Car following models

Intro to traffic flow modeling and ITS

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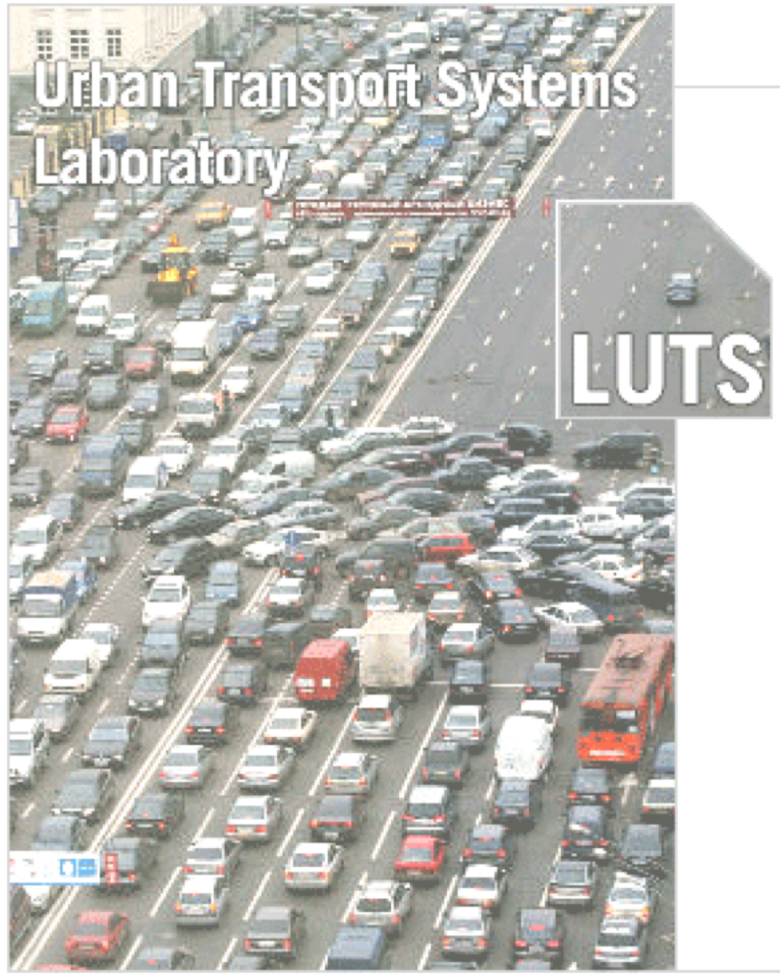
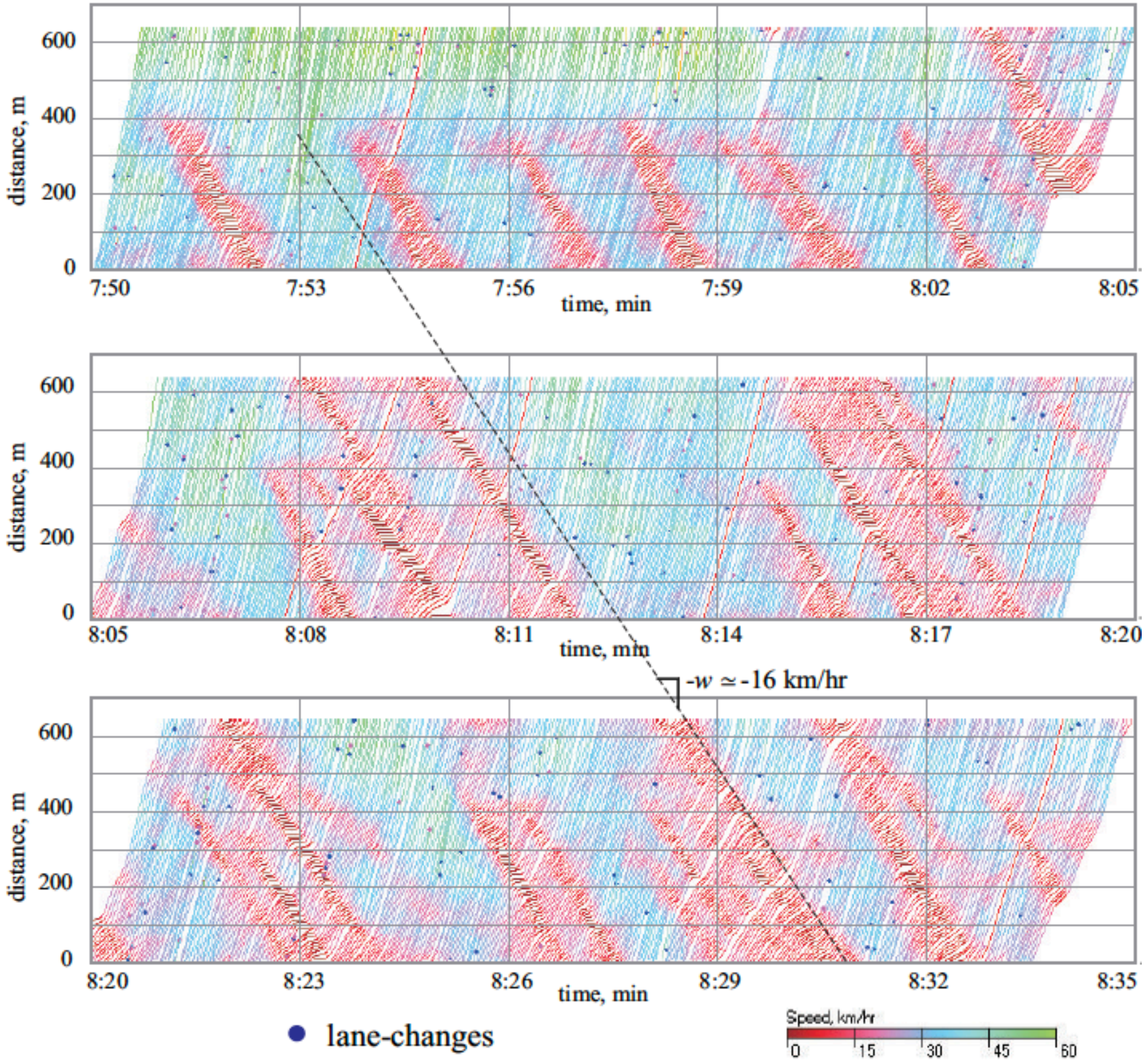


