Freeway On-Ramp Bottleneck Activation, Capacity, and the Fundamental Relationship

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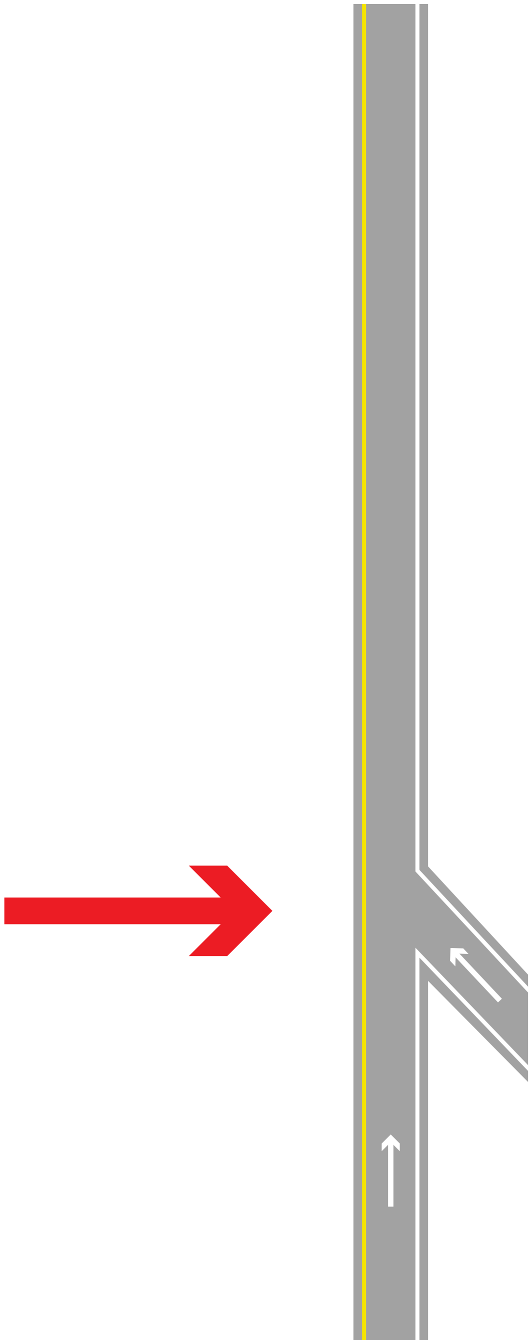
July 26, 2013

An on-ramp bottleneck



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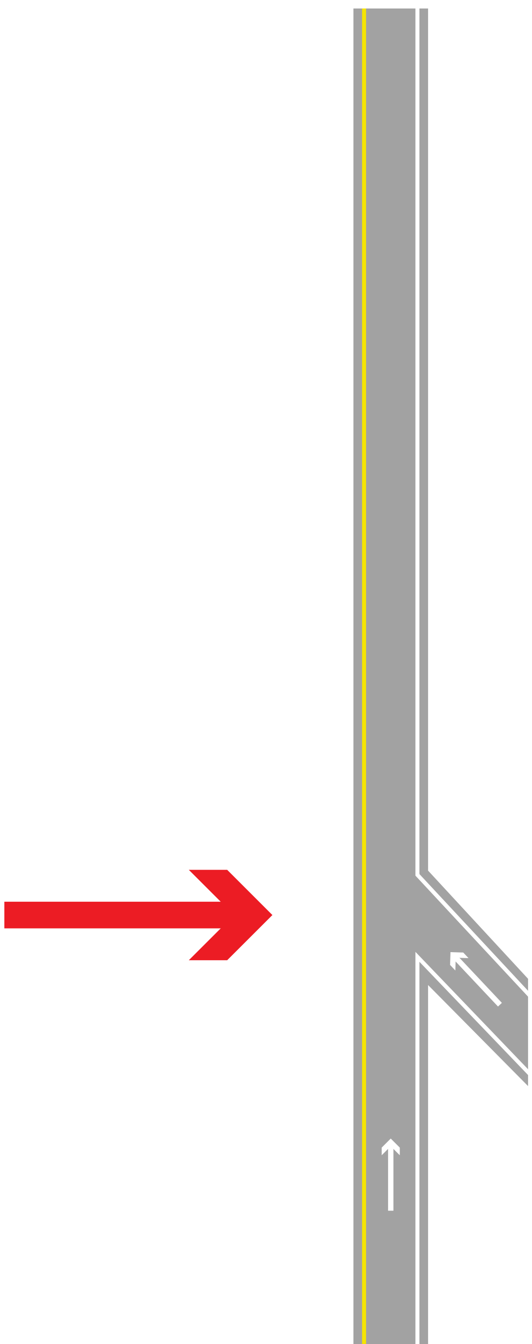
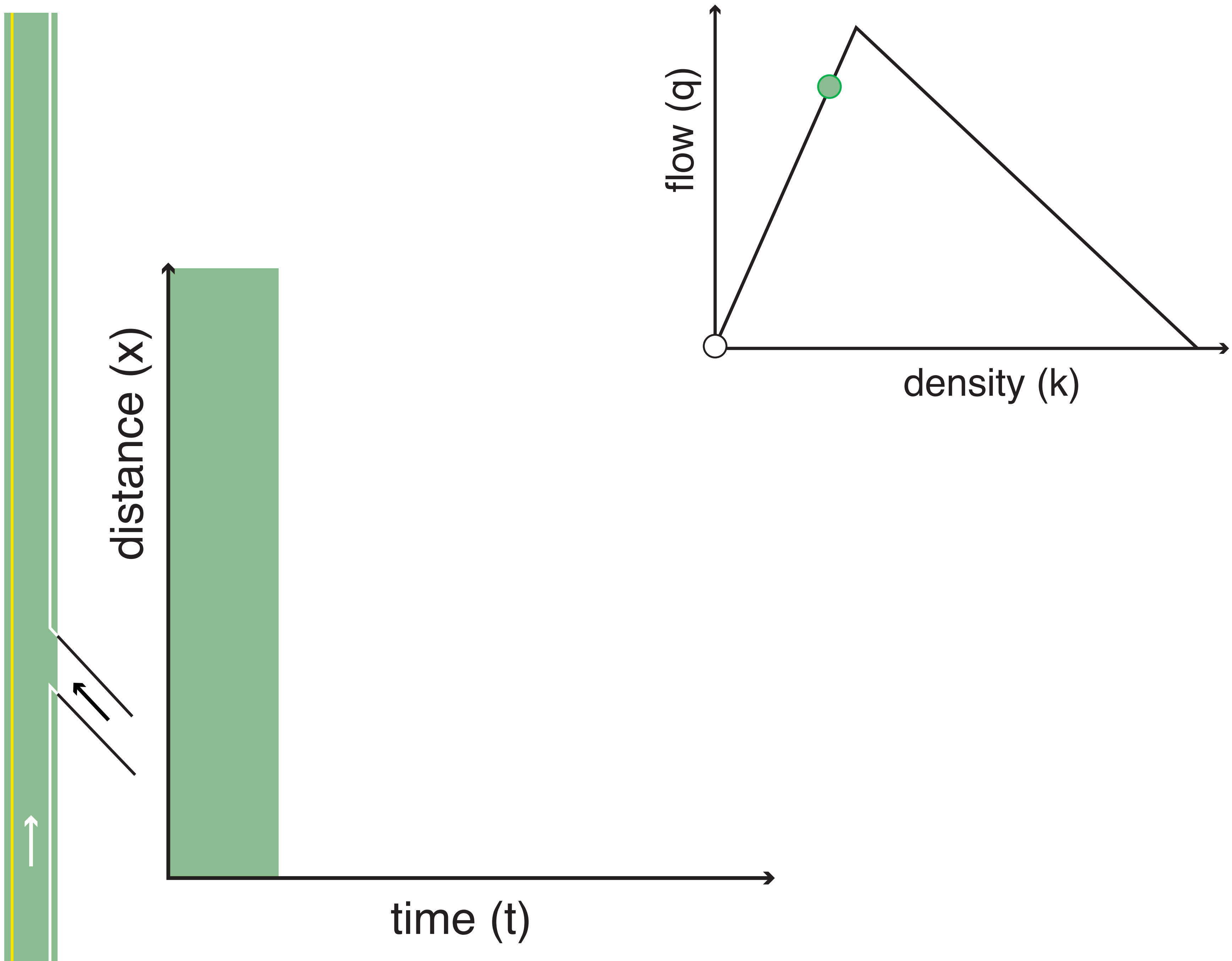


What we think we know...

a quick review of conventional wisdom

An on-ramp bottleneck

Conventional wisdom



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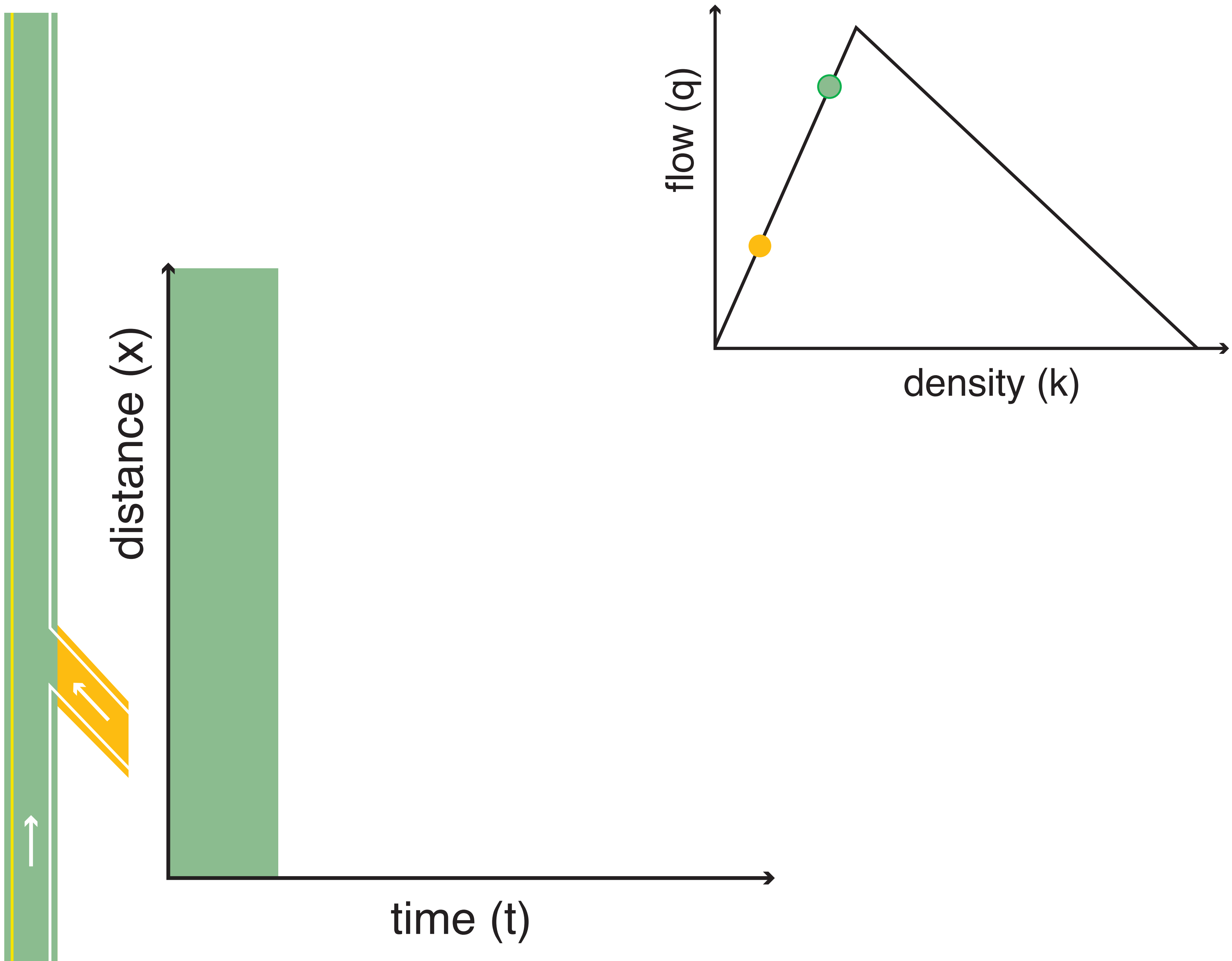

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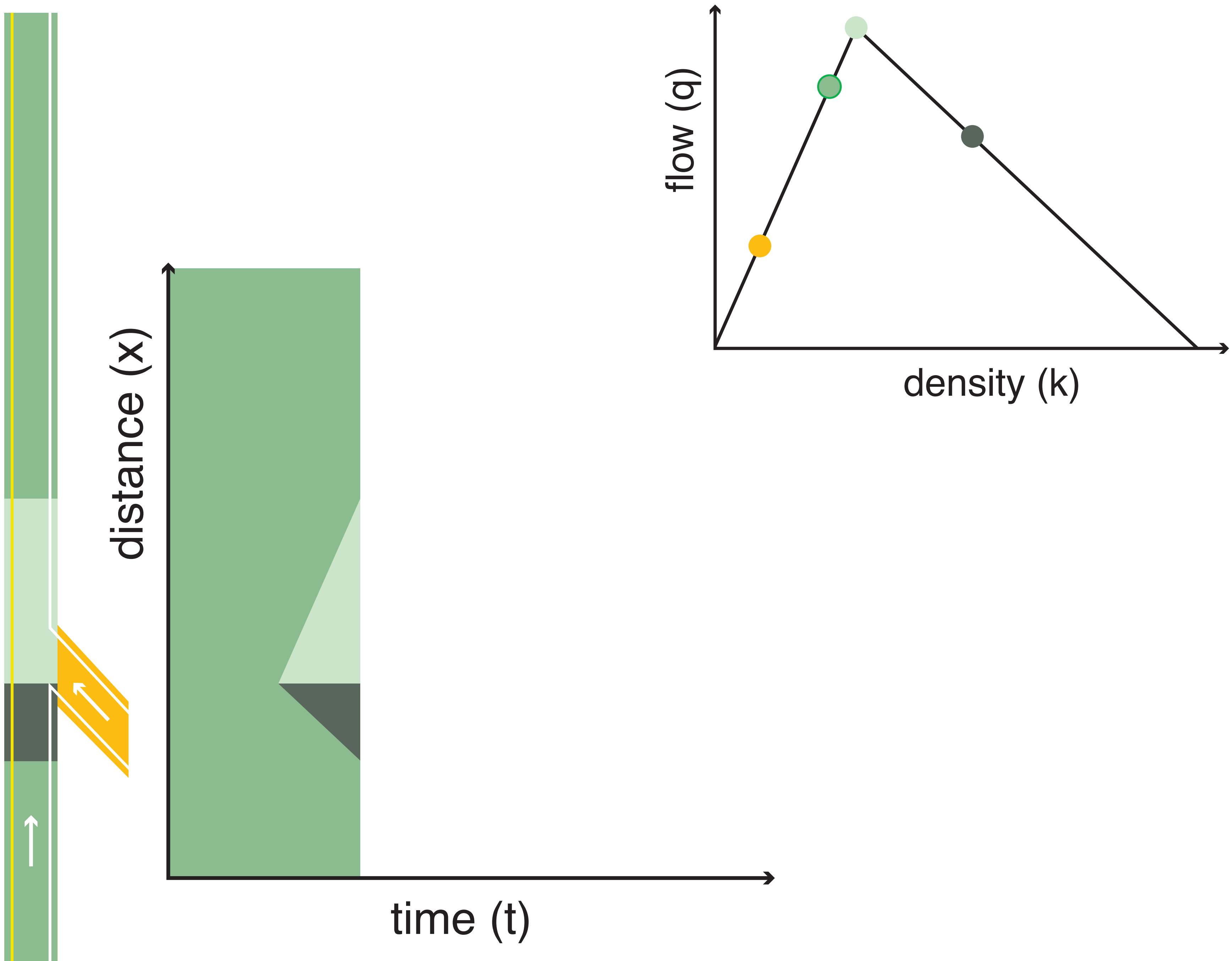

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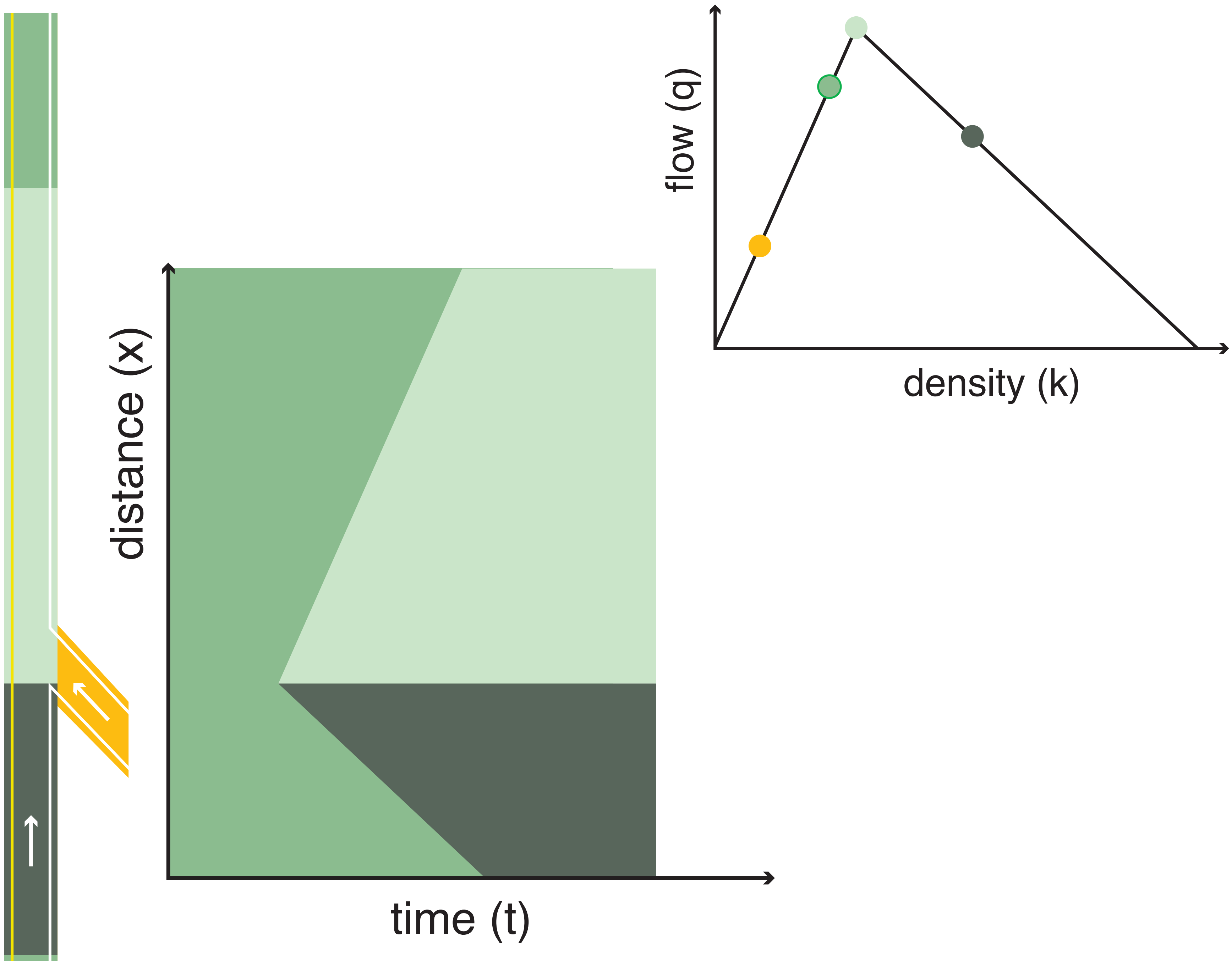
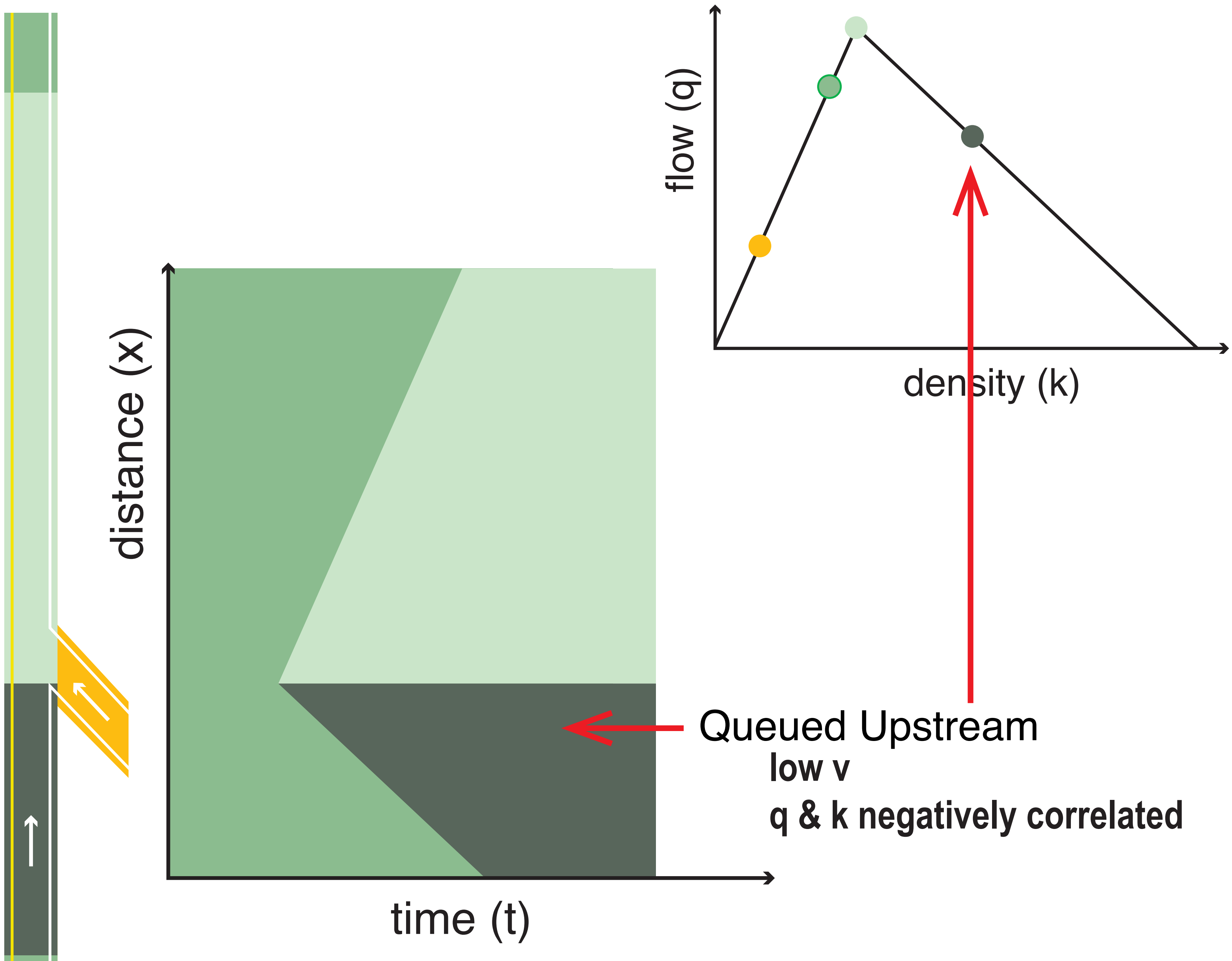


