Traffic Flow on Pedestrianized Streets

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Variables

q	Flow
$q_o = 1$	Capacity
$k_j = 1$	Critical density
k_0	Jam density
k	Density
f	Pedestrian flow
$\tau = 1$	Pedestrian crossing time

Abstract

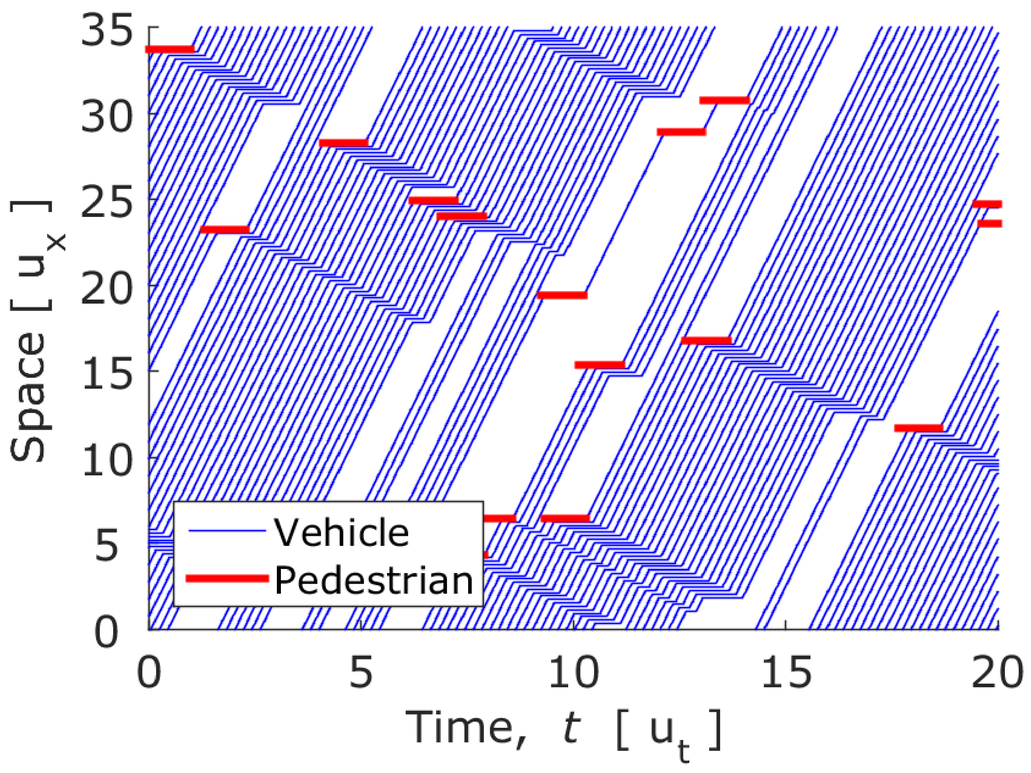
Pedestrians can influence the vehicular flow. If pedestrians have priority over cars, it can be derived that drivers and pedestrians benefit from more cross walks. An ultimate consequence would be a road which is a crossroad over it's entire length, and pedestrians which cross in between cars. This paper derives an equation for the capacity of the road, and the MFD for the road under random pedestrian crossings.

Dimensional analysis

- Units: time, space, and vehicle number
- Without loss of generality, choose units: $q_o = k_j = \tau = 1$
- Pedestrian flow now in units: peds/τ/(v_fT), with v_f free flow speed
- **Increase of crossing duration same effect as square of increase of pedestrian flow**