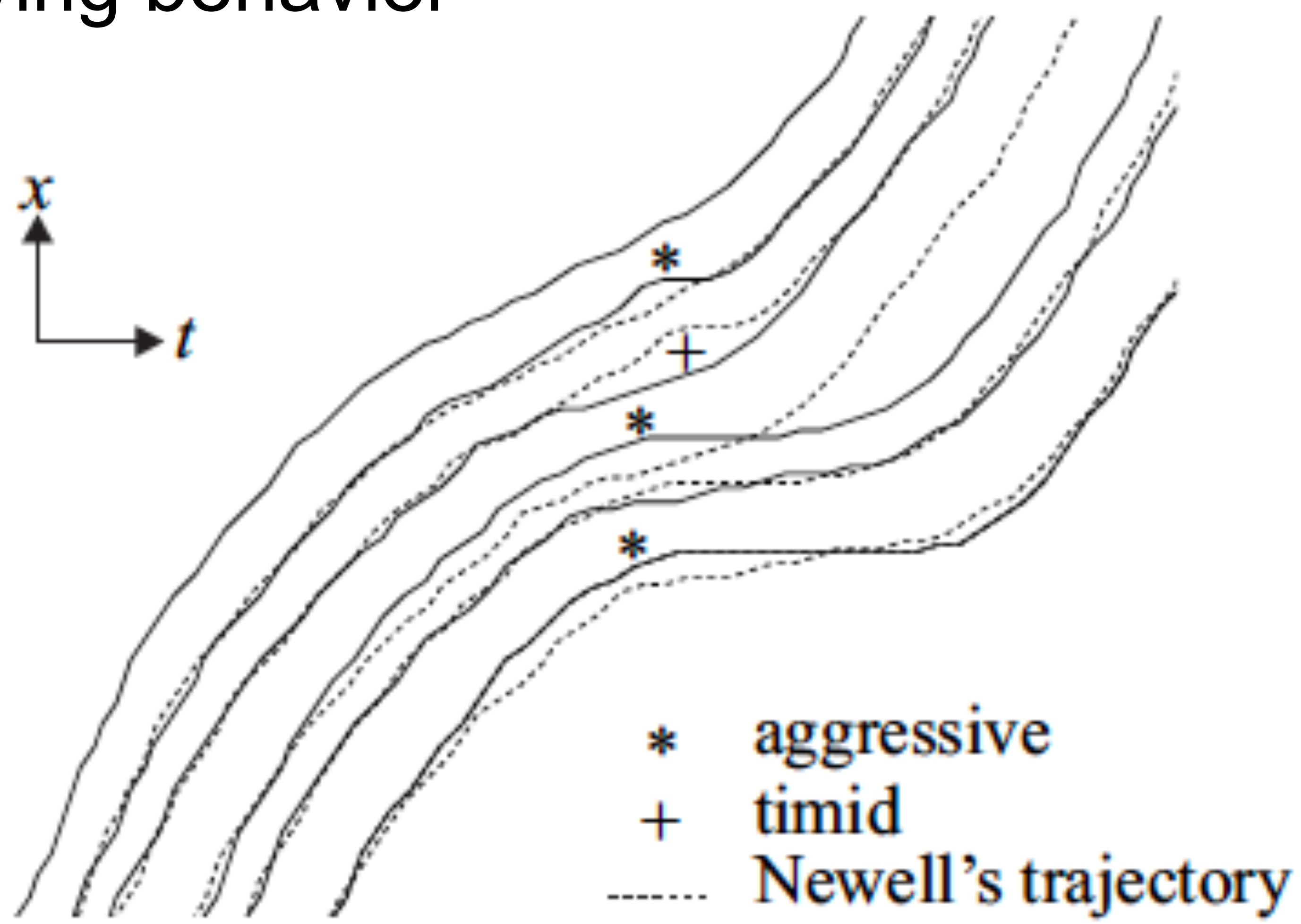
Welcome

Empirical trajectory freeway data



Observations

- Stop-and-go phenomena
- Propagation of congestion and oscillations
- Different magnitude of oscillations
- Shockwaves
- Driving behavior