An on-ramp bottleneck

Conventional wisdom- Identifying when it is active



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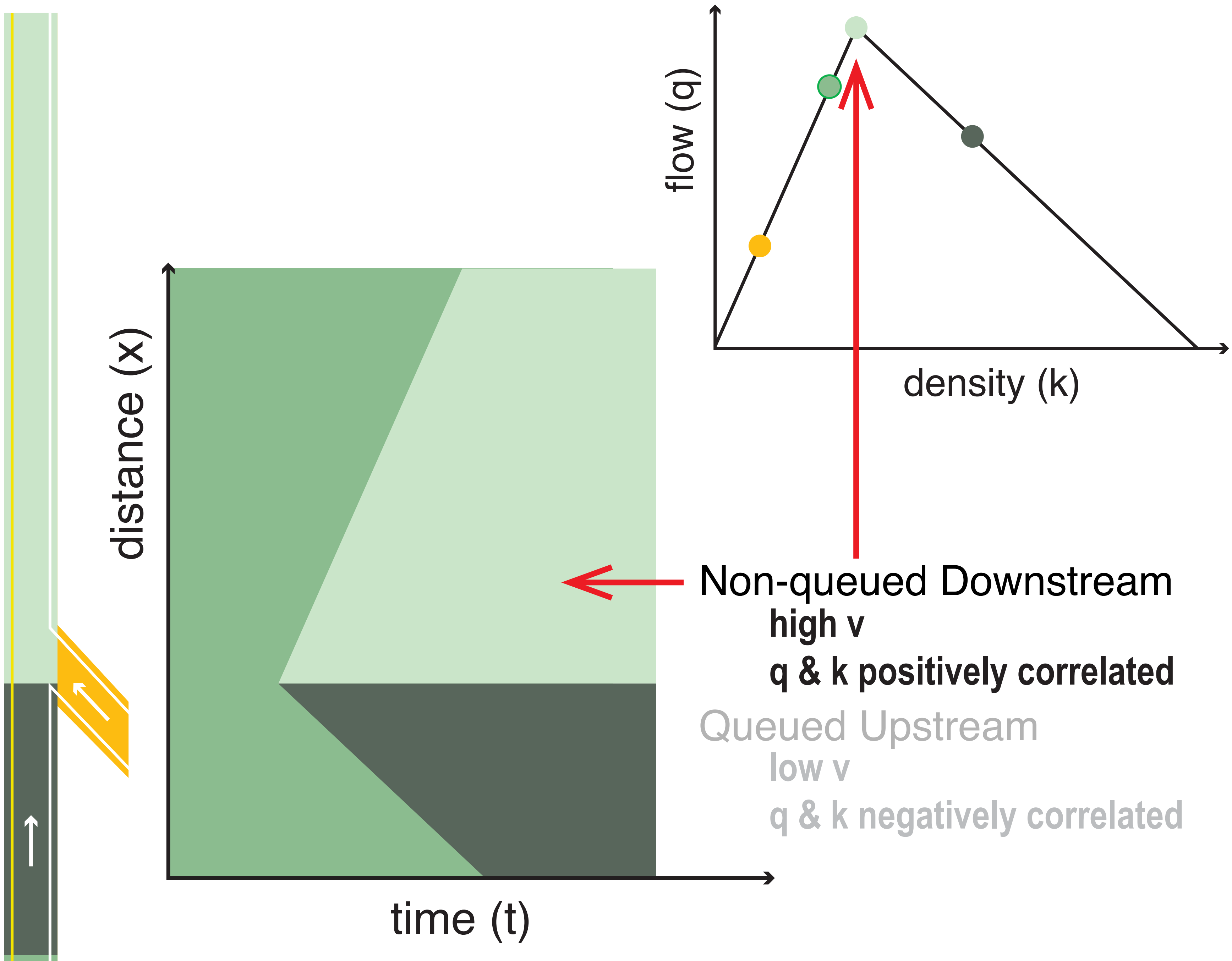
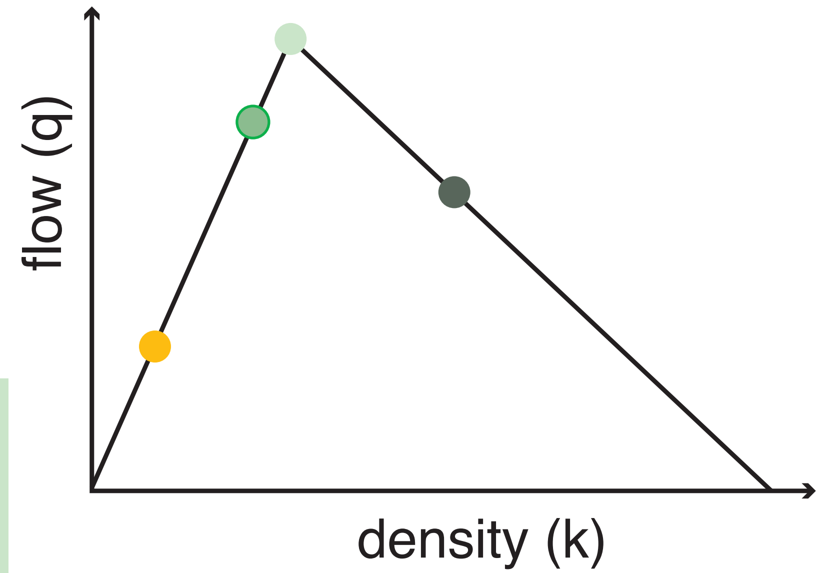
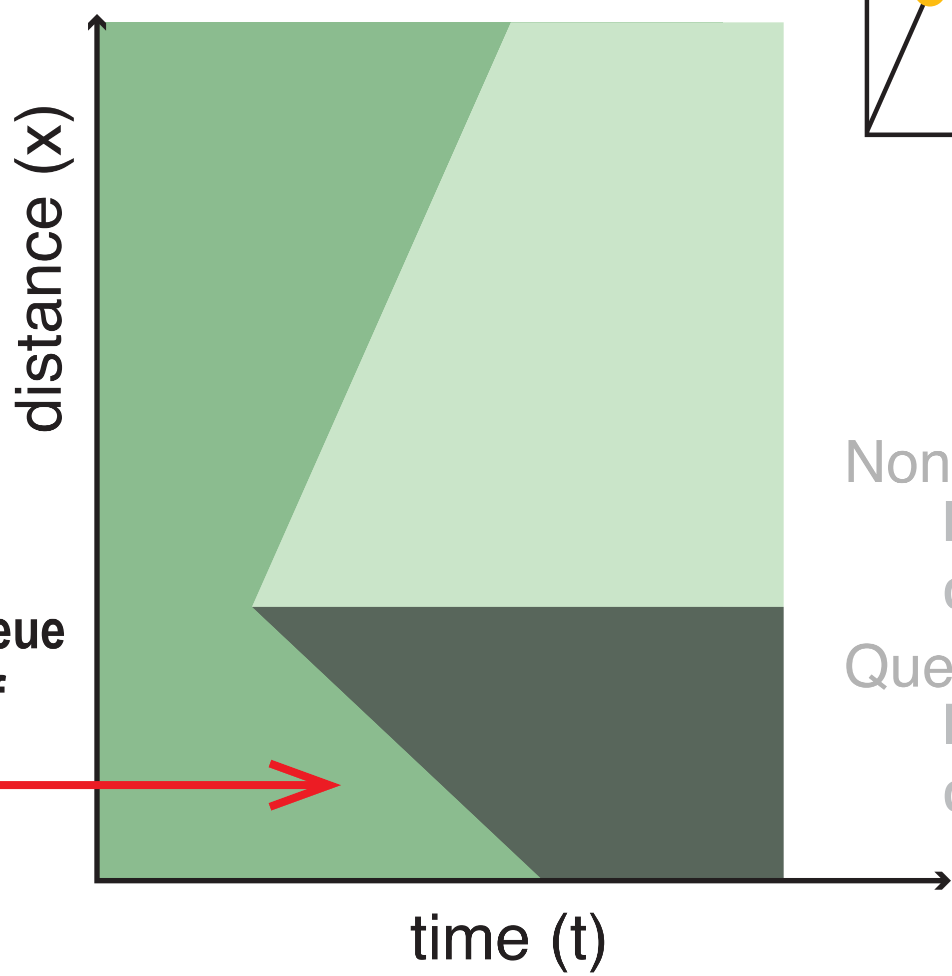
Conventional wisdom- Identifying when it is active



An on-ramp bottleneck

Conventional wisdom- Measuring capacity





q upstream of queue likely in excess of capacity so... Do not measure capacity here

Non-queued Downstream

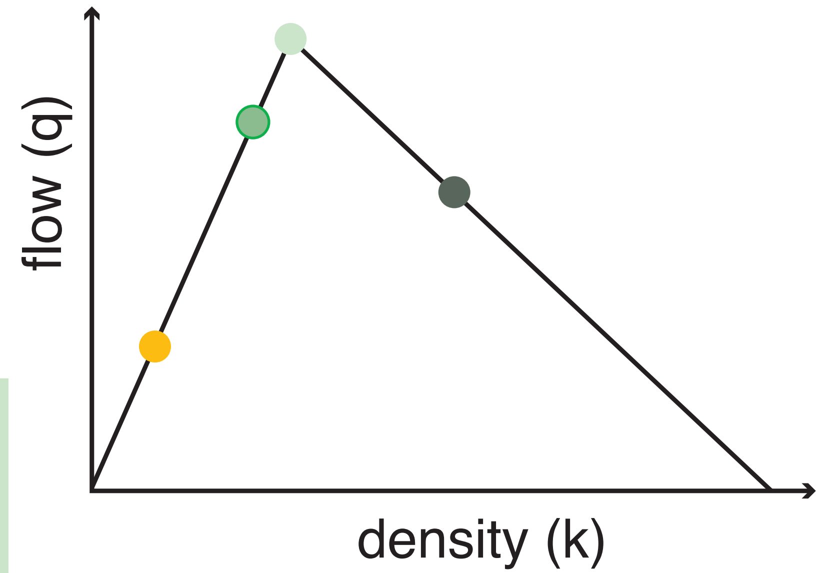
- high v
- q & k positively correlated

Queued Upstream

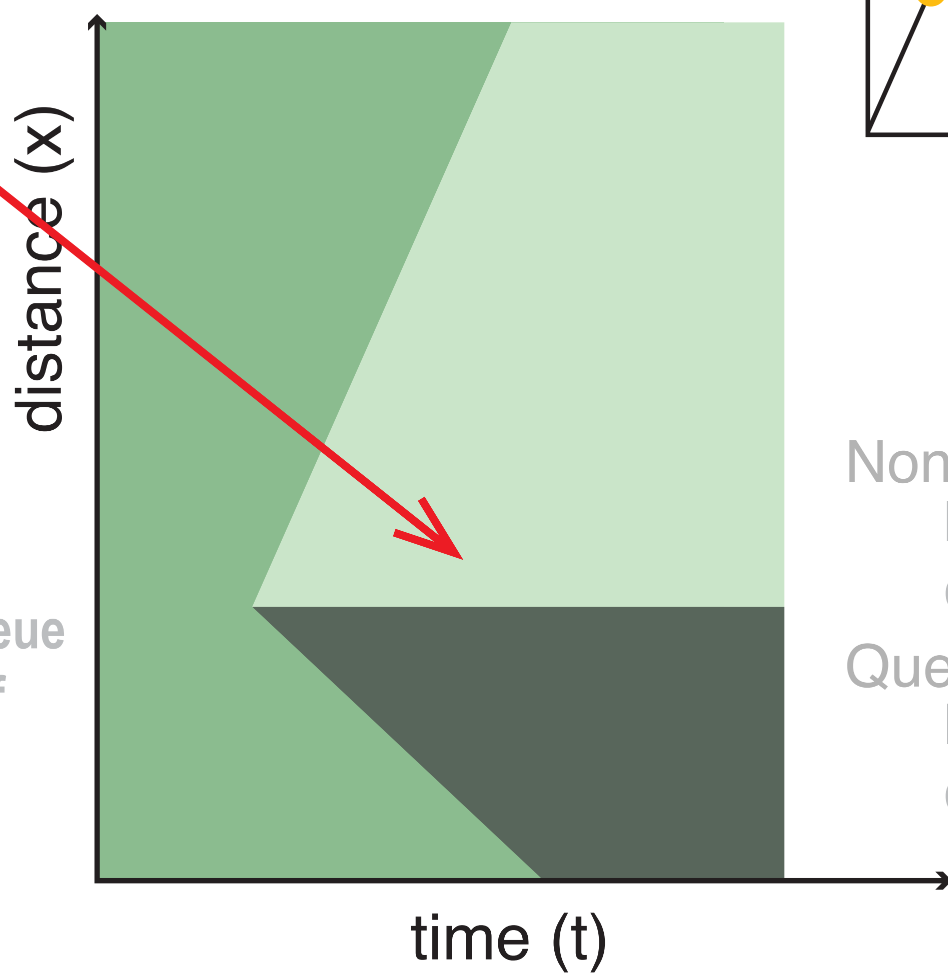
- low v
- q & k negatively correlated

An on-ramp bottleneck

Conventional wisdom- Measuring capacity



Discharging q should be at capacity, so measure capacity here



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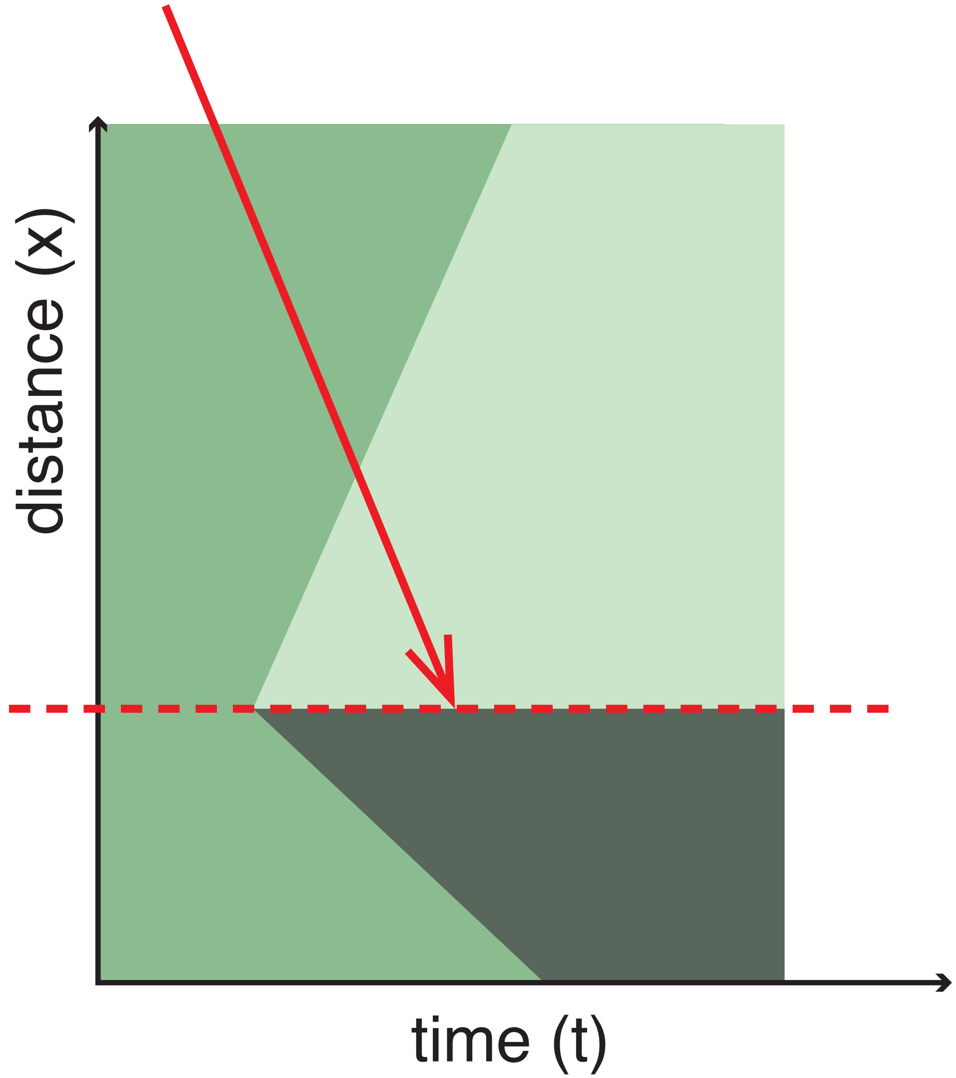
Conventional wisdom

Point bottleneck model

The bottleneck mechanism occurs at a point in space



An on-ramp bottleneck

Conventional wisdom

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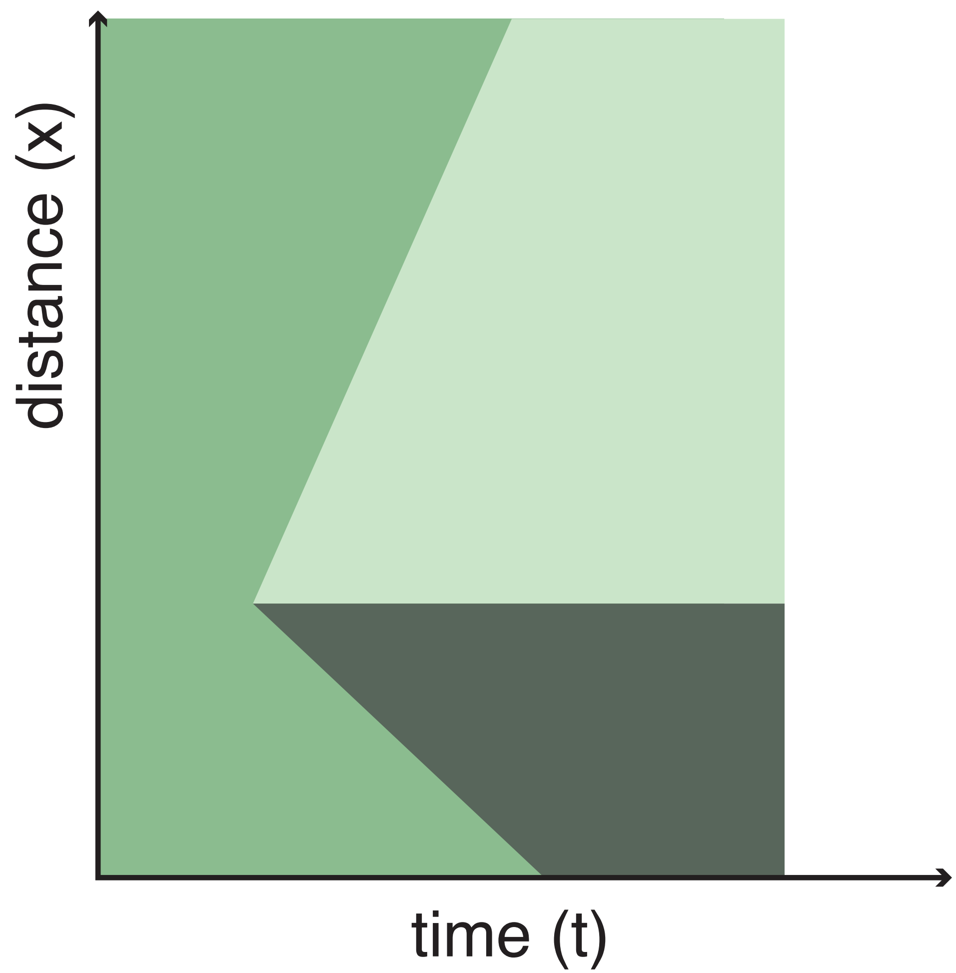
... but now drivers change speed instantaneously



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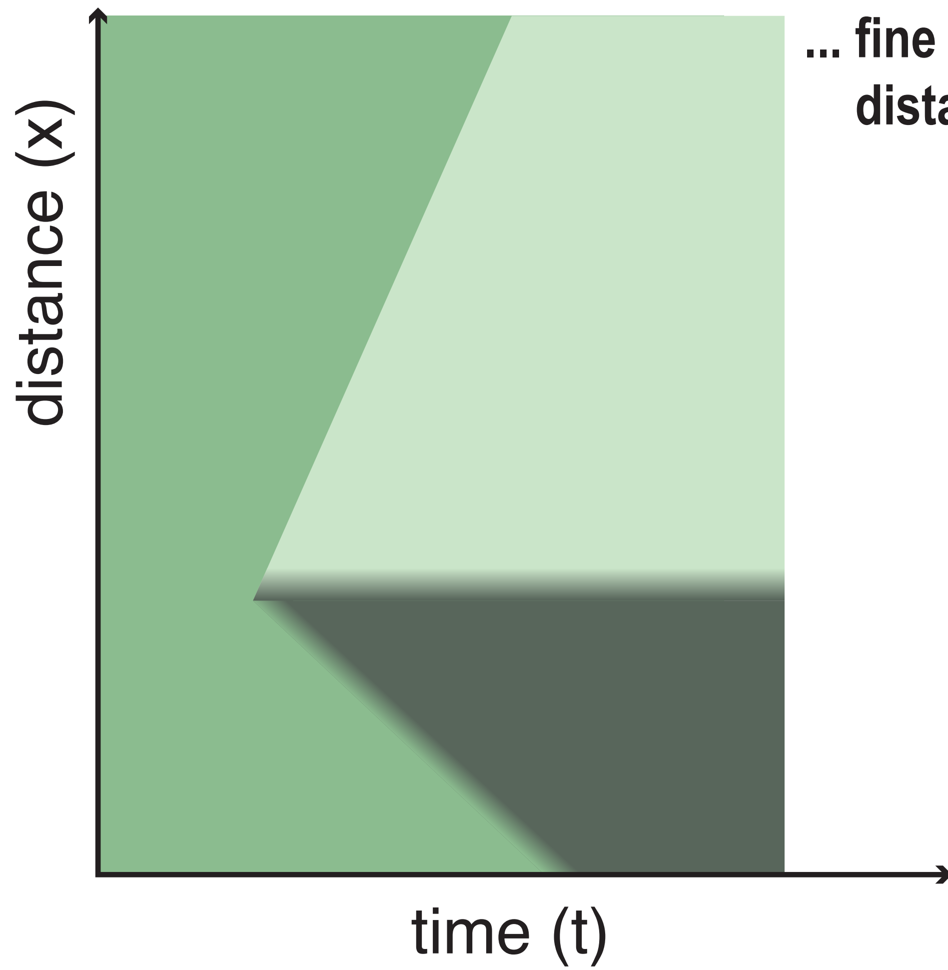
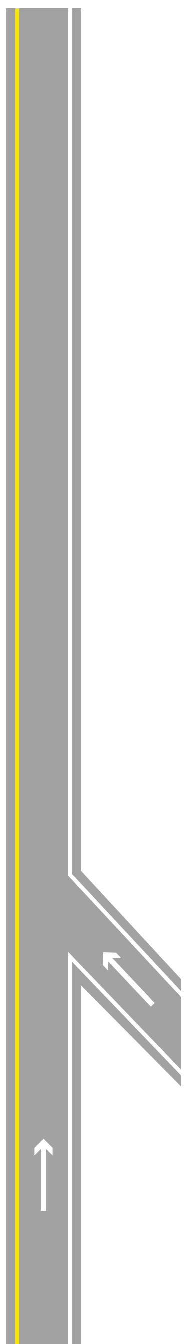


... fine model it as if the transition distances are negligible

An on-ramp bottleneck



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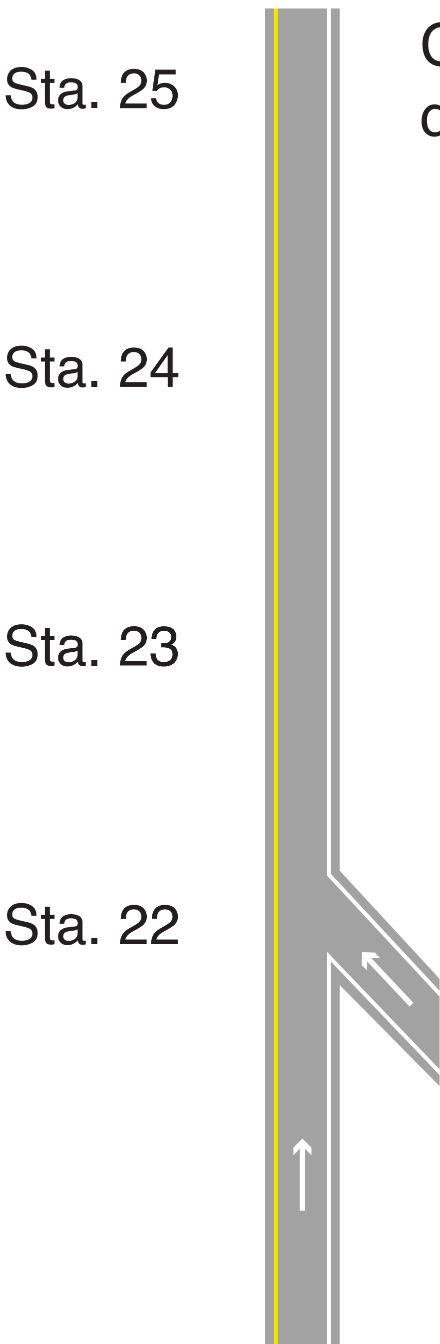
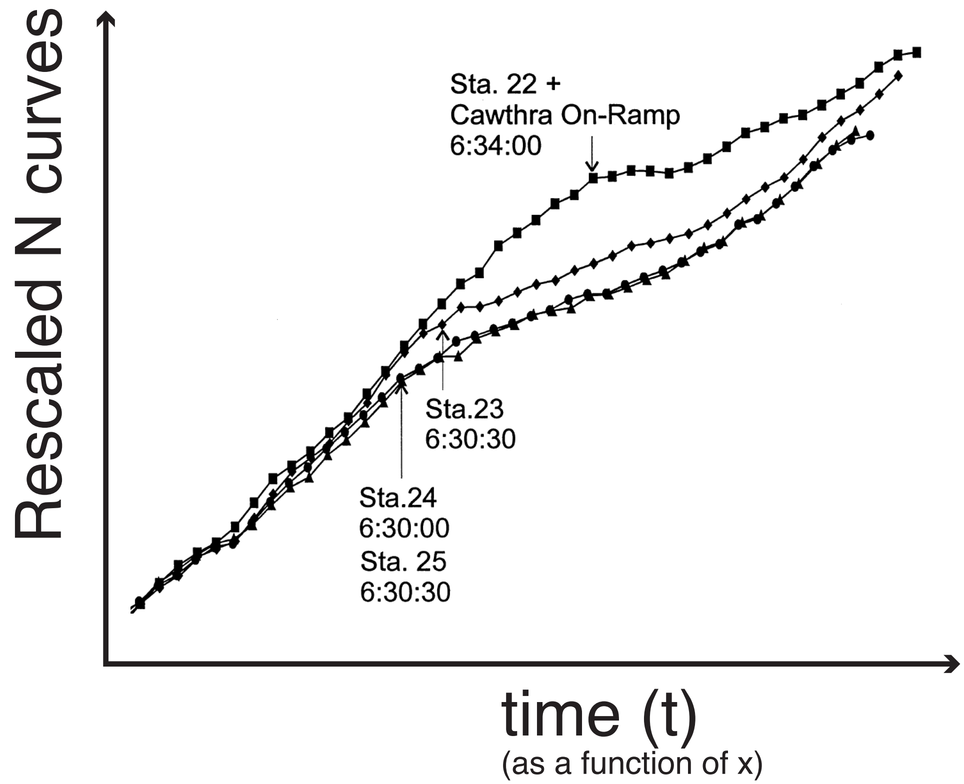
What has been overlooked...
conventional wisdom has failed us

An on-ramp bottleneck

The first crack in the wall



Cassidy and Bertini (1999) use a modified queuing diagram to study an on-ramp bottleneck



