Distribution of Waiting Time in Traffic Congestion

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WHAT IT IS ALL ABOUT

Congestion in urban traffic flow is characterised by *waiting time distribution* : probability that a car is stuck up for a time τ

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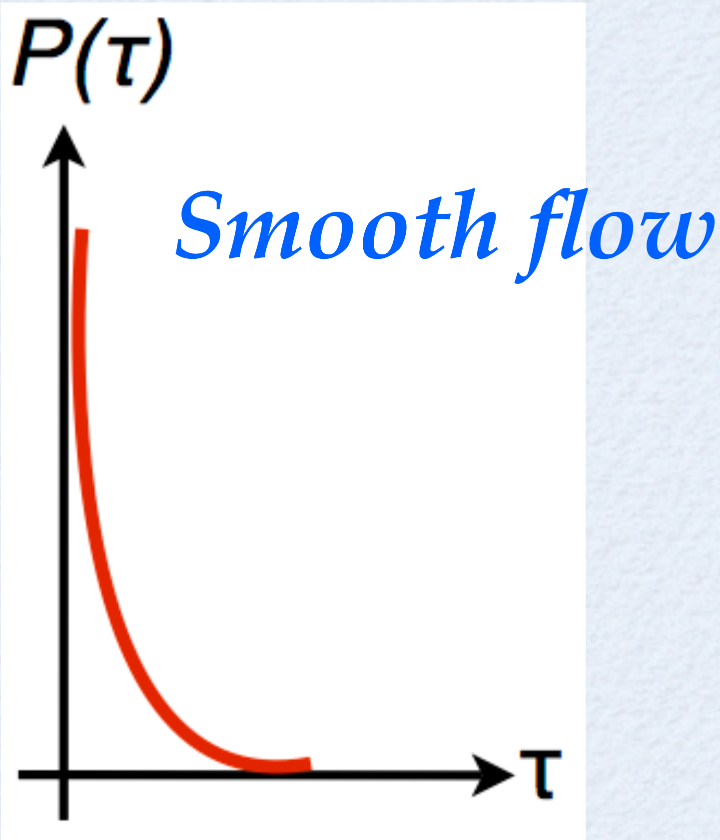

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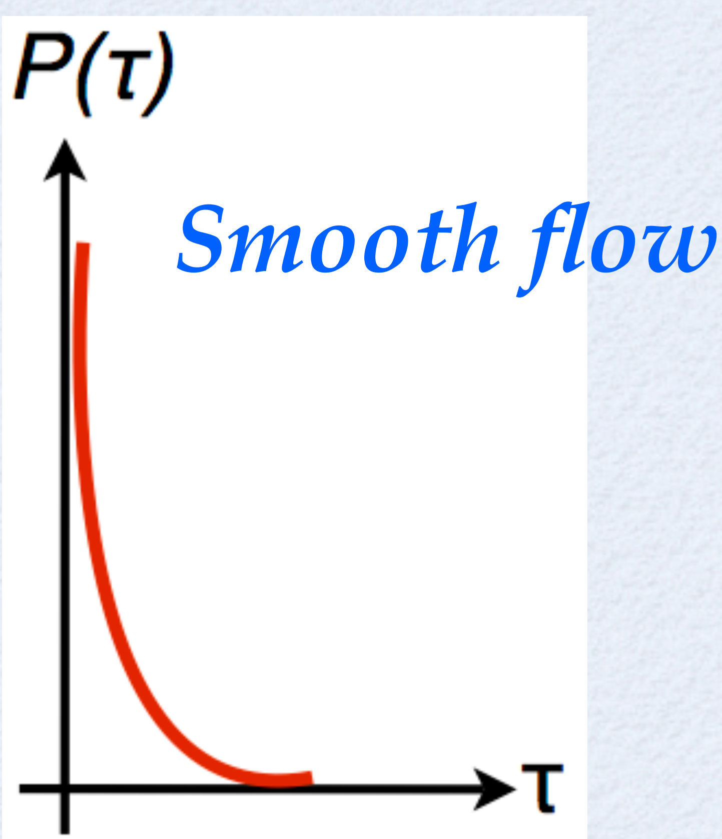