Laval and Leclercq, 2010

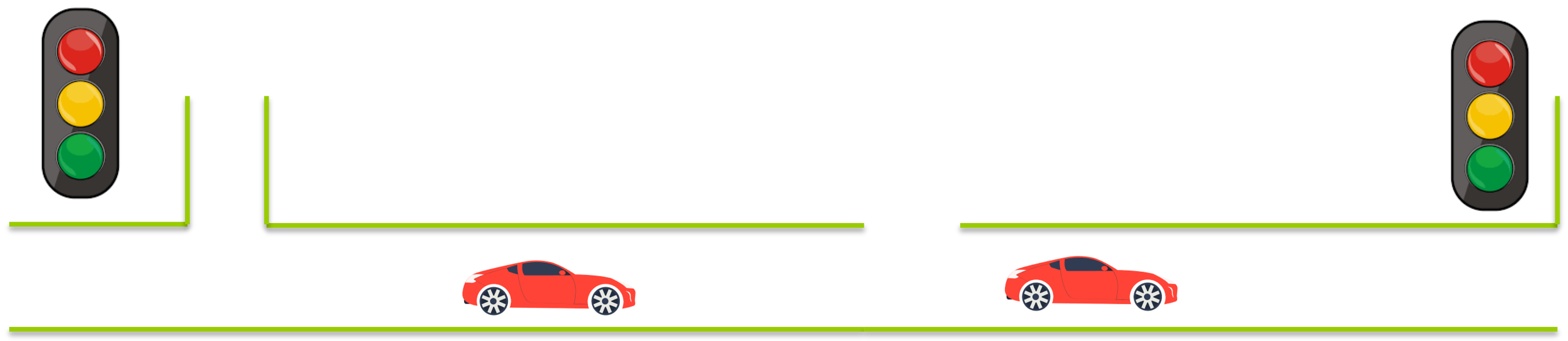
Why a micro modeling approach?

Advantages

- Towards automated and connected vehicles
- More “behavioral”
- Fundamental diagram contains scatter
- Important for safety
- Develop microsimulation models

