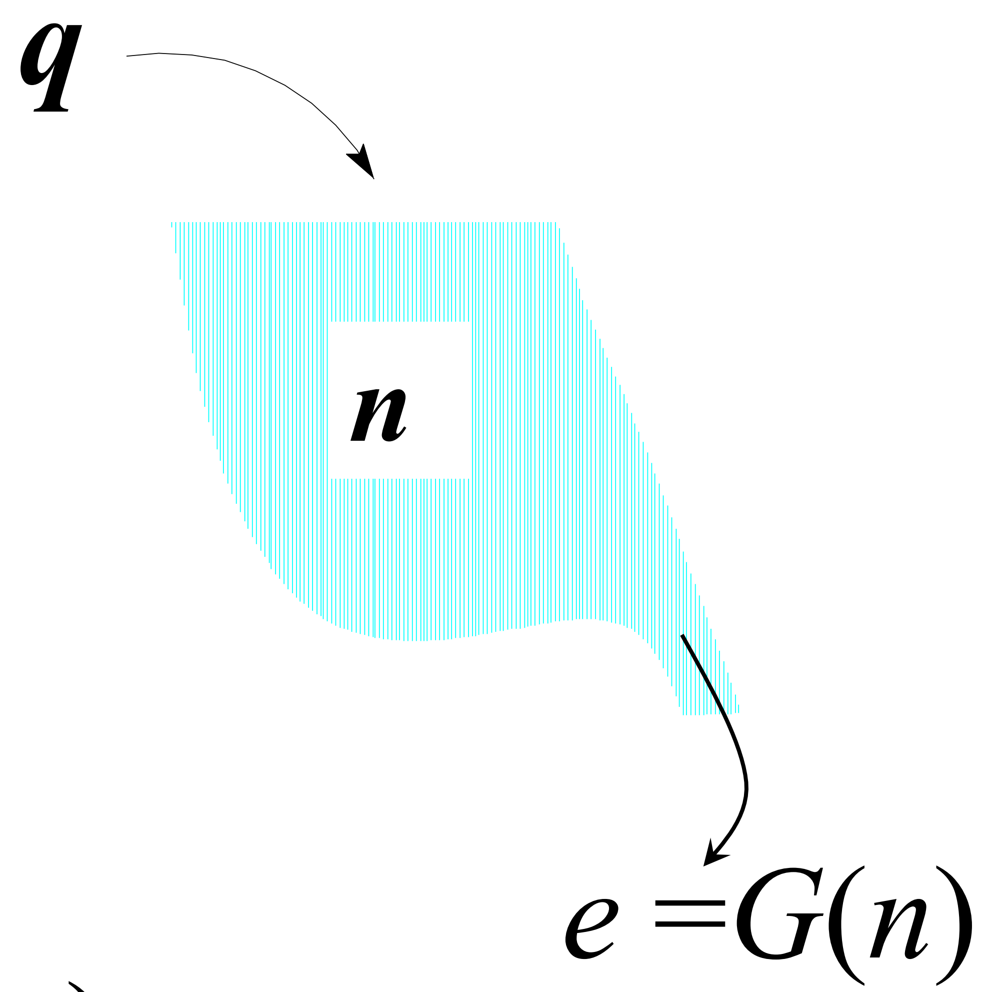
Intro to traffic flow modeling and ITS

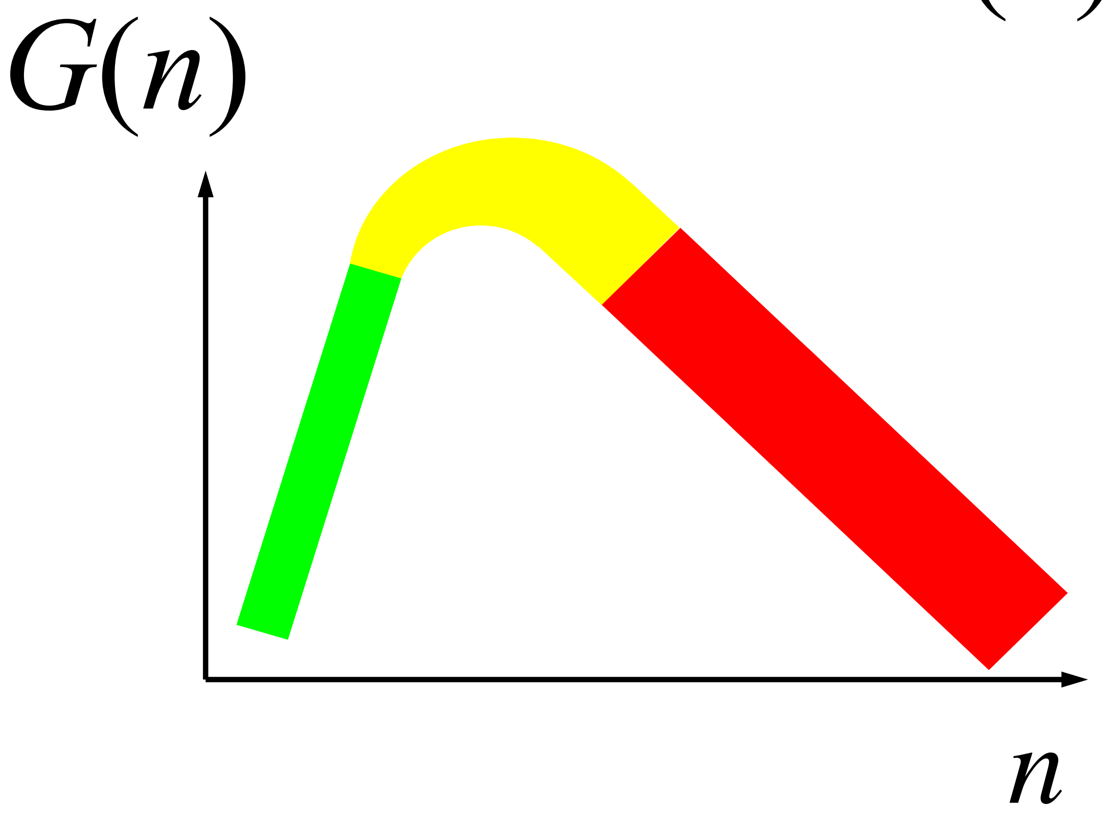
Prof. Nikolas Geroliminis

MFD Dynamics of a single-reservoir system

$$n_1 = n_0 + q_0 - G(n_0)$$
$$n_2 = n_1 + q_1 - G(n_1)$$
$$\vdots$$
$$n_t = n_{t-1} + q_{t-1} - G(n_{t-1})$$