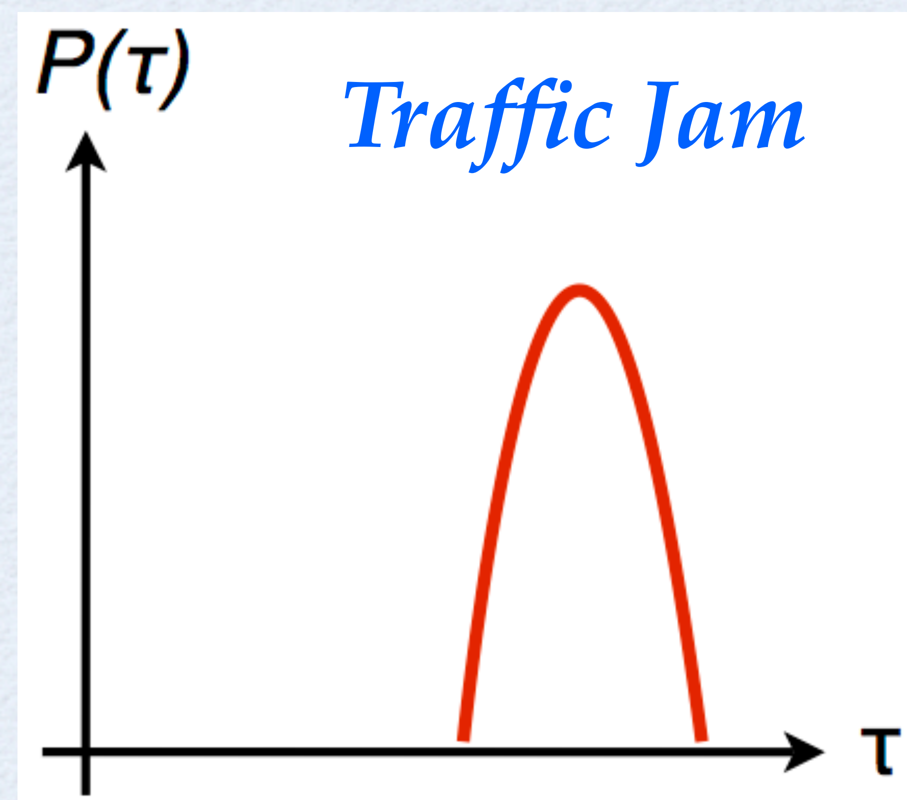

OUTLINE

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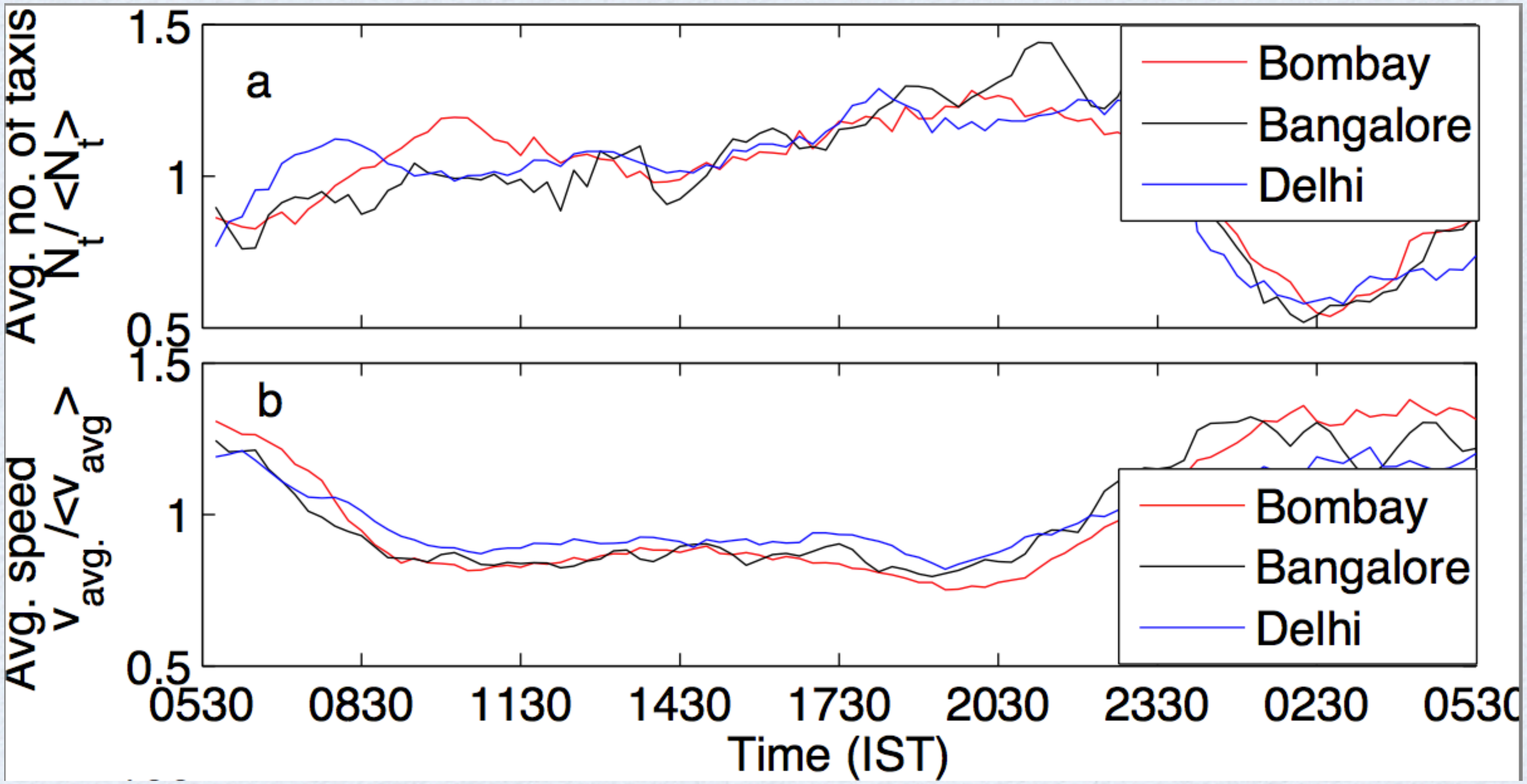
- Analysis of real-life data for traffic congestion
- Model explaining the results. Based on aggressiveness of the drivers at traffic signals

