Mainstream traffic flow control at sags

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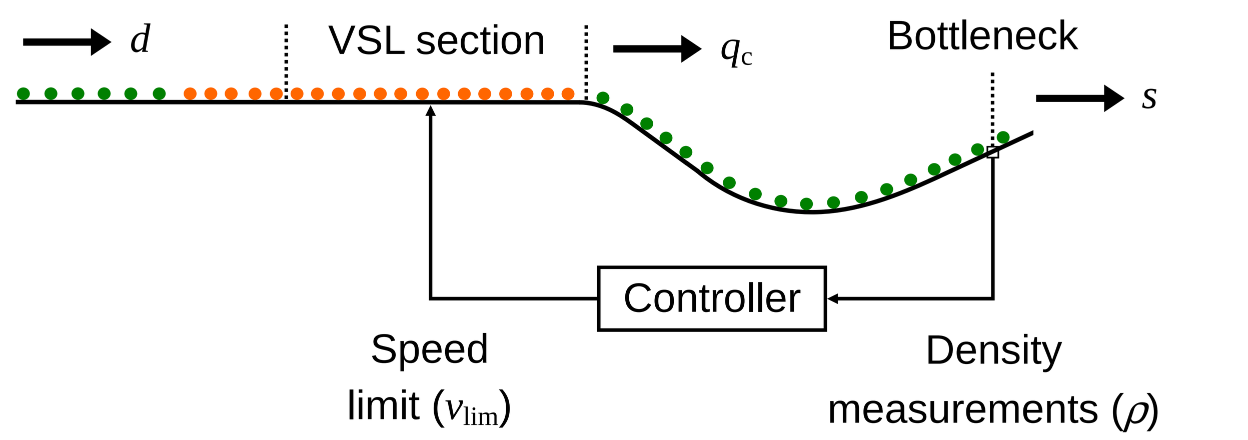
Abstract

We present a new control strategy that aims to reduce total delay at sags. The strategy is based on the concept of mainstream traffic flow control. The traffic density at the bottleneck area is regulated in order to keep it slightly below the critical density, hence preventing traffic from breaking down while maximizing outflow. Density is regulated by means of a variable speed limit section that regulates the inflow to the bottleneck. Speed limits are set based on a proportional feedback control law. We evaluate the effectiveness of the control strategy by means of a case study using microscopic traffic simulation. The results show a significant increase in bottleneck outflow, particularly during periods of high demand, which considerably reduces delay.

Control strategy

Regulate the inflow to the bottleneck ($c^s_{\text{cong}} < q_c < c^s_{\text{free}}$), so that the bottleneck does not activate:

- Exit flow (s) = VSL section outflow (q_c) > discharge capacity (c^s_{cong})
- VSL section outflow (q_c) < demand (d)



Control law

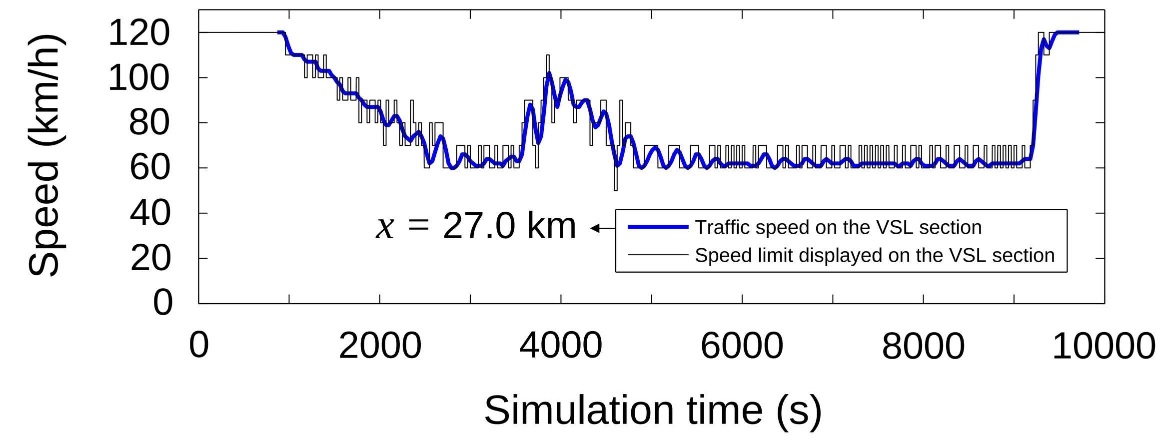
Proportional feedback:

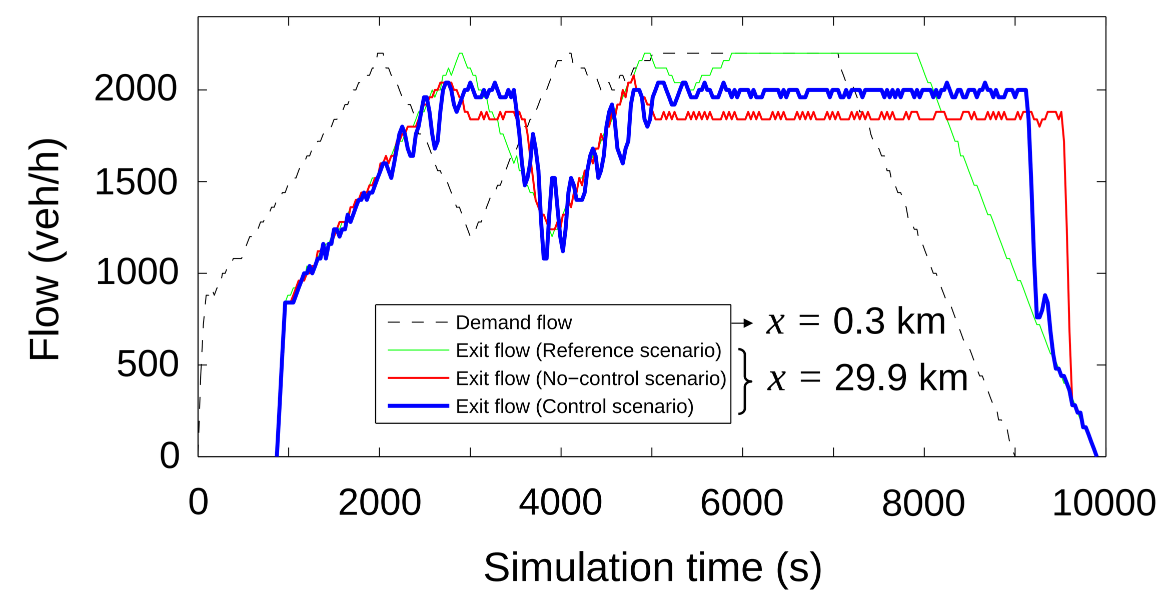
$$v_{\text{lim}}(k) = \underbrace{v^*_{\text{lim}}}_{\text{Target speed}} + \underbrace{K_p}_{\text{Gain}} \cdot [\underbrace{\rho^*}_{\text{Target density}} - \rho(k - \underbrace{r}_{\text{Delay}})]$$

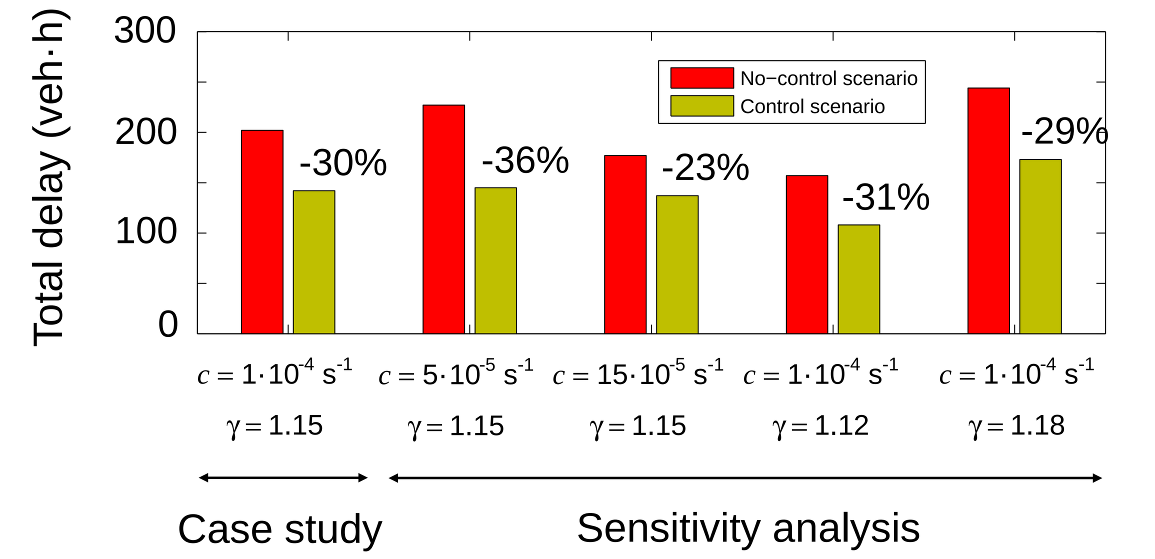
Speed limit constraints
$$\begin{cases} v_{\text{lim}}(k) = [v_{\text{lim\_min}}, v_{\text{lim\_max}}] \\ v_{\text{lim}}(k) \text{ is a multiple of 10} \\ |v_{\text{lim}}(k+1) - v_{\text{lim}}(k)| \leq \Delta v_{\text{lim}} \end{cases}$$

