Modeling driving behavior and traffic flow at sags

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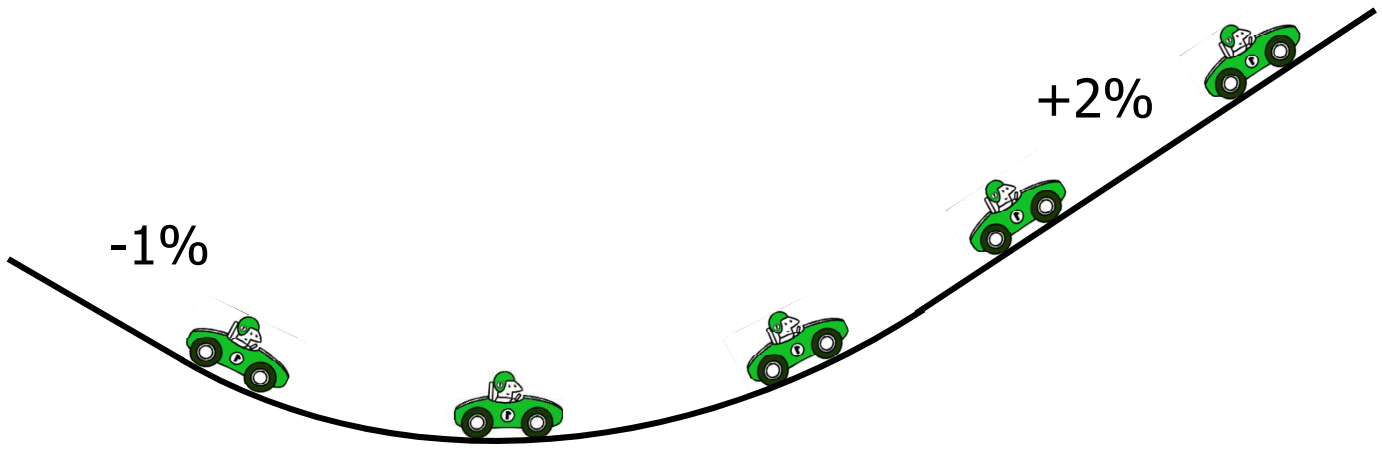
Outline

1. Background
2. Research objective
3. Microscopic traffic flow model / Car-following model
4. Simulation study
5. Conclusions

Background

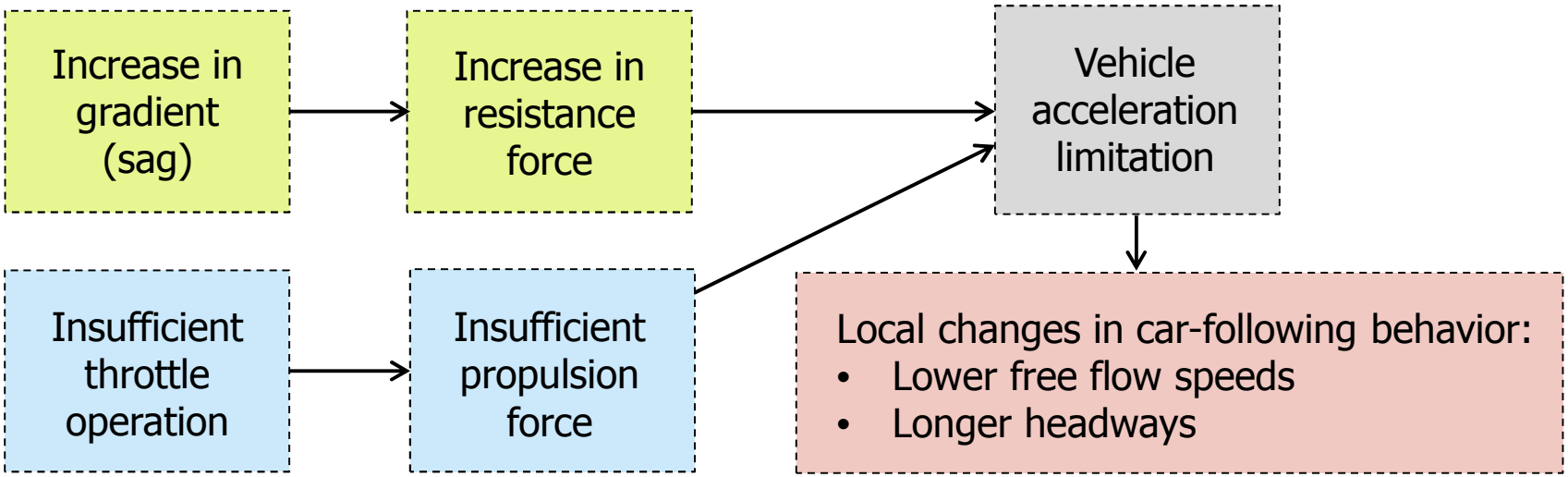
What is a sag?