Available Data

GPS data of ~ 1000 taxis in Delhi, Bengaluru, Mumbai, for several months in 2013- 2014

Collaboration with IIT Madras (Prof. K. Jagannathan)

For each vehicle : time, latitude, longitude, velocity



Congestion time

When a car has speed < 10 kmph for τ secs, we call it a *congestion time* of τ secs

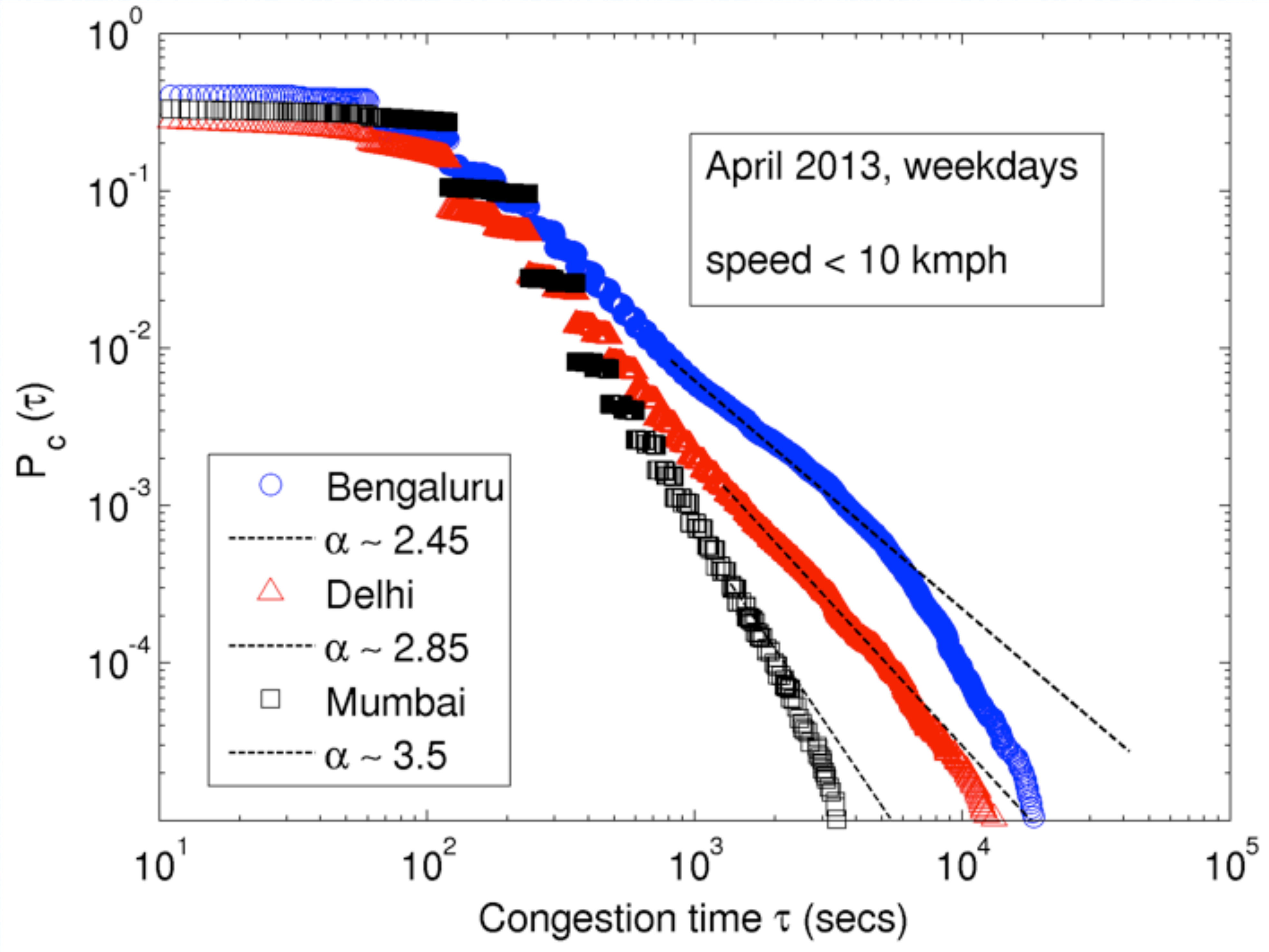
Compute the statistics of this τ for all cars, on all days to obtain the probability distribution function $P(\tau)$