Results

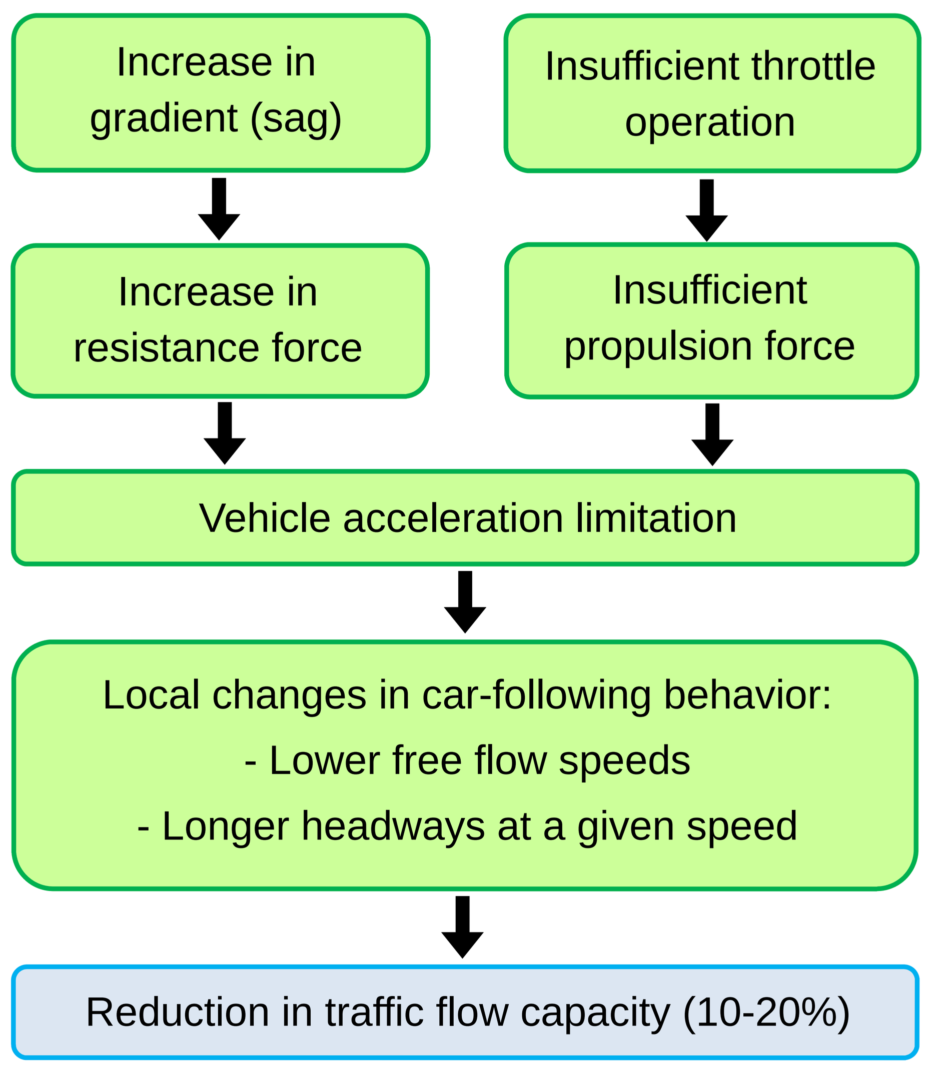
- The controller reacts adequately to changes in demand
- 7% increase in exit flow (s) in periods of high demand
- 30% reduction in total delay / Significant reduction also with different car-following model parameter values