$$n_t = n_0 + \sum_{j=0}^{j=t-1} q_j - \sum_{j=0}^{j=t-1} G(n_j)$$

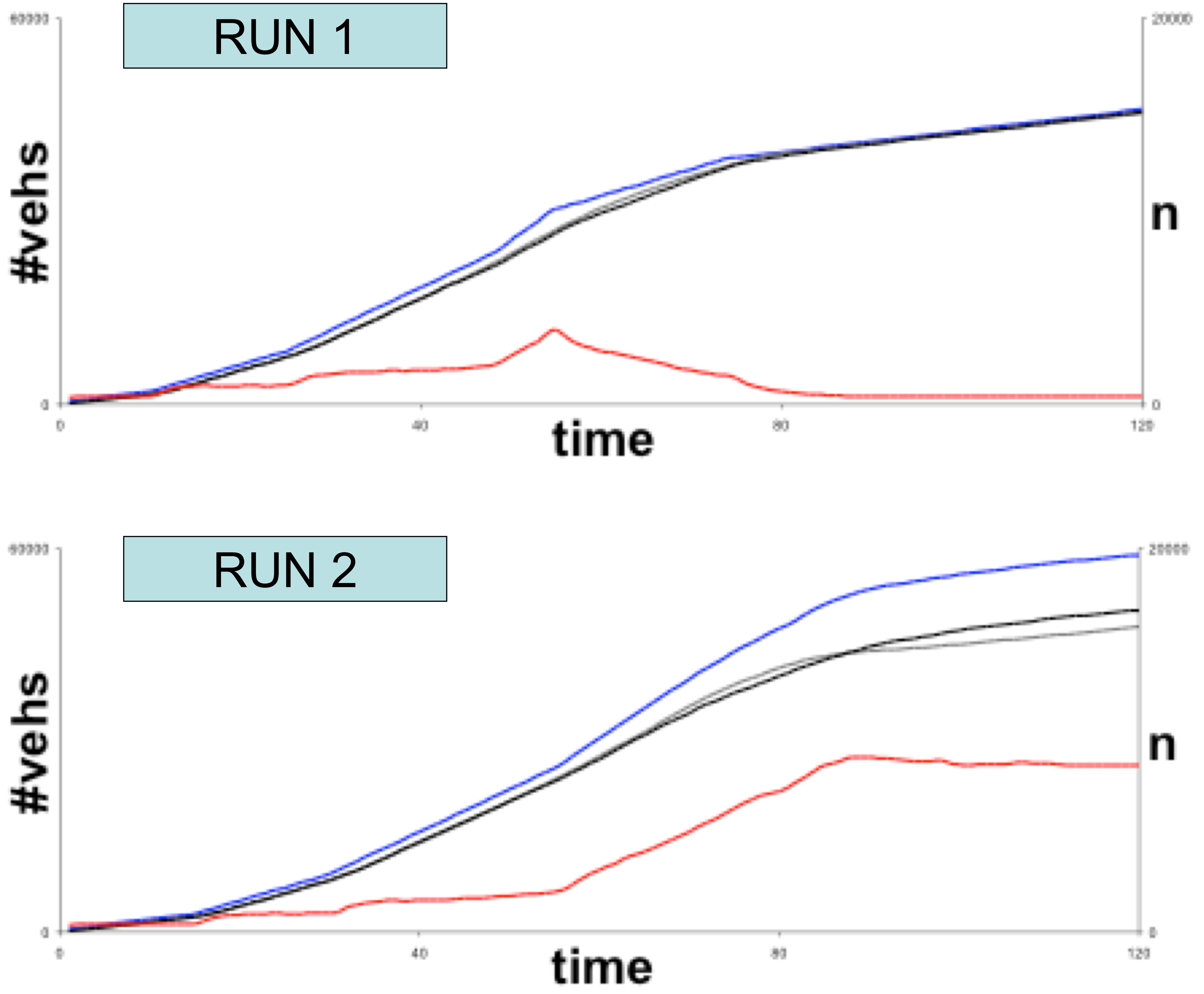




$$\frac{dn}{dt} = q(t) - G(n(t))$$

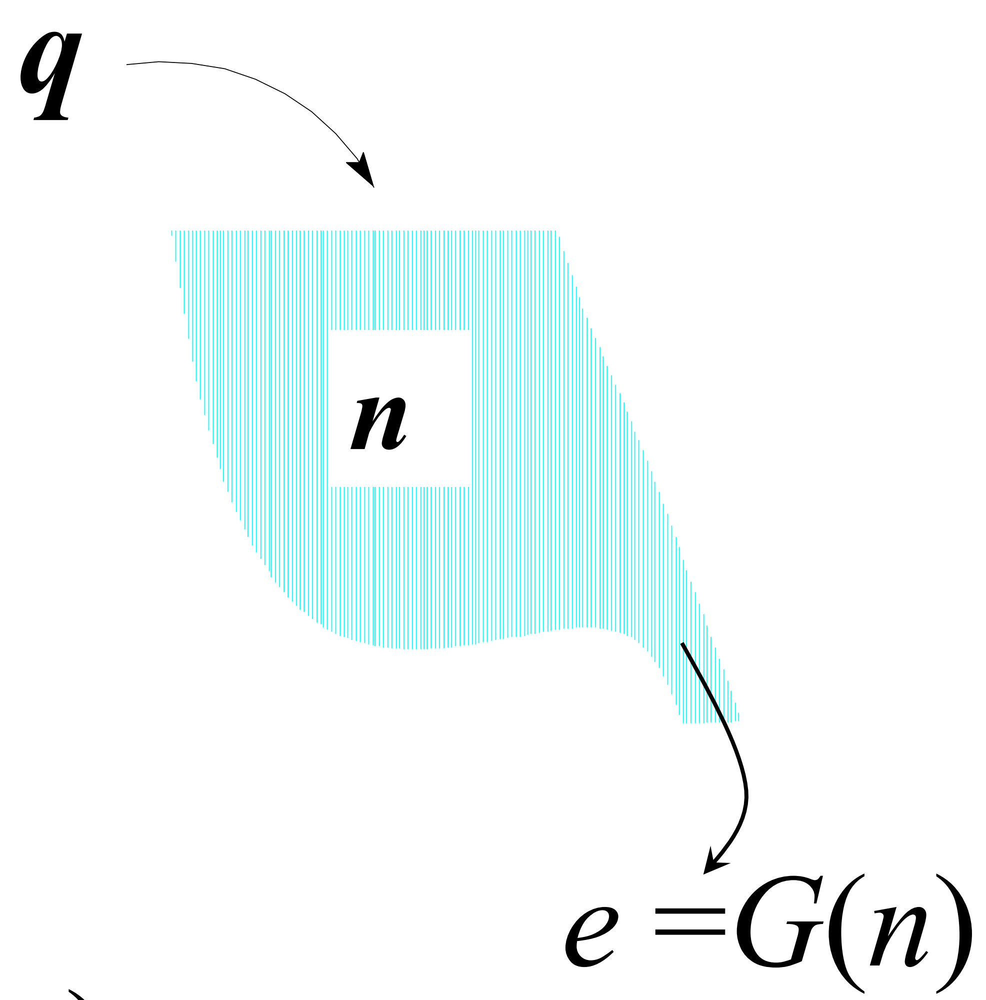
Daganzo, 2007

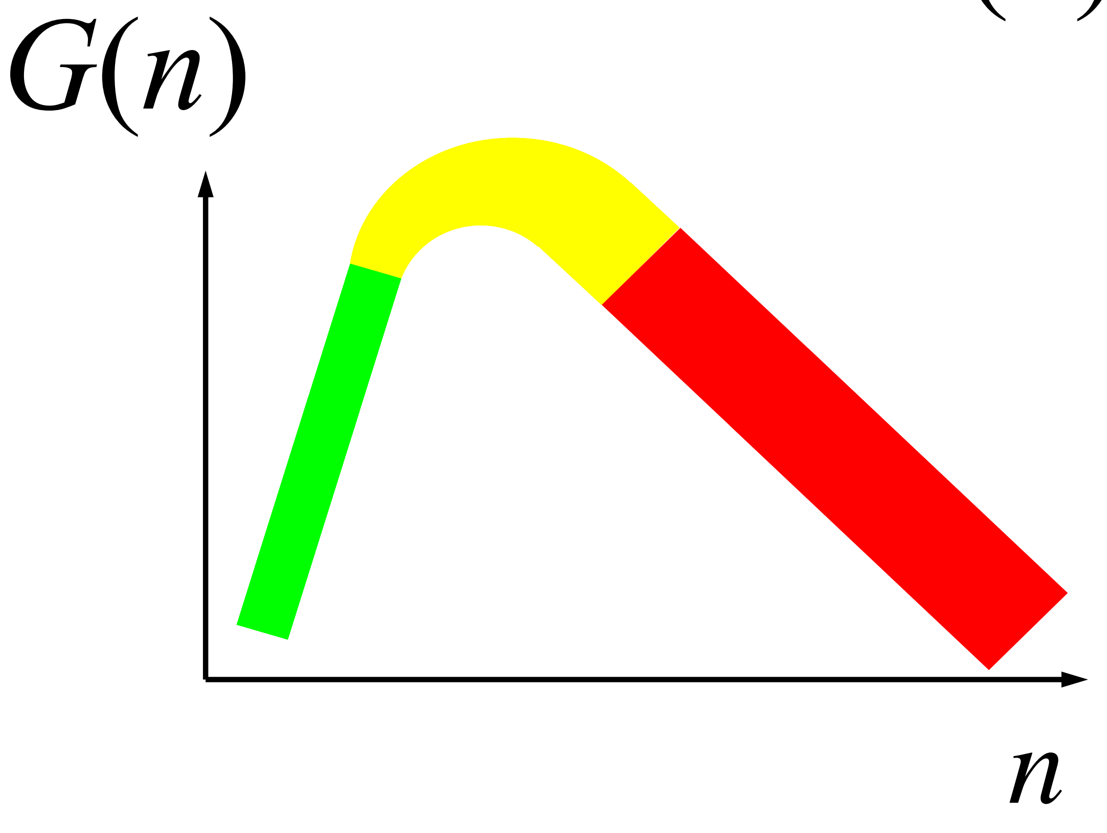
MFD Dynamics of a single-reservoir system