Result for congestion time

$P(\tau) \sim \tau^{-\alpha}$
scale free

Why power-law??

Microscopic model ??

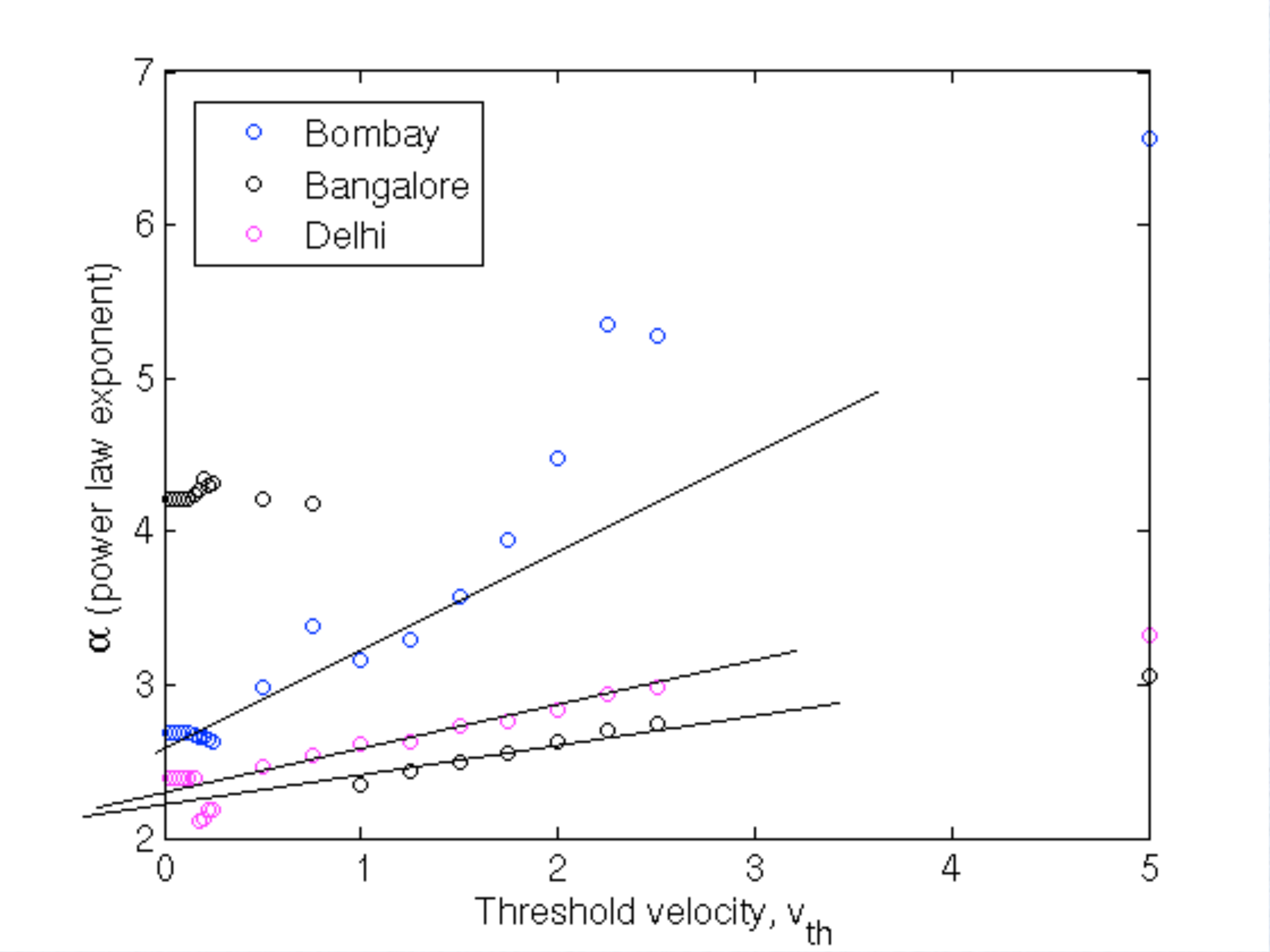


Majith, Rajakumar, Sinha (2016)

Value of Exponent

The value of exponent depends on the choice of the threshold velocity.