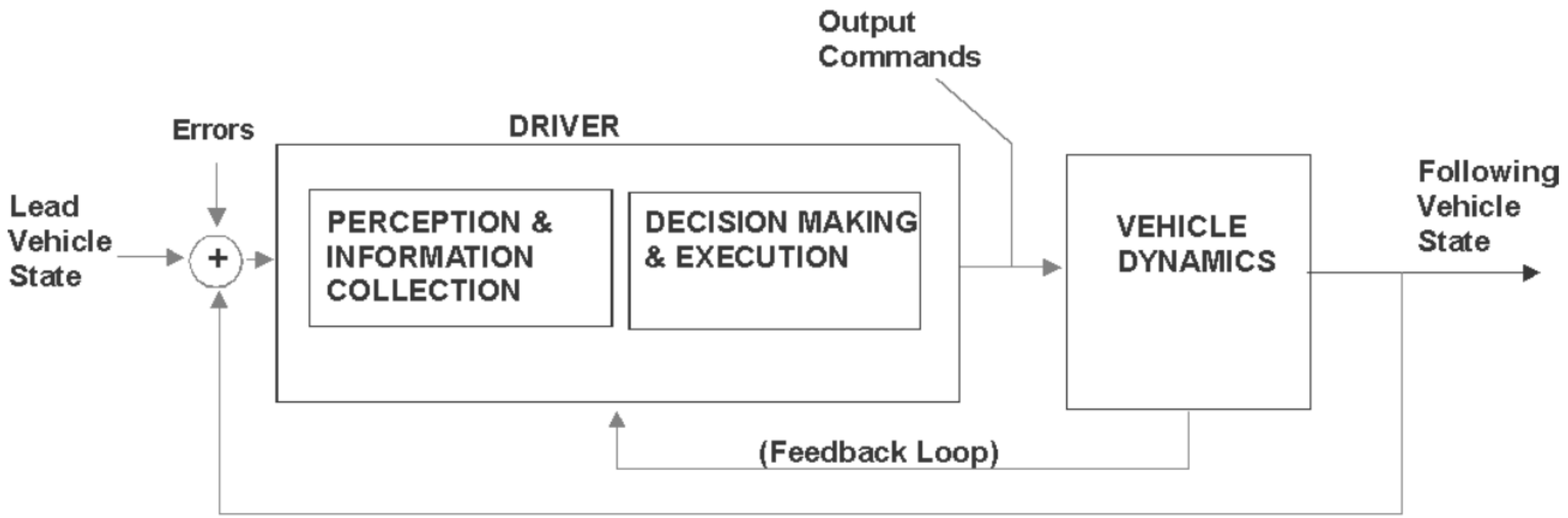
Challenges

- Calibration
- Stability
- System integration

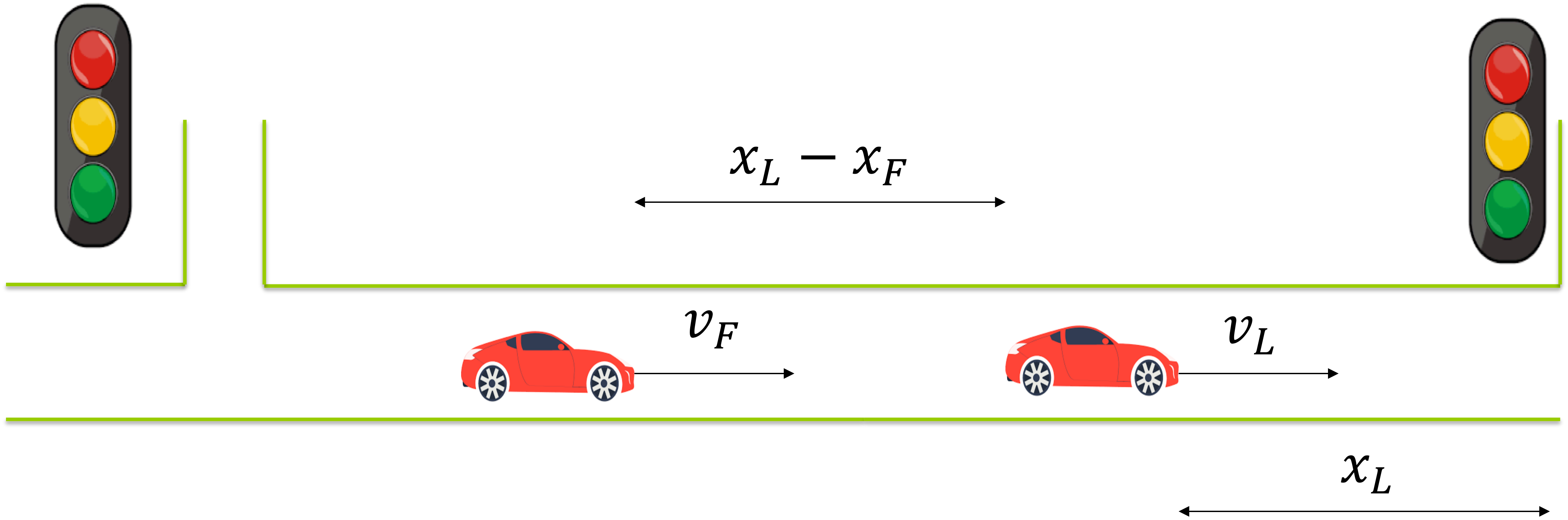