INPUT **OUTPUT** **ESTIMATED OUTPUT** **ACCUMULATION**

Geroliminis and Daganzo, 2007



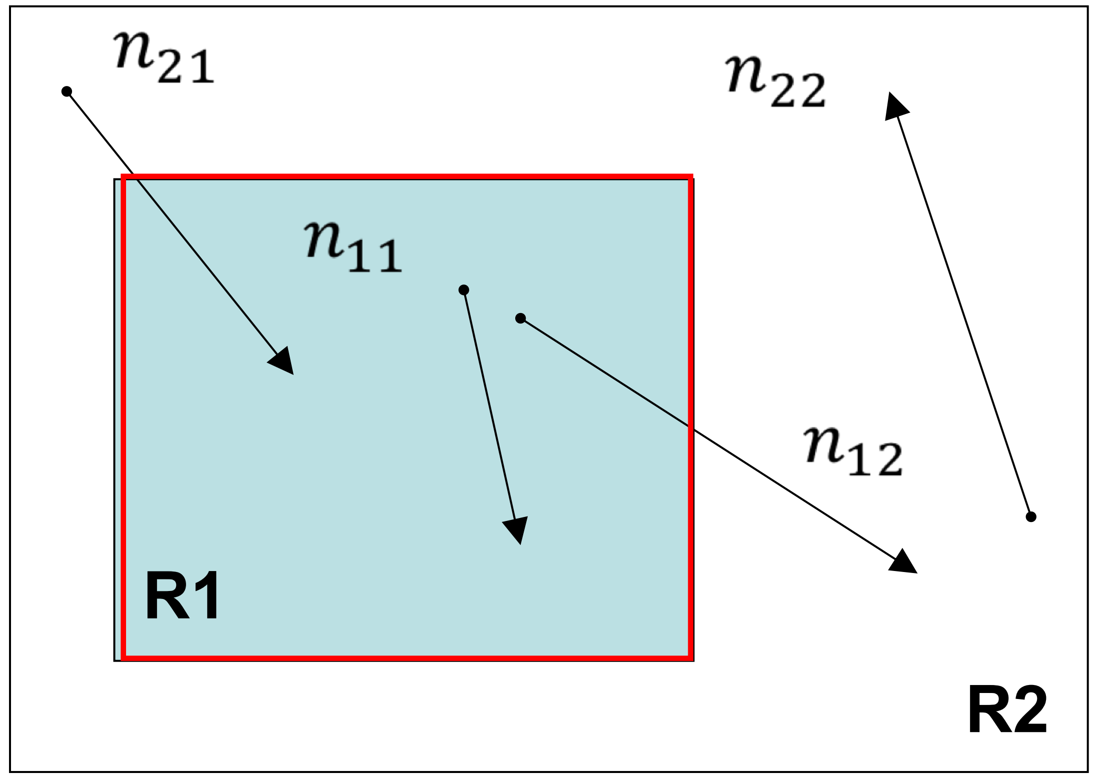


$$\frac{dn}{dt} = q(t) - G(n(t))$$

Daganzo, 2007

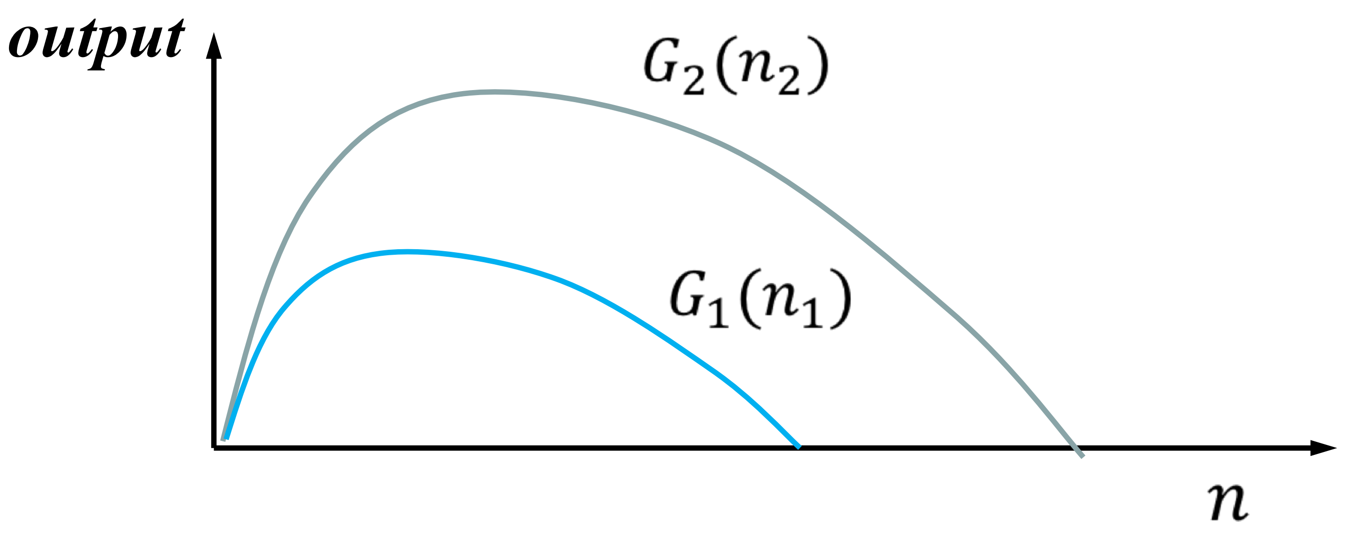
Dynamics of a two-reservoir system

- State Variables
- Dynamic Equations



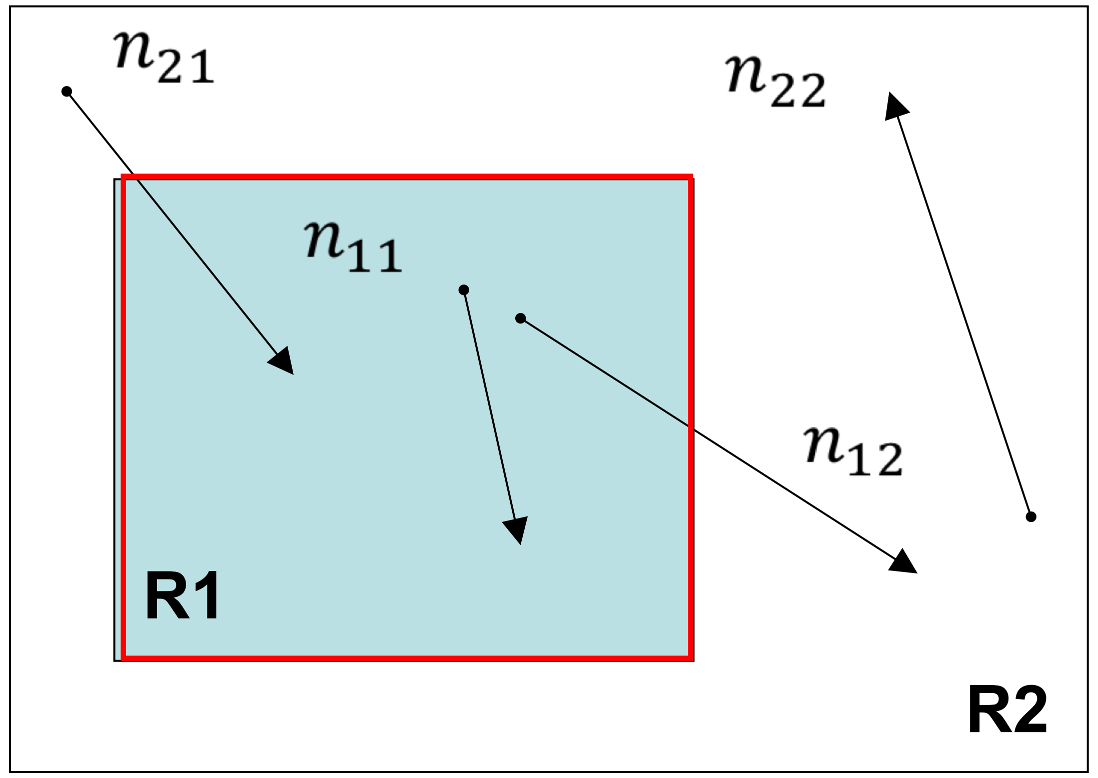
$$\frac{dn_{11}}{dt} = q_{11} + Q_{1\to 2} - \frac{n_{11}}{n_1} * G_1(n_1)$$

$$\frac{dn_{12}}{dt} = q_{12} - Q_{1\to 2}$$



Dynamics of a two-reservoir system

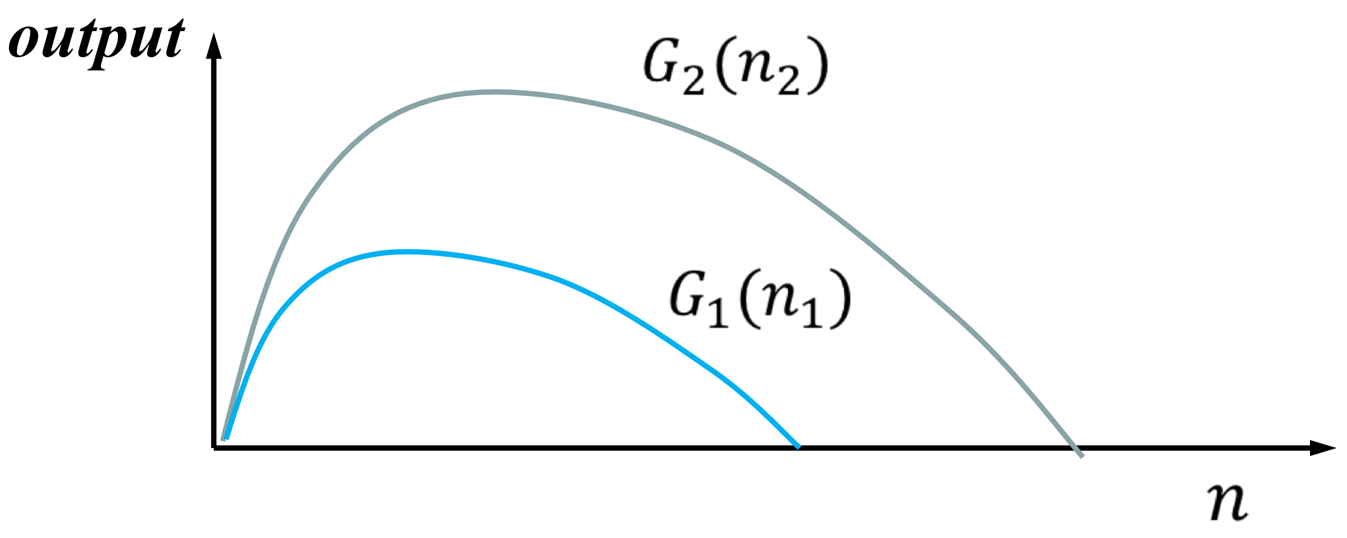
- State Variables
- Dynamic Equations
- Boundary Capacity