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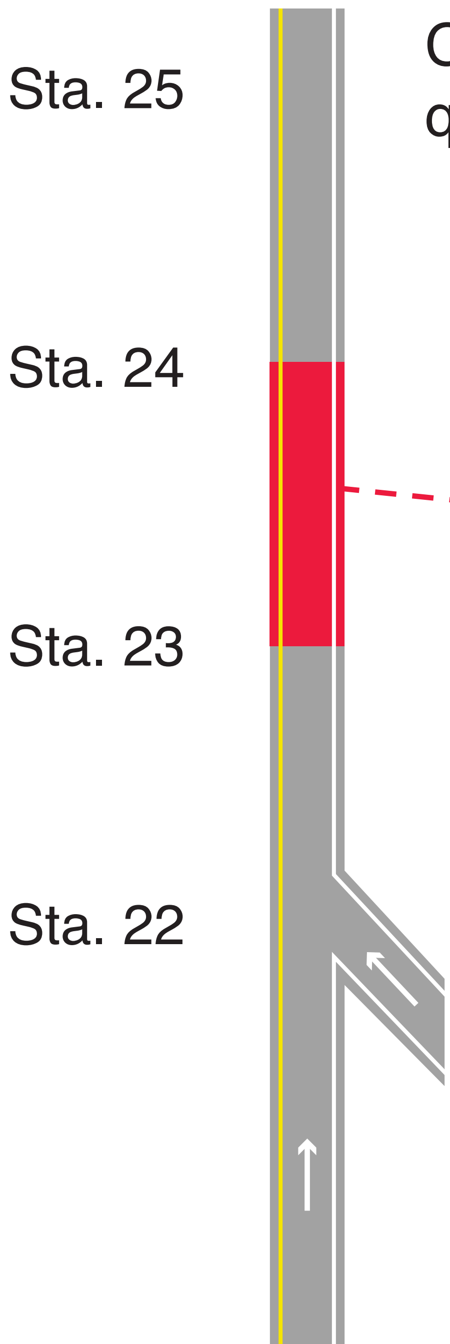
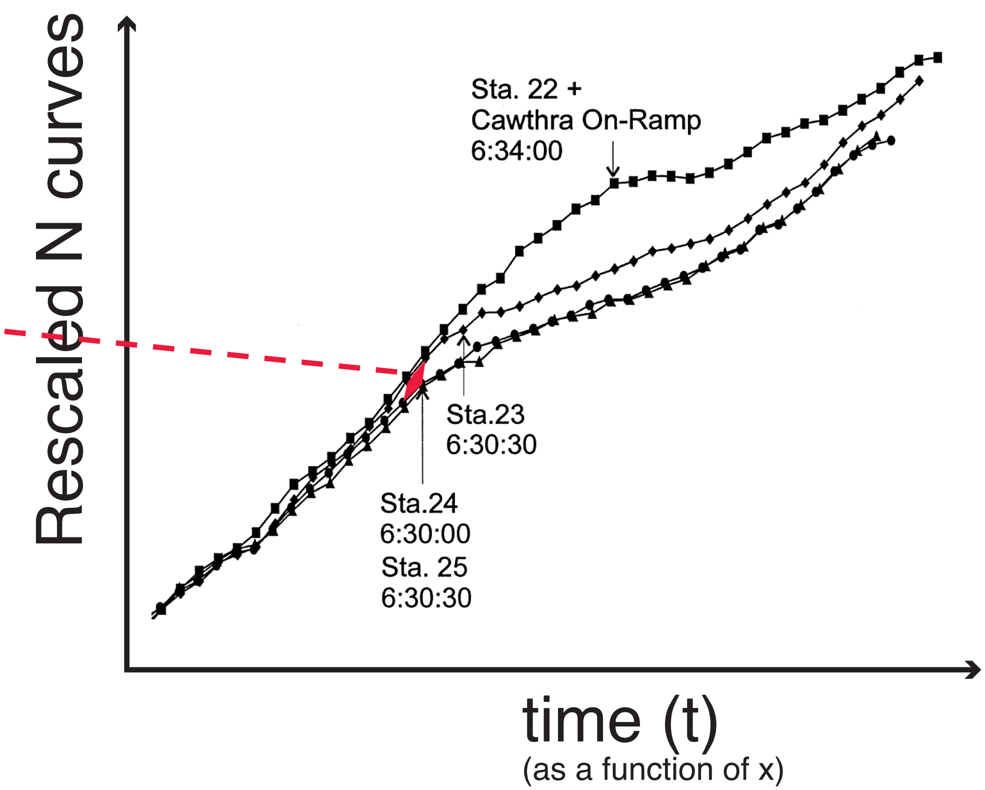
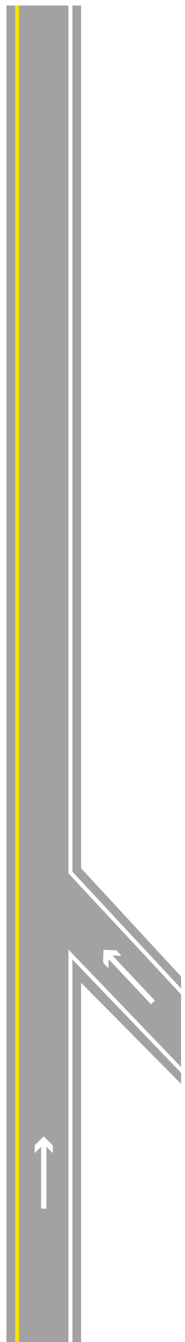




They find the initial queue formation 1km downstream of the on-ramp

An on-ramp bottleneck



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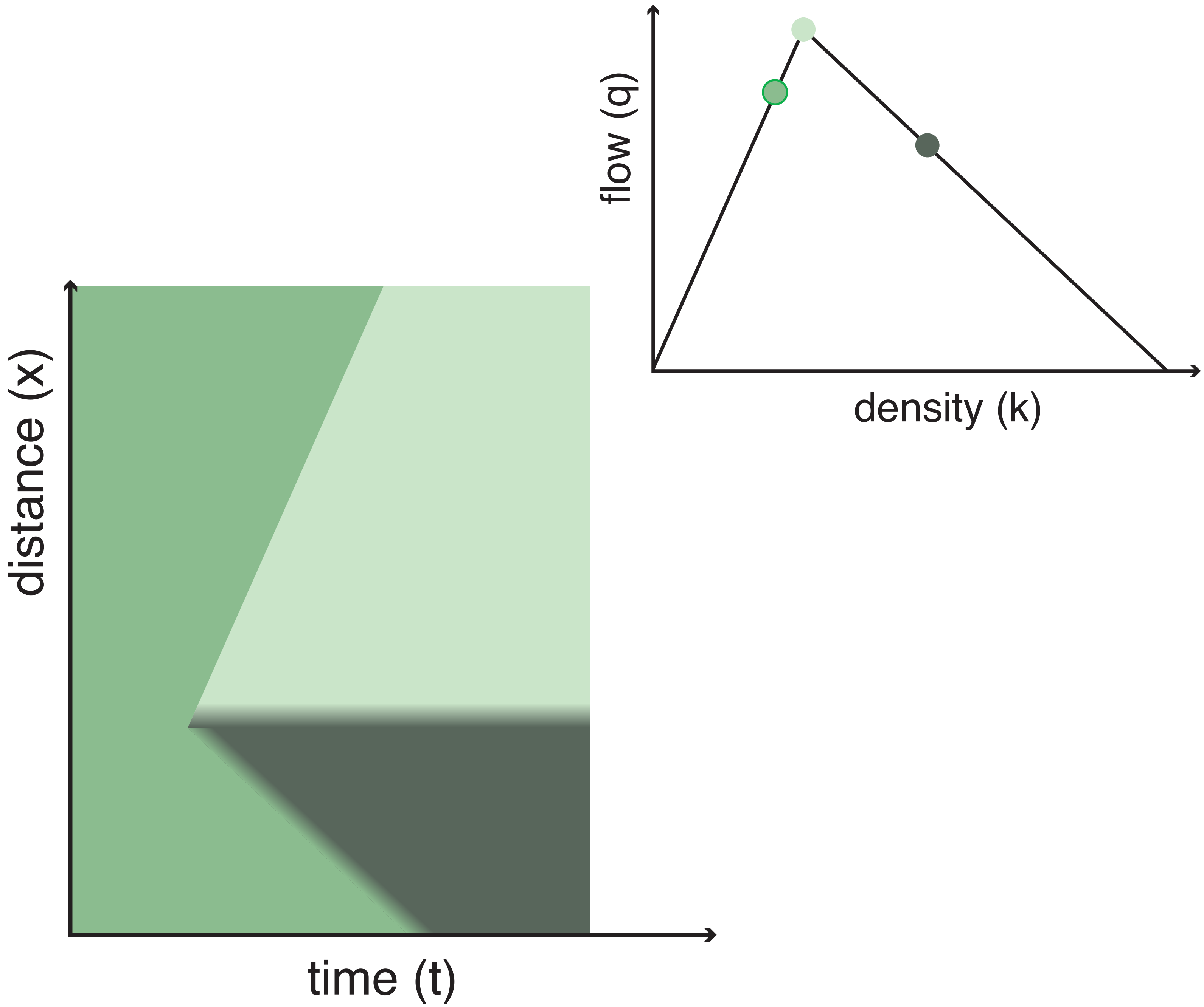
Moving into our work...
consider the microscopic driver behavior

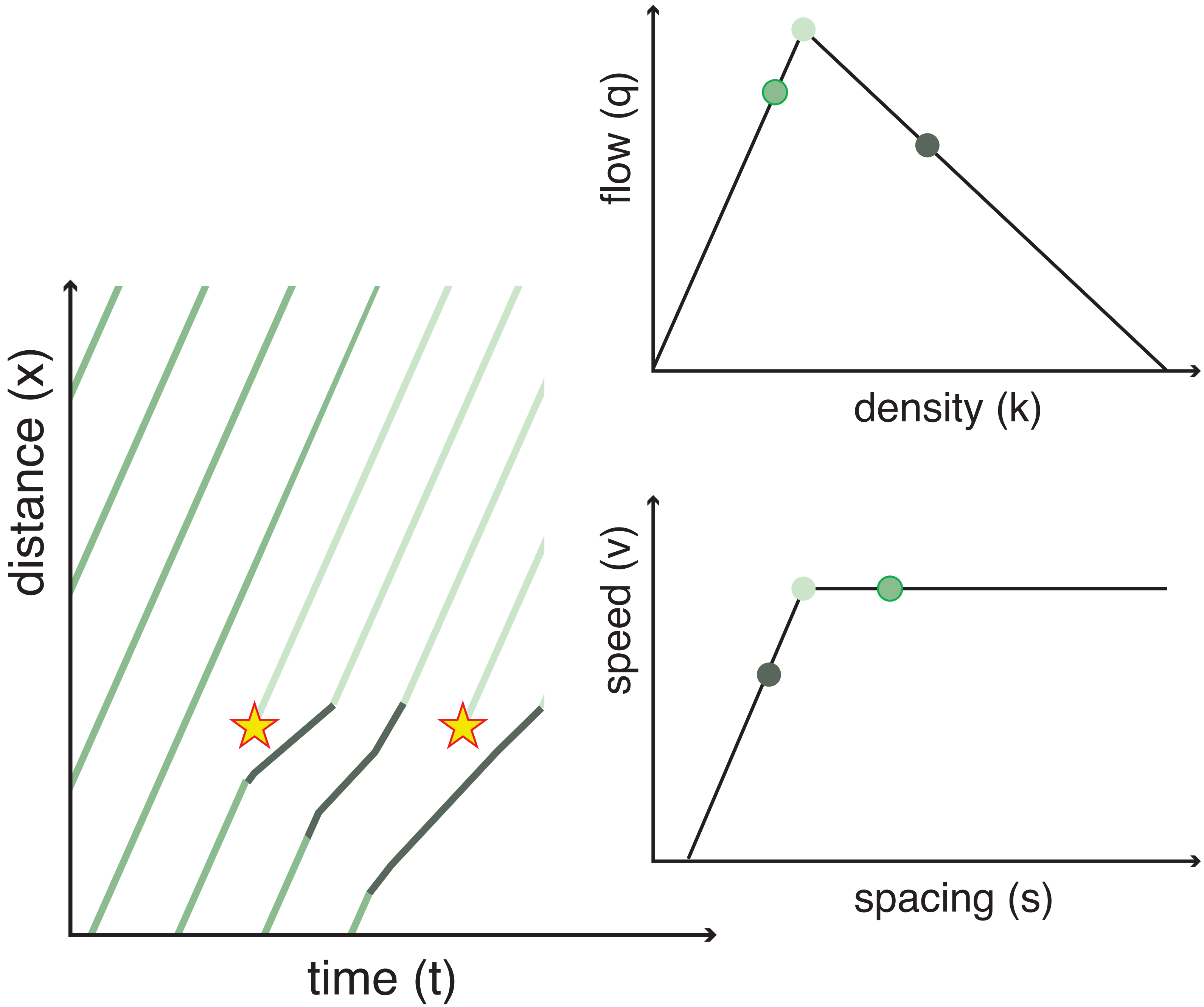
An on-ramp bottleneck

The macroscopic perspective



An on-ramp bottleneck

The microscopic perspective- what the drivers see



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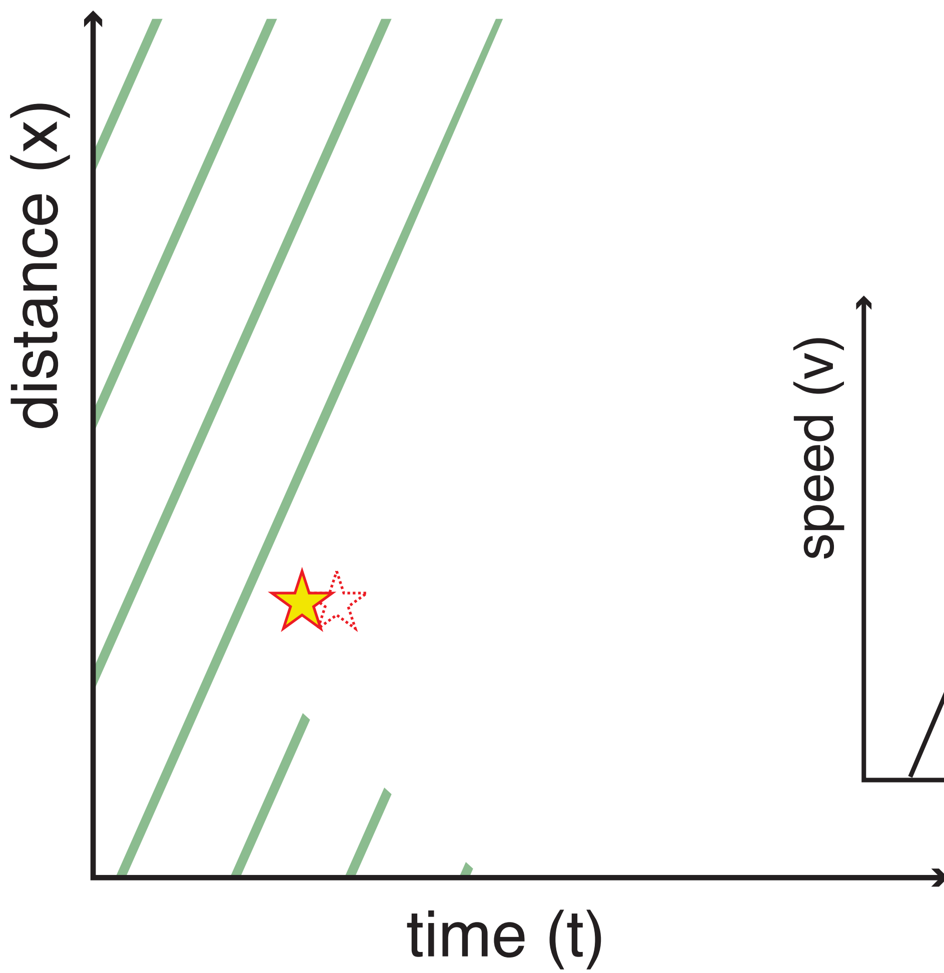
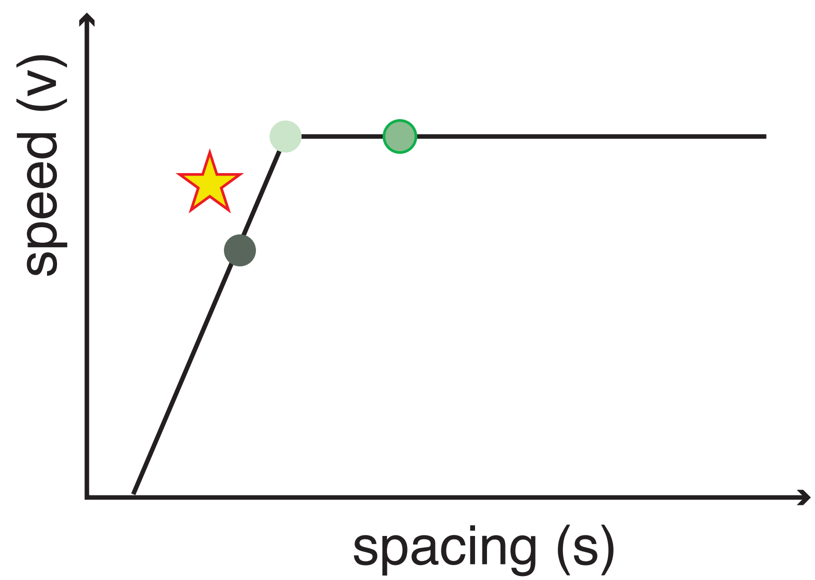
But drivers do not adjust their spacing over a short distance!

a driver will accept a short headway for 20 sec or more so that they can enter a lane that is constrained by downstream conditions





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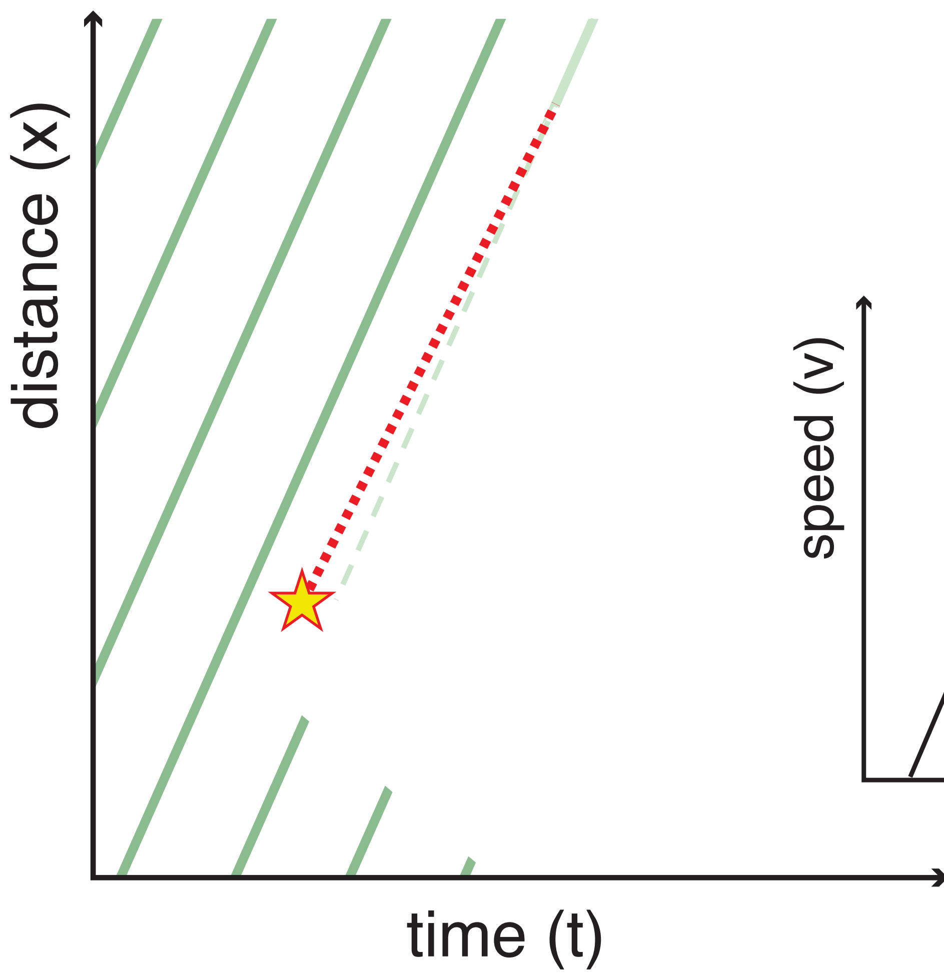

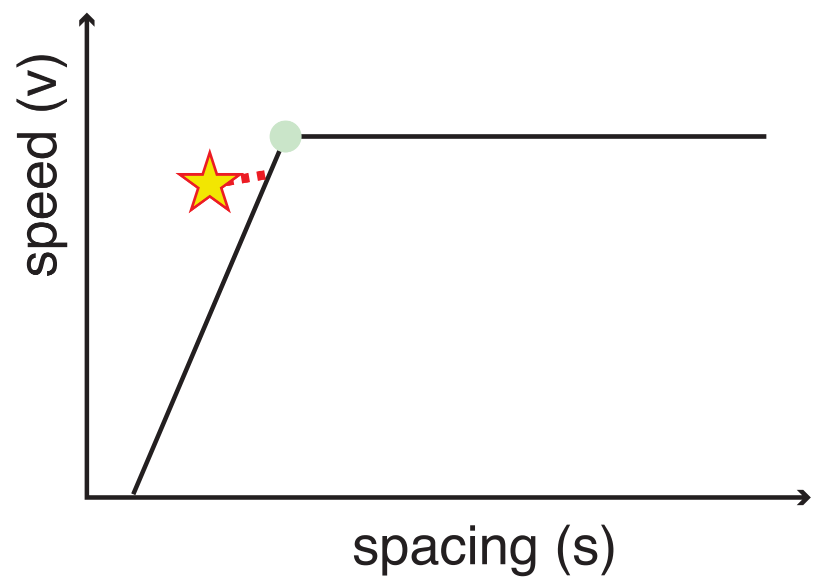

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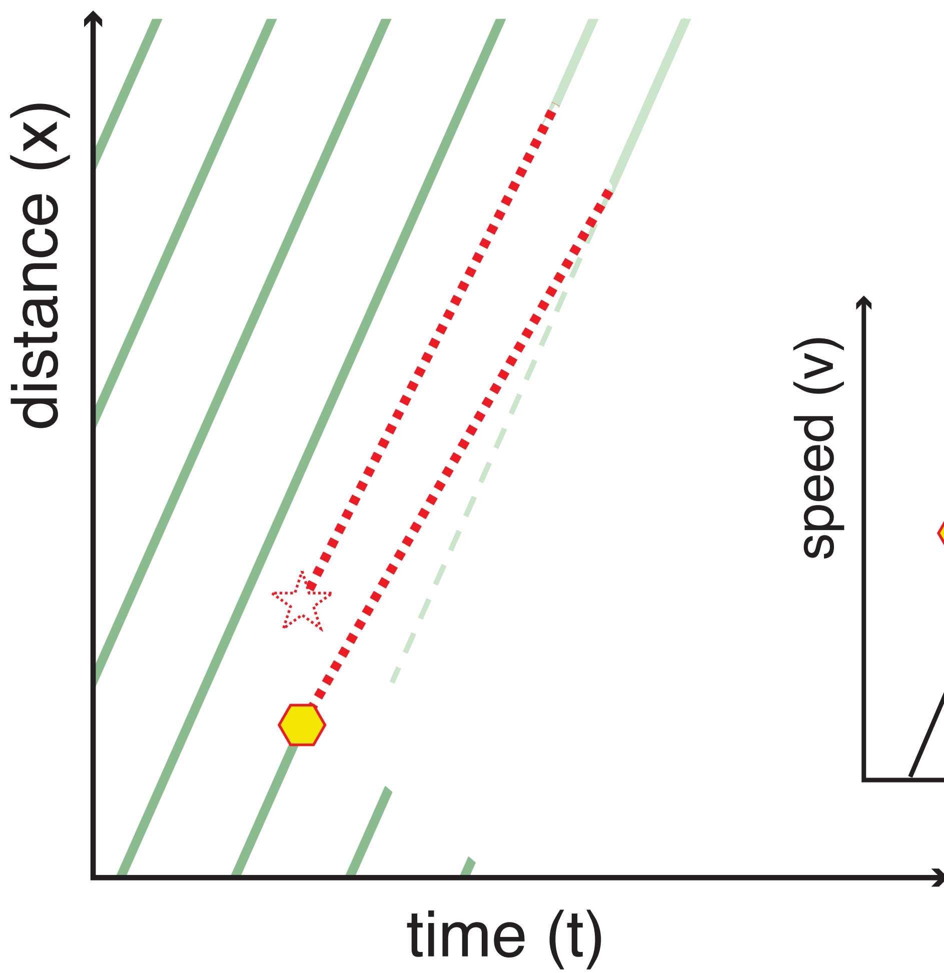

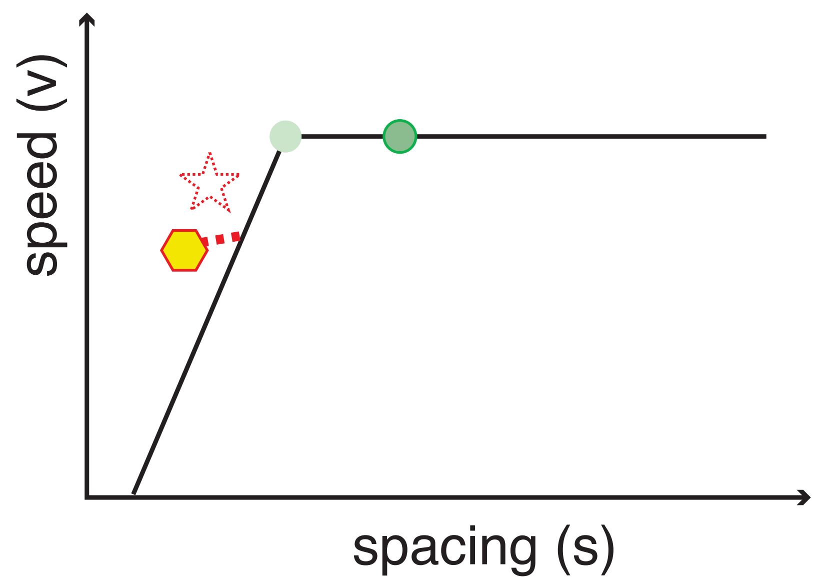

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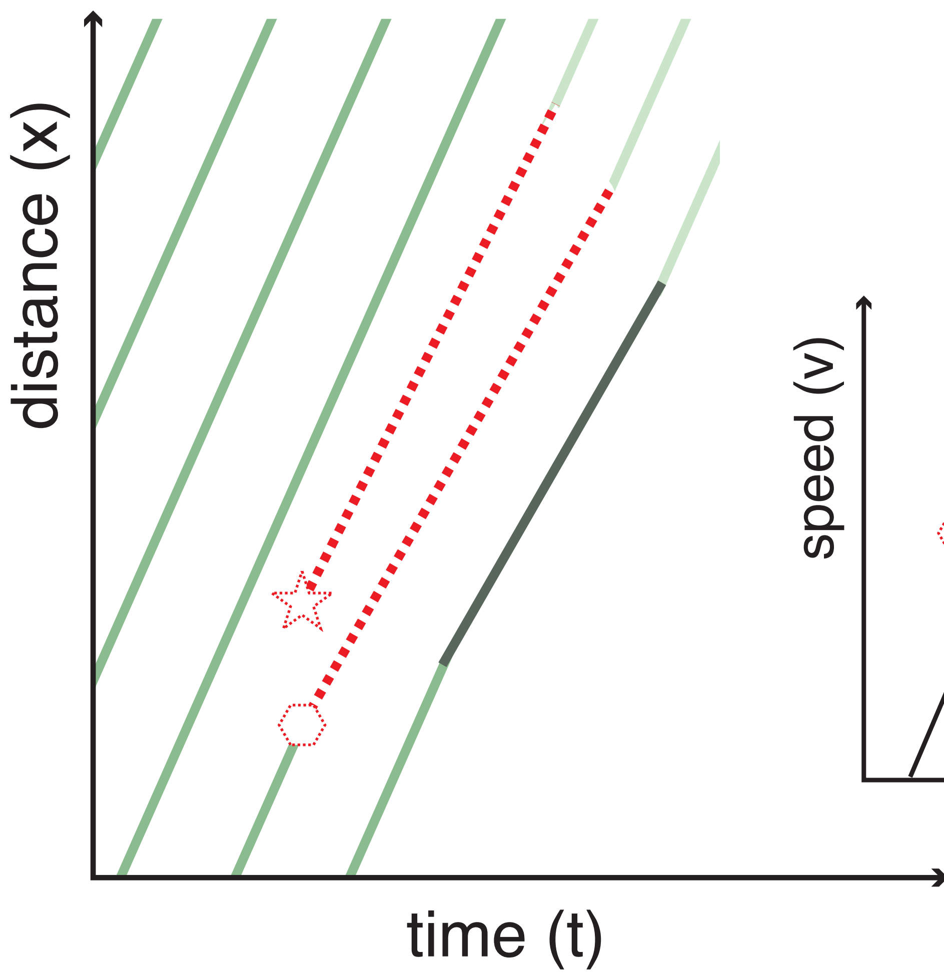