General characteristics of car-following models

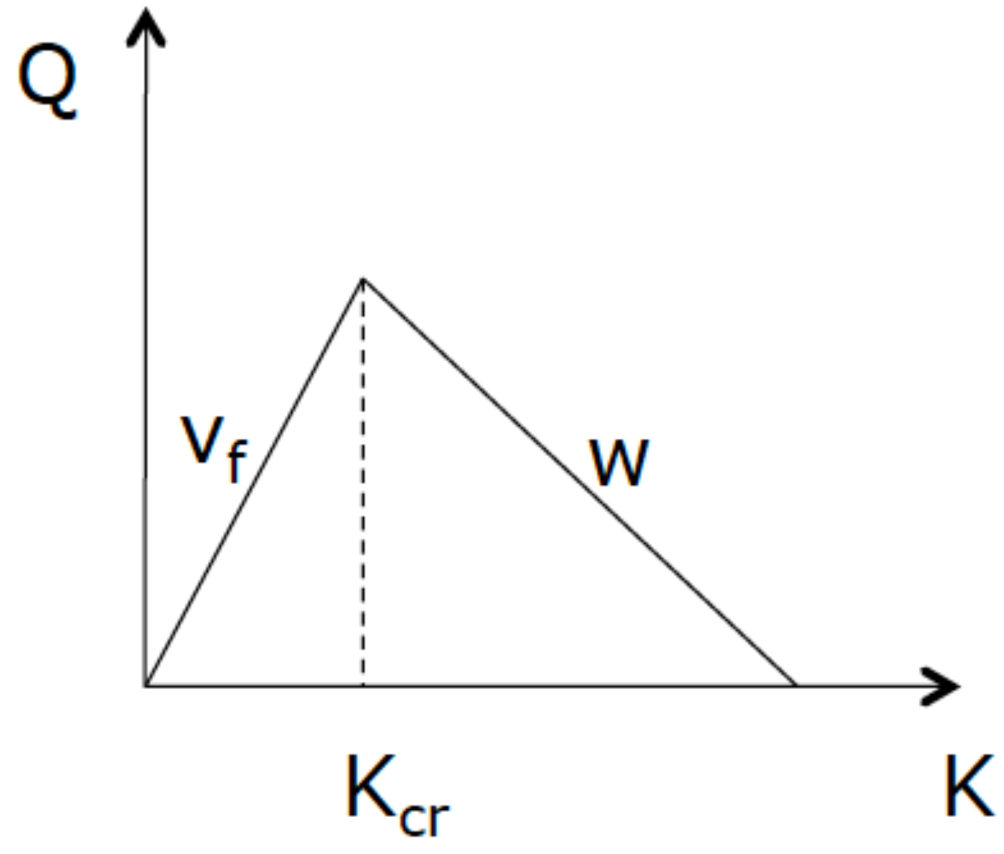
- Perception
- Decision Making
- Control/Reaction
- Safety
- Efficiency
- Vehicle Dynamics