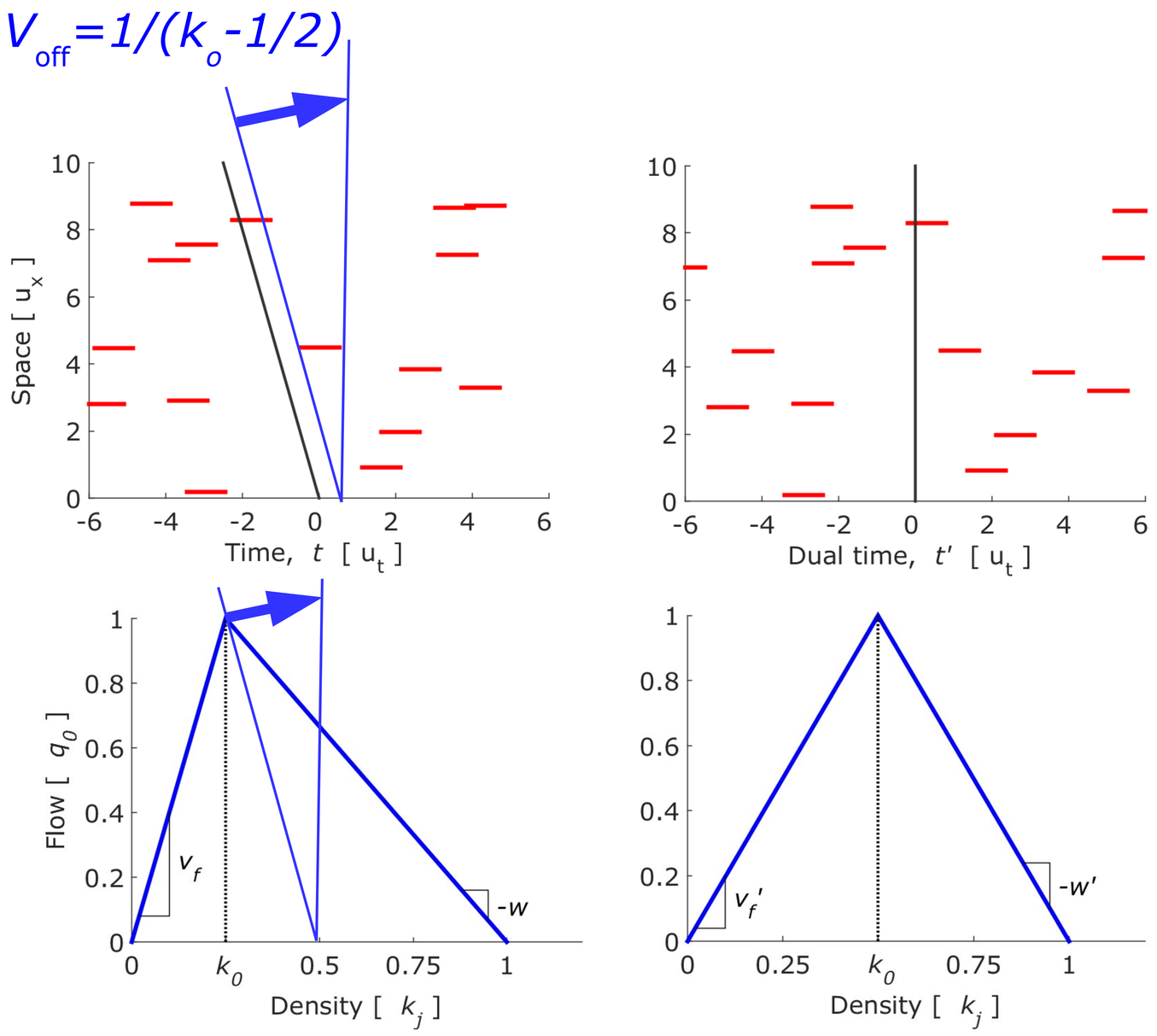
Approach:

- Theory: variational theory
- Simulations:
  - Newell car-following model
  - Circular road



Symmetry

- Assume pedestrians random arrivals (uniform location, exponential headway)
- Goal: eliminate ko
- Transform time to $t'=t+v_{off}x$ ($k_o \neq 0.5$)
- Space and time at one location unchanged so pedestrian flow from same distribution
- Same paths, same costs
  - Equal shortest path and equal costs
  - Equal capacity