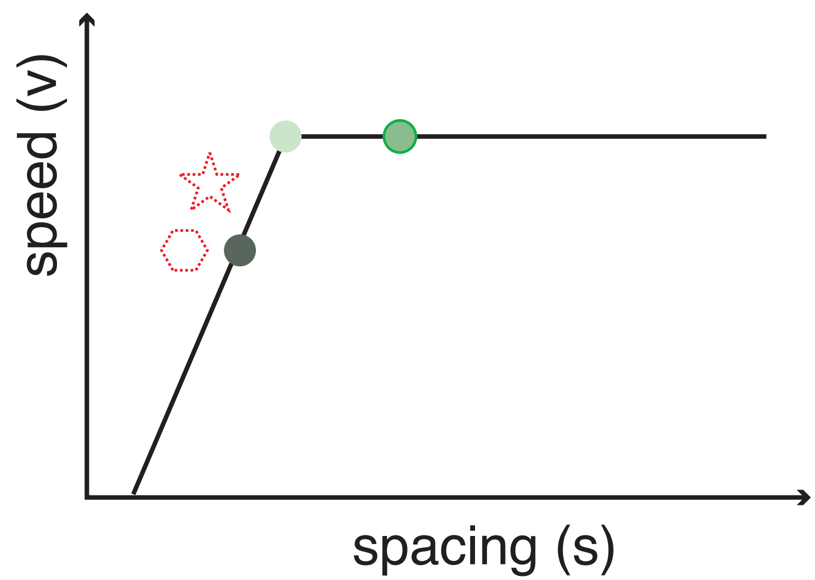

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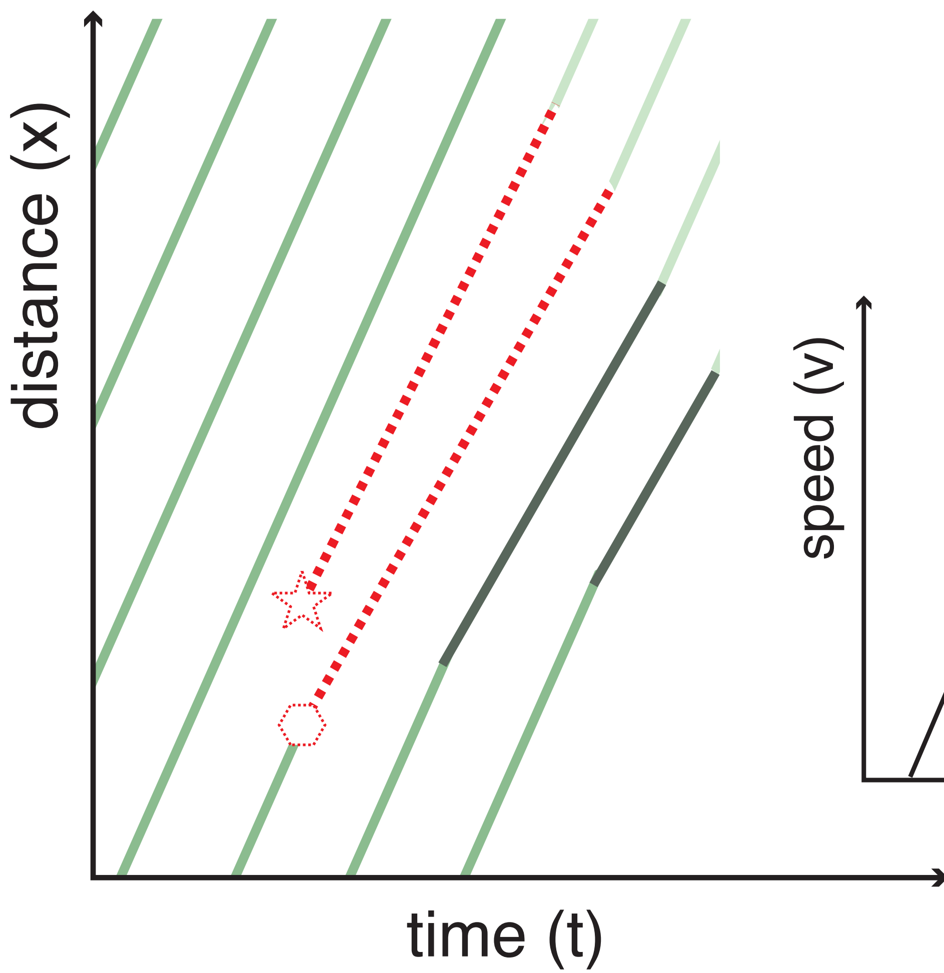

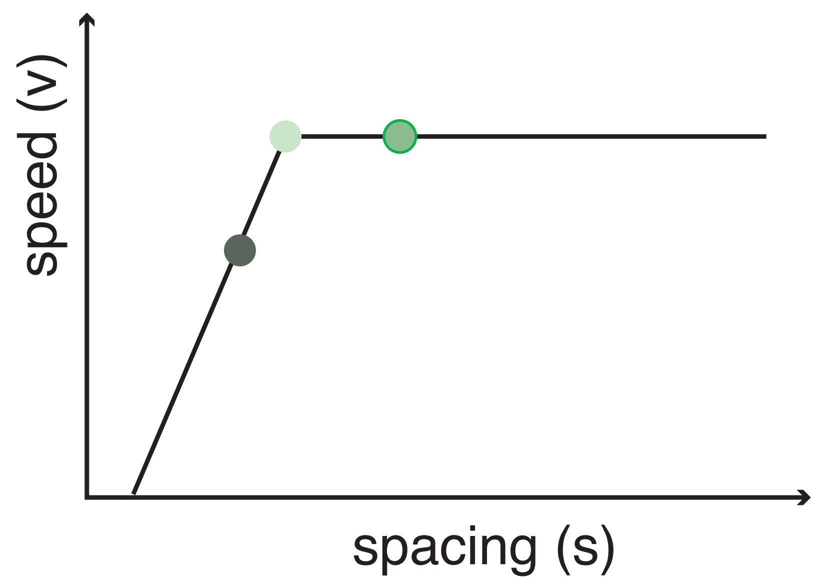

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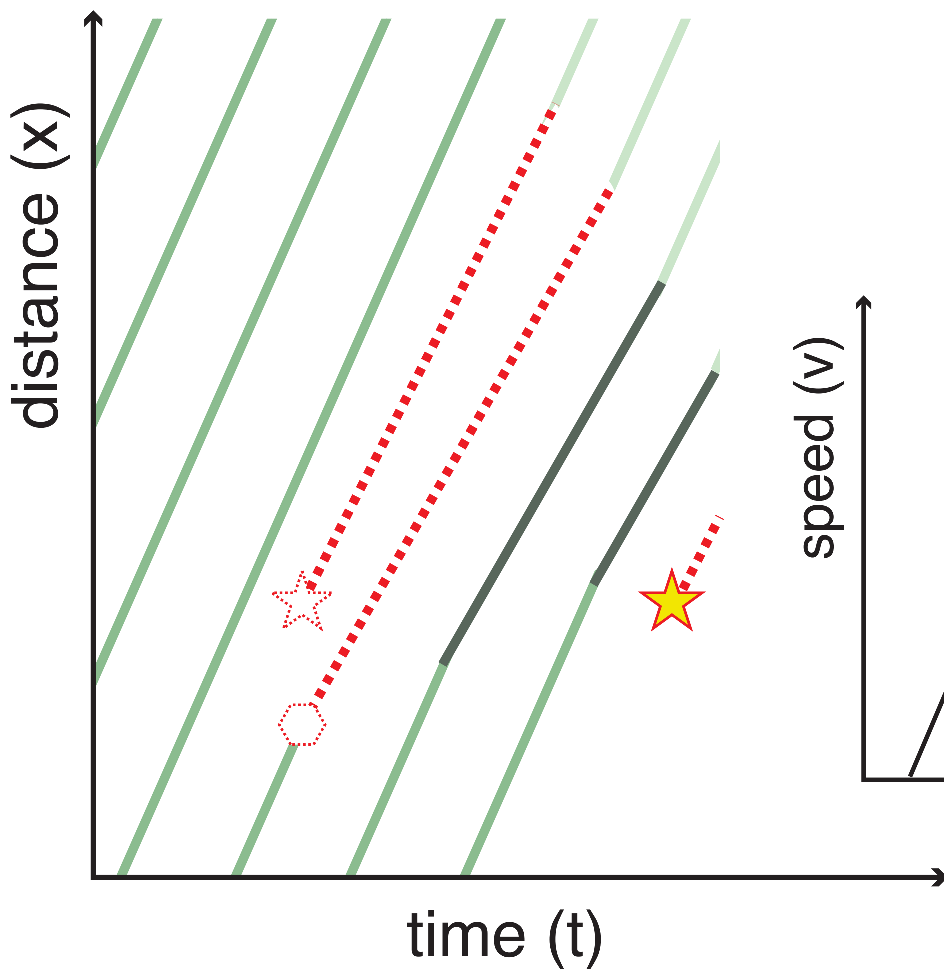

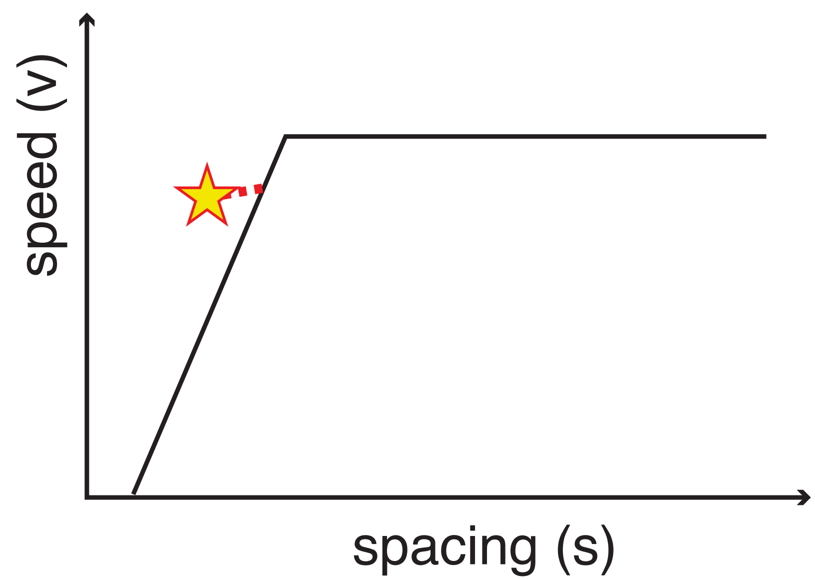

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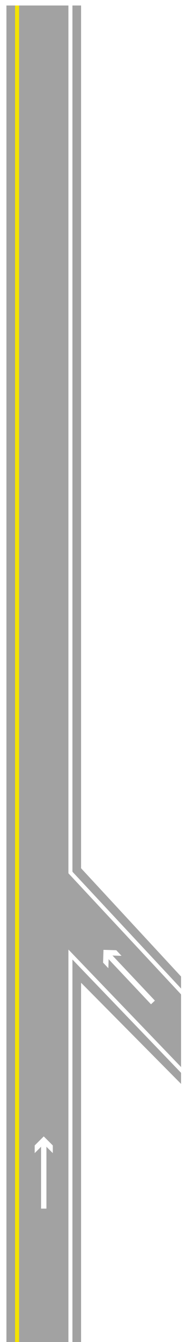

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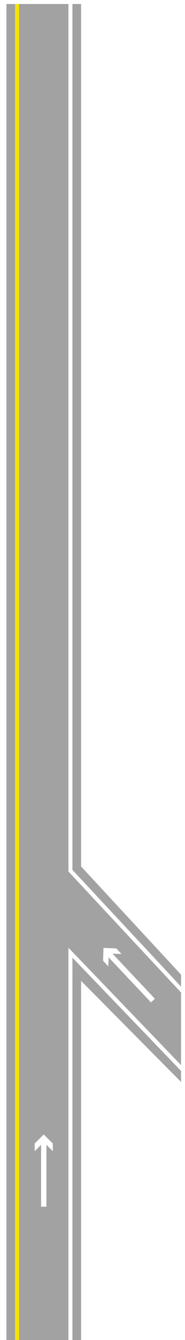
conventional wisdom has failed us

Moving into our work...
consider the microscopic driver behavior

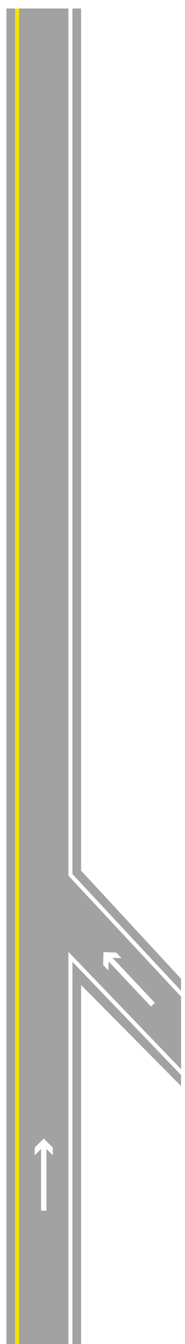
So what, who cares?
seems like splitting microscopic hairs to me

An on-ramp bottleneck



Simulate vehicle trajectories in the vicinity of an on-ramp bottleneck

An on-ramp bottleneck

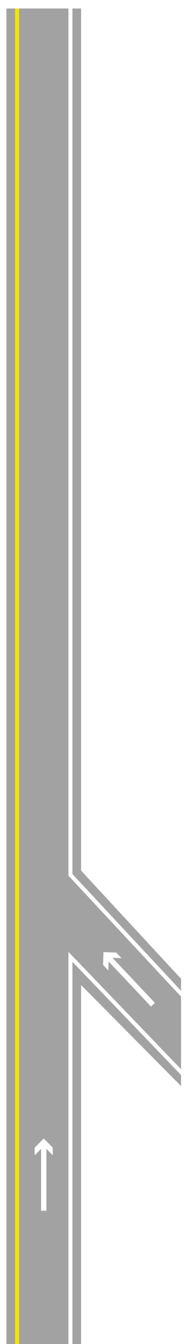


Simulate vehicle trajectories in the vicinity of an on-ramp bottleneck

Examine two cases

- -without relaxation
- -with relaxation

An on-ramp bottleneck



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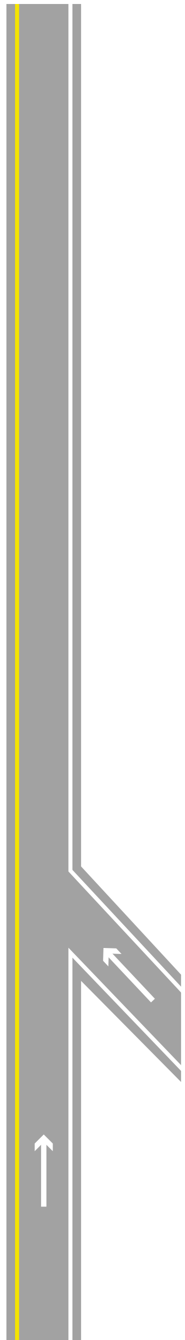
-RCap:	2200 vph
-Mainline flow:	2080 vph
-Ramp flow:	360 vph
-Free Speed:	60 mph

An on-ramp bottleneck



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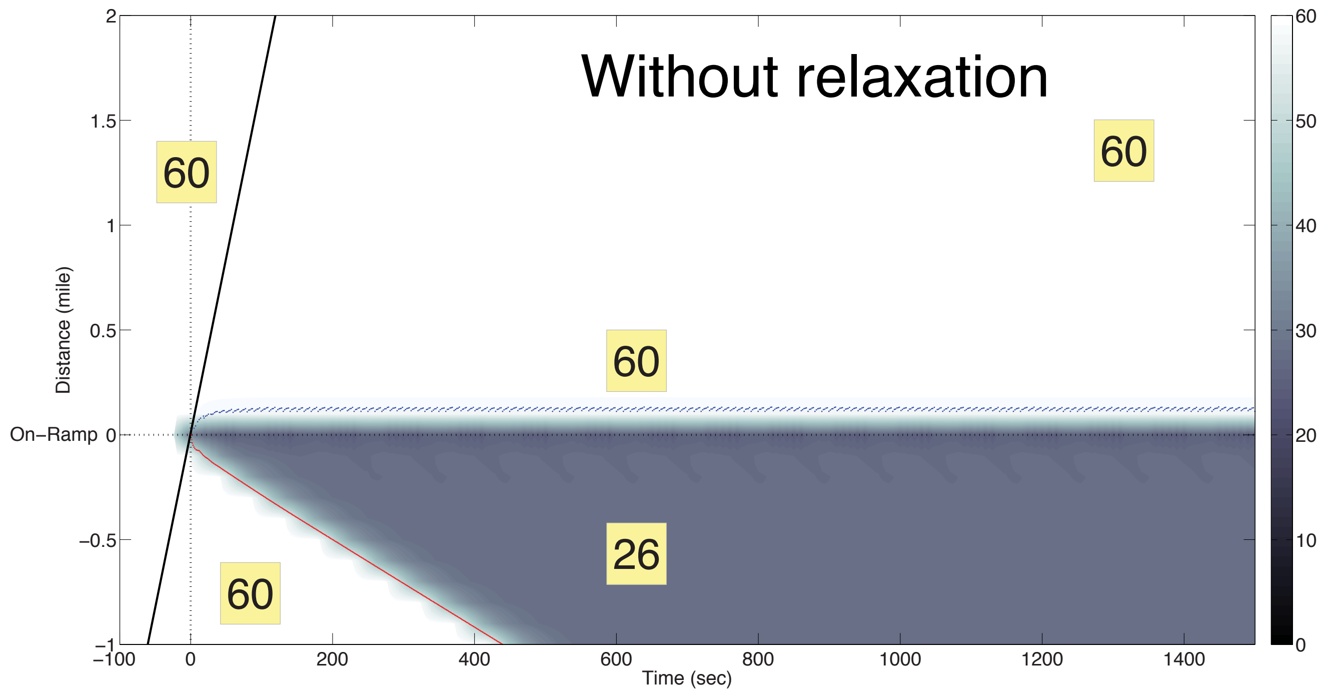
Many more scenarios can be found in the paper

An on-ramp bottleneck



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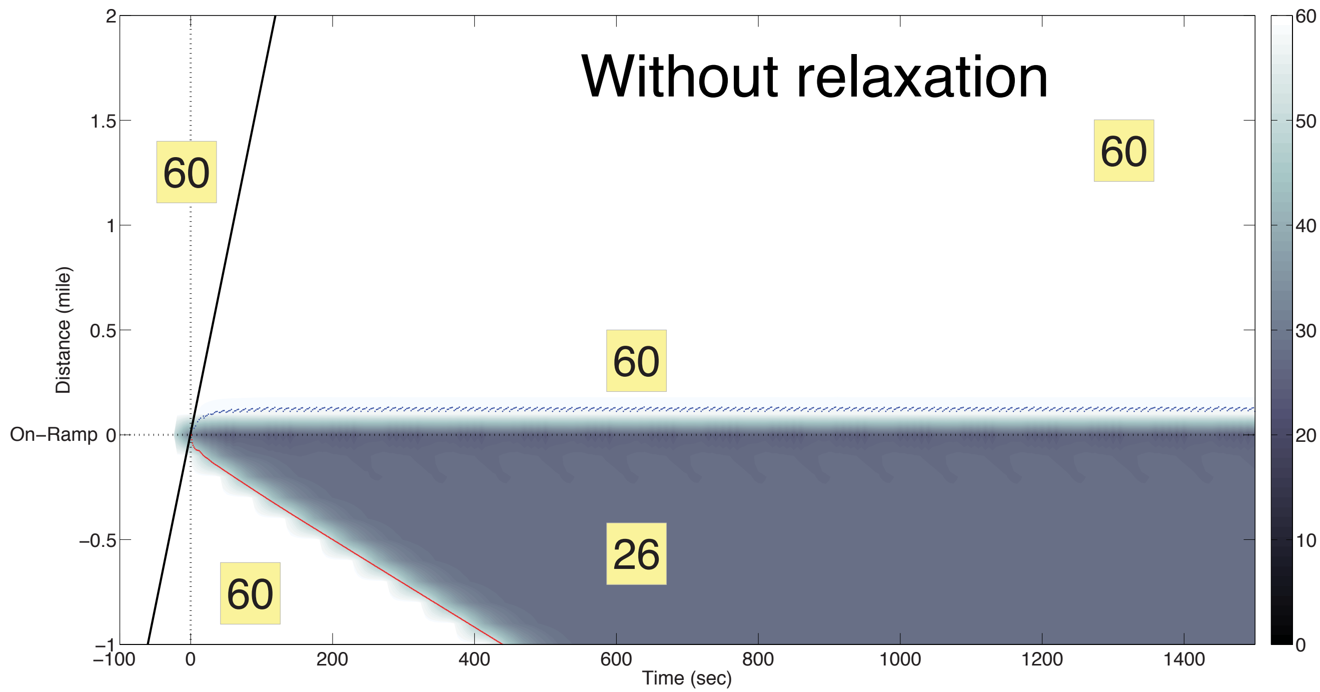
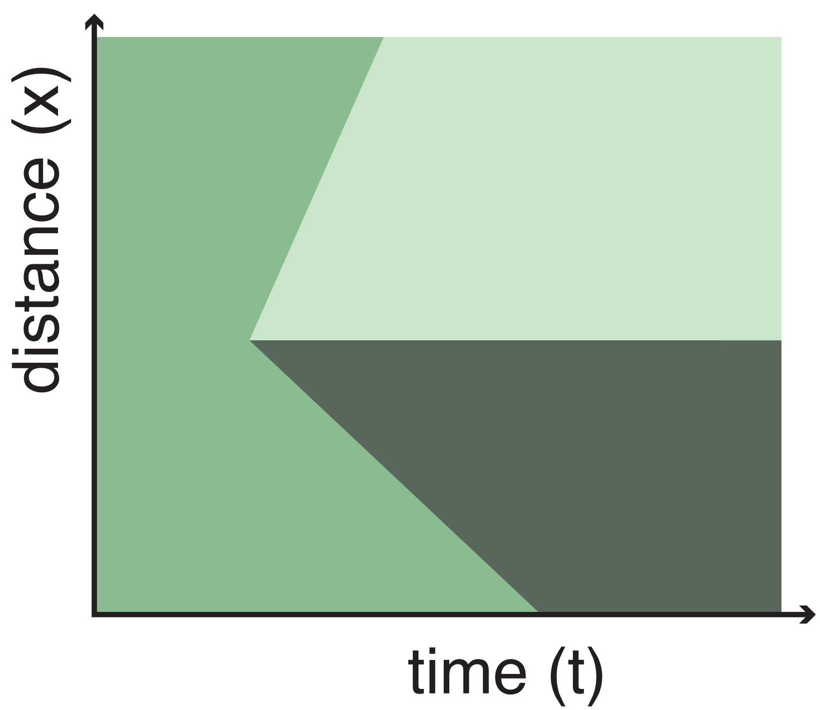
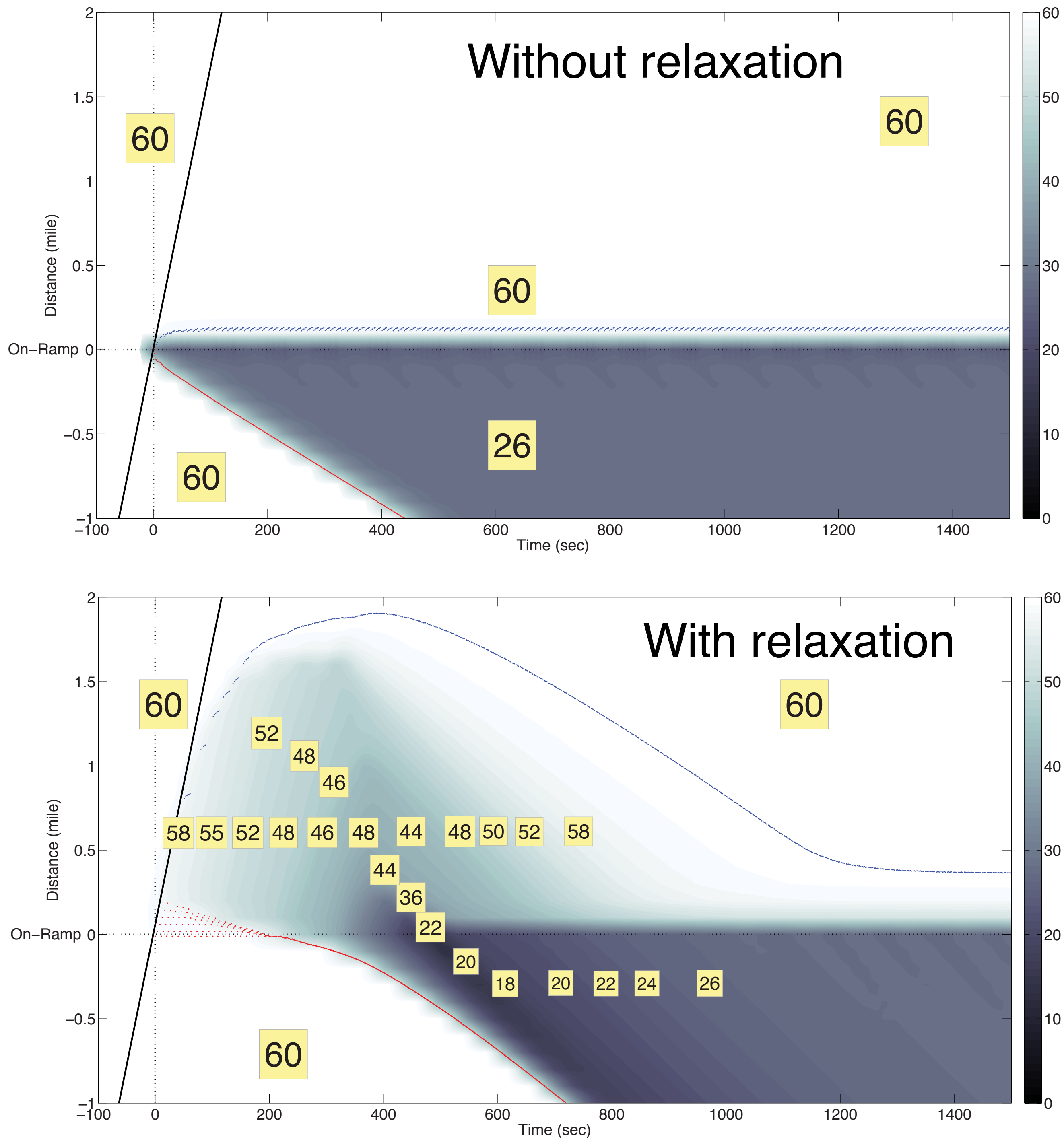