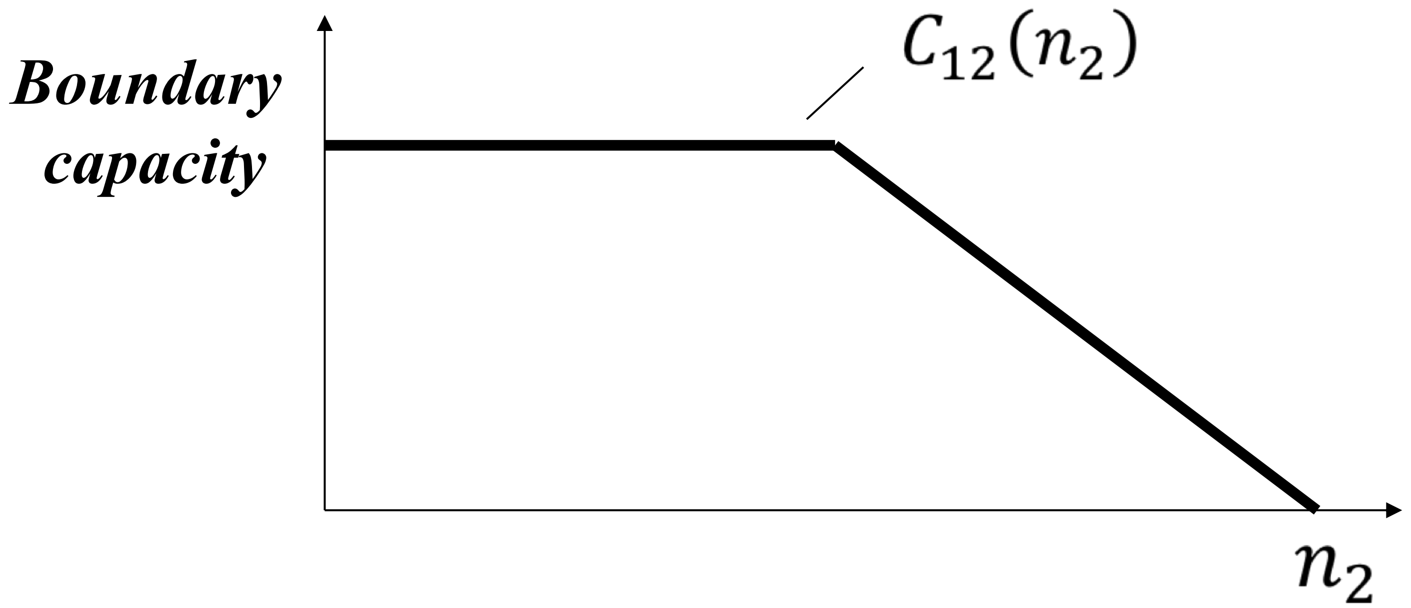


$$\frac{dn_{11}}{dt} = q_{11} + Q_{1\to 2} - \frac{n_{11}}{n_1} * G_1(n_1)$$

$$\frac{dn_{12}}{dt} = q_{12} - Q_{1\to 2}$$

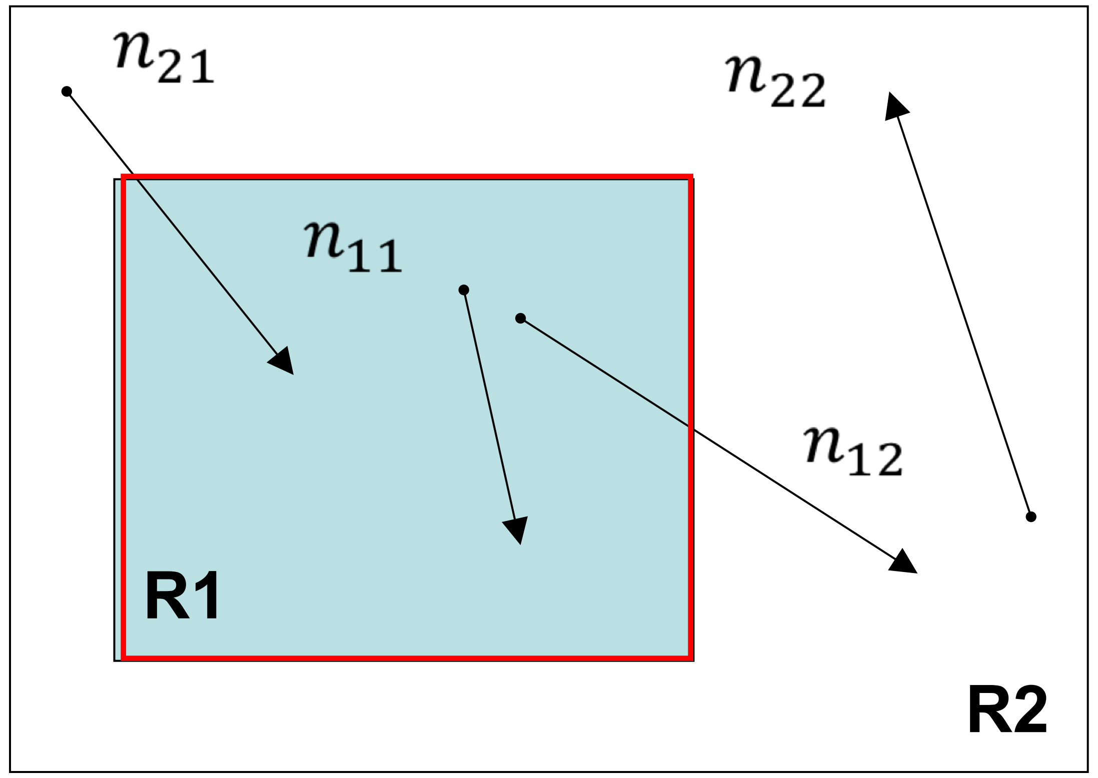
$$Q_{1\to 2} = \min\left(\quad C_{12}(n_2), \frac{n_{12}}{n_1} * G_1(n_1) \right)$$





Dynamics of a two-reservoir system

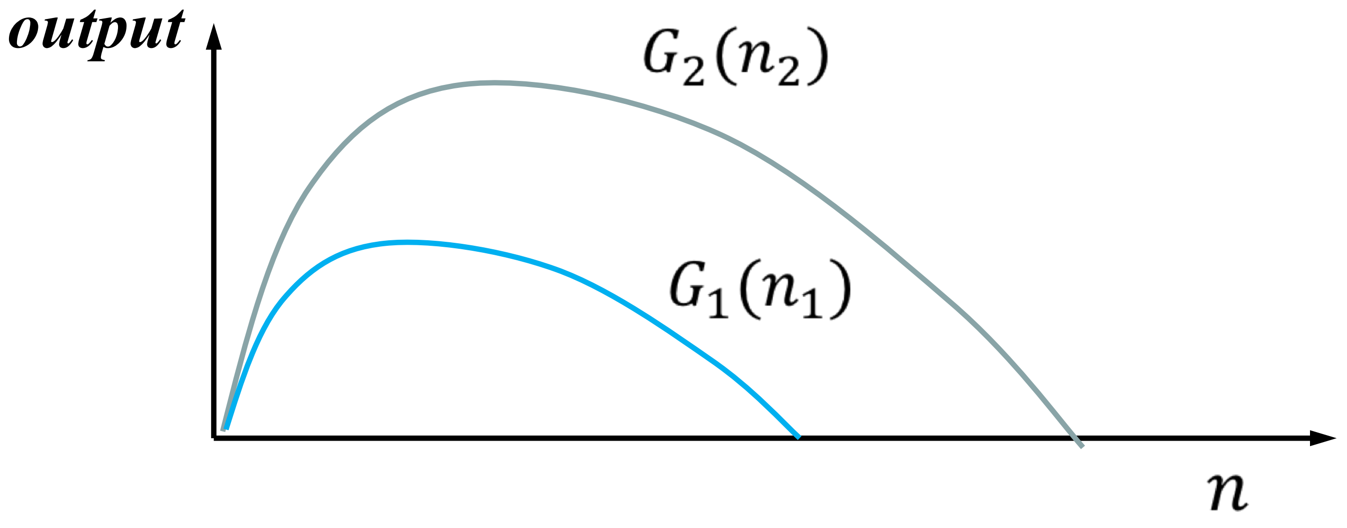
- State Variables
- Dynamic Equations
- Boundary Capacity
- Perimeter Control

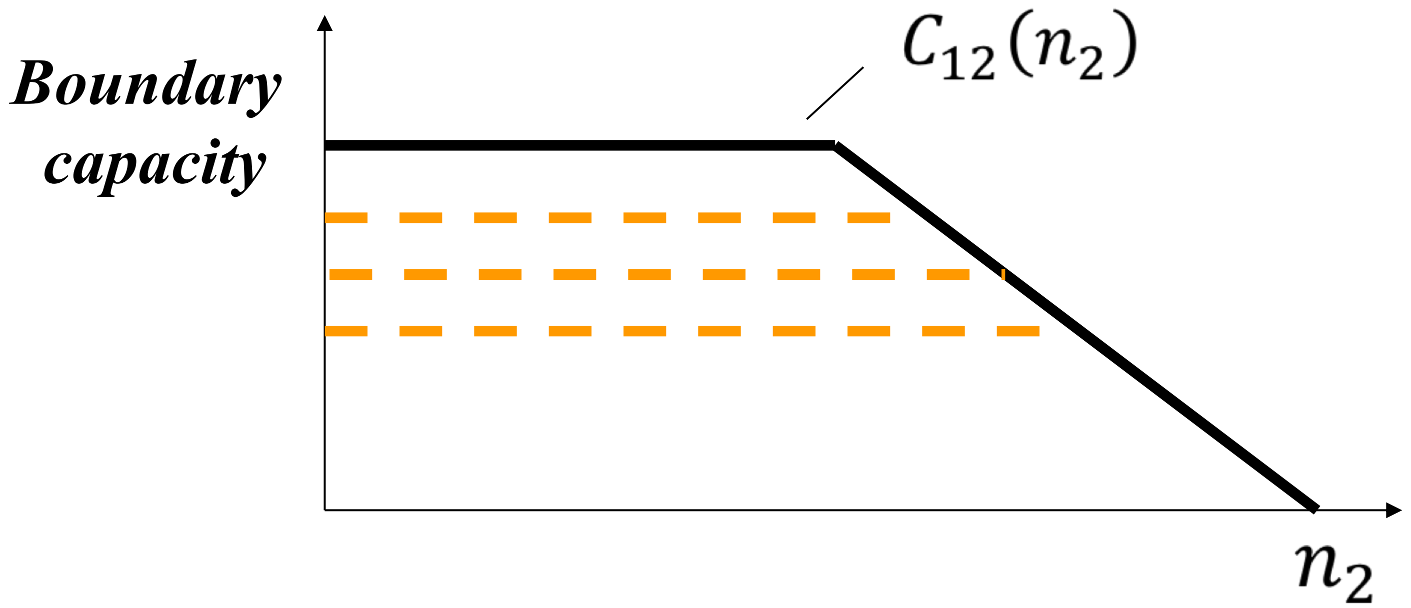


$$\frac{dn_{11}}{dt} = q_{11} + Q_{1\to 2} - \frac{n_{11}}{n_1} * G_1(n_1)$$

$$\frac{dn_{12}}{dt} = q_{12} - Q_{1\to 2}$$

$$Q_{1\to 2} = \min\left(\quad C_{12}(n_2), \frac{n_{12}}{n_1} * G_1(n_1)\right)$$





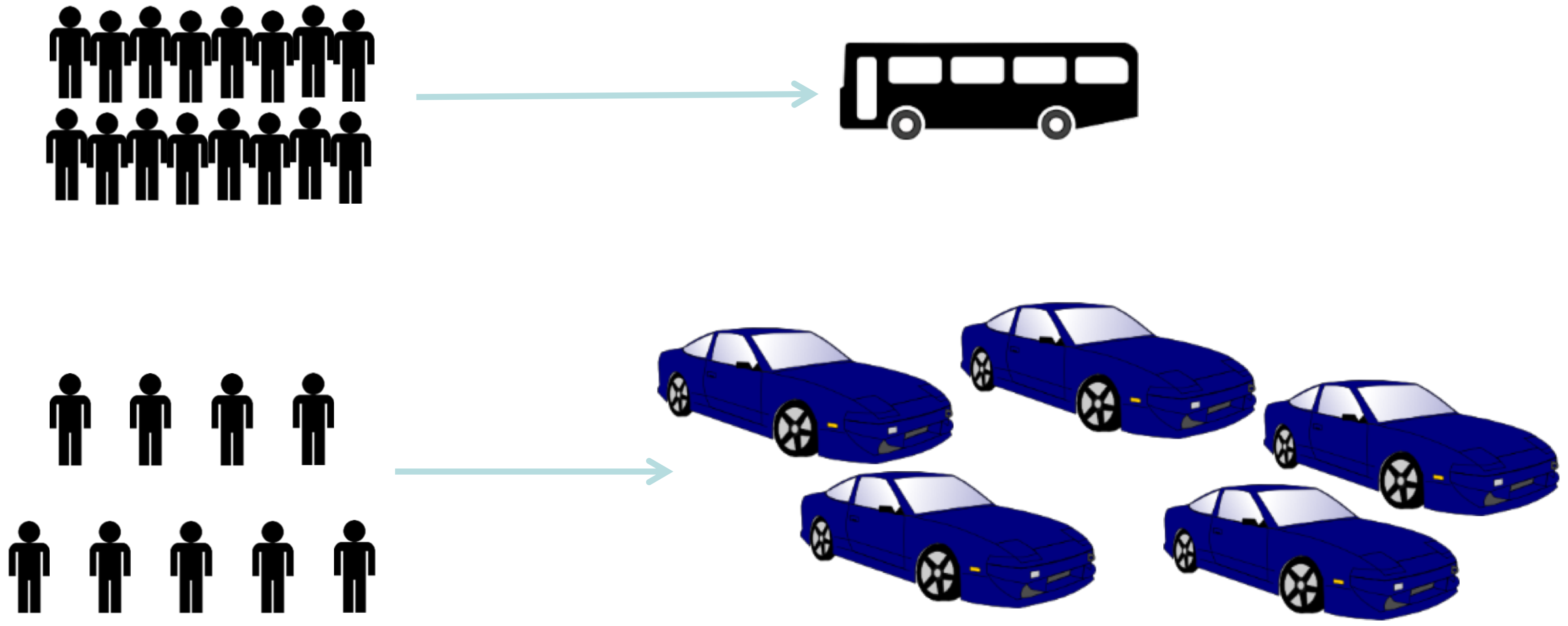
Multimodal networks

- In urban networks, buses <u>share</u> the same network with the other vehicles.
- <u>Conflicts</u> in multi-modal urban traffic systems:
- Bus stops affect the system like red signals in a single lane (instead of blocking all lanes).