The limiting value of the exponent for small threshold velocity seems to be between 2 to 3.



MORE DATA

Motorway in Cologne, Germany

Krause, Habel, Guhr, Schreckenberg (2017)

$P(\tau) \sim \tau^{-\alpha}$ α=1.5

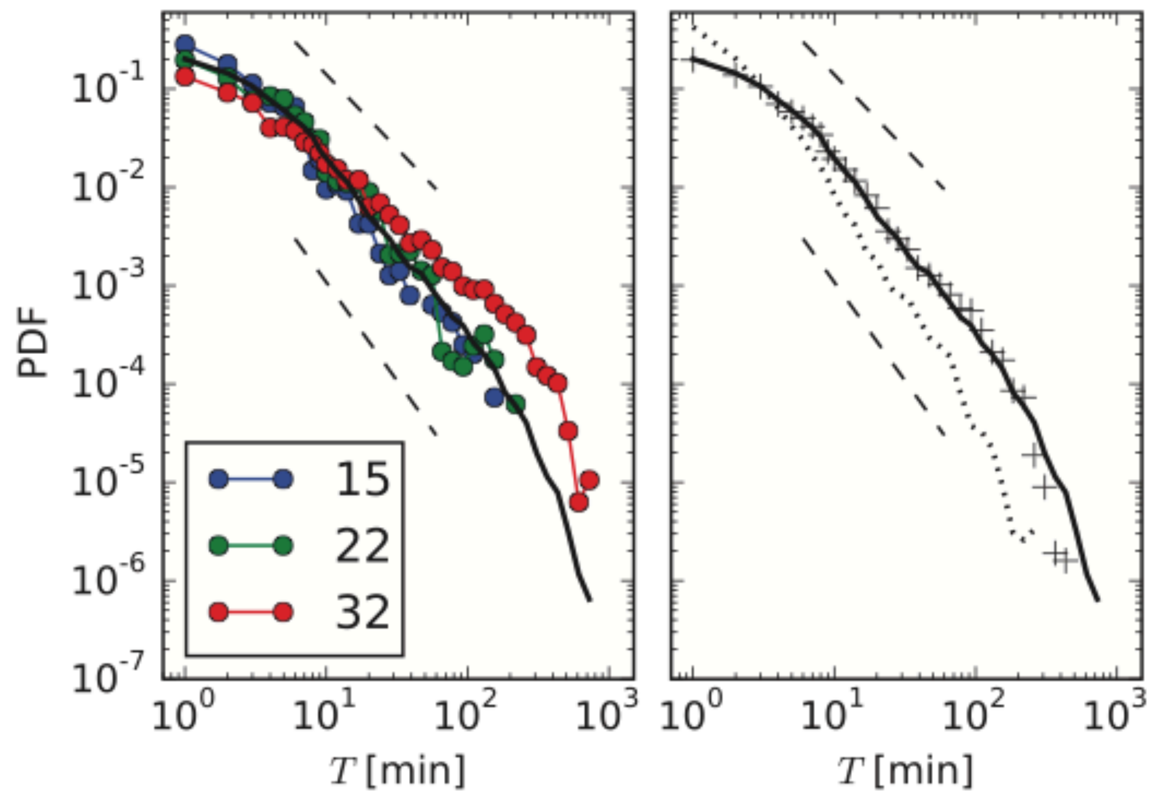


Fig. 3: (Colour online) Left: PDF of traffic congestion durations T for $v_{\mathrm{jam}} = 50$ km/h in double logarithmic plot. Symbols indicate different cross-sections, the black solid line is the average over cross-sections 3 to 33. For comparison, power laws $T^{-\gamma}$ with exponent $\gamma = 3/2$ (upper dashed line) and $\gamma = 2$ (lower dashed line) are shown. Right: The average result (black solid line) changes only slightly for data reduced to the first three months (crosses), or for reduced $v_{\mathrm{jam}} = 20$ km/h (dotted line).

MODEL

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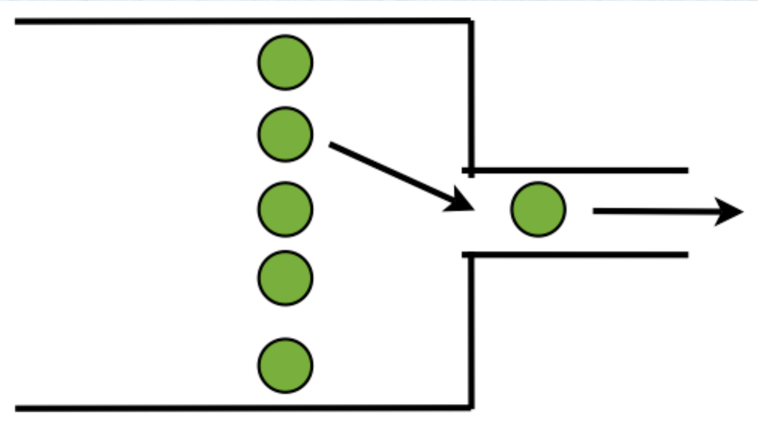
Consider a bottleneck.
Only one car can pass through.