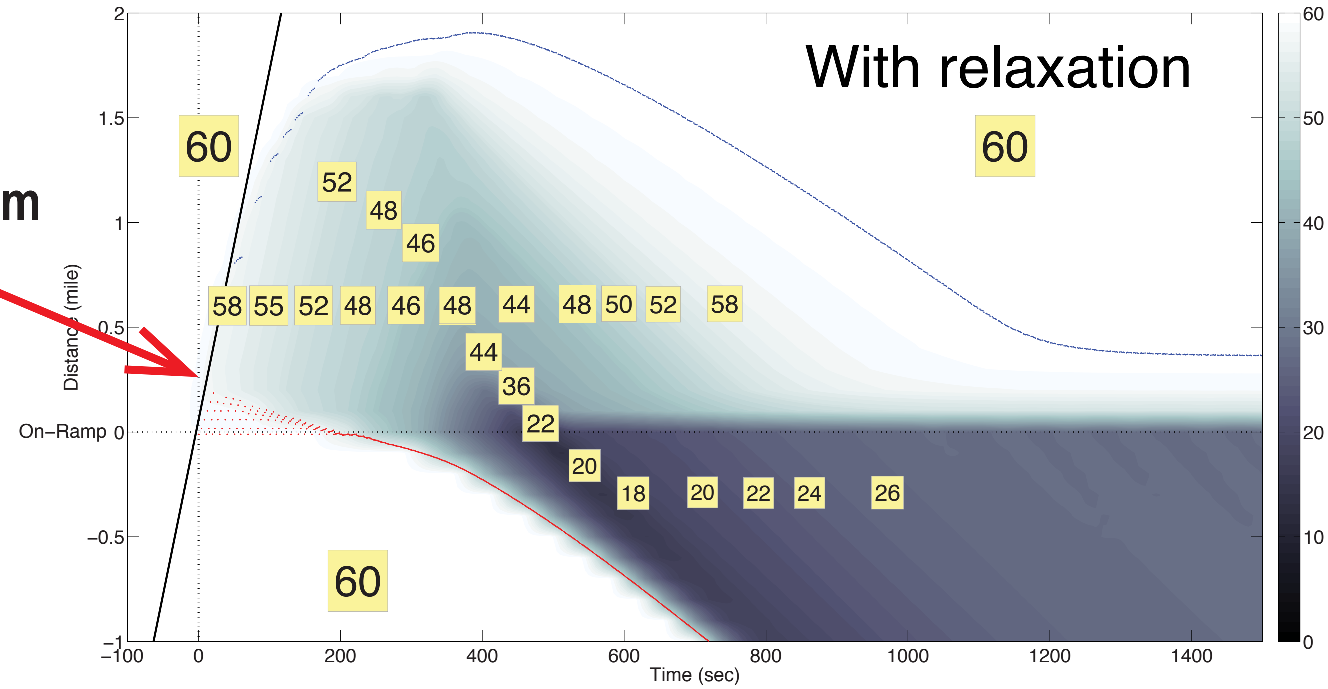
Similar to the earlier macroscopic diagram

An on-ramp bottleneck



An on-ramp bottleneck

initial standing queue forms 0.3 mi downstream of on-ramp



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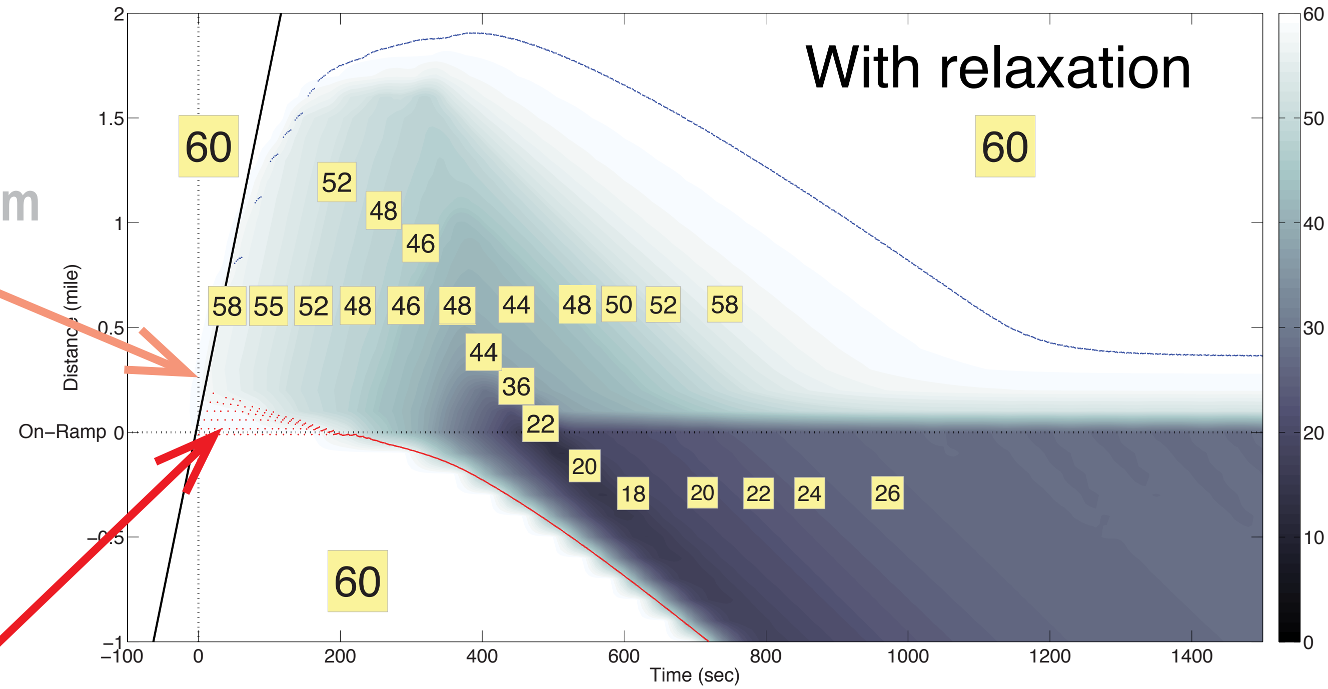

seemingly non-queued at on-ramp immediately after activation

An on-ramp bottleneck

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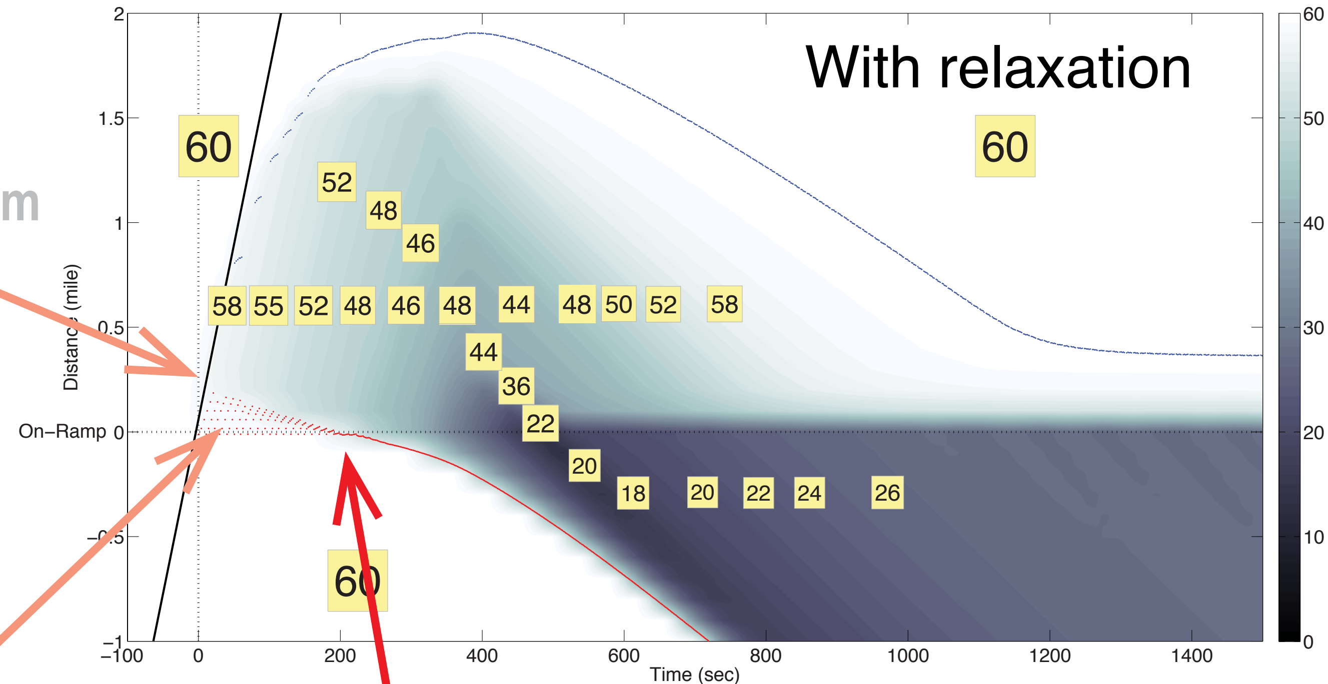


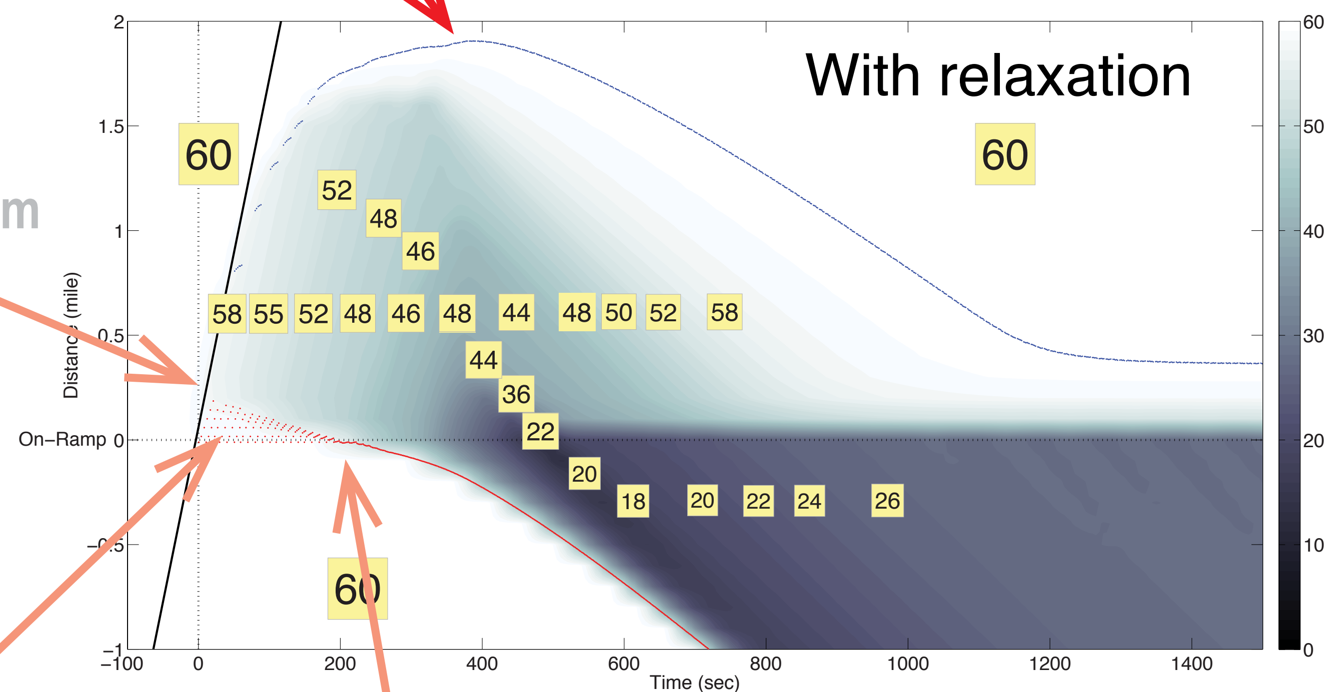
seemingly non-queued at on-ramp immediately after activation

upstream end of queue first reaches the on-ramp several minutes after activation

An on-ramp bottleneck

downstream end of queue grows to 1.8 mi downstream of on-ramp

initial standing queue forms 0.3 mi downstream of on-ramp



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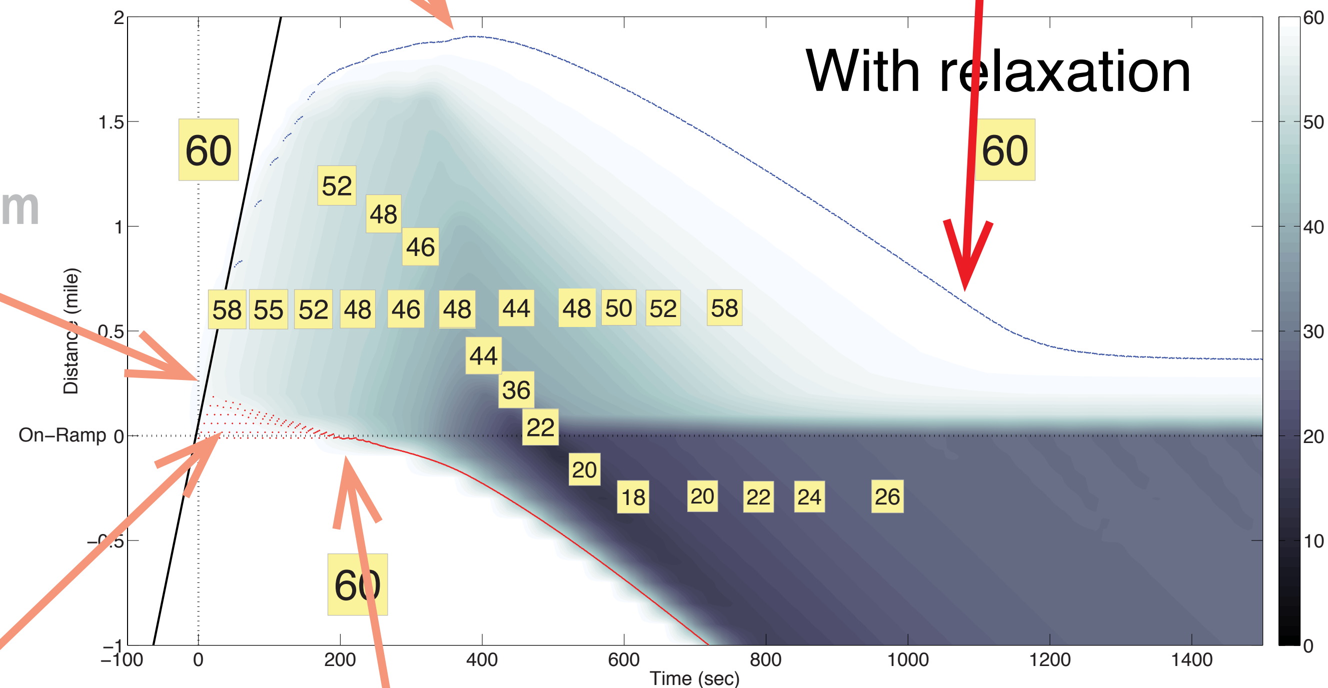
downstream end of queue grows to 1.8 mi downstream of on-ramp

downstream end of queue receeds back towards on-ramp

initial standing queue forms 0.3 mi downstream of on-ramp



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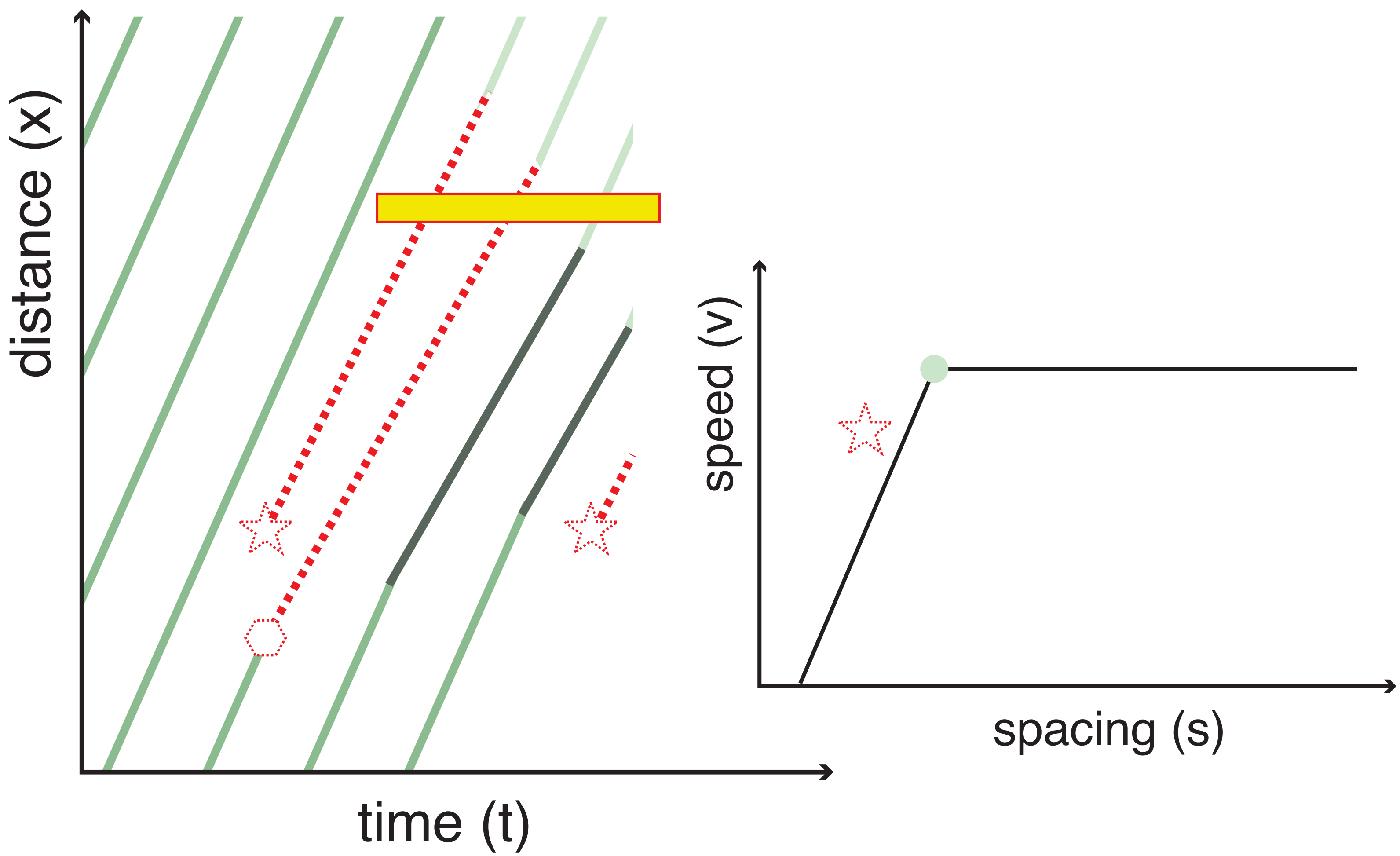
An on-ramp bottleneck

The macroscopic perspective again

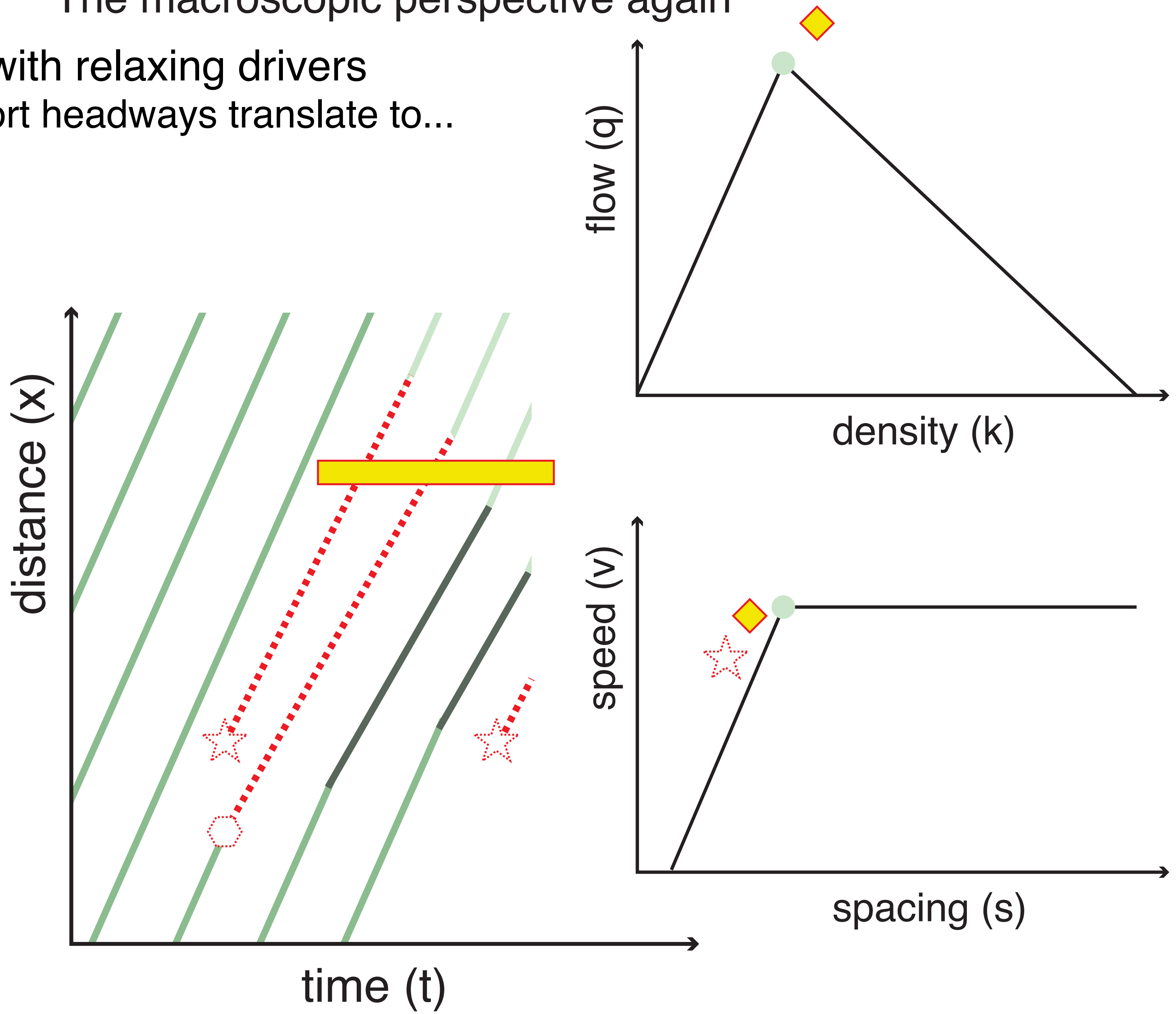
Any sample with relaxing drivers



An on-ramp bottleneck

The macroscopic perspective again

Any sample with relaxing drivers
transient short headways translate to...