bus frequency

flow of vehicles

flow of passengers



Performance Measures

Vehicle Hours Traveled
Vehicle Kilometers Traveled

Passenger Hours Traveled
Passenger Kilometers Traveled

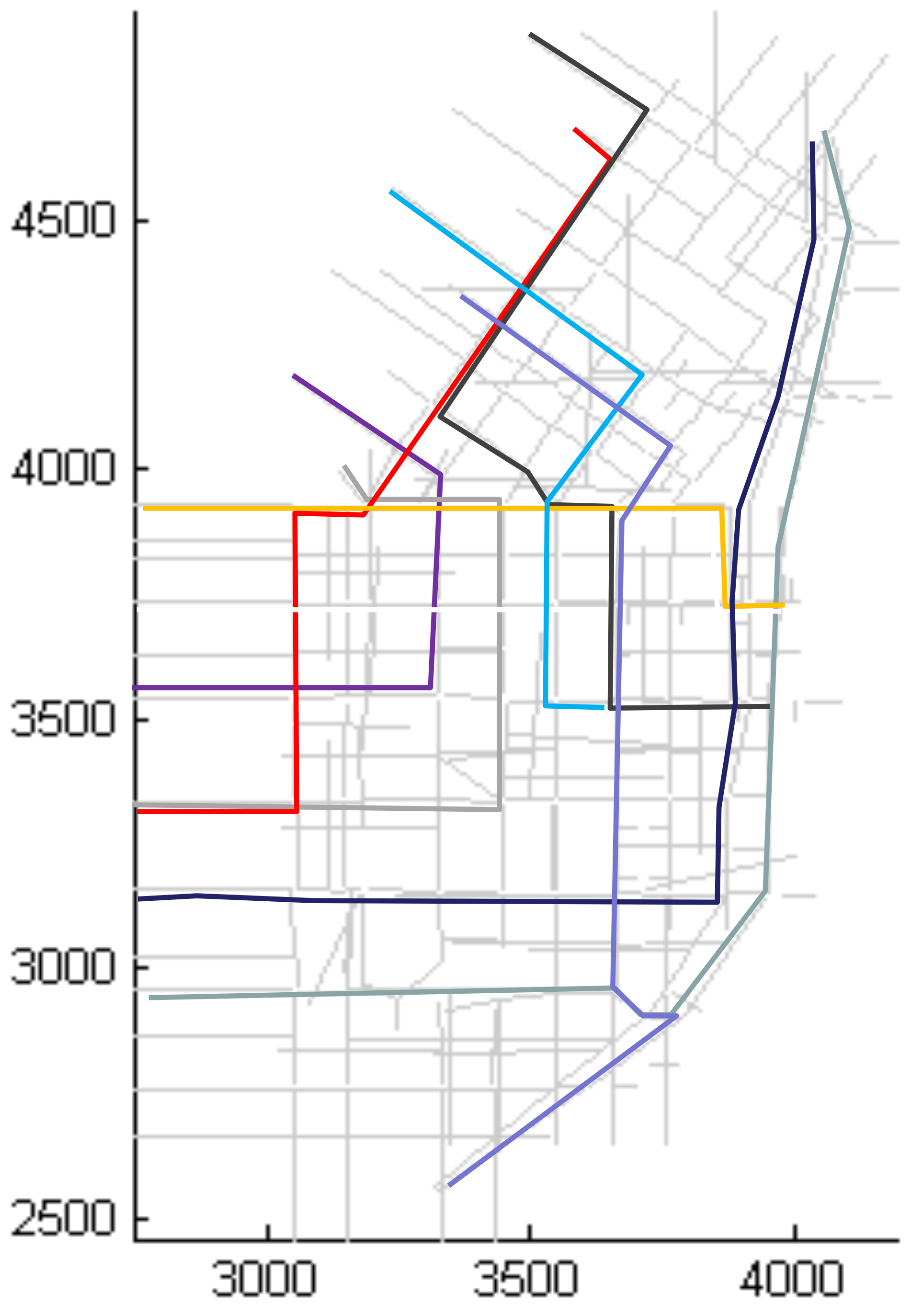
Mobility (Accessibility)

Emissions (Environ. Impacts)

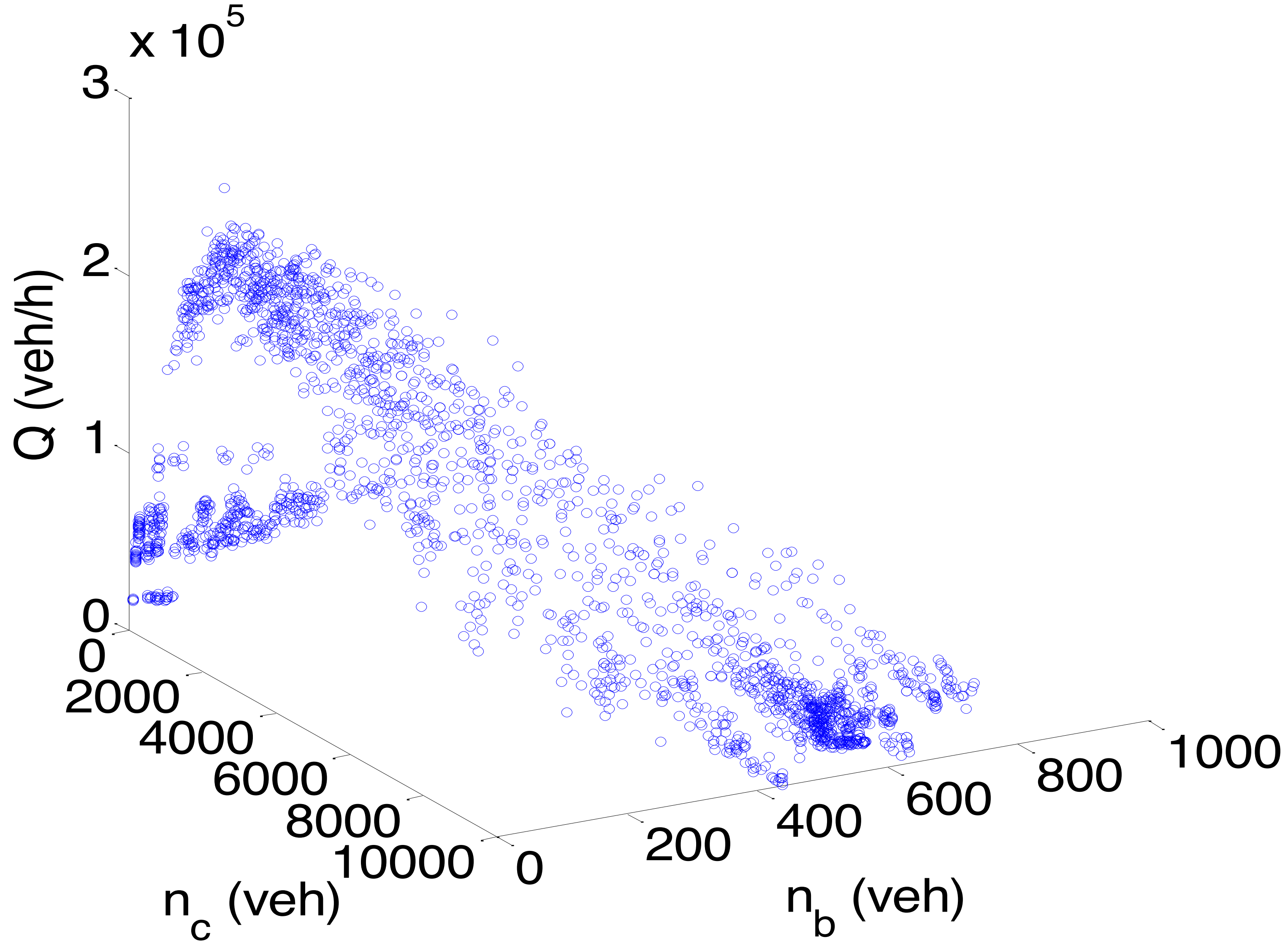
Costs (Users, Providers, etc.)