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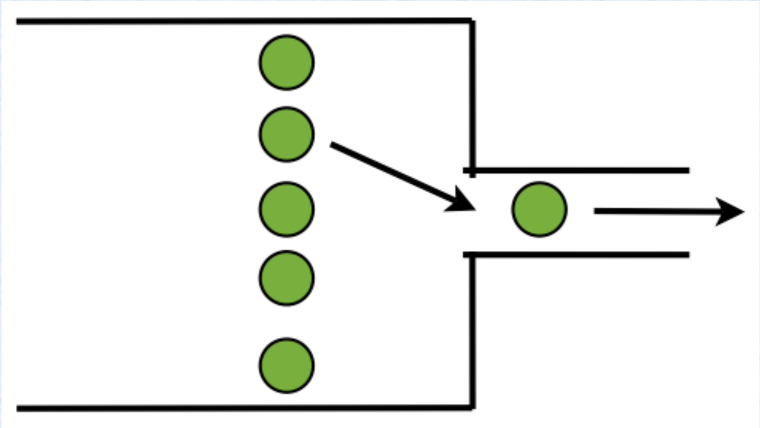

The most *aggressive* driver will pass

HYPOTHESIS:

Aggressiveness

can be quantified by an attribute A

depends only on
(i) the intrinsic nature
(ii) the duration of waiting

MODEL

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HYPOTHESIS:

Aggressiveness (for *i*-th person waiting for time τ)

$$A_i = N_i \, \tau^{\sigma}$$

- ★ N_i varies randomly from person to person (uniformly distributed between 0 and 1)
- ★ σ is the same for all persons

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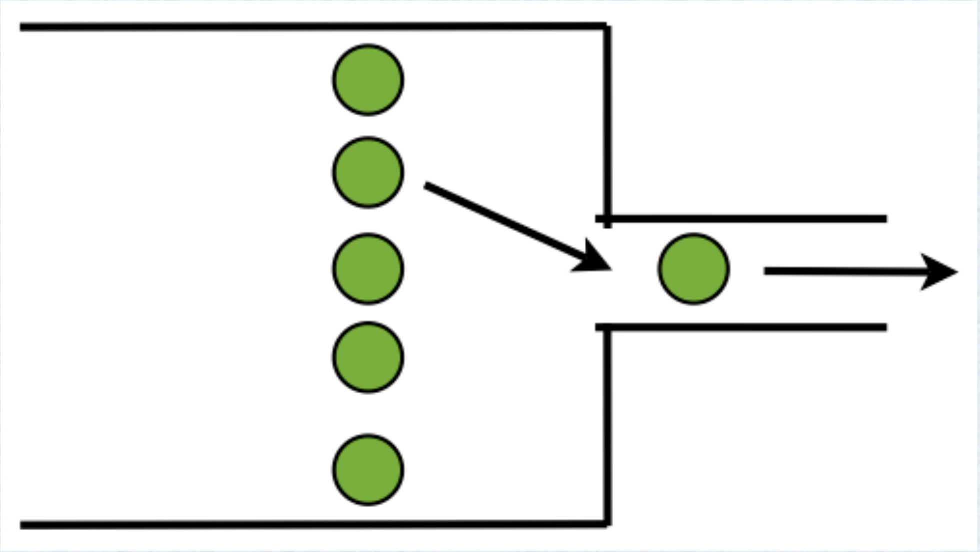
This gives (numerical, analytic) $P(\tau) \sim \tau^{-\alpha}$ $\alpha = \sigma + 1$

(probability of congestion time)

