Car-Following Behavior at Sags and its Impacts on Traffic Flow

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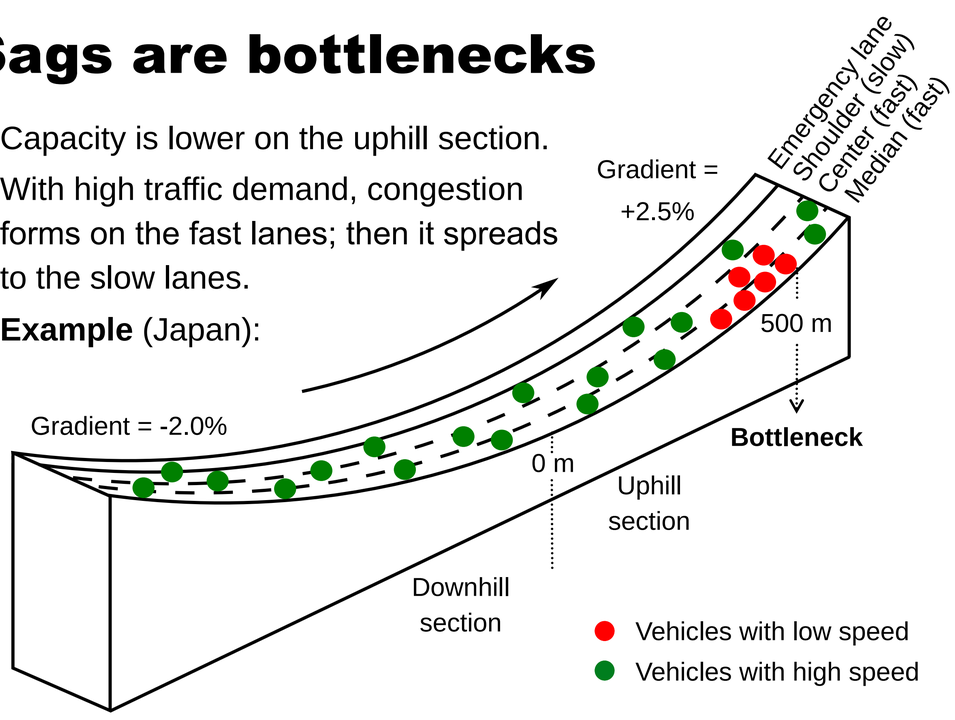
Abstract

The aim of this paper is to identify the main factor triggering the formation of congestion at sags. To this end, we analyze vehicle trajectories collected by means of video cameras on a sag in Japan. Our findings indicate that, at similar speeds, drivers tend to keep longer headways on the uphill section than on the downhill section, reducing lane capacity on the uphill section. We also found that, in almost all cases, the formation and growth of traffic flow disturbances on the uphill section is caused by changes in car-following behavior. Disruptive lane changes are a less frequent cause. We conclude that capacity decreases at sags primarily as a result of the changes in car-following behavior that occur on the uphill section.

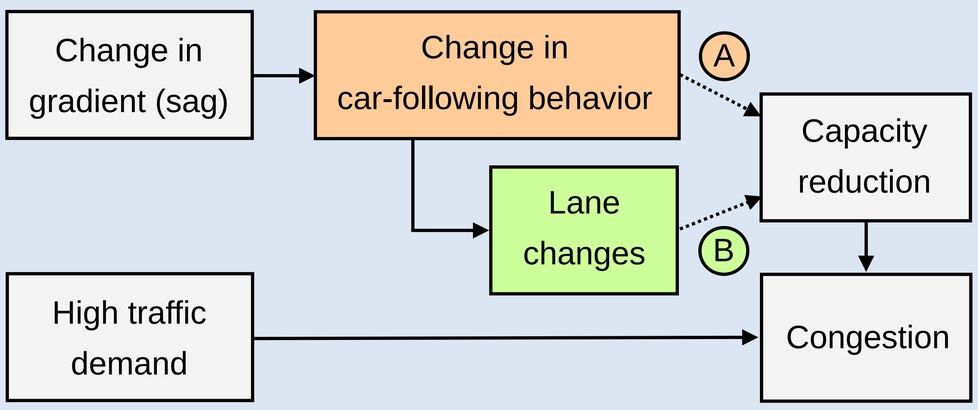
Sags are bottlenecks

- Capacity is lower on the uphill section.
- With high traffic demand, congestion forms on the fast lanes; then it spreads to the slow lanes.
- **Example** (Japan):