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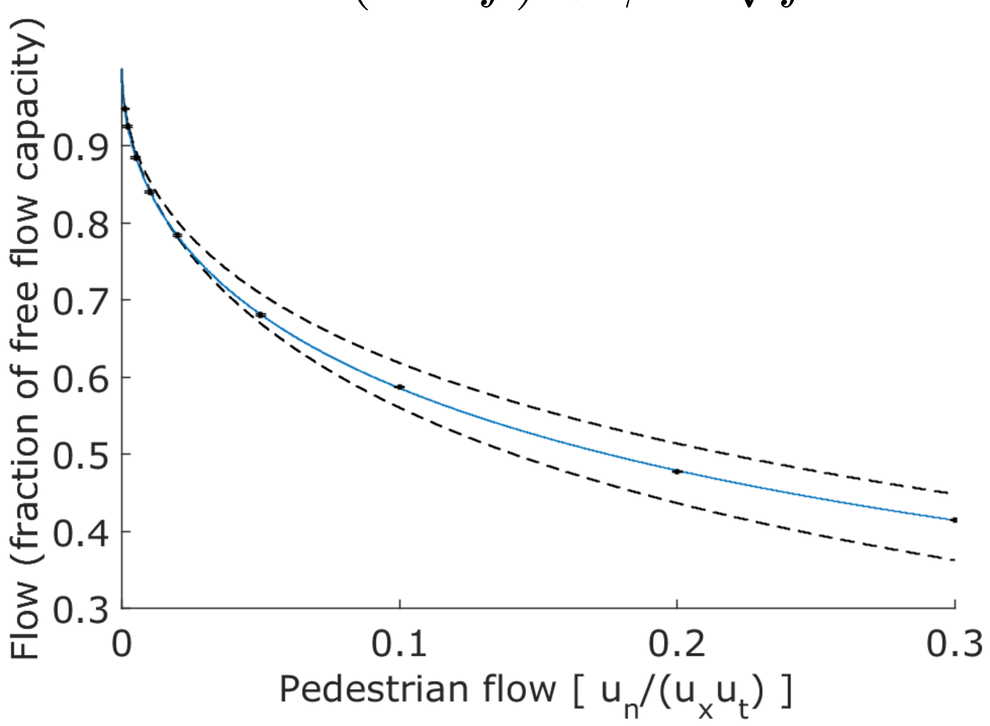
Upper bound

- Capacity C: mean cost of lowest cost path
- Cost at pedestrian 0; maximize overlap time
- Greedy algorithm: choose at end of pedestrian (O) next pedestrian by increasing selection area by increasing *z*
- Overlap with pedestrians *z*/2
- Upper bound for capacity

$$\boldsymbol{q_o^U} = \frac{\tilde{\Phi}\cdot(3+f)-\phi\cdot\sqrt{f}}{\tilde{\Phi}\cdot(3-f)+\phi\cdot 5\sqrt{f}}$$



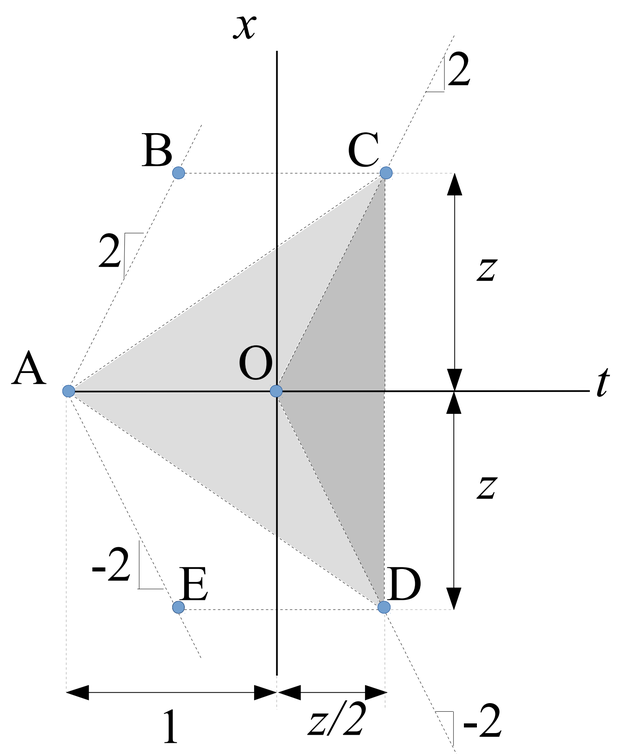
Lower bound

- C = cost of lowest-cost path:

$$\sum L_i/(\sum O_i + \sum L_i)$$

- Over-estimate overlap *O*, under-estimate time to next pedestrian *L* by time to first pedestrian within reach
- Use probabilities for lower bound:

$$1/\boldsymbol{q_o^L} = 1 + \left[\frac{2f}{\pi e^{4f}}\right]^{\frac{1}{2}}\left[\tilde{\Phi}(2\sqrt{f})\right]^{-1}$$