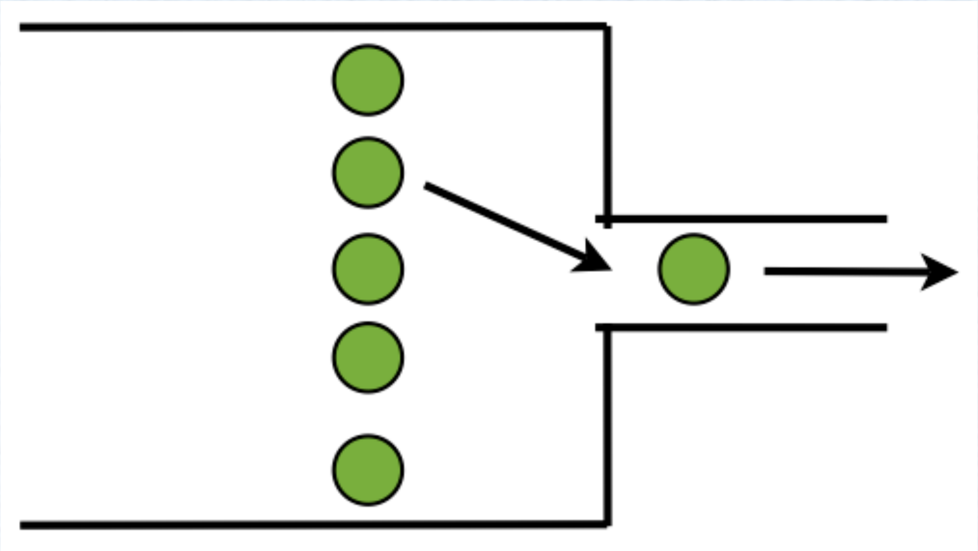
σ=1 to 2 in India & σ=0.5 in Germany

Detailed Algorithm



Detailed Algorithm

- Start at time t=0 with a queue of L cars with N_1, N_2, ... N_L drawn from a uniform distribution in (0, 1).



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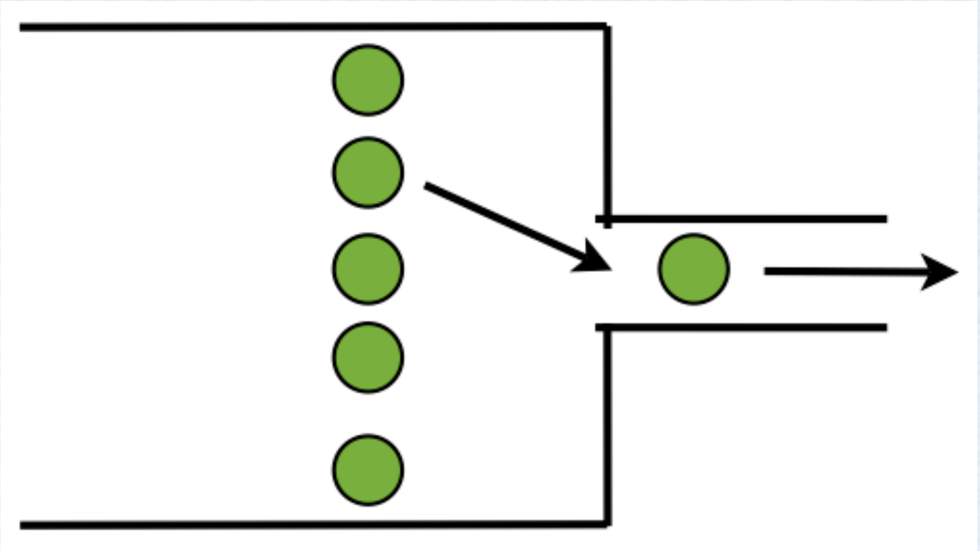

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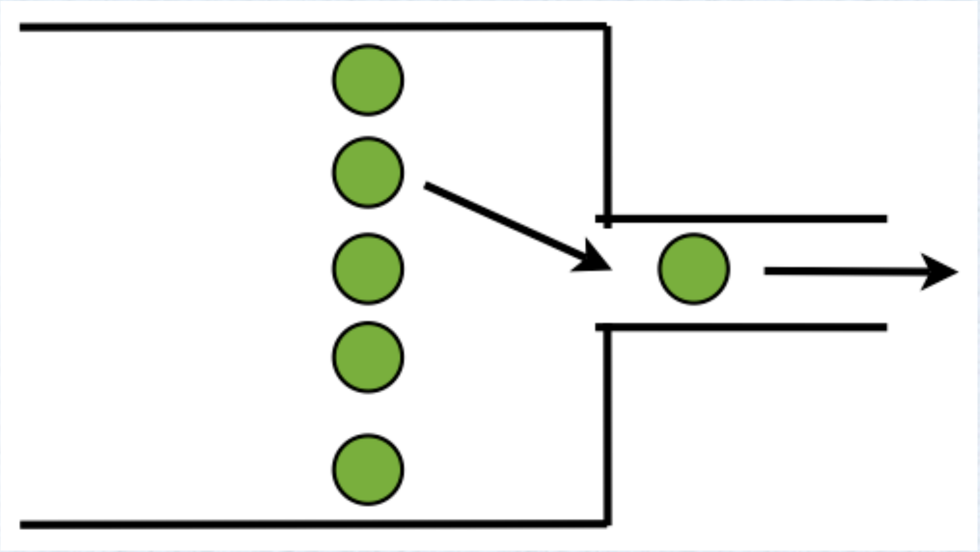
DETAILED ALGORITHM