An on-ramp bottleneck

The macroscopic perspective again

Any sample with relaxing drivers
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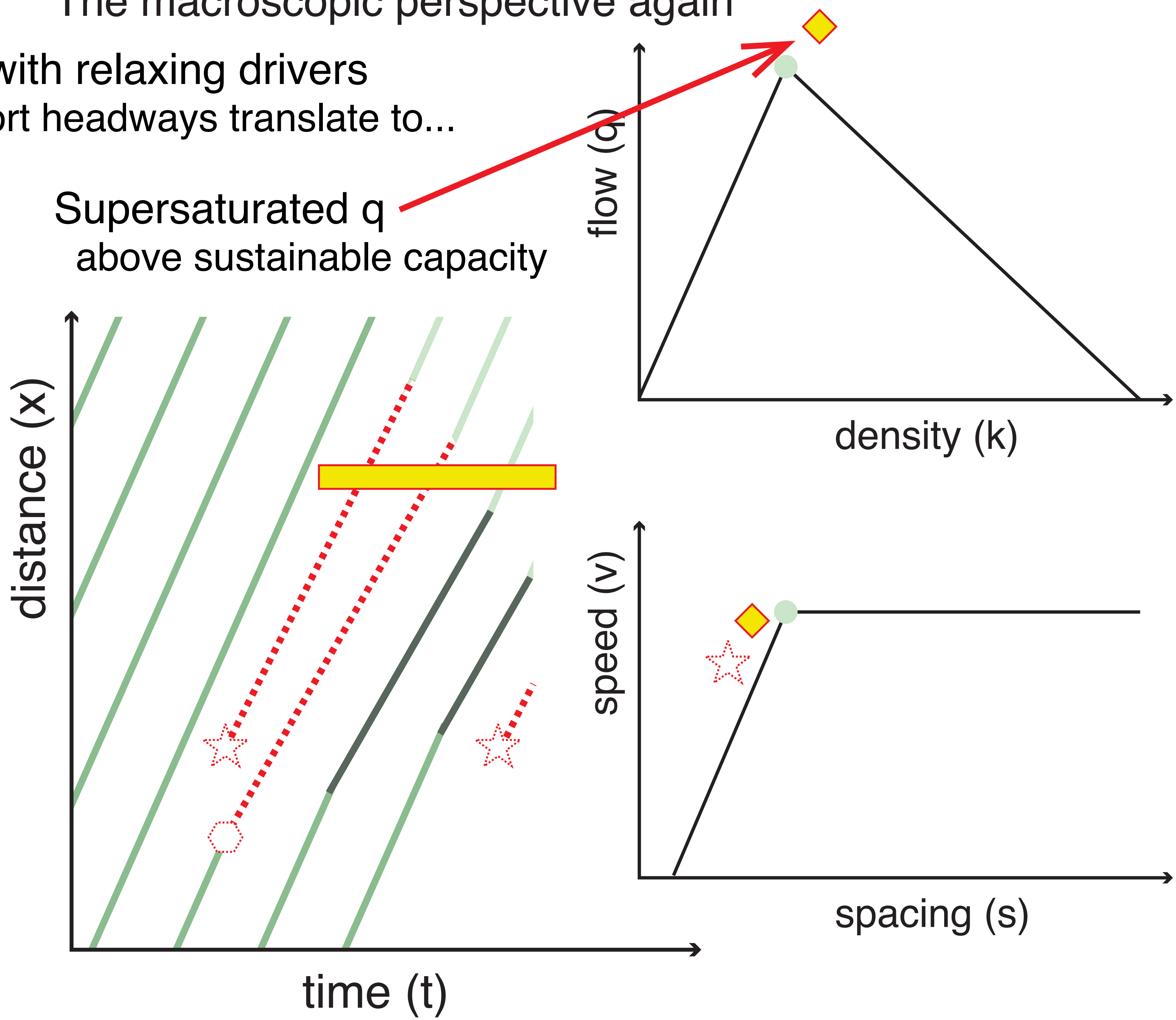
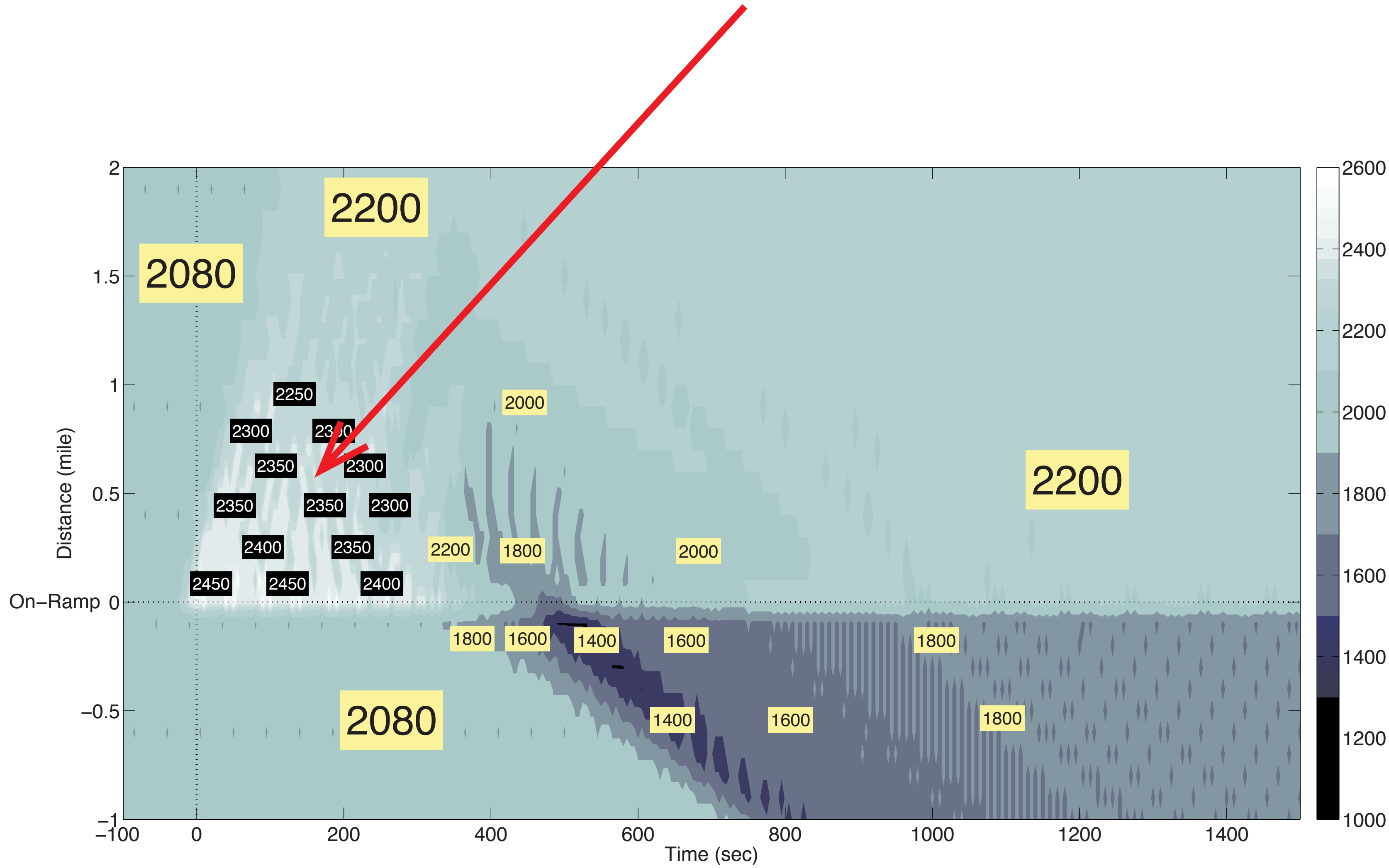
Supersaturated q
above sustainable capacity



An on-ramp bottleneck

The macroscopic perspective again

Initial queue formation characterized by supersaturated flows downstream of on-ramp, i.e., q > 2200 vph



An on-ramp bottleneck

The macroscopic perspective again

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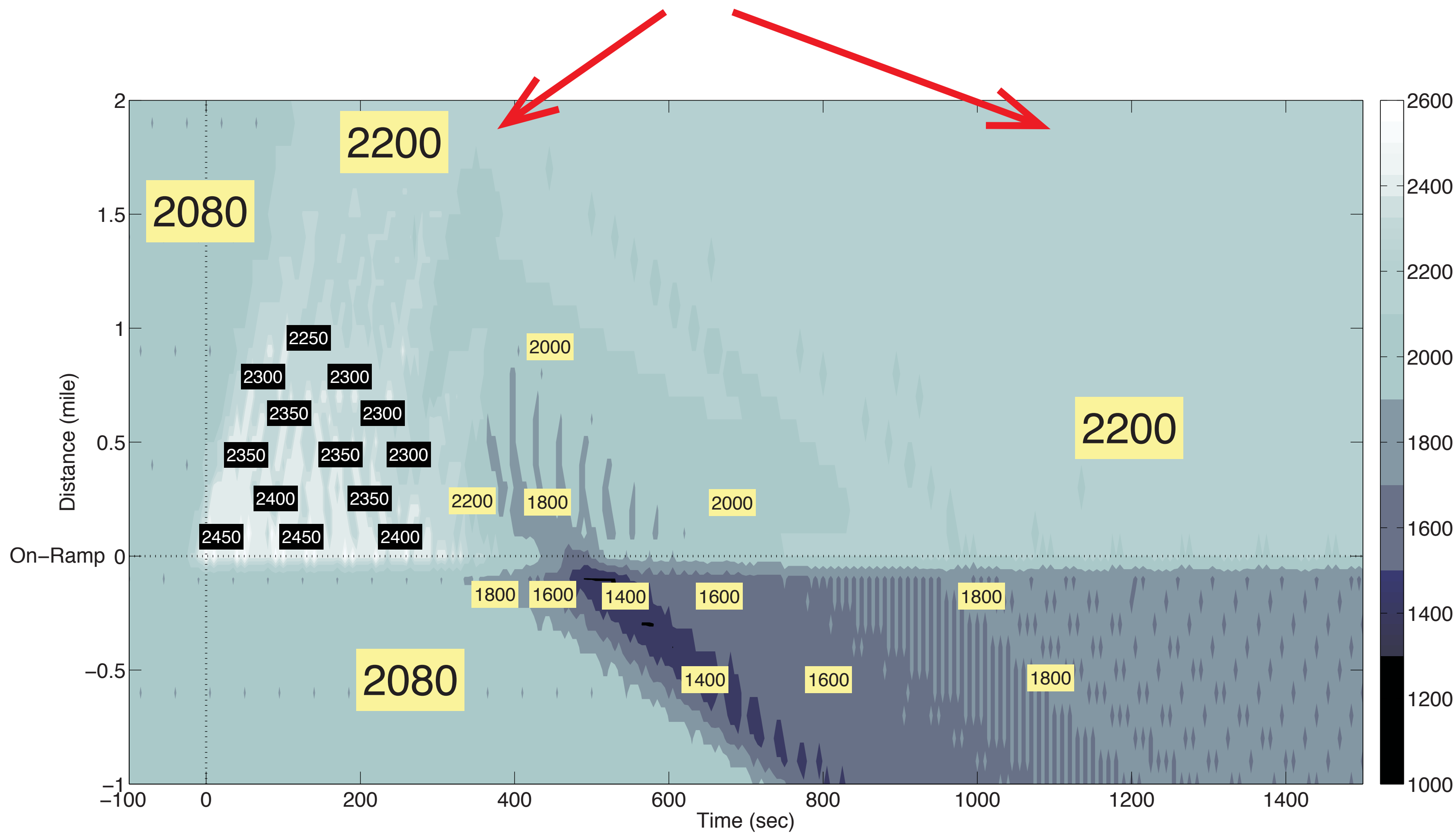
Far downstream of the on-ramp q never exceeds capacity, 2200 vph



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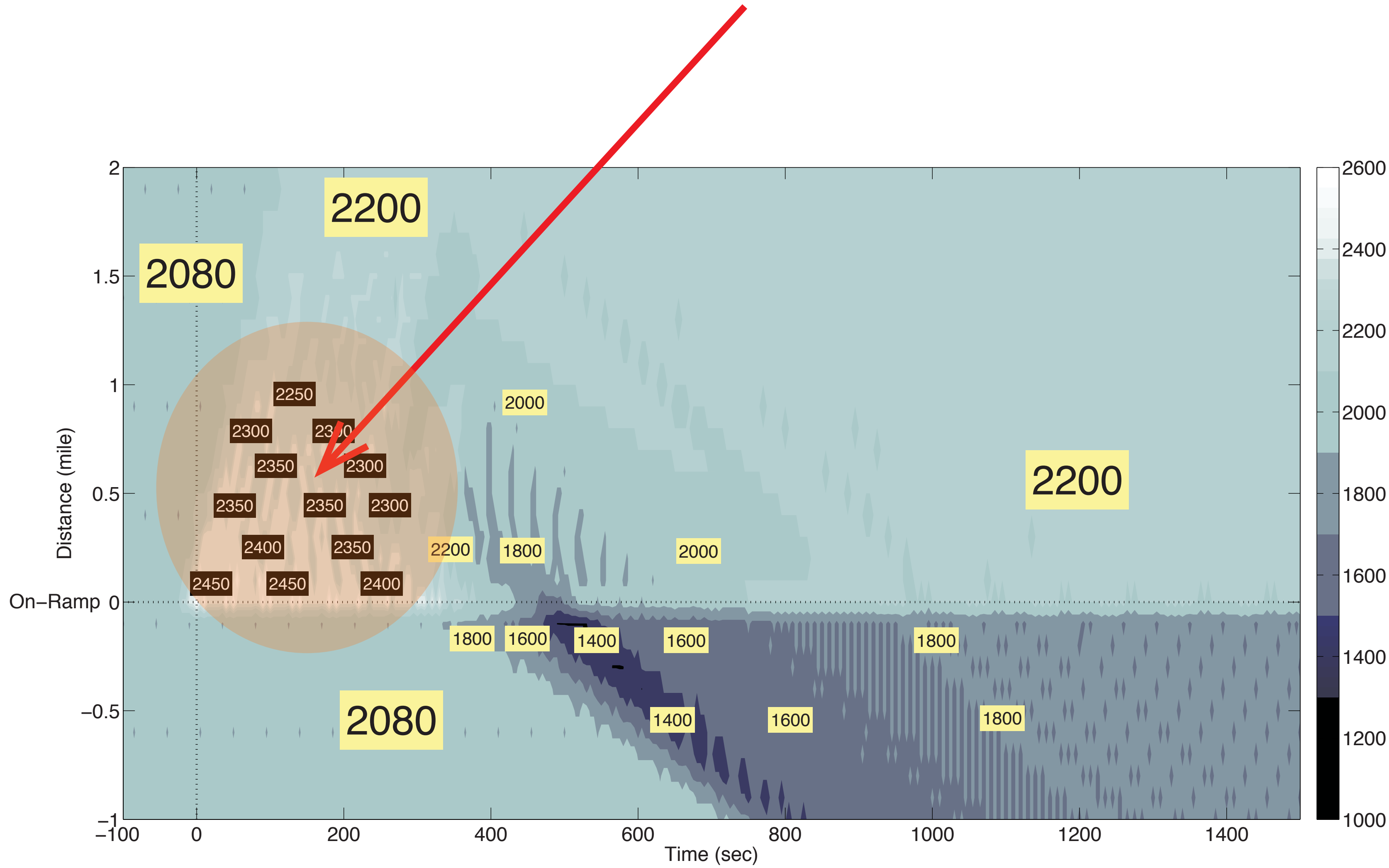
The macroscopic perspective again

We call this the “loading period” because the q over capacity will be stored somewhere further downstream, loading up the segment

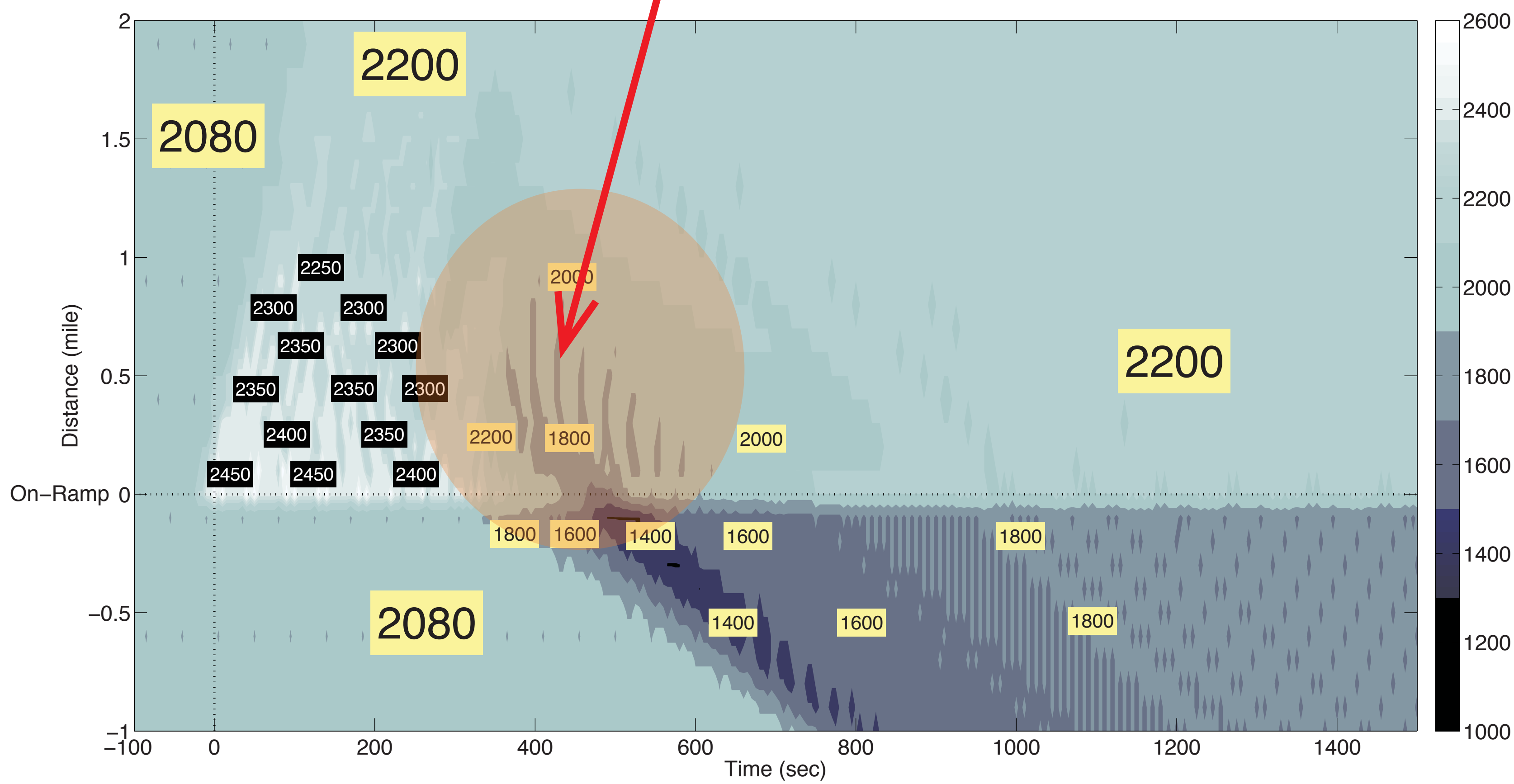


An on-ramp bottleneck

The macroscopic perspective again

We call this the "loading period" because the q over capacity will be stored somewhere further downstream, loading up the segment

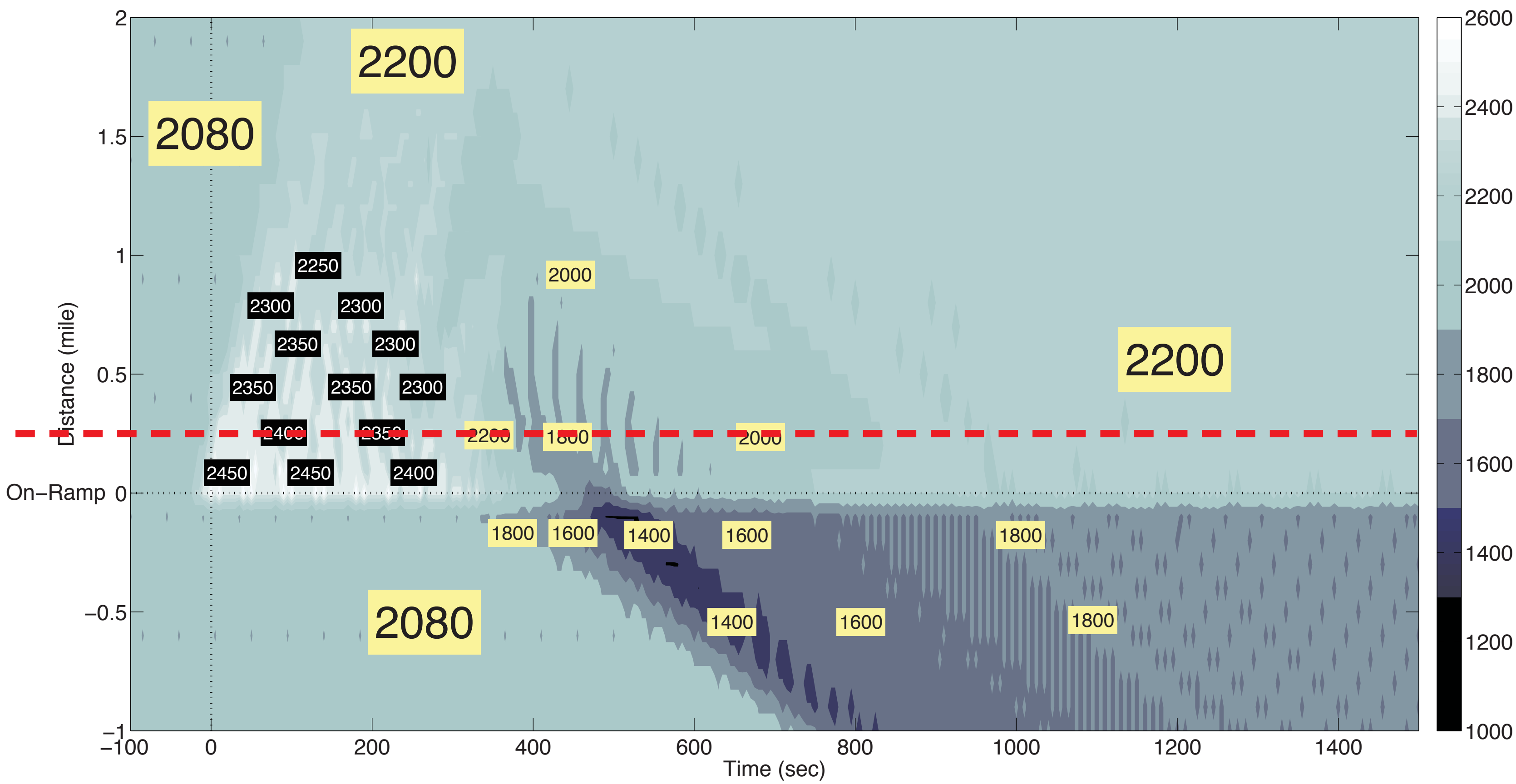
We call this the "settling period" because some of the stored vehicles discharge and consume capacity that would otherwise serve the on-ramp



An on-ramp bottleneck

But what would an empirical study see?

Place a detector at 0.2 mi and look at the measurements...



An on-ramp bottleneck

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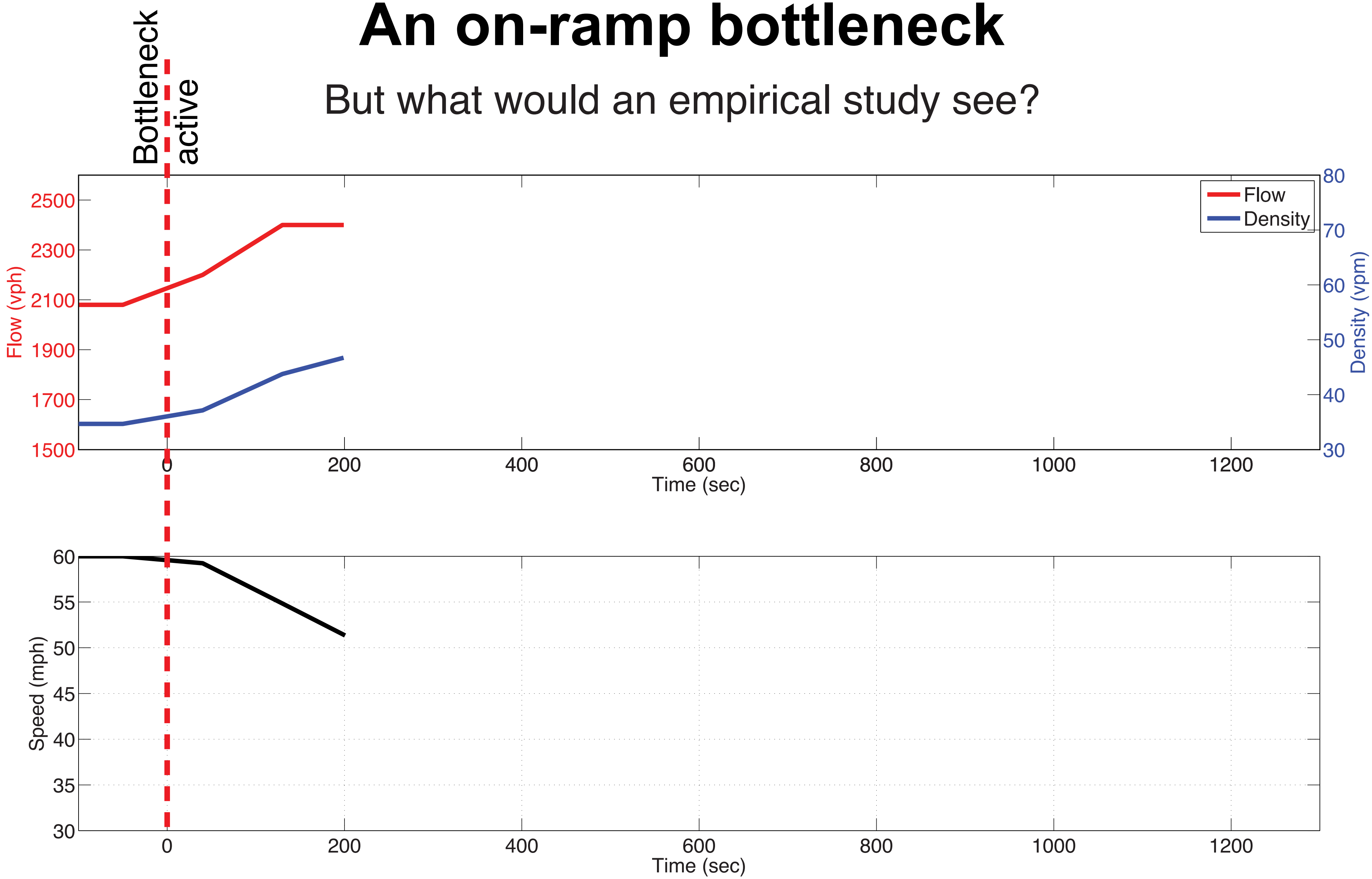

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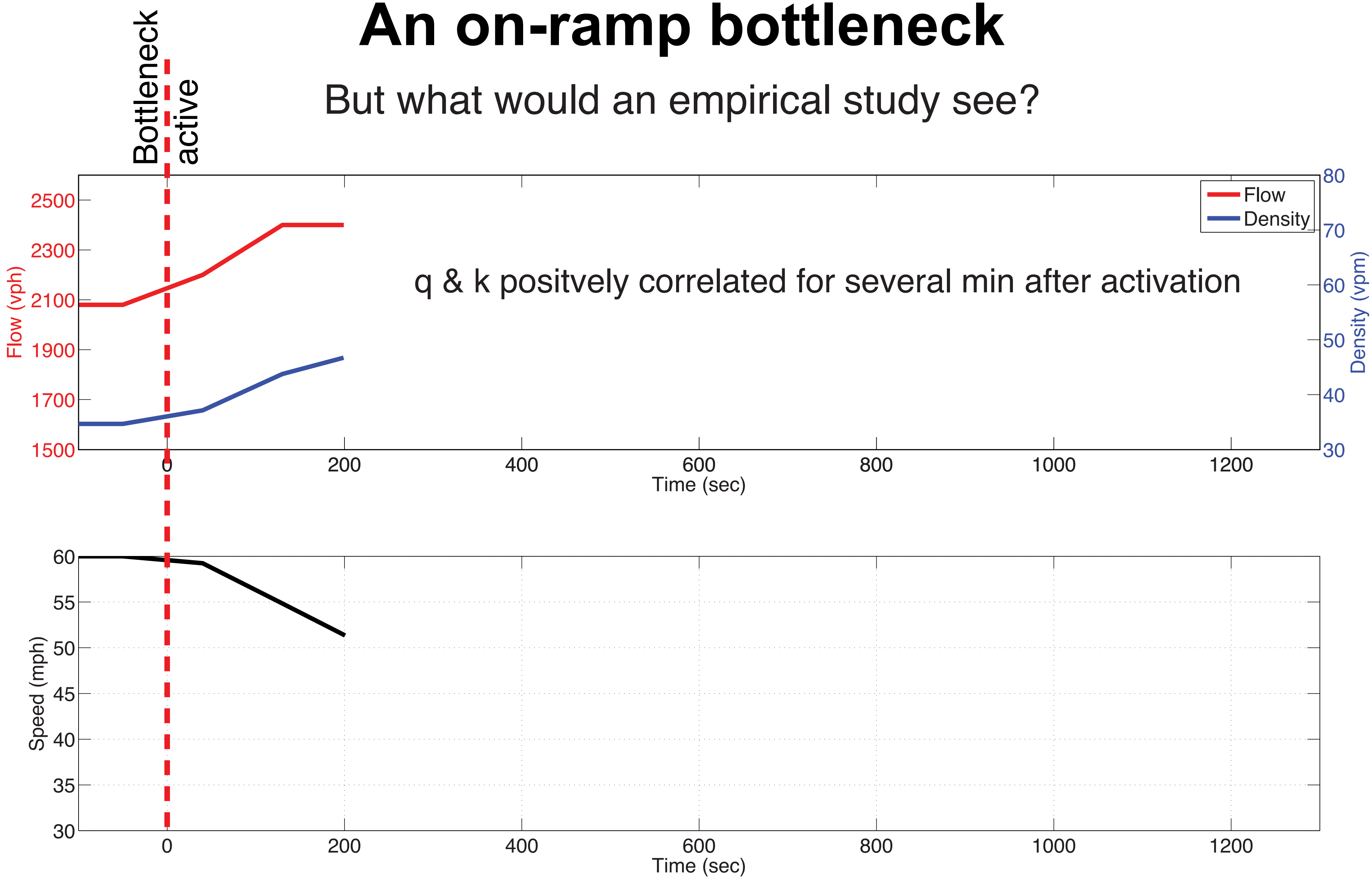