Road Space Used

3-dimensional MFD for bus-car systems

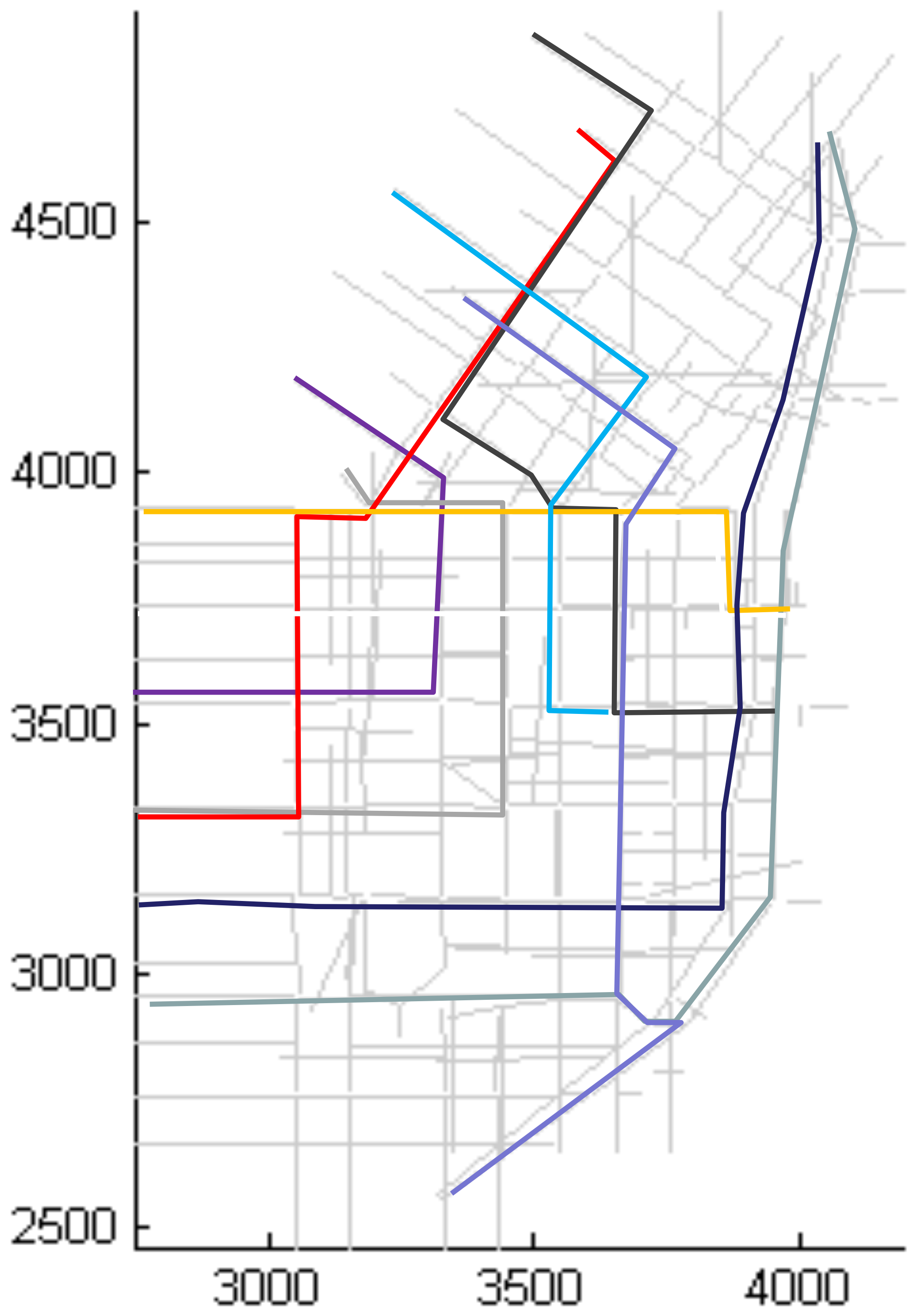


$$Q = Q_c + Q_b = n_c * v_c + n_b * v_b$$



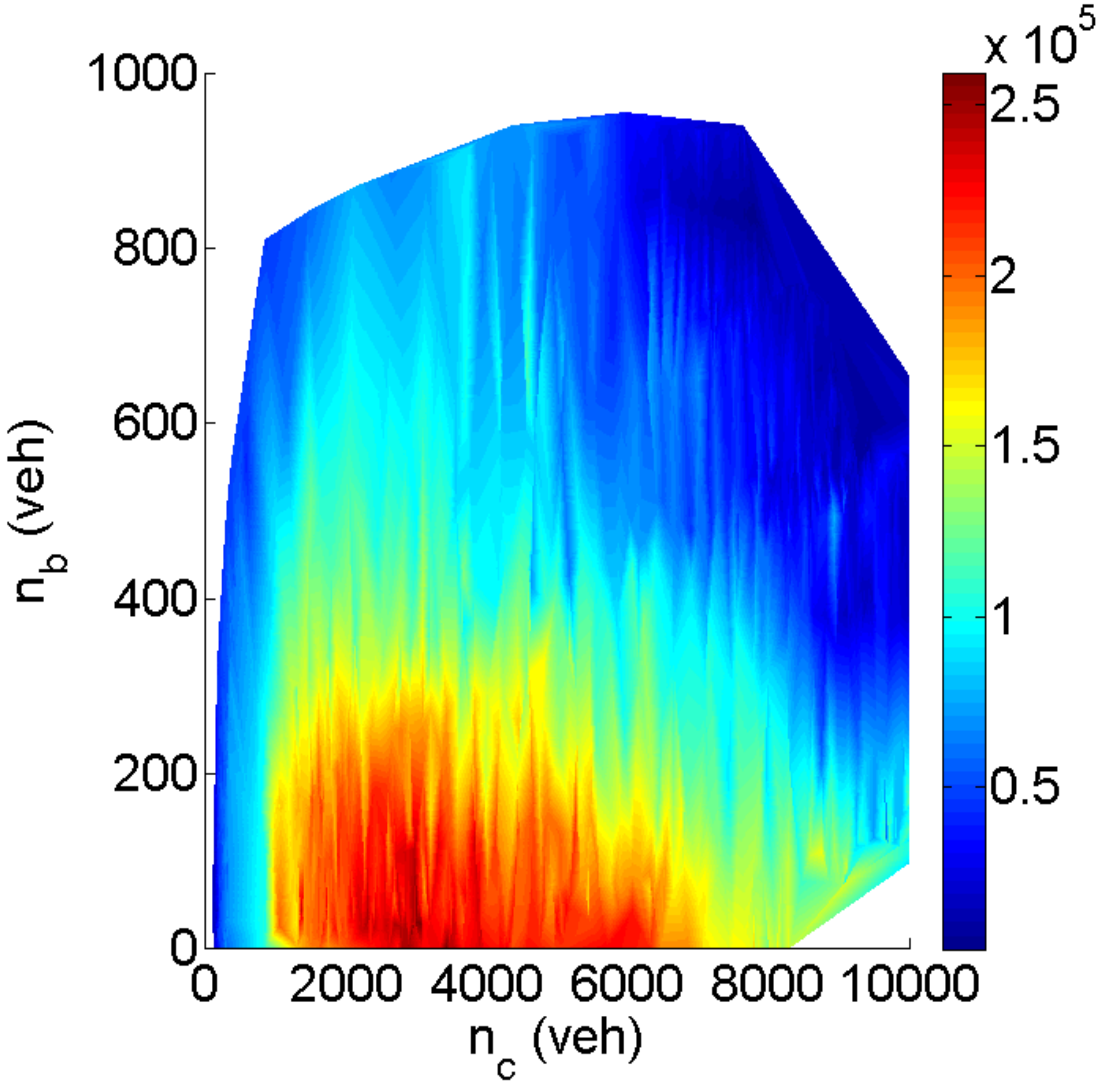
h_c the occupancy of cars (passengers/veh)
h_b the occupancy of buses(passengers/veh)
P_v Production of vehicles (VKT/u.t.)
P_p Production of passengers (VKT/u.t.)