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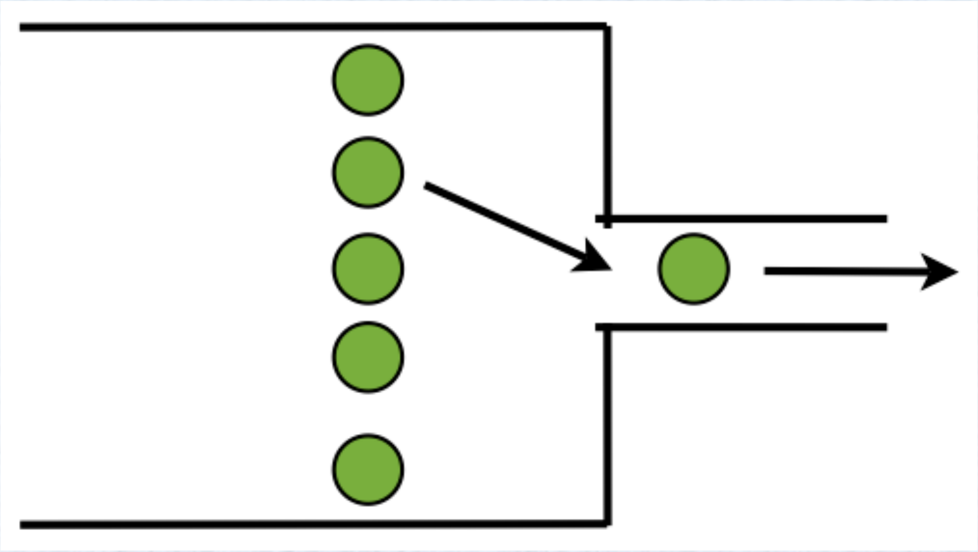

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Note : The number of cars queued up remains the same with time.

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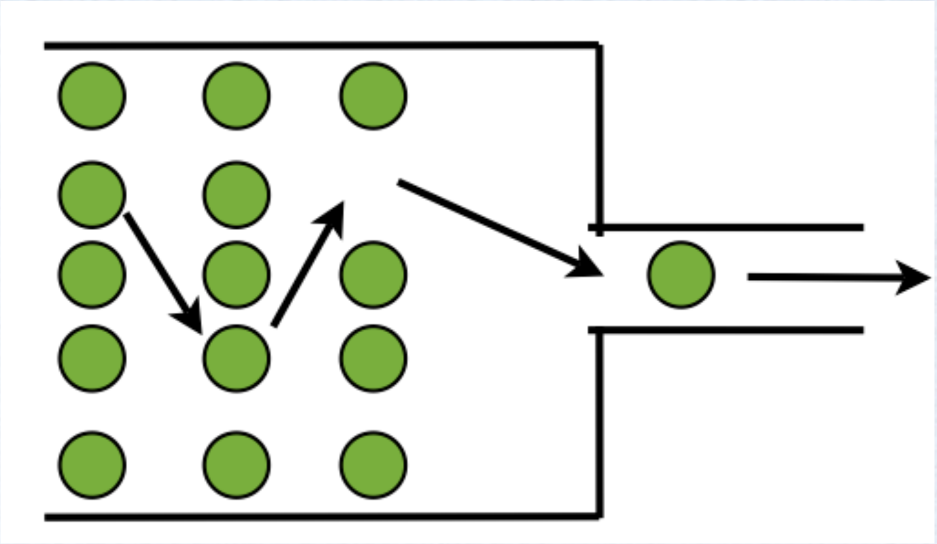
★Similar result, if the total number of cars vary randomly about a mean value.

★A variant of the model with multiple layer also gives similar result

Replace removed car
by the one with the largest *A*
in the row just behind



Summary

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★In a traffic bottleneck, only the most *aggressive* driver passes through at a time.

★The aggressiveness can be quantified as $A_i = N_i\,\tau^{\sigma}$ where $N_i \in (0,1)$ varies randomly from person to person, σ is the same for all, and τ is the time for which it is stranded.

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HYPOTHESIS

★In a traffic bottleneck, only the most *aggressive* driver passes through at a time.

★The aggressiveness can be quantified as $A_i = N_i\, \tau^{\sigma}$ where $N_i \in (0,1)$ varies randomly from person to person, σ is the same for all, and τ is the time for which it is stranded.

THIS GIVES : $P(\tau) \sim \tau^{-\alpha}$ with $\alpha = \sigma+1$ which agrees with available empirical data, with σ=1 to 2 in India & σ=0.5 in Germany. *Does σ depend on country?*

CAUTION

Data for 3 cities in India (in 2013) and 1 city in Germany (in 2016) show that probability distribution of congestion time is $P(\tau) \sim \tau^{-\alpha}$

Data for many other places need to be analysed.

Thank you for your attention