Objective

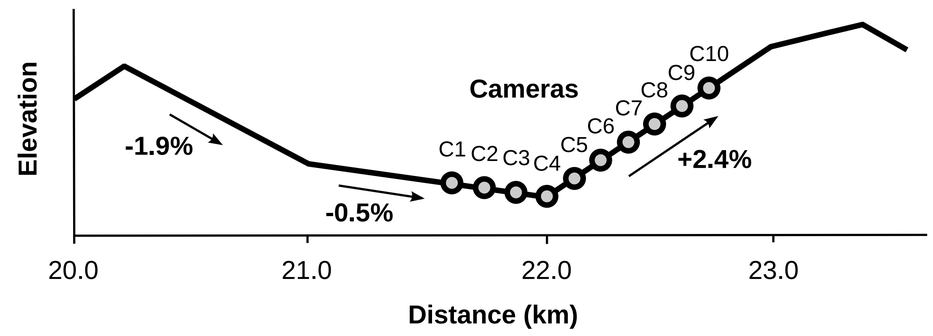
Dominant factor: (A) or (B) ?



Data characteristics

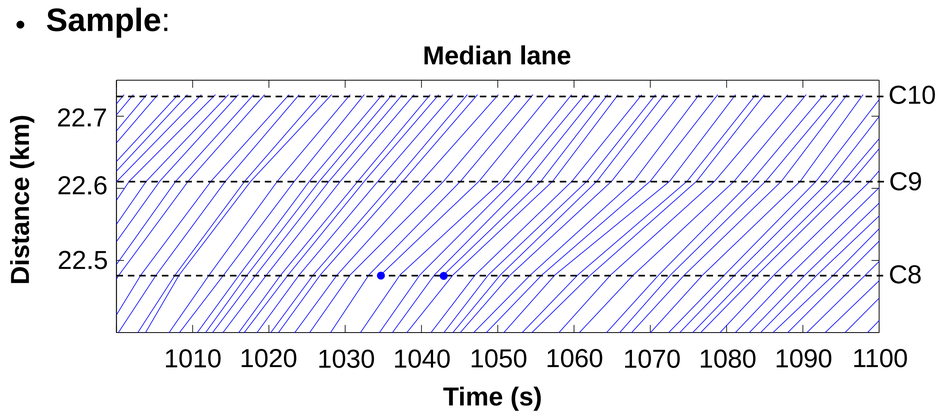
Study site

- Yamato sag, Tomei Expressway (near Tokyo, Japan).
- 3 lanes for traffic: median, center and shoulder lanes.
- 10 video cameras: located 120 m apart.

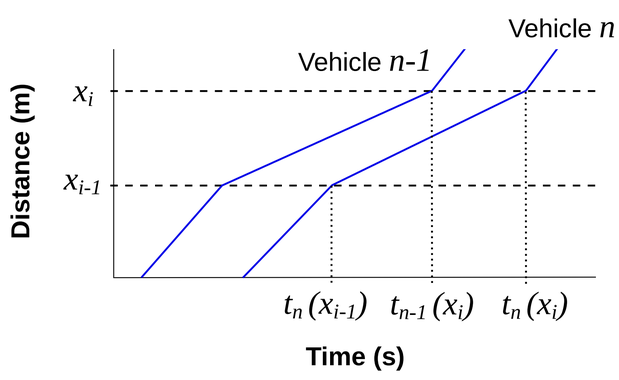


Vehicle trajectories

- Vehicle trajectories obtained from video recordings: one passing time and lane per vehicle per camera location
- Resolution: 120 m, 4-12 seconds
- Data set: 2284 vehicle trajectories (including lane changes •) during the morning peak hour
- **Sample**:



Microscopic flow variables



Headway

$$h_{n,i} = t_n(x_i) - t_{n-1}(x_i)$$

Speed

$$v_{n,i} = \frac{x_i - x_{i-1}}{t_n(x_i) - t_n(x_{i-1})}$$

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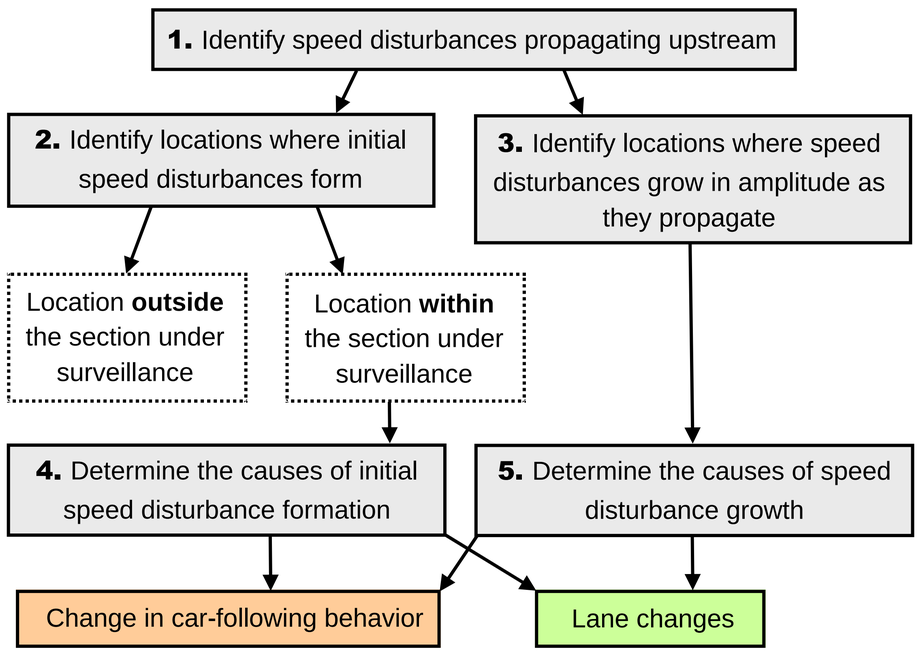
Data analysis methods

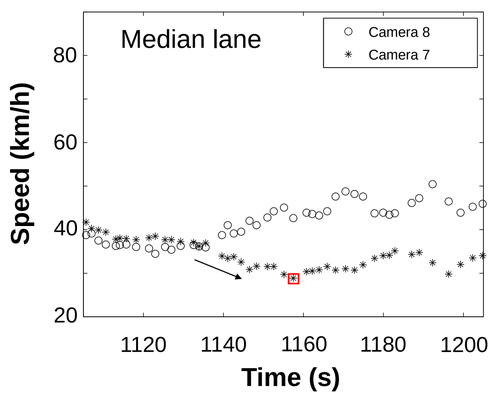
1. Average car-following behavior

- Analysis of the relation between time headway (h_i) and vehicle speed (v_i) at downhill and uphill camera locations.