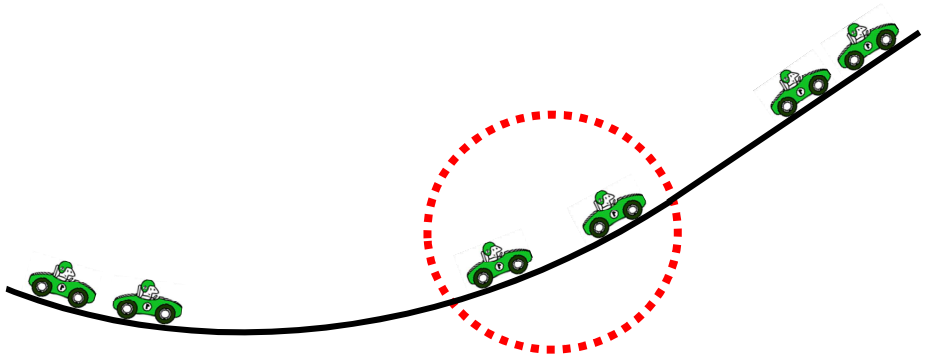
- **Sag** = Freeway section along which the gradient changes significantly from downwards to upwards



Background

Car-following behavior at sags

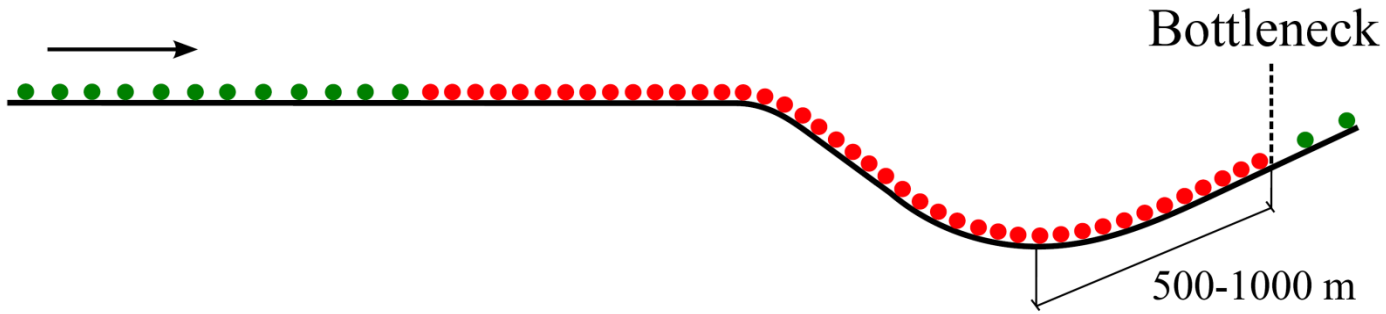




Background

Sags as freeway bottlenecks

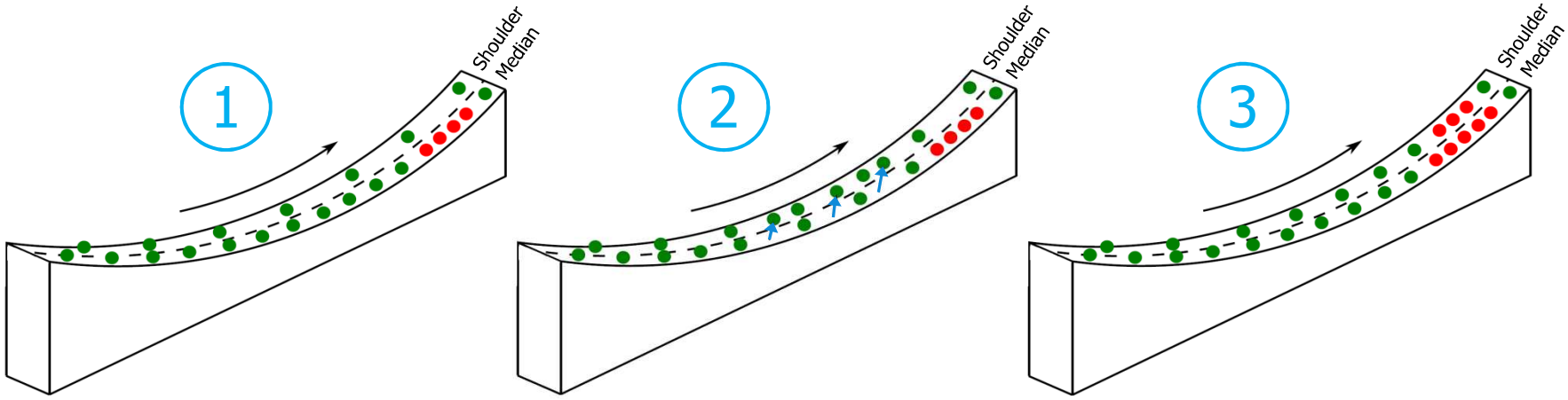
- Local changes in car-following behavior → Reduced freeway capacity → Bottleneck
  - ❑ Capacity is 10-20% lower at sags than at flat sections
- Hence: High demand → Traffic breakdown [→ Capacity drop]



Background

Process of congestion formation at sags

1. Traffic breaks down on the **median lane** of the uphill section