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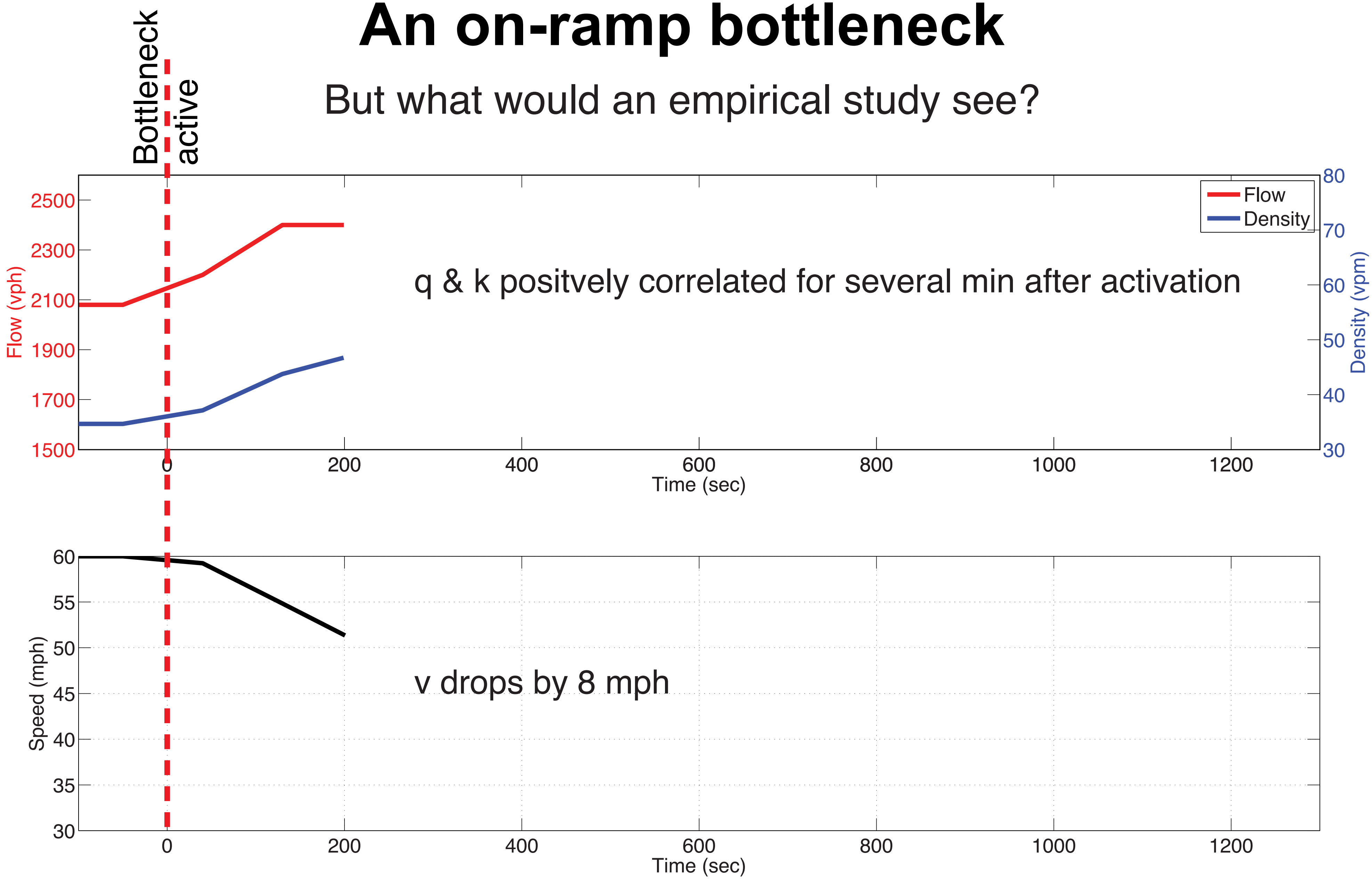

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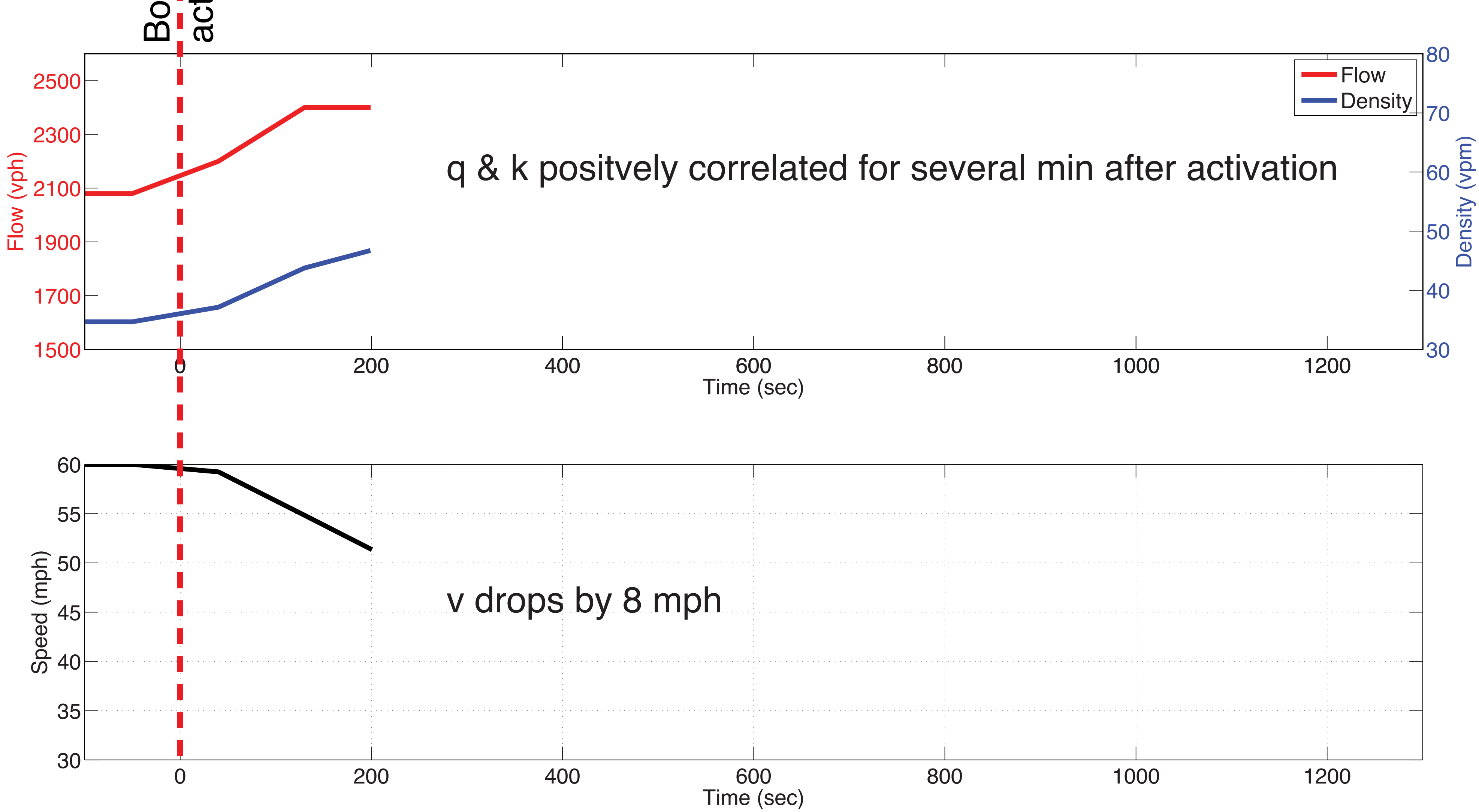

If we did not already know that q > capacity
we would not know that the bottleneck was active

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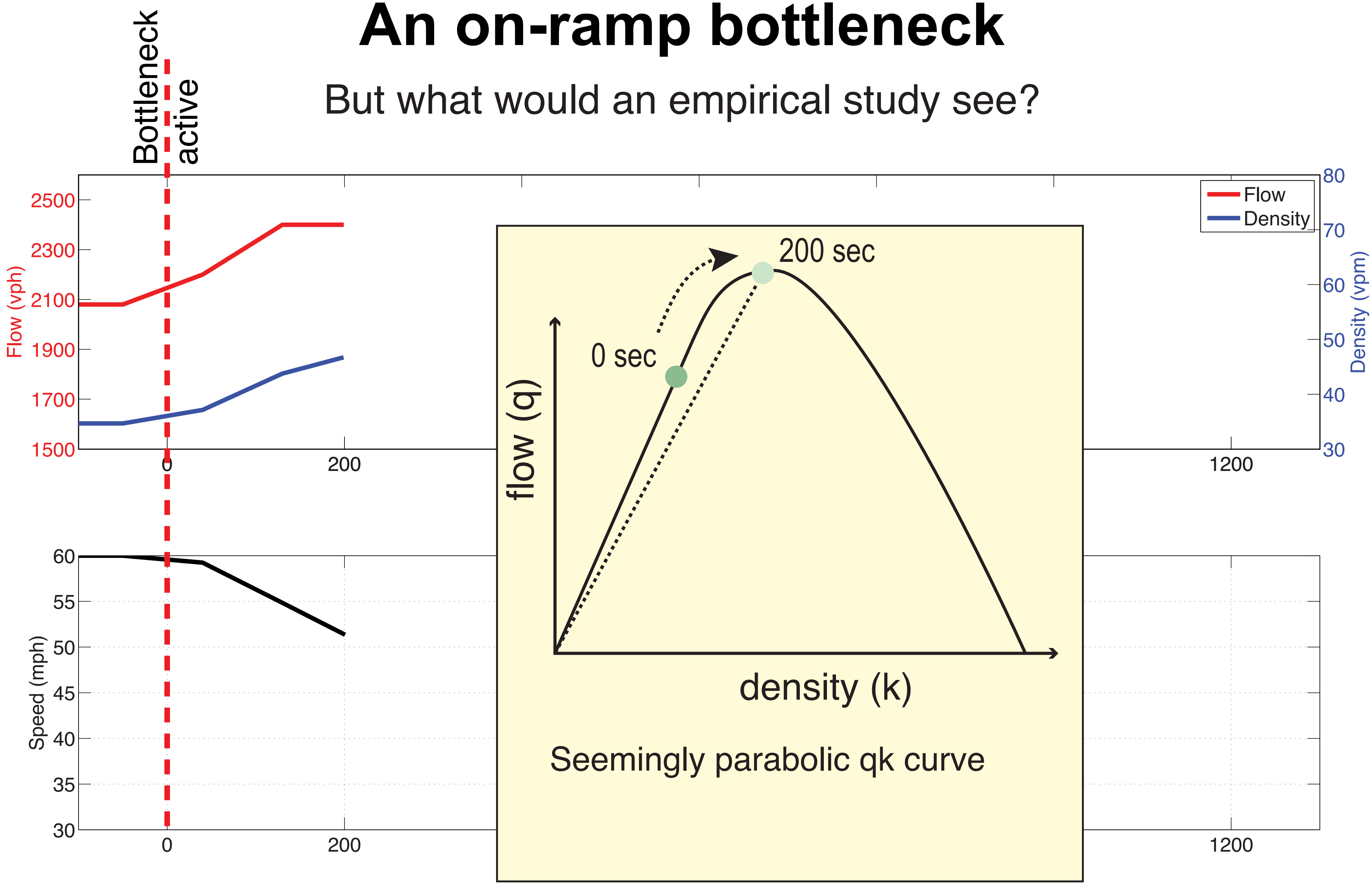

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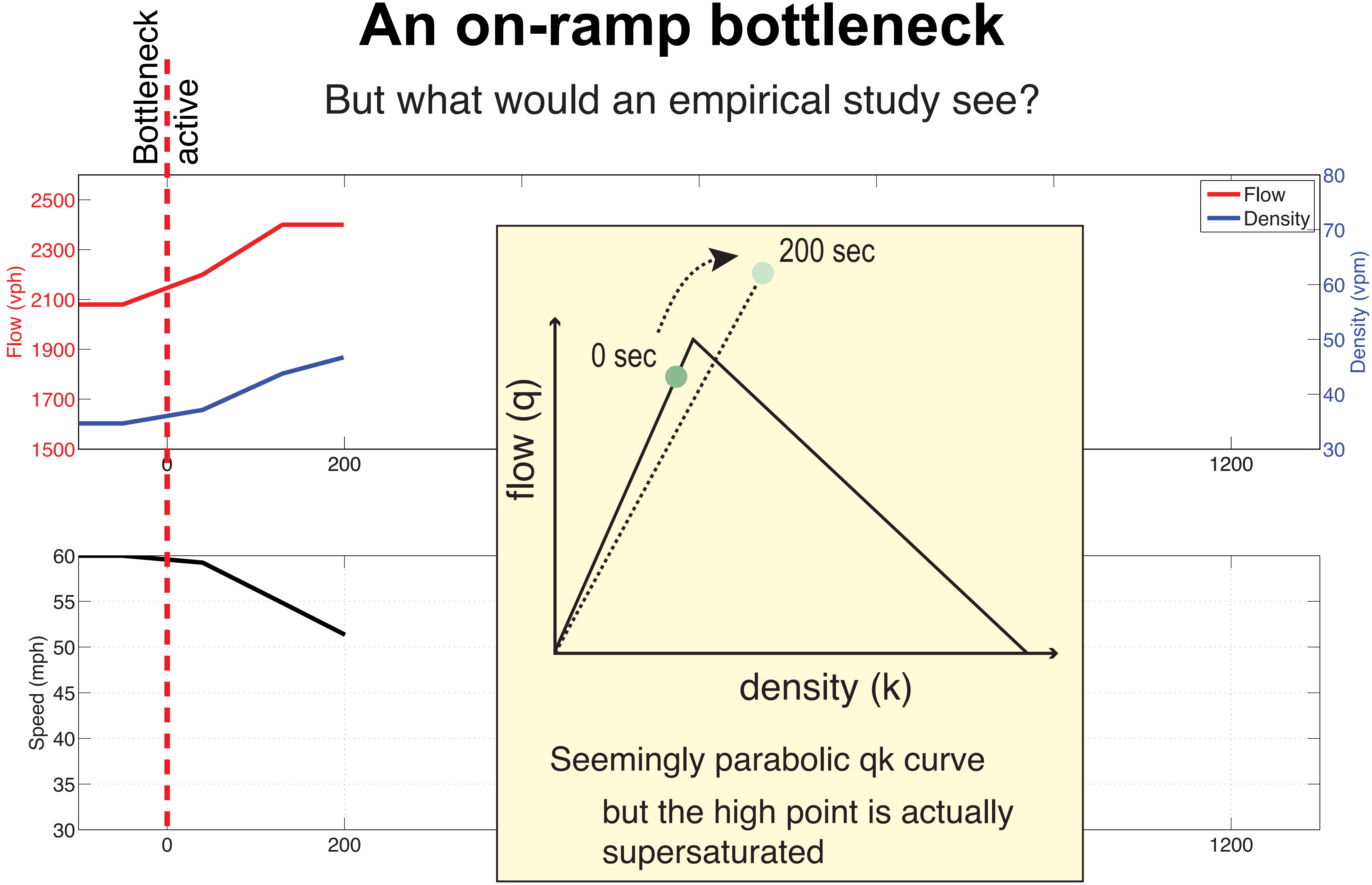

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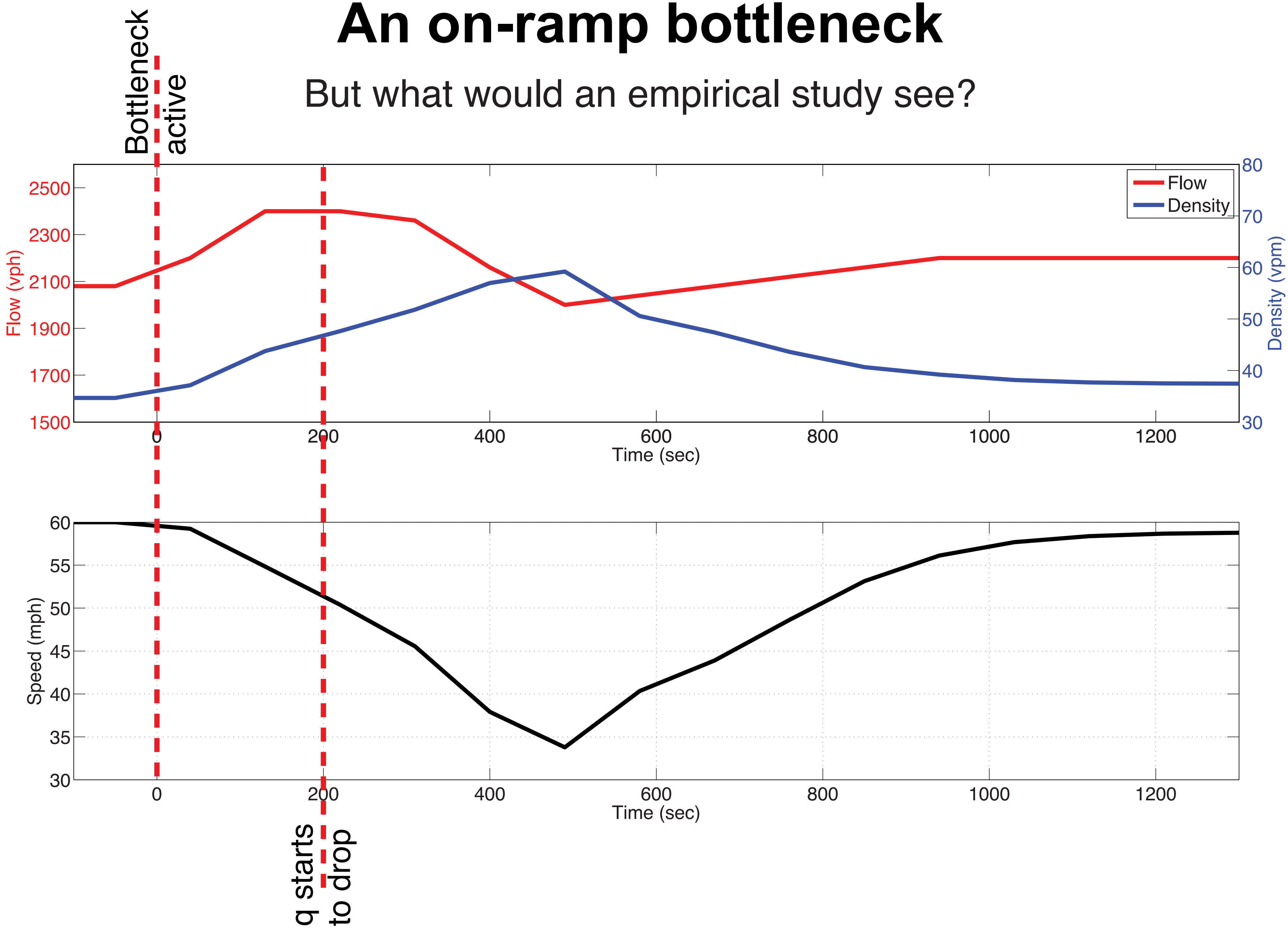

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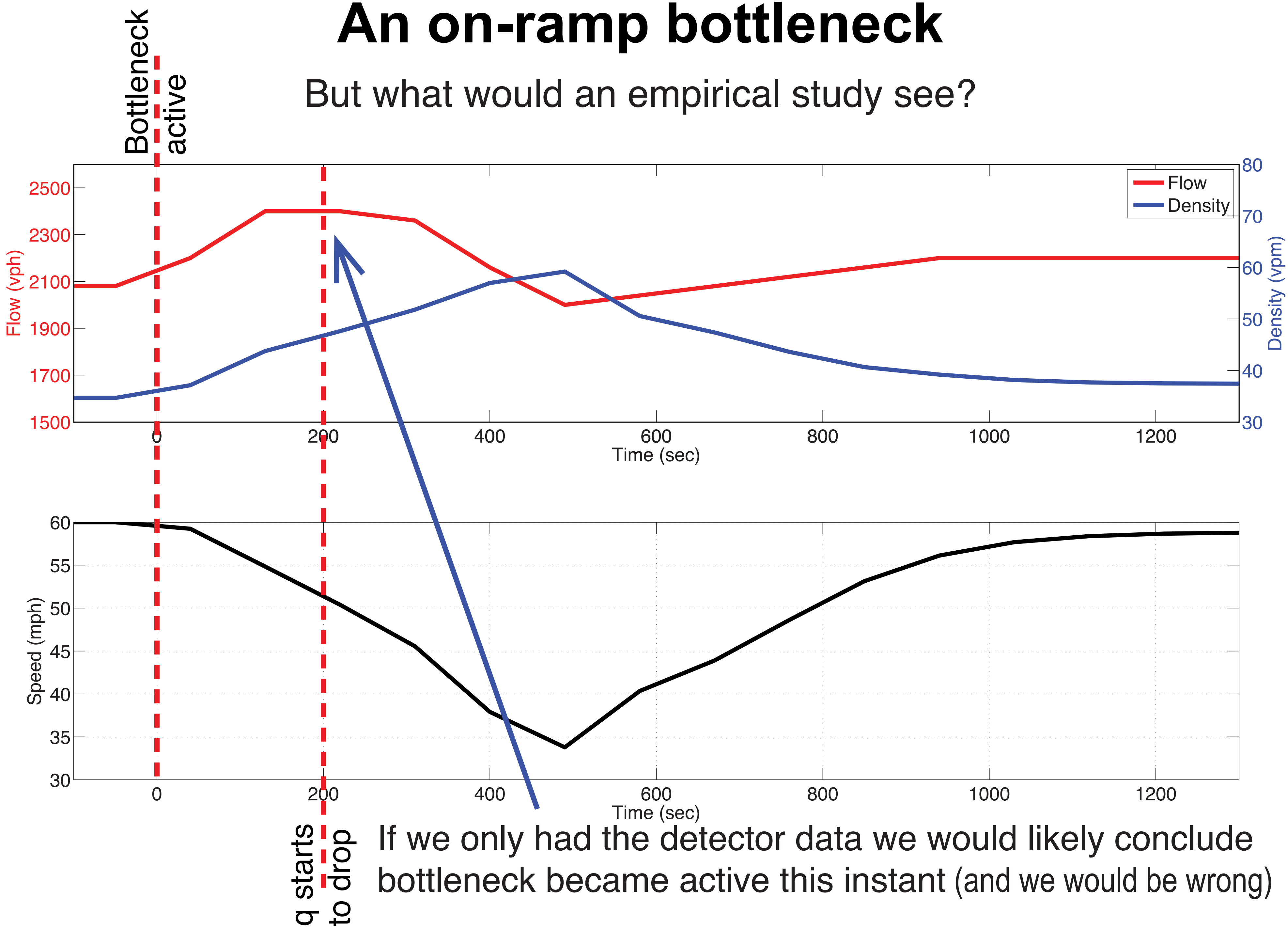

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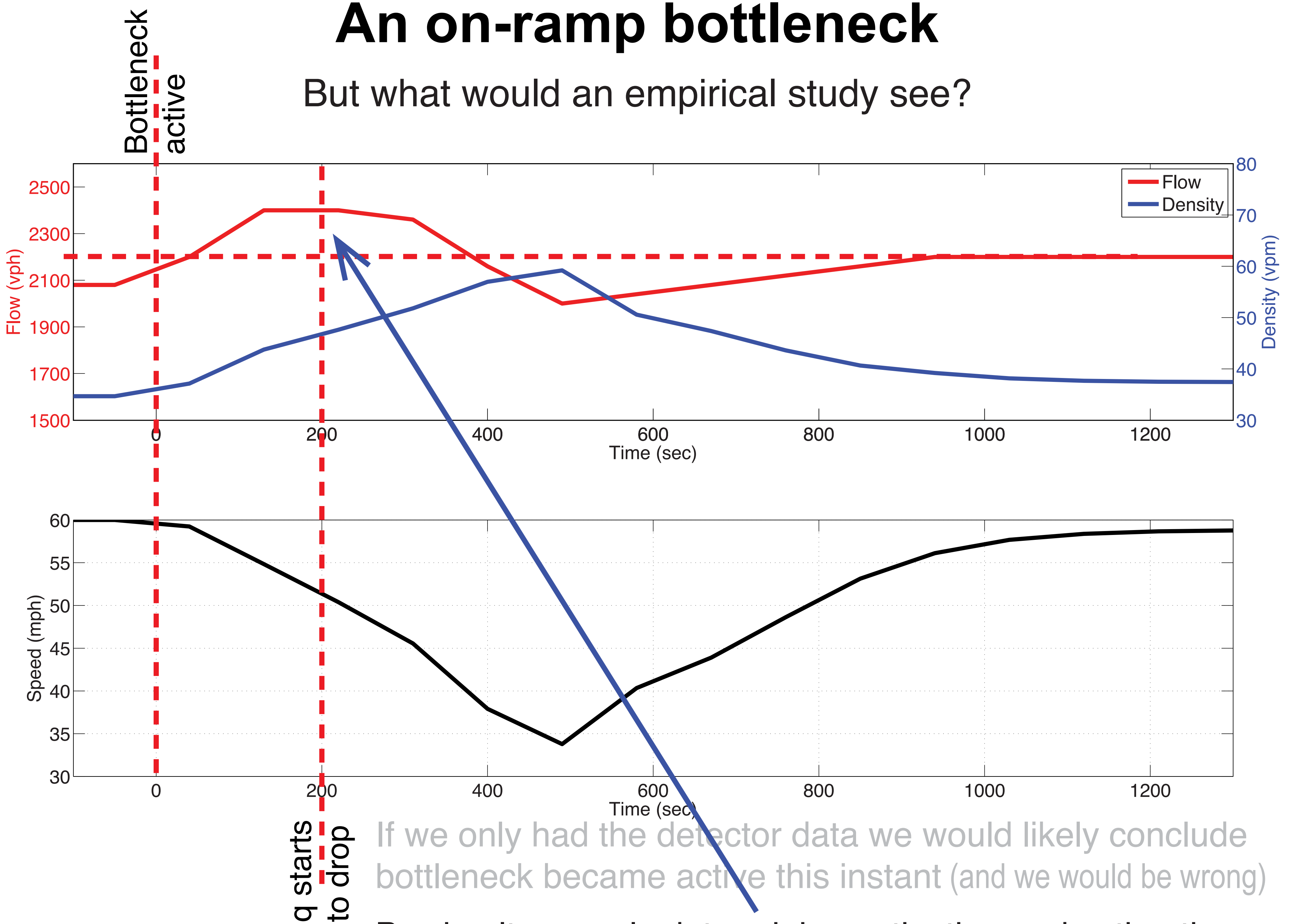