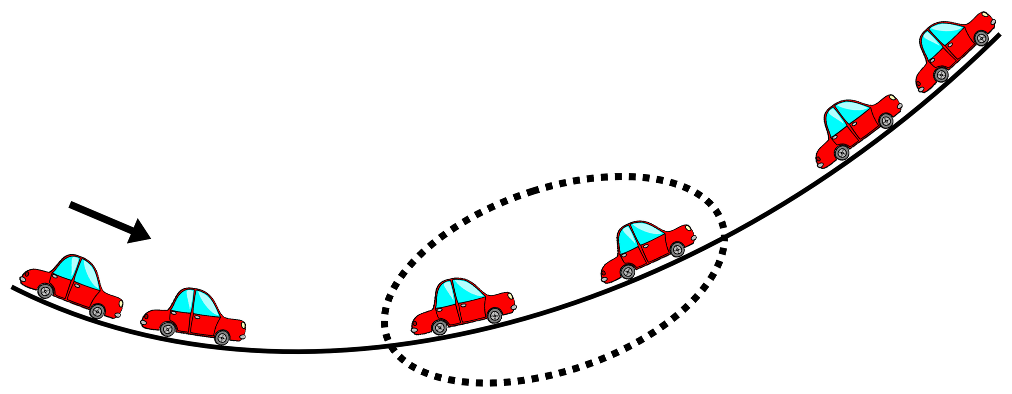


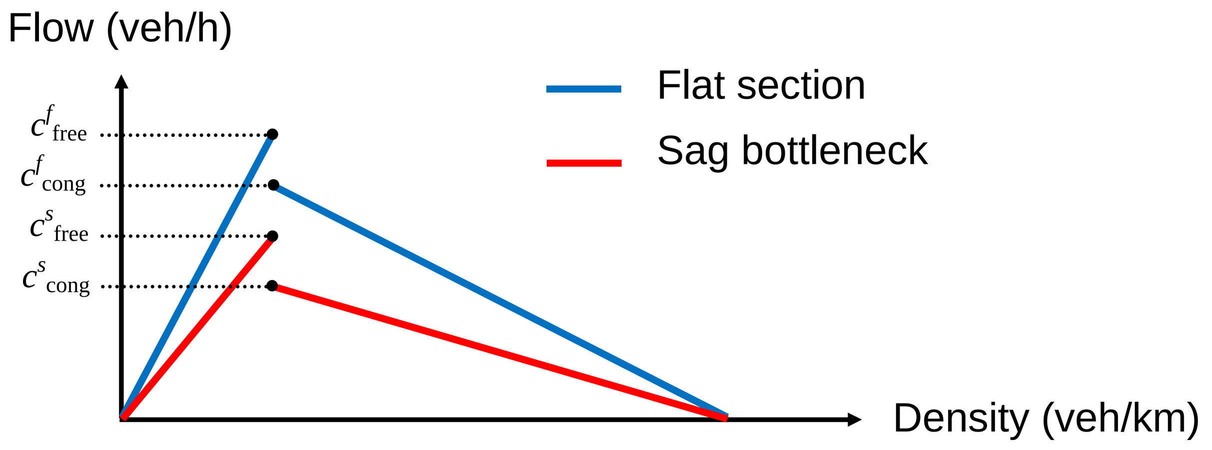




Sags are bottlenecks in freeway networks

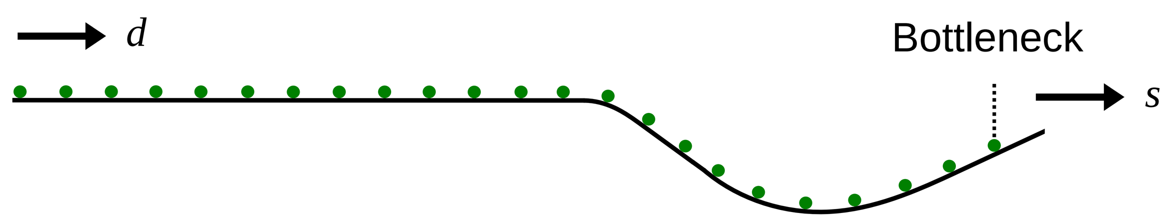






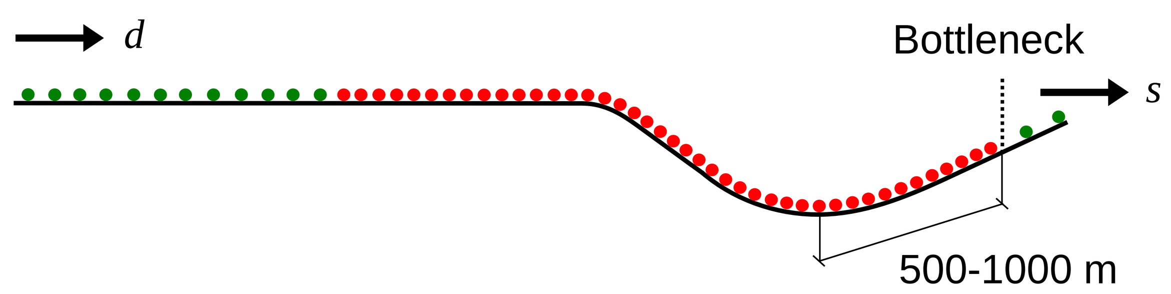
With low demand ($d < c^s_{\text{free}}$), the bottleneck does not activate:

- Exit flow (s) = demand (d)



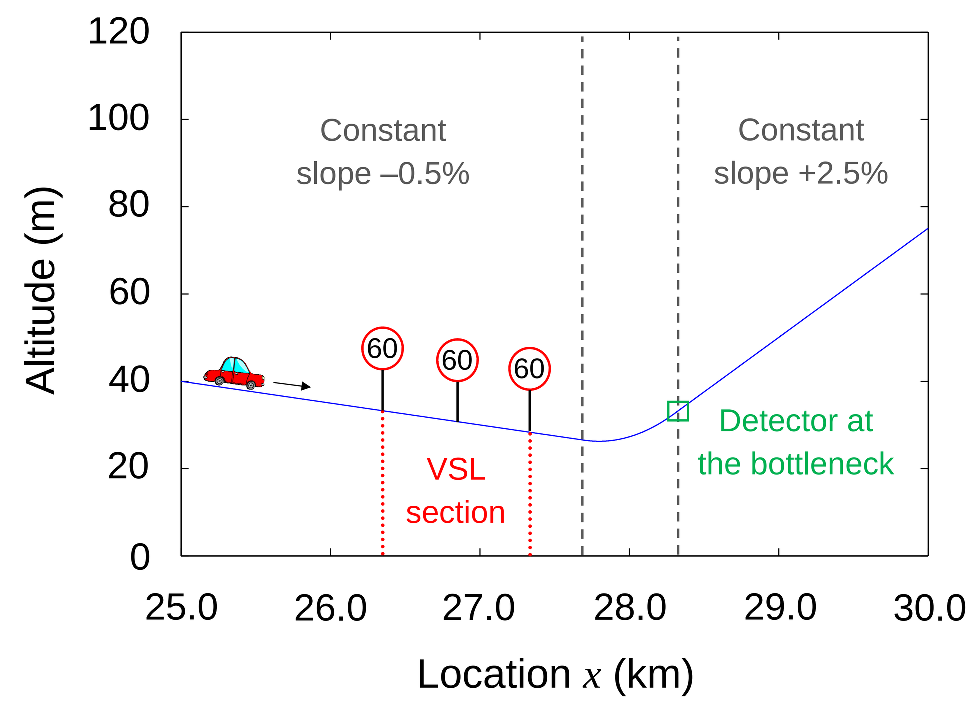
With high demand ($d > c^s_{\text{free}}$), the bottleneck activates:

- Exit flow (s) = discharge capacity (c^s_{cong}) < demand (d)



Case study setup

- **Simulation time**: 10000 s
- **Network**: 30 km, 1 lane, 1 sag



- **Traffic composition**: 100% passenger cars, 1 driver class
- **Car-following model**:
  Acceleration = f(speed, relative speed, spacing, gradient)
  100% compliance with speed limits
- **Scenarios**: a) Reference scenario (no influence of gradient)
  b) No-control scenario
  c) Control scenario
- **Network performance measure**:
  Total delay (TD) = Total travel time (TTT) – $\text{TTT}_{\text{Reference}}$

Conclusions

- The proposed control strategy has the potential to reduce total delay at sags
- Further research:
  - Evaluation: multi-lane network, heterogeneous traffic
  - Controller design: mitigation of oscillatory behavior, combination with other control measures

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