2. The flow on the shoulder lane increases due to lane changes
3. Traffic breaks down on the **shoulder lane**



Research objective

- Develop a model that can reproduce traffic flow dynamics at sags in a realistic way

[The model should be suitable for evaluating the effectiveness of possible traffic management measures]

Microscopic traffic flow model

Sub-models

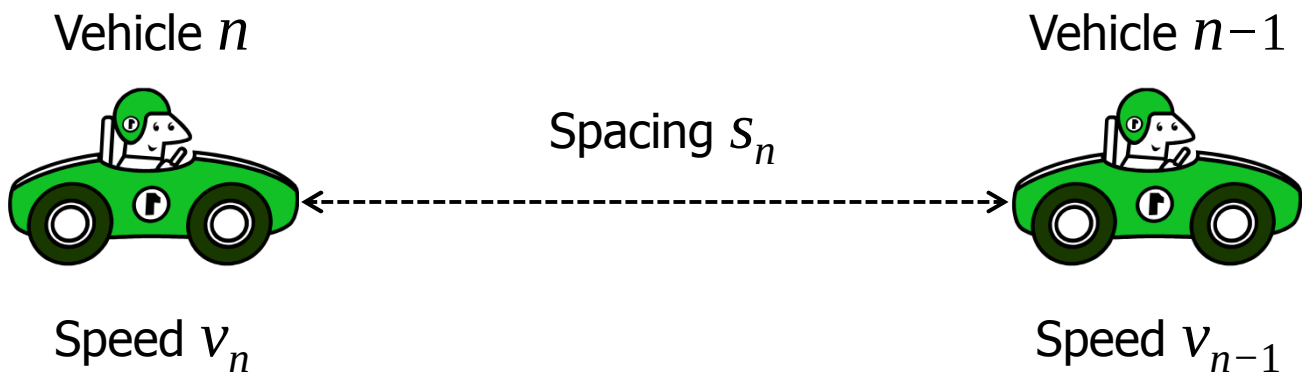
1. Network model
   - Gradient
   - Number of lanes
2. Traffic demand model
   - Traffic inflow
   - Traffic composition
3. Car-following model → Our main contribution
4. Lane change model