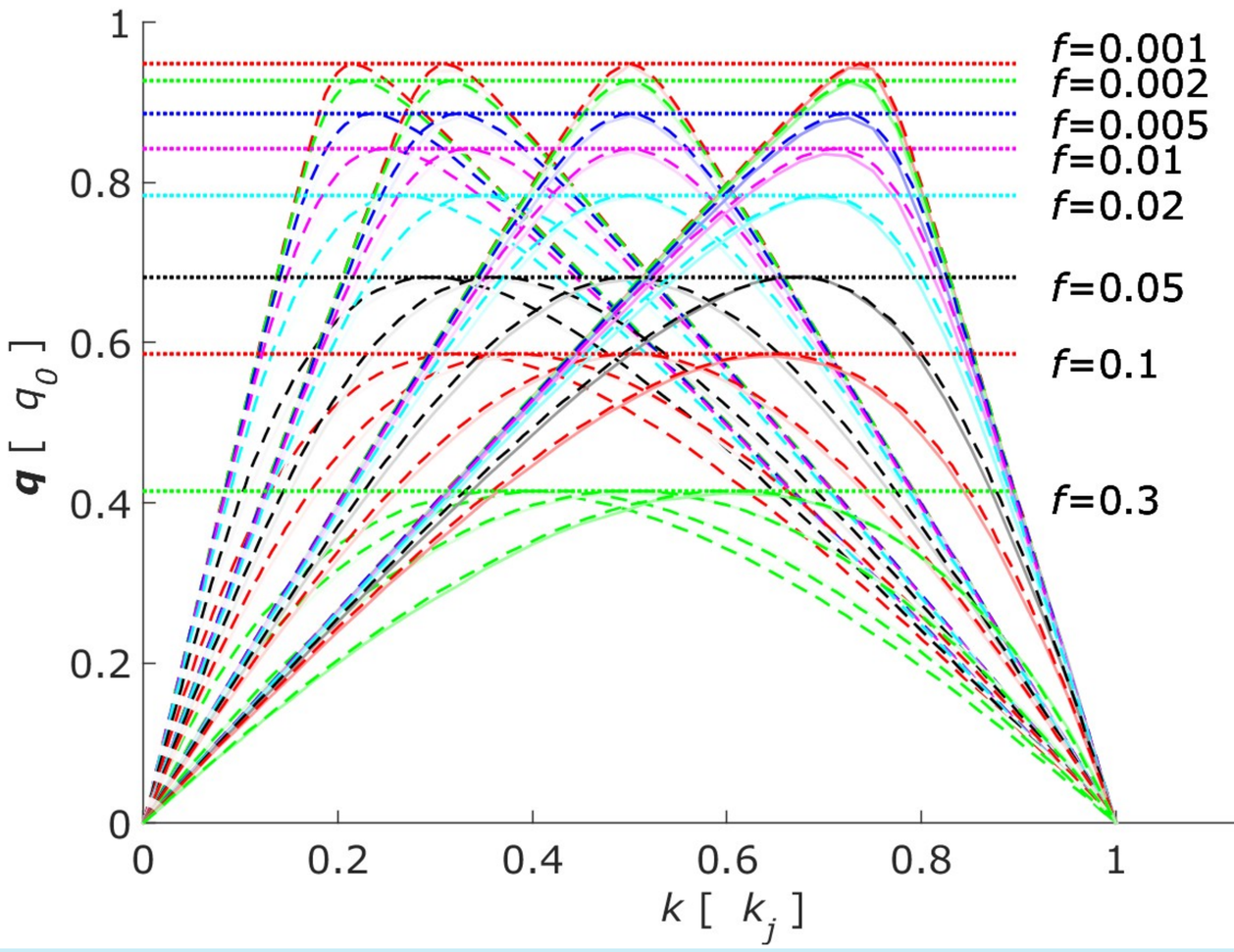


φ	Probability density function of normal distribution at $\sqrt{f}$
$\tilde{\Phi}$	1-cumulative distribution function of normal distribution at $\sqrt{f}$

Approximation

- For low f, upper bound = lower bound
- Use functional forms of bounds, estimate paramters
- Capacity within 0.2% of free flow capacity
- Also accurate MFD equation:

$$\boldsymbol{q_o}(f) \approx 1/(1+\sqrt{8f/\pi}+1.27f+0.35f^{2/3})$$



Conclusions

- Traffic flow dependent on $f\cdot\tau^2$
- Approximation MFD possible
- Capacity:
  - Upper bound and lower bound computable
  - Approximation of capacity within 0.2%

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