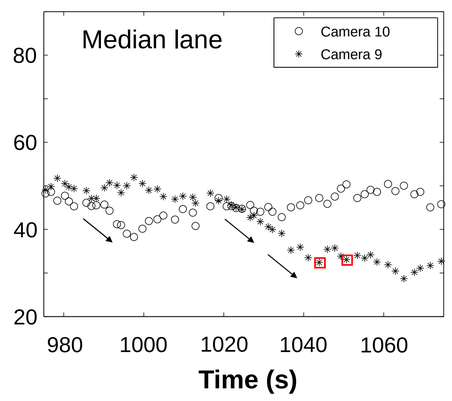
2. Disturbance formation and growth



Example: formation of initial speed disturbance

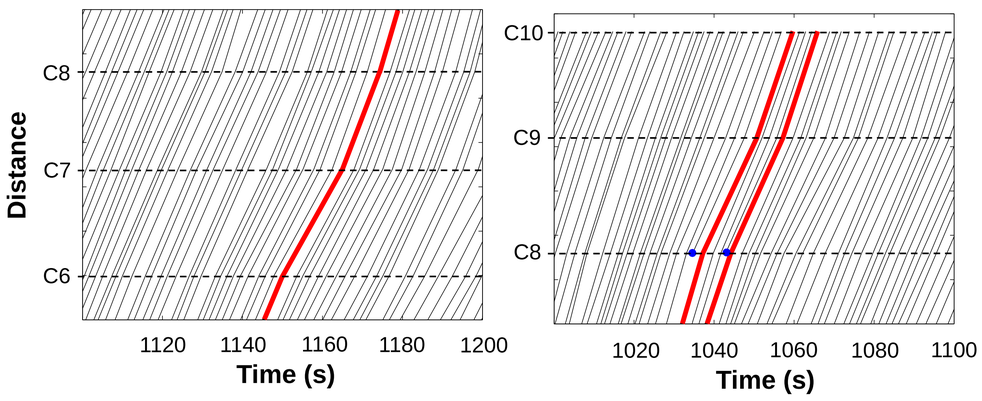


Example: growth of a speed disturbance



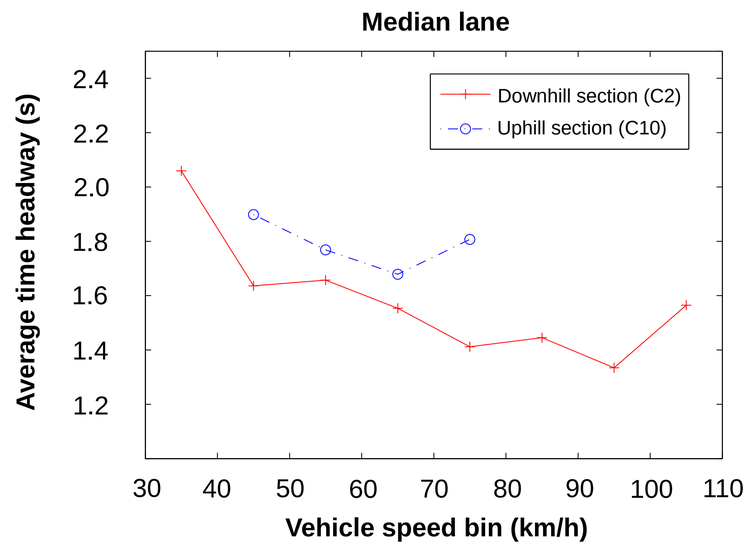
Cause: change in car-following behavior

Cause: lane changes (•)



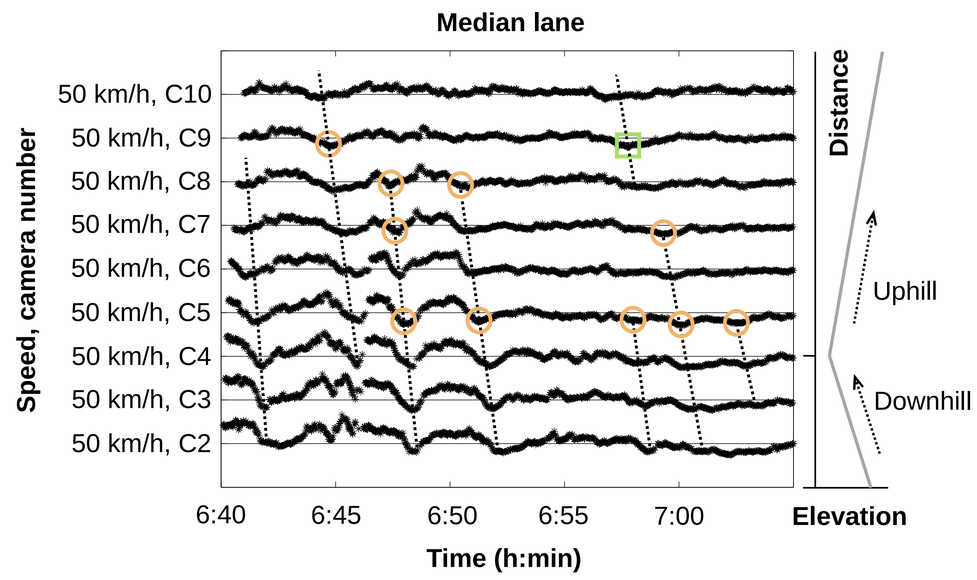
Finding 1

- Drivers tend to keep longer time headways on the uphill section than on the downhill section at similar speeds.
- This reduces lane capacity on the uphill section.



Finding 2

- The most frequent cause of speed disturbance formation and growth is related to changes in car-following behavior on the uphill section (90% of cases).



Speed disturbances propagating upstream: .....
Cause of speed disturbance formation / growth: ○ Changes in car-following behavior
□ Lane changes

Conclusions

A >> B

- When vehicles reach the uphill section, average car-following behavior changes, which reduces lane capacity.
- This change in car-following behavior is the dominant factor reducing the capacity of the fast lanes on the uphill section (lane changes are a less important factor).

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