Car-following model

Formulation

- Acceleration: $\dot{v}(t) = f_1(t) + f_2(t)$
- **First term** ≈ Intelligent Driver Model (IDM)

f_1 = function of spacing, speed and relative speed

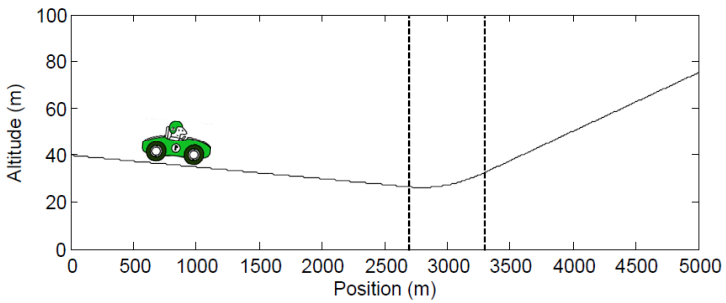


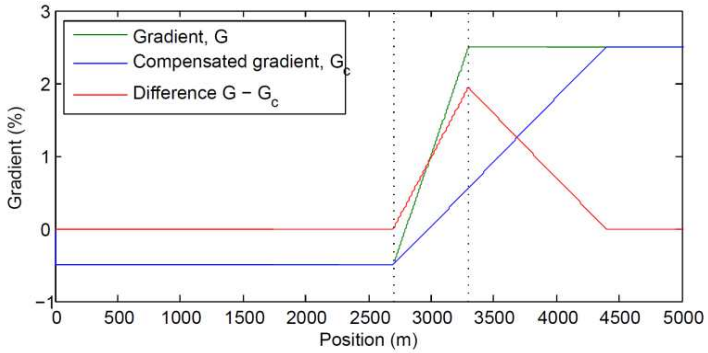
Relative speed $\Delta v_n = v_{n-1} - v_n$

Car-following model

Formulation

- Acceleration: $\dot{v}(t) = f_1(t) + f_2(t)$
- **Second term**: influence of gradient on vehicle acceleration





$$f_2(t) = -g \cdot [G(t) - G_c(t)]$$

Compensated gradient

where:

$$G_c(t) = \begin{cases} G(t) & \text{if } G(t) \leq G(t_c) + c \cdot (t - t_c) \\ G(t_c) + c \cdot (t - t_c) & \text{if } G(t) > G(t_c) + c \cdot (t - t_c) \end{cases}$$

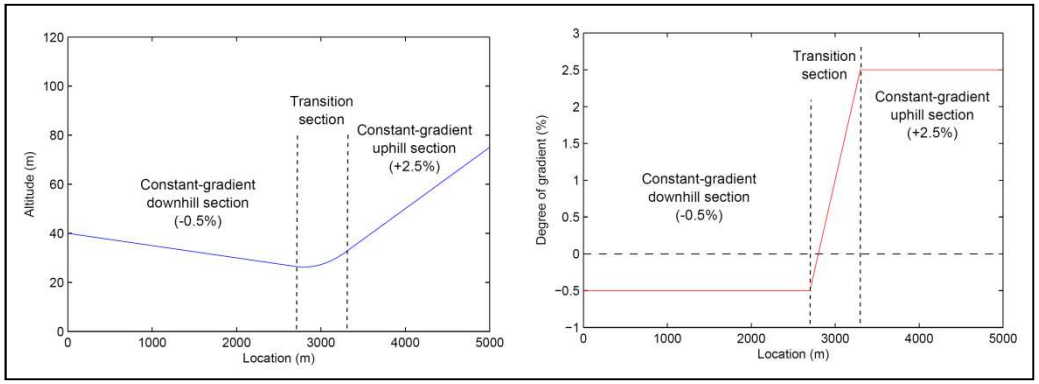
Maximum gradient compensation rate (s^{-1})