Block Diagram of CF models (Rothery, 2001))

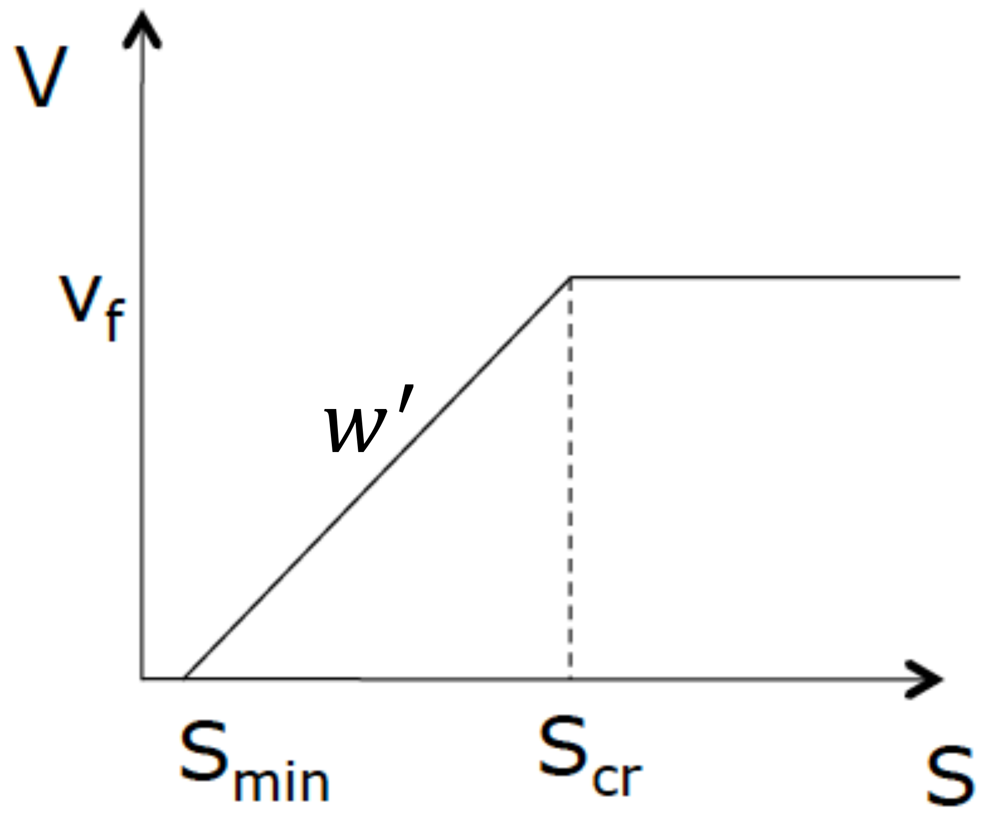


Consistency of CF and FD



Fundamental diagram

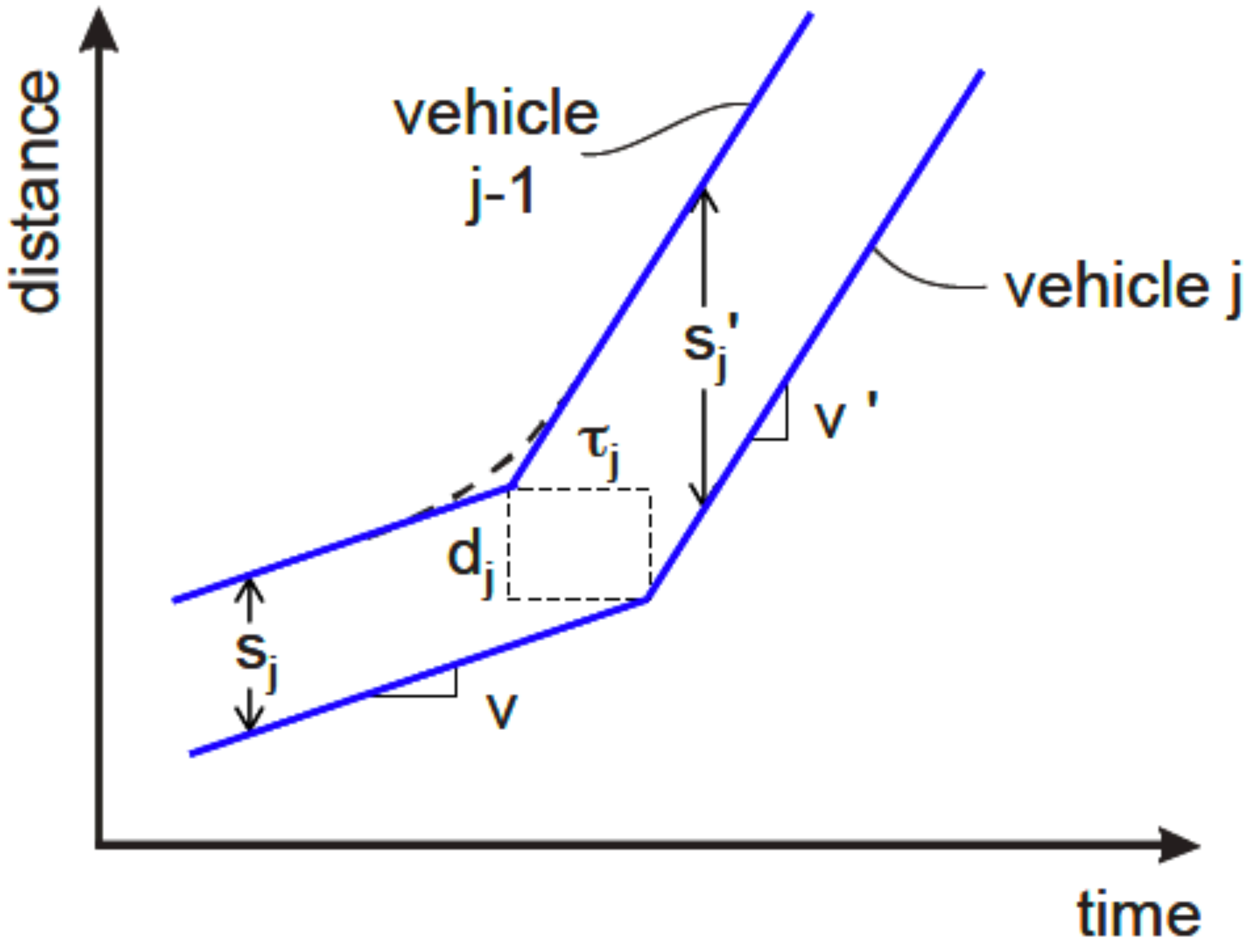
$$w' = \frac{u_f}{\frac{1}{k_{cr}} - \frac{1}{k_{jam}}}$$