If we only had the detector data we would likely conclude bottleneck became active this instant (and we would be wrong)

By simultaneously determining activation and estimating capacity, we would overestimate capacity by 200 vph

An on-ramp bottleneck

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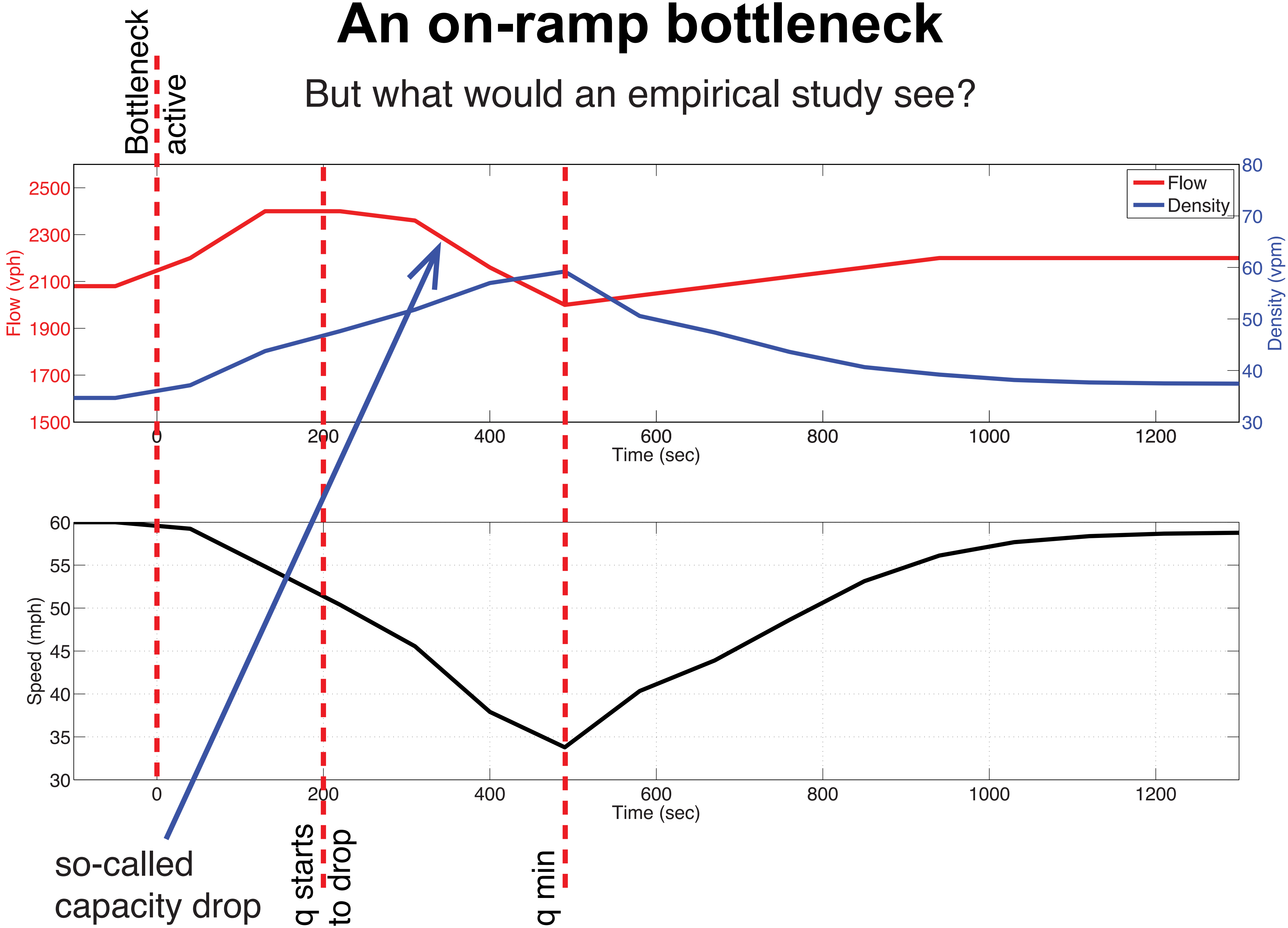

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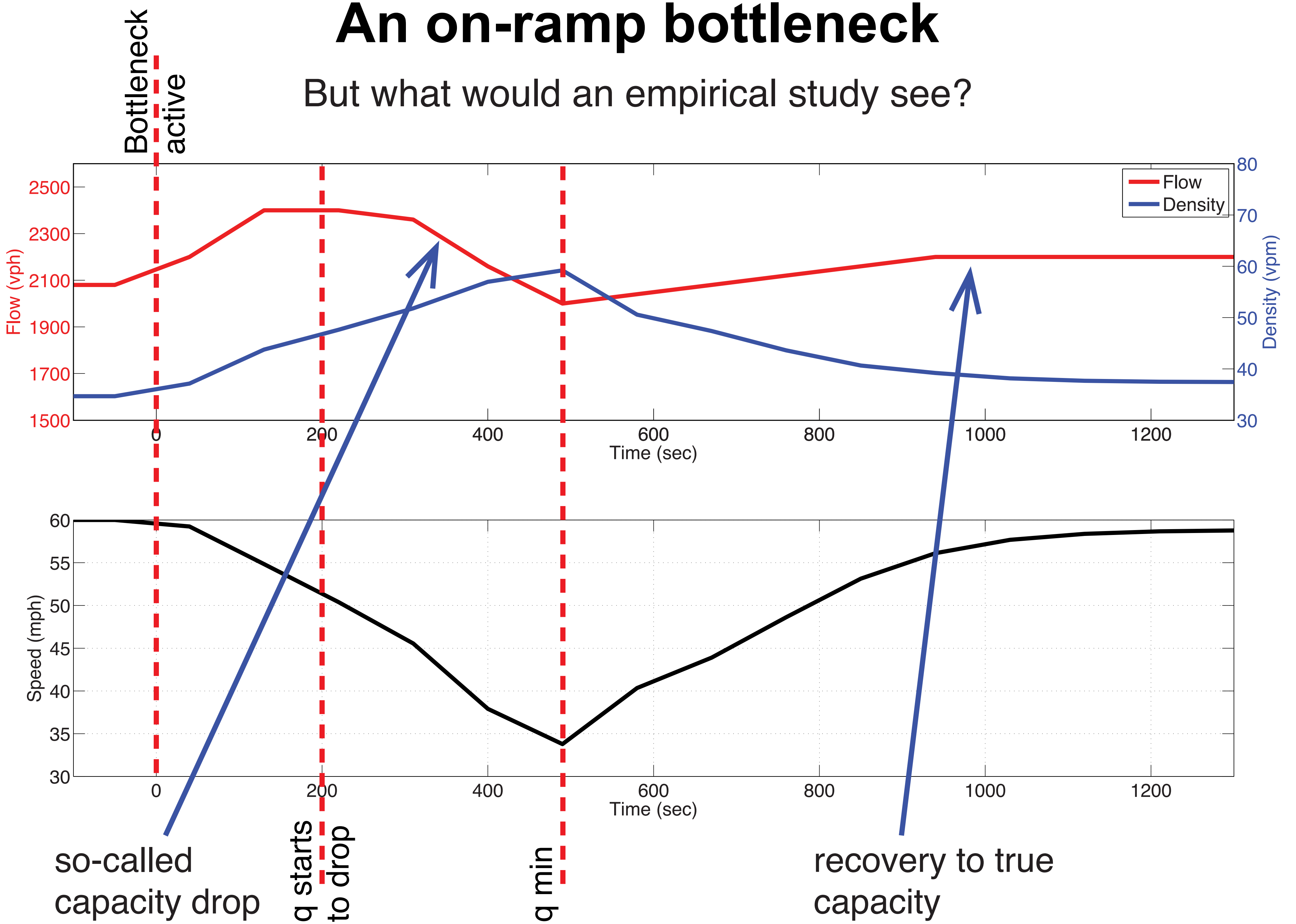

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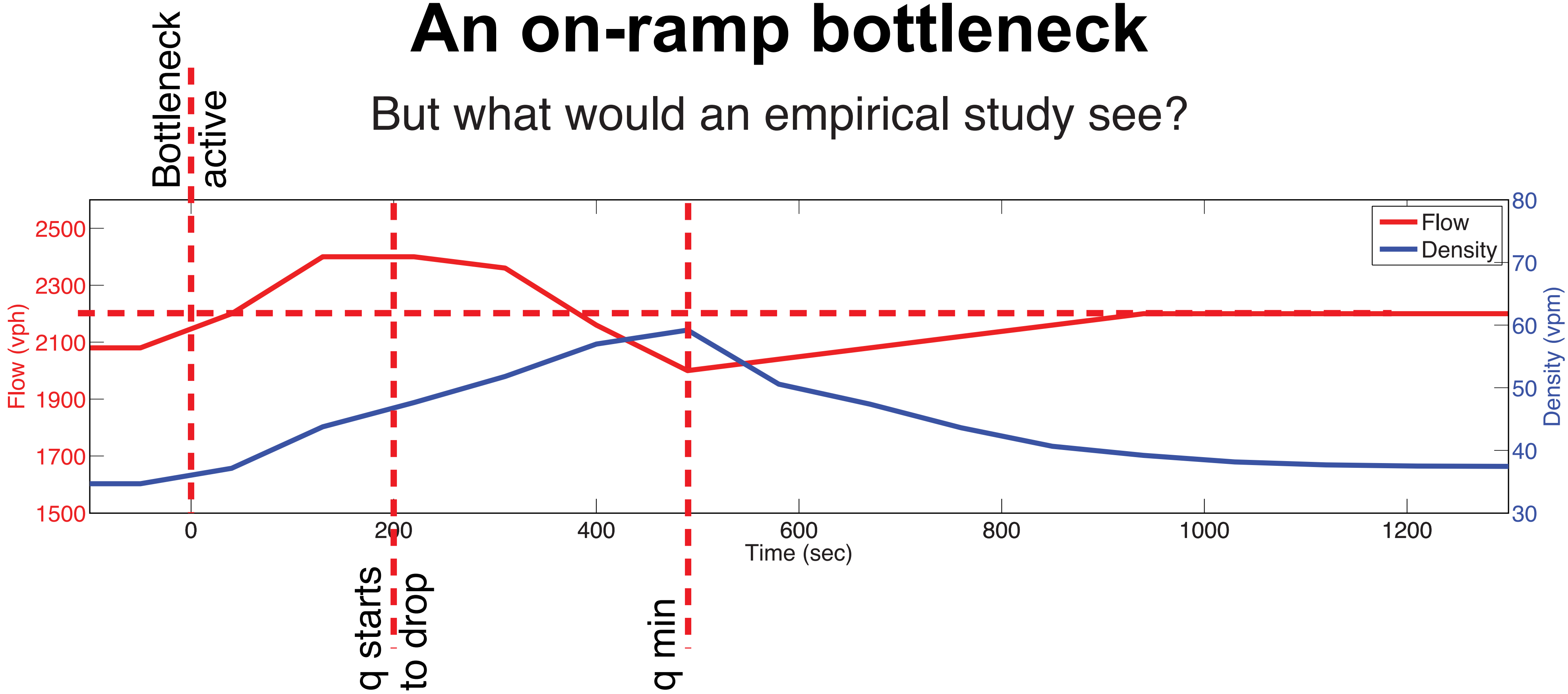

An empirical study would see q drop around 200 sec, take the highest throughput prior to that point and (erroneously) call it capacity

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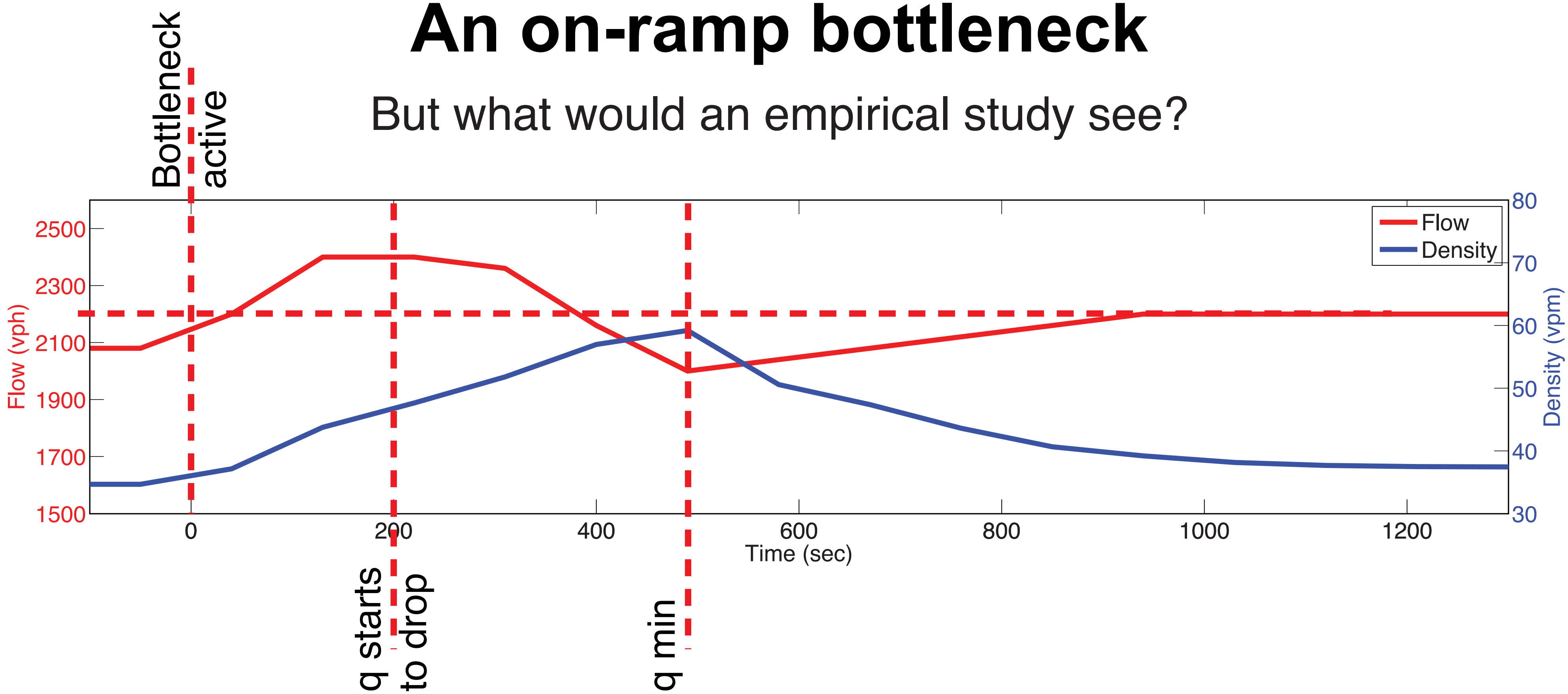
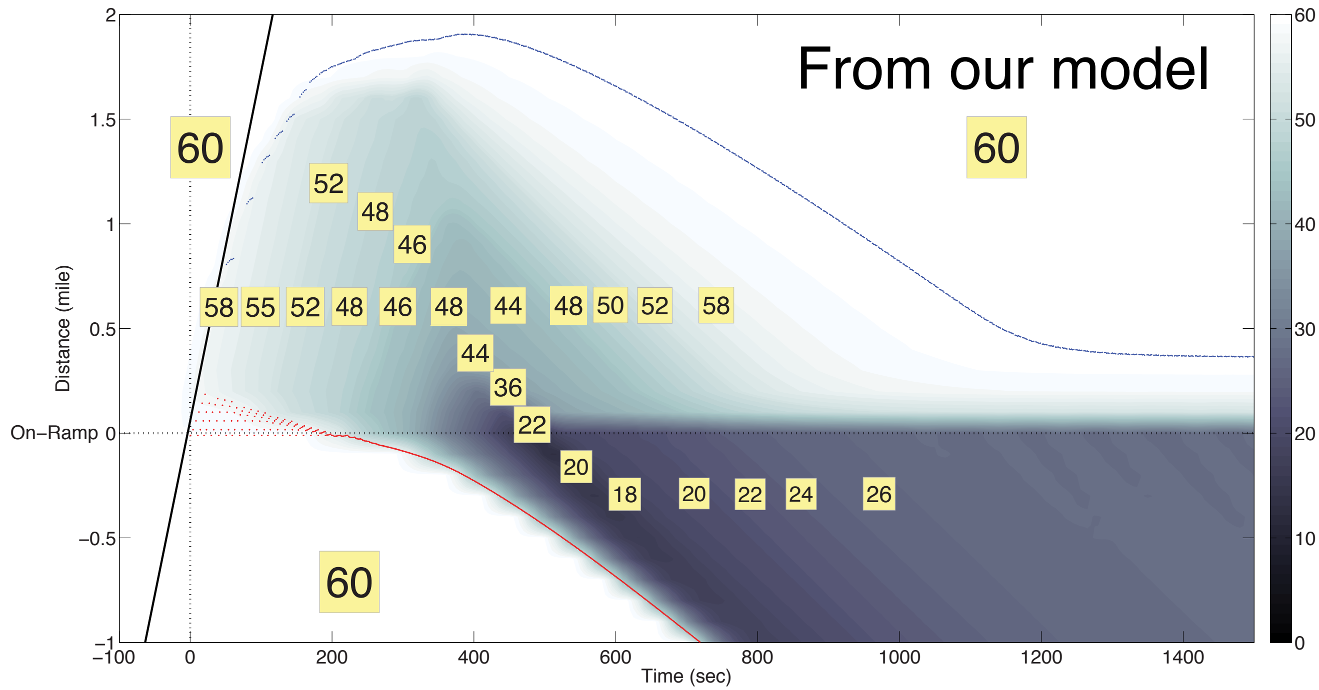
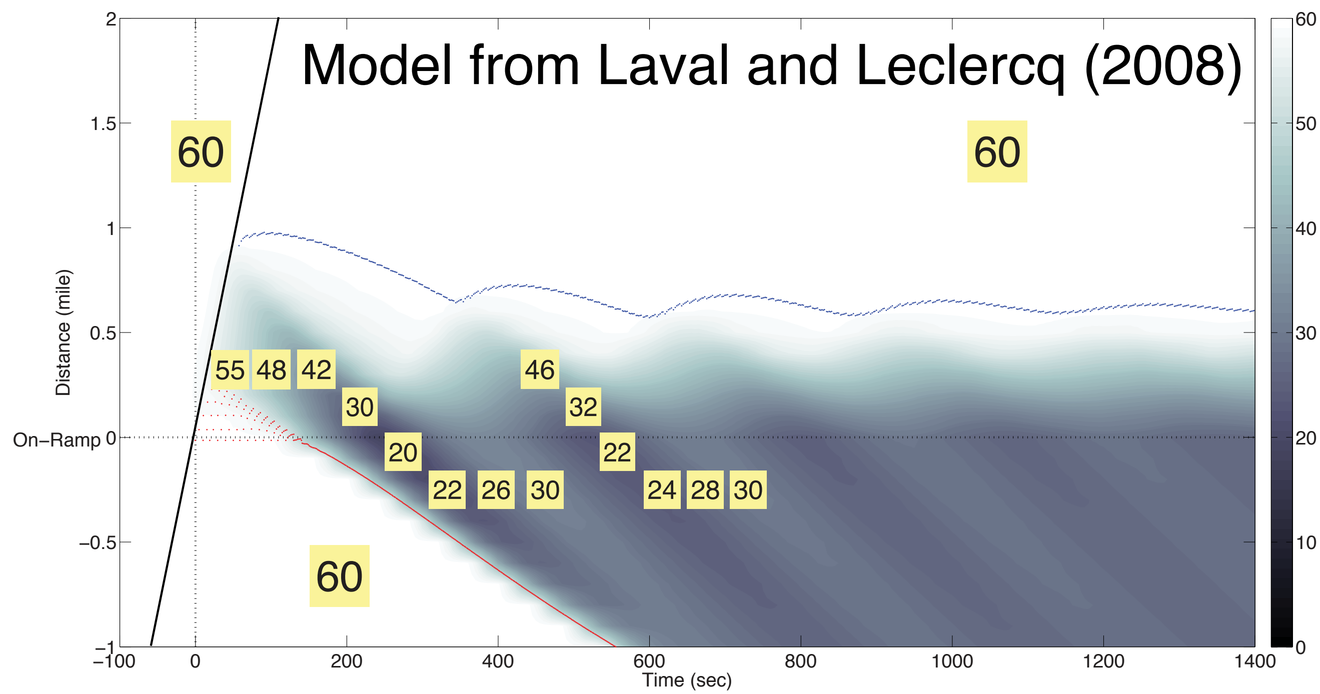


An empirical study would see q drop around 200 sec, take the highest throughput prior to that point and (erroneously) call it capacity

This drop would occur several minutes after the bottleneck had actually become active, misslabeling the intervening period as being unqueued

An on-ramp bottleneck





An on-ramp bottleneck

Conclusions

The point bottleneck model is too simple to capture the entire bottleneck process

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The bottleneck process occurs over an extended distance

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If one fails to recognize the fact that the bottleneck is already active and flows supersaturated due to driver relaxation:

- -Overestimate bottleneck capacity
- -Record the activation time too late

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The bottleneck process occurs over an extended distance

If one fails to recognize the fact that the bottleneck is already active and flows supersaturated due to driver relaxation:

- -Overestimate bottleneck capacity
- -Record the activation time too late

Instead of q dropping "from capacity", we see q drop "to capacity" from supersaturation

An on-ramp bottleneck

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We suspect these confounding effects have largely gone unnoticed due to ambiguity in defining exactly what is "unqueued" conditions

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We seemingly see the unqueued regime of a parabolic qk curve during the first few minutes of activation

The driver relaxation process is a confounding factor far below the resolution of conventional macroscopic data, and empirical traffic flow theory studies usually fail to account for it.

An on-ramp bottleneck

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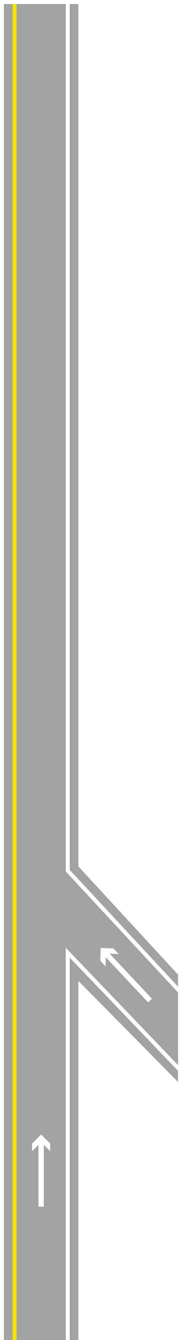
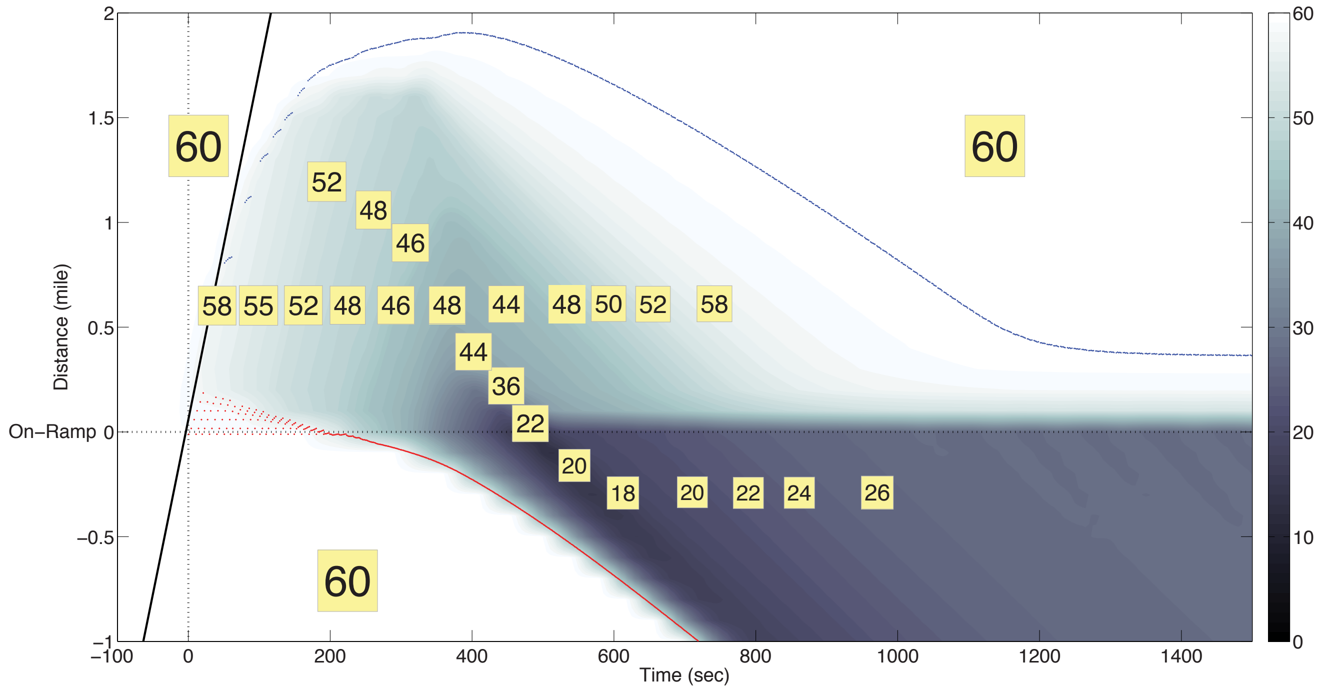
Rather we sought to highlight previously unaccounted for impacts of driver relaxation on bottleneck studies

The forthcoming paper in TR-C has been retitled:

"Driver relaxation impacts on bottleneck activation, capacity, and the fundamental relationship"

Thank you!

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22
24
26
60
60
Distance (mile)
On–Ramp
Time (sec)
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1.5
1
0.5
0
−0.5
−1
−100
0
200
400
600
800
1000
1200
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