$$t_c = \max(t \mid G_c(t) = G(t))$$

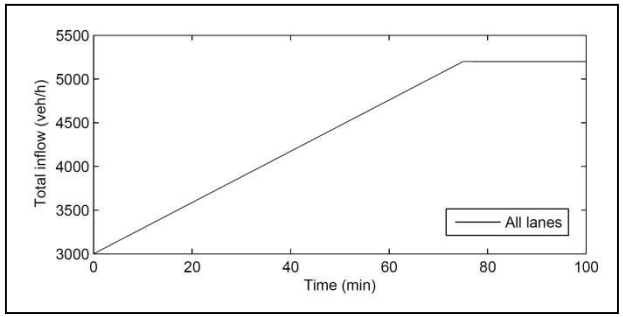
Simulation study

Settings

1. Network model
   - 3 sections
   - 3 lanes



2. Traffic demand model
   - Traffic inflow
   - Traffic composition



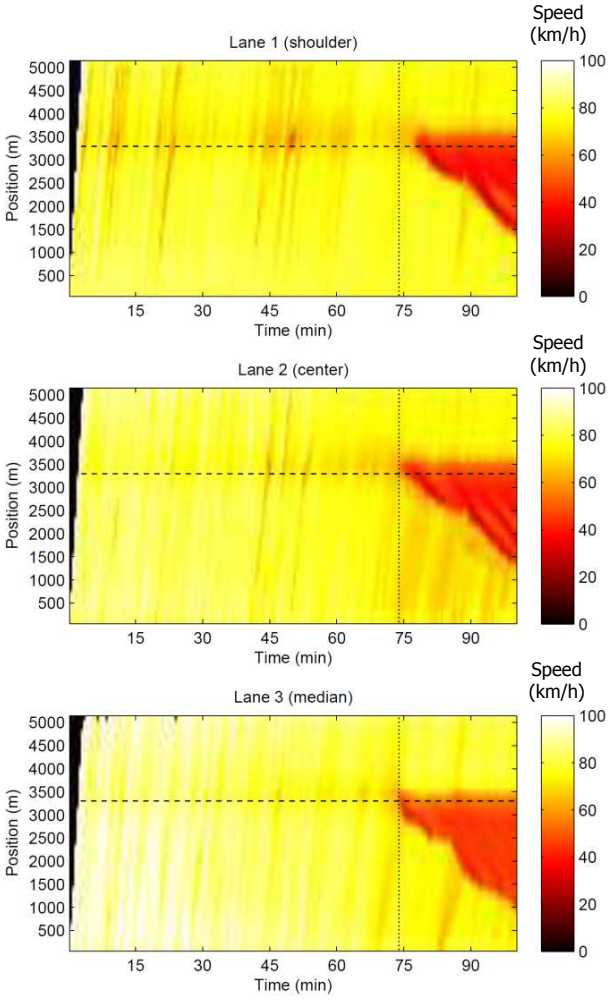
3. Car-following model
   - Stochastic parameters

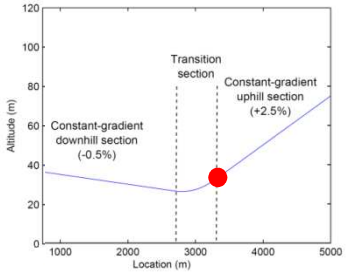
4. Lane change model
   - LMRS (Schakel et al., 2012)