3-dimensional MFD for bus-car systems



$$Q = Q_c + Q_b = n_c * v_c + n_b * v_b$$

$$P_p = h_c P_c + h_b P_b$$



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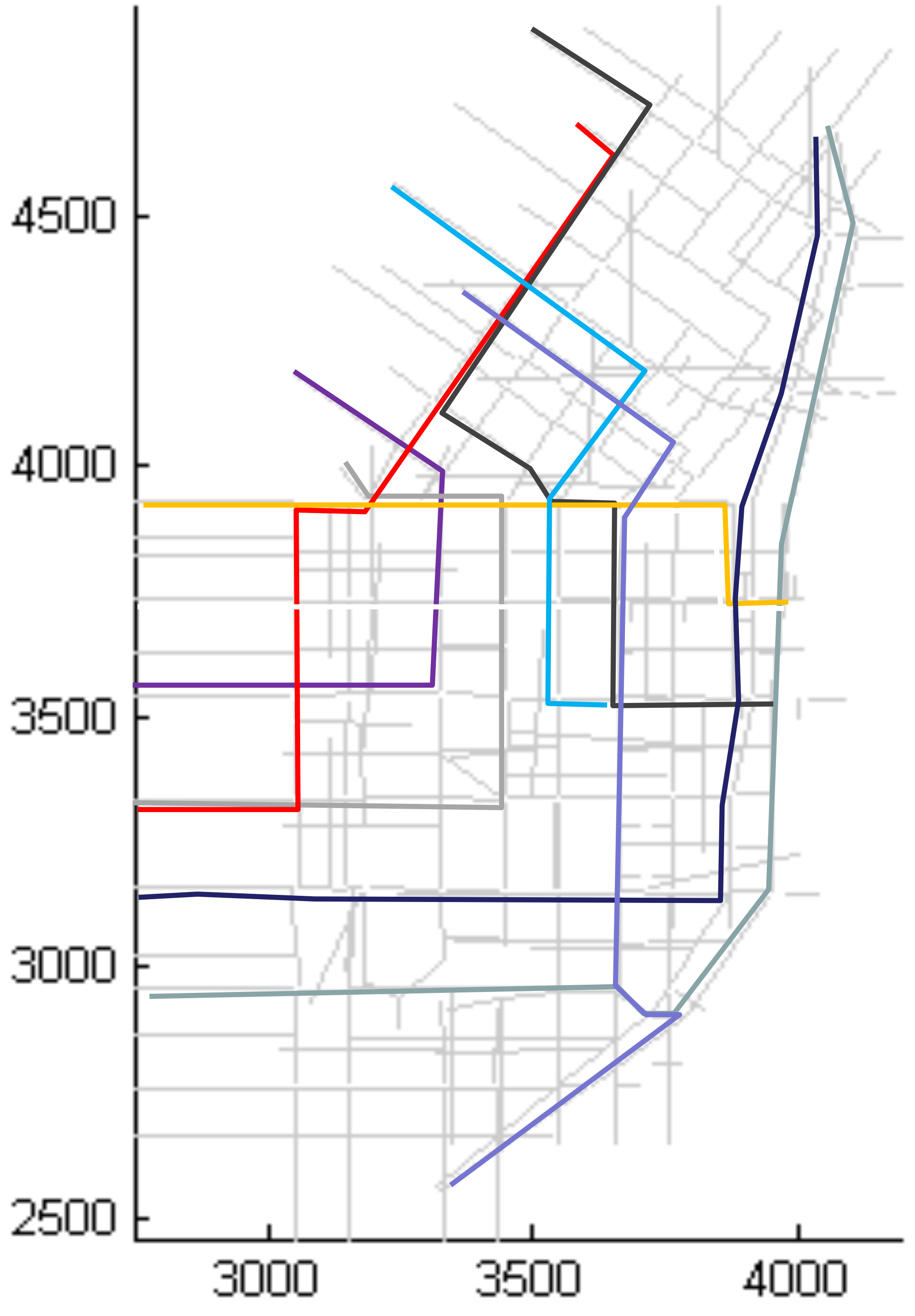
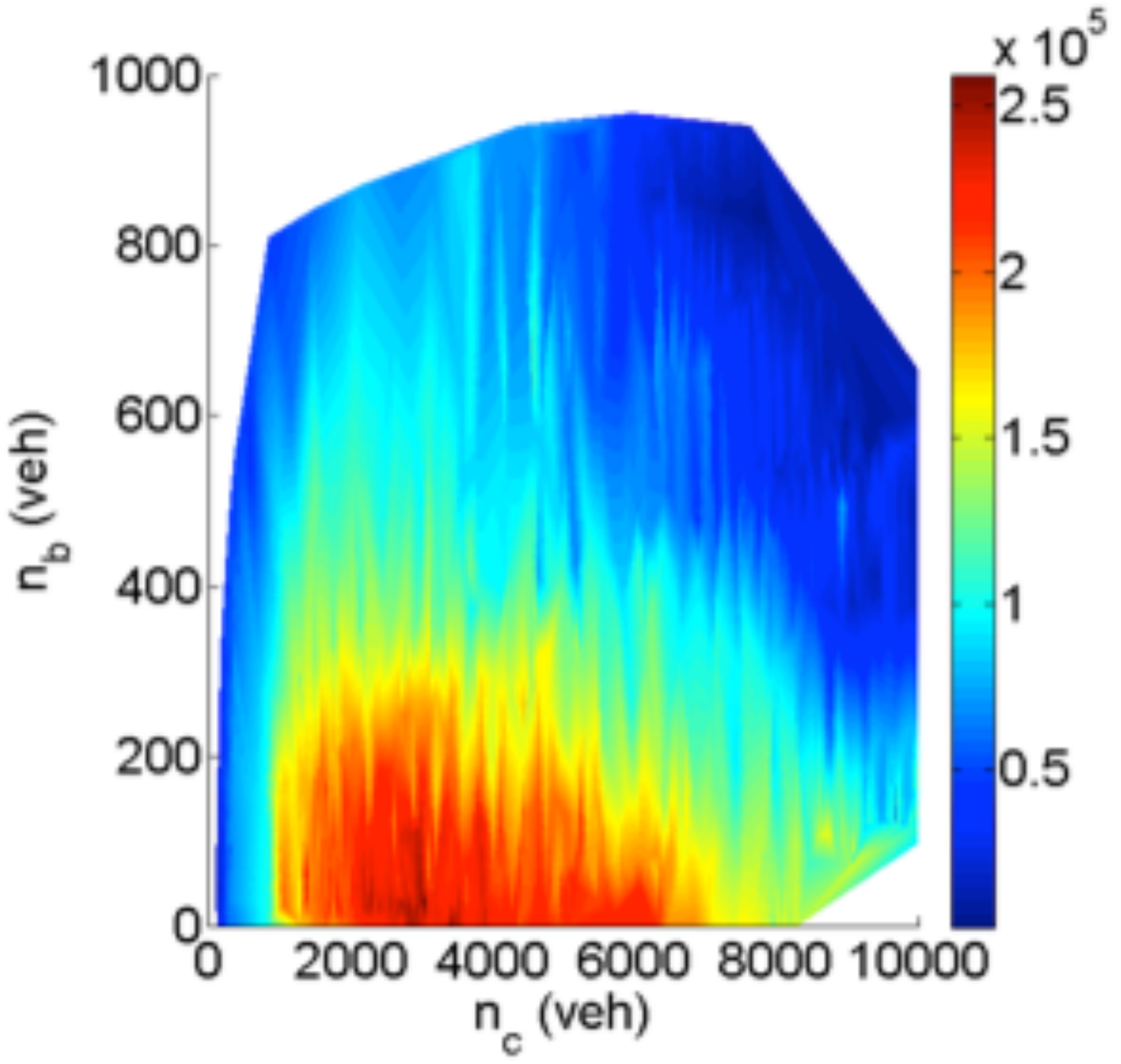
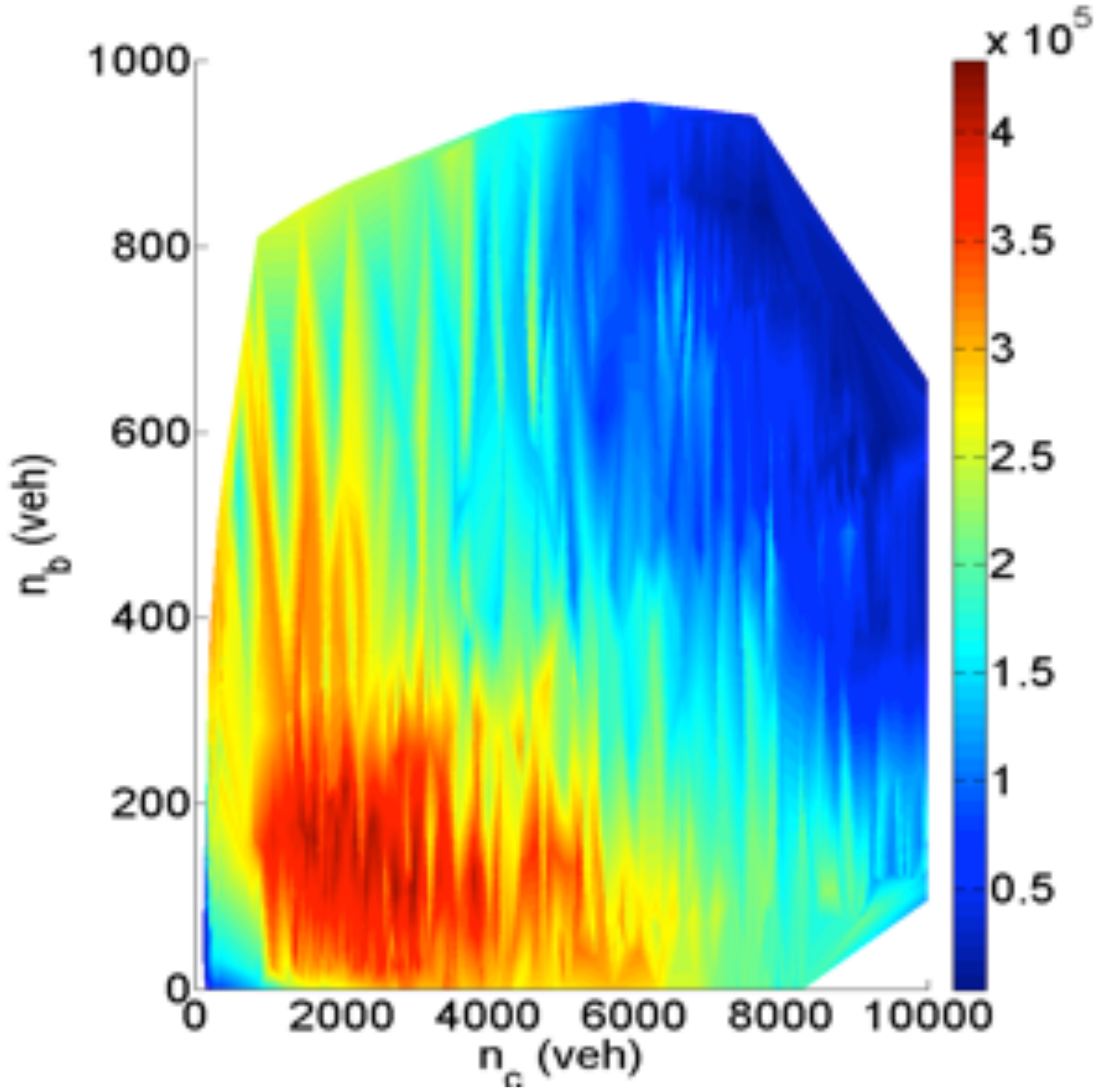
3-dimensional MFD for bus-car systems