Speed – Spacing relation

Newell's CF model

$$x_F(t+\tau_n) = x_L(t) - d_n$$

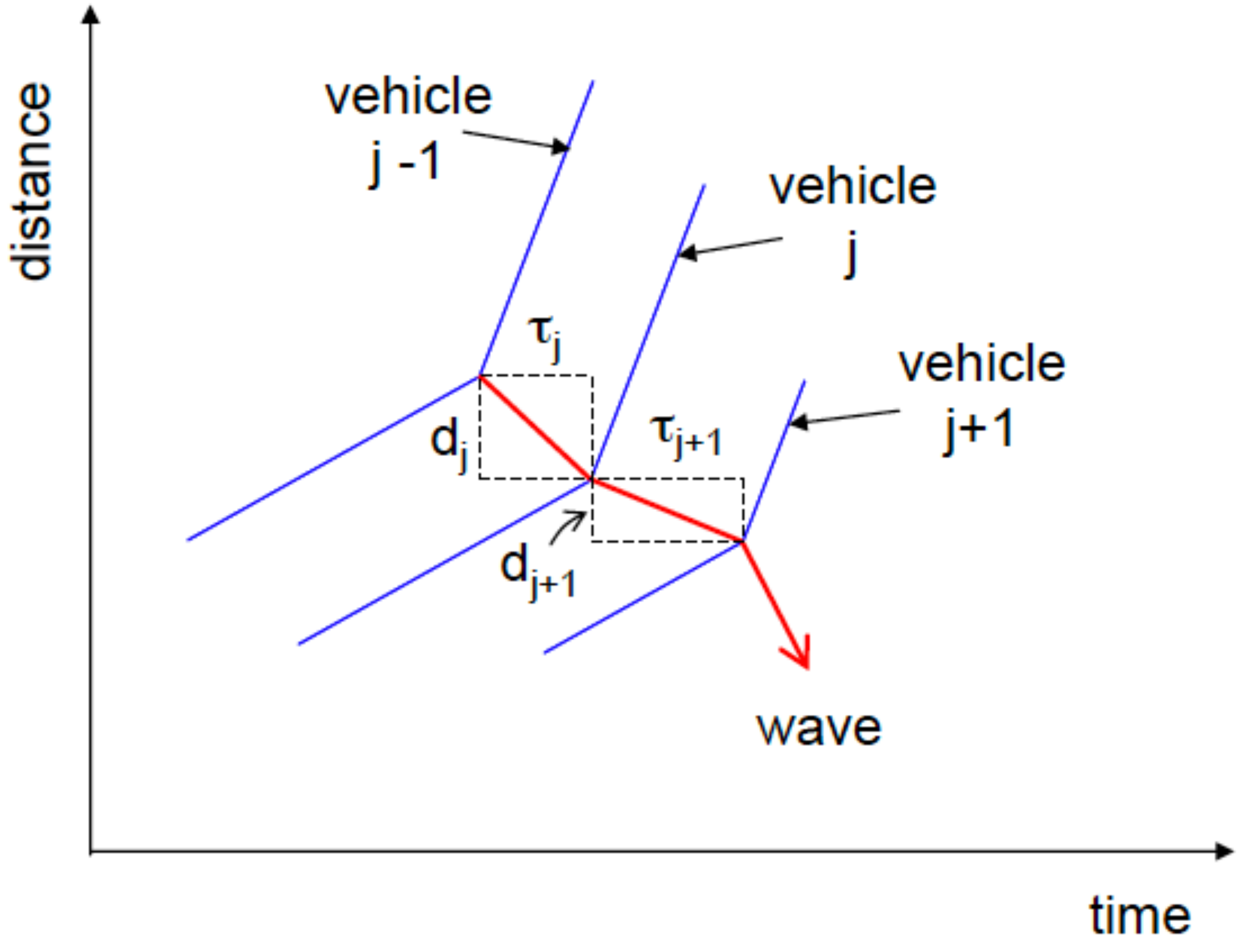


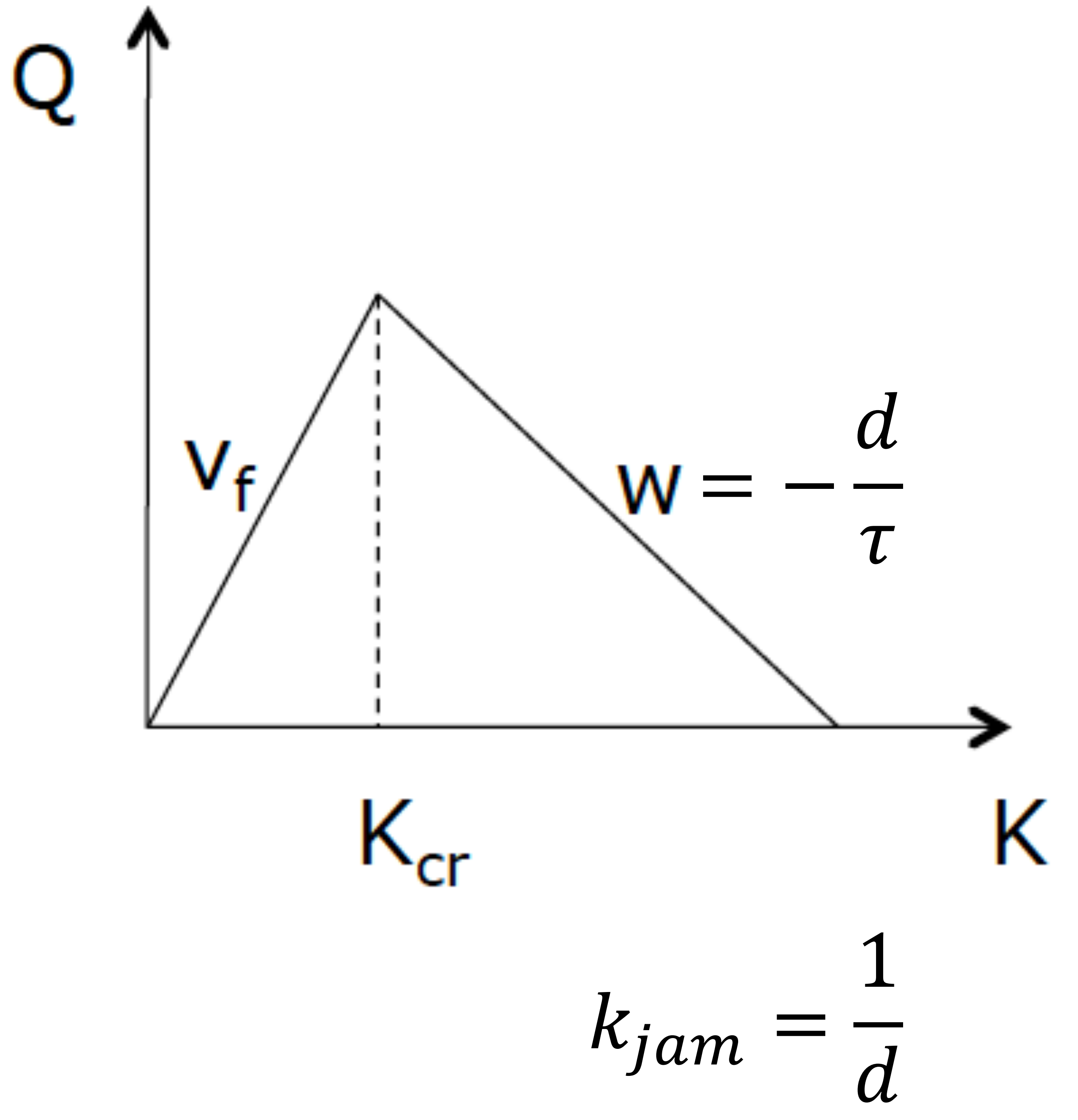
- **One simple equation**
- x_F, x_L represent the positions of the follower and the leader
- Same trajectory except for a translation in time and space
- τ_n , d_n May vary across drivers *n*