Lane	% Cars	% Trucks
Shoulder	90	10
Center	95	5
Median	100	0

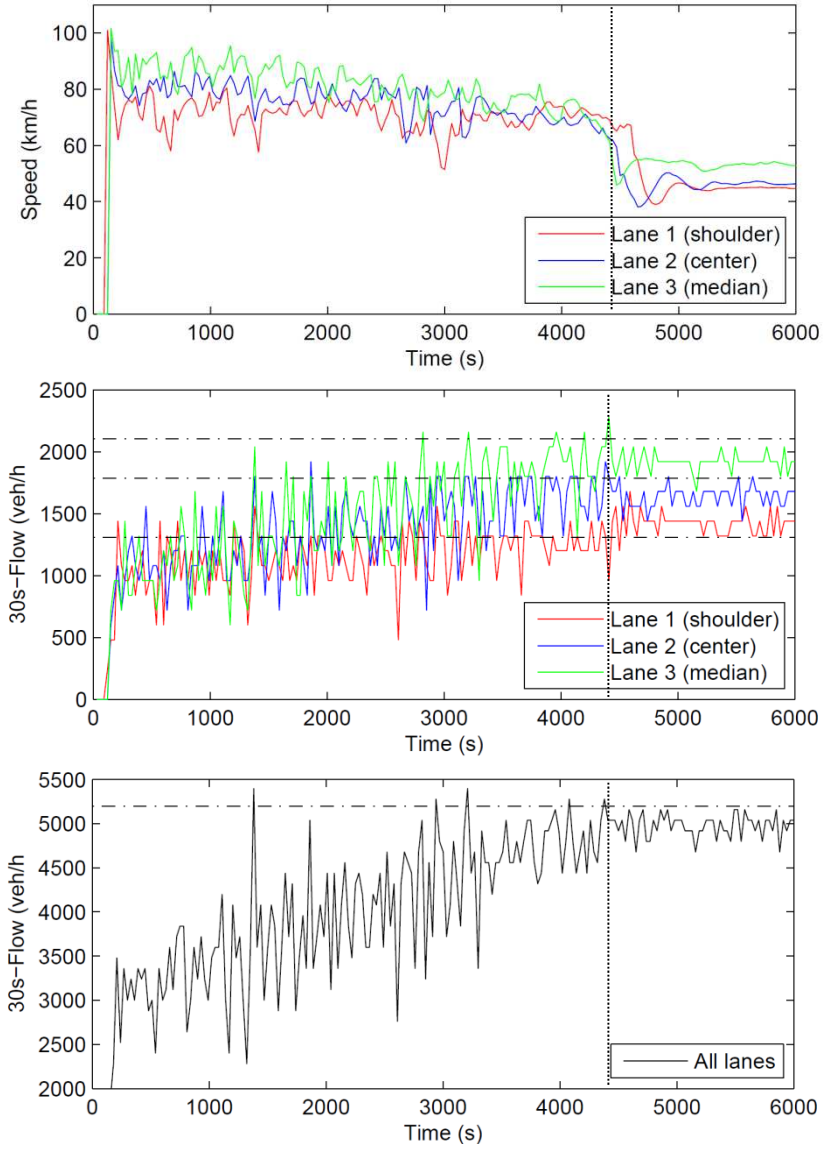
Simulation study

Results





x =3200 m (bottleneck)



Conclusions

- Microscopic traffic flow model
  - ❑ Including: a new car-following model that takes into account the influence of gradient on vehicle acceleration
- Key phenomena reproduced by our traffic flow model:
  - ✓ Reduced capacity due to vertical curvature
  - ✓ Bottleneck location at sags
  - ✓ Capacity drop due to congestion
  - ✓ Process of congestion formation at multi-lane sags (3 steps)
- The model is face-valid
- The model still needs to be calibrated and validated

Questions?

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