VEHICULAR FLOW



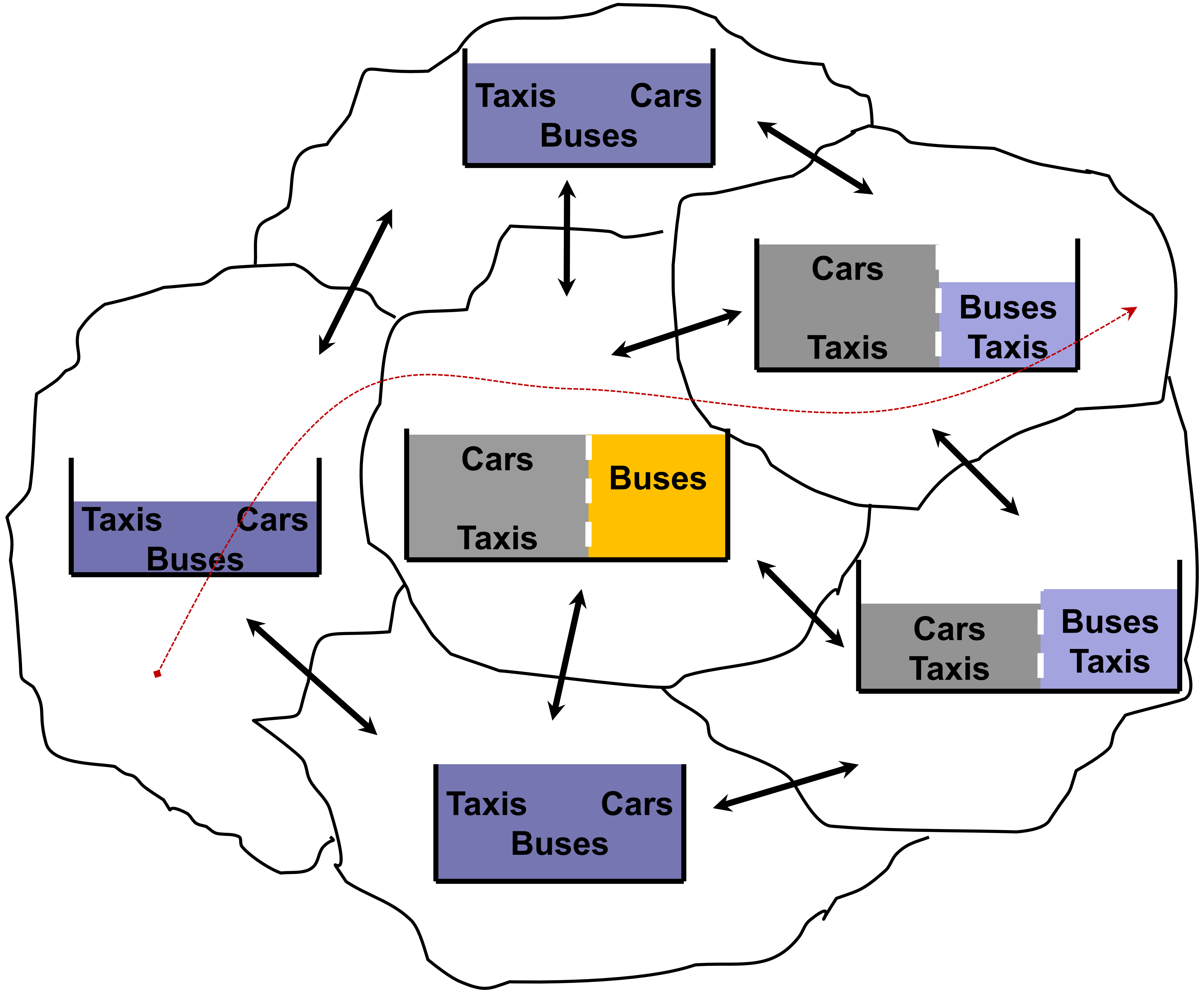
PASSENGER FLOW



h_c the occupancy of cars (passengers/veh)
h_b the occupancy of buses(passengers/veh)
P_v Production of vehicles (VKT/u.t.)
P_p Production of passengers (VKT/u.t.)

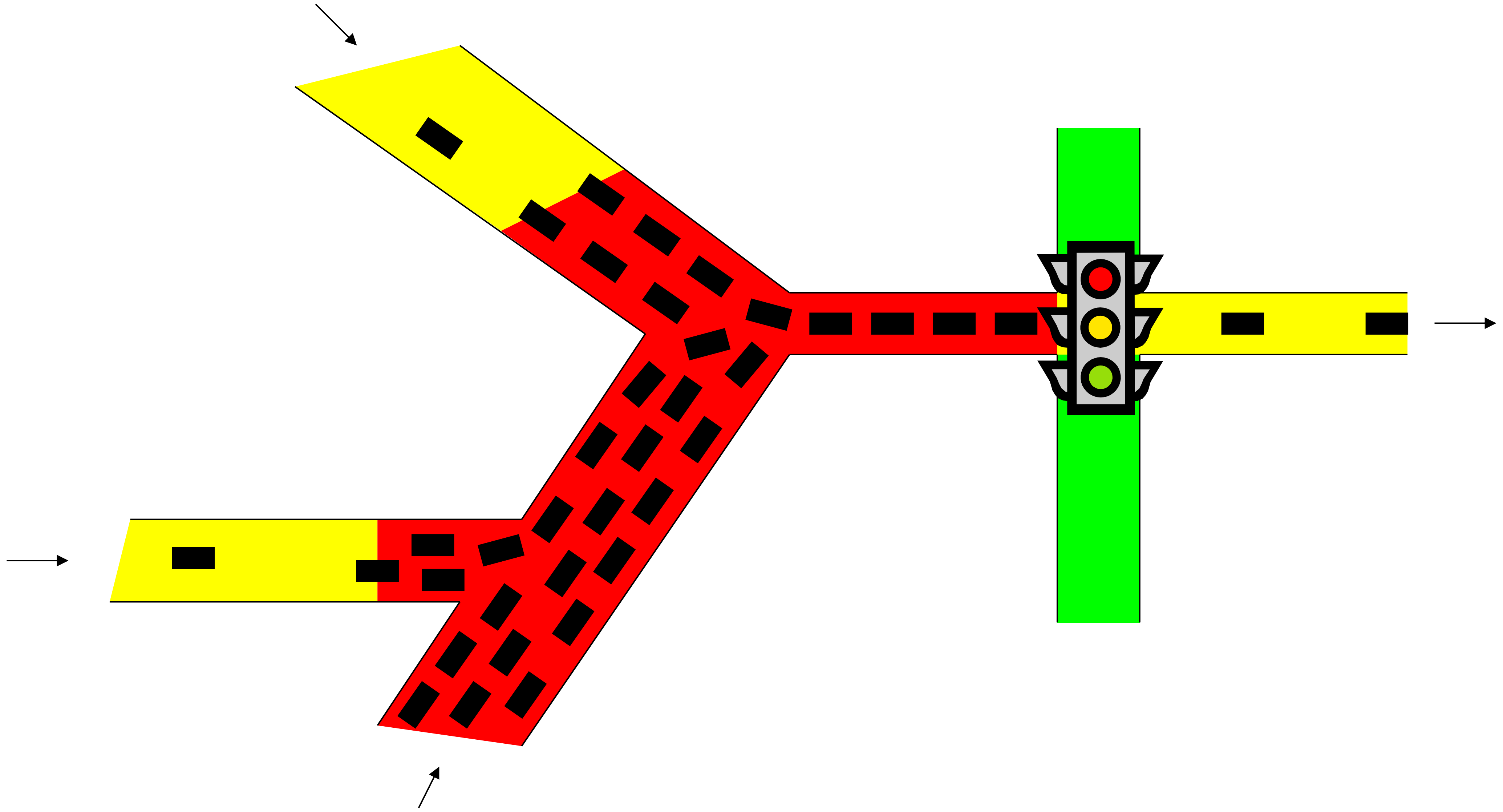
$$P = P(n_c, n_b) = h_c Q_c + h_b Q_b$$

Multimodal multi-reservoir networks



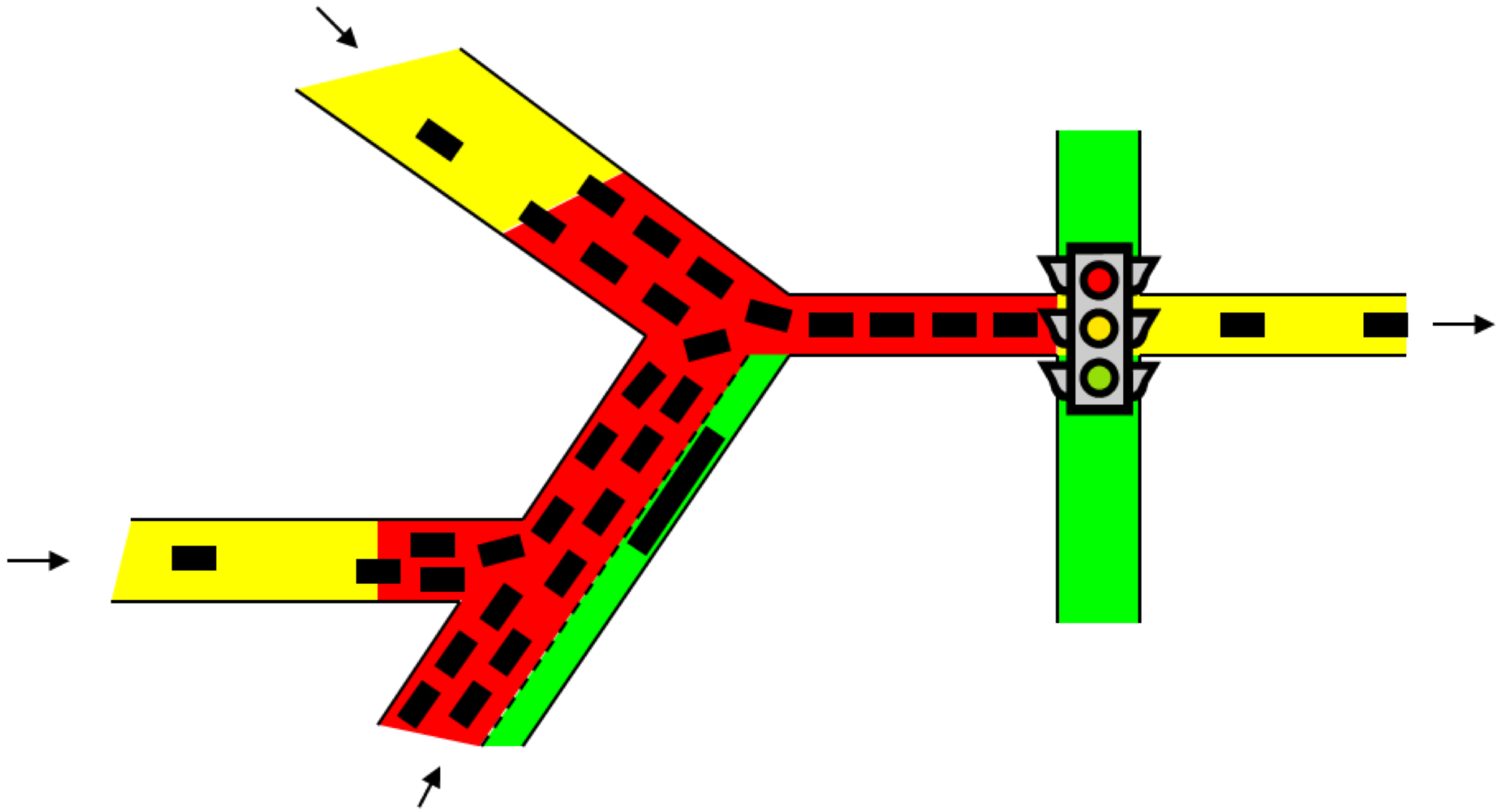
- Spatial allocation of road space
- Special treatment of buses

An example of bus-car interactions



Queues form at locations with limited capacity,
but spill-over to other locations

An example of bus-car interactions



Queues form at locations with limited capacity, but spill-over to other locations