Properties of τ_n , d_n

- independent of vehicle's velocity
- drawn independently from a joint probability distribution

Newell’s CF multiple vehicles





Each wave propagates as a random walk

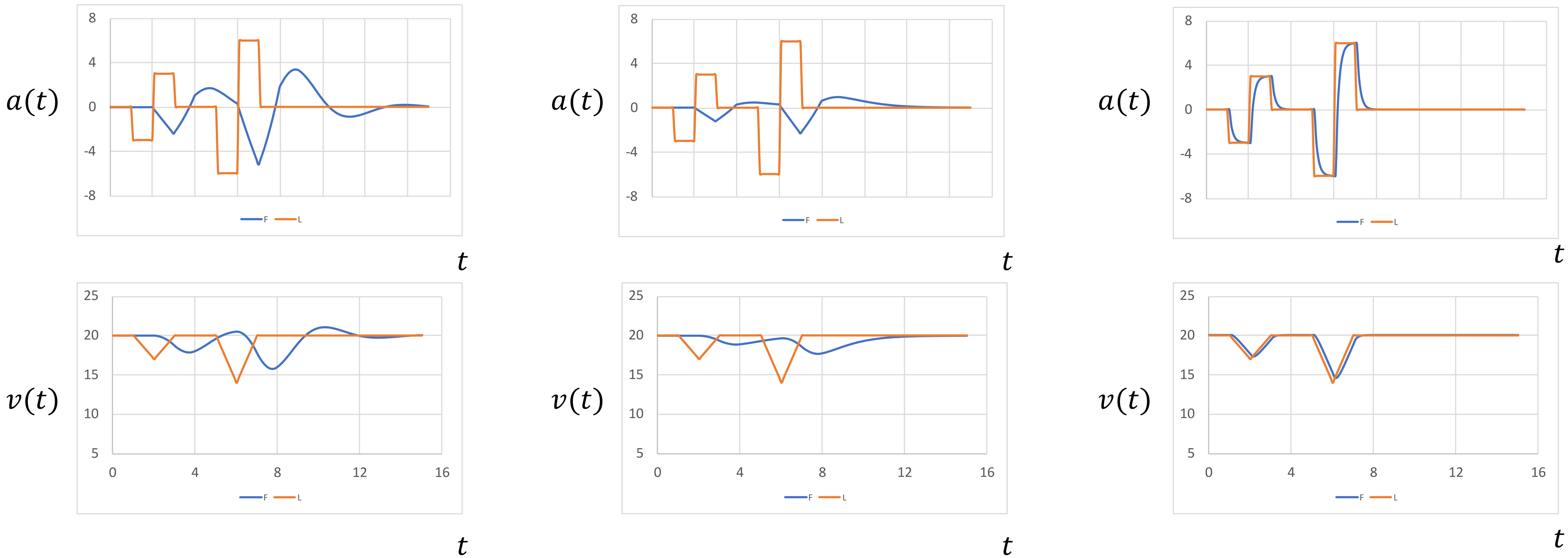
A linear car following model

Response = sensitivity * stimulus

$$\ddot{x}_F(t+\tau) = \frac{C}{\tau}\left(\dot{x}_L(t) - \dot{x}_L(t)\right)$$

τ: reaction time
$a(t)$: acceleration
$v(t)$: speed

$C = 0.8,\ \tau = 1sec$ | $C = 0.4,\ \tau = 1sec$ | $C = 5,\ \tau = 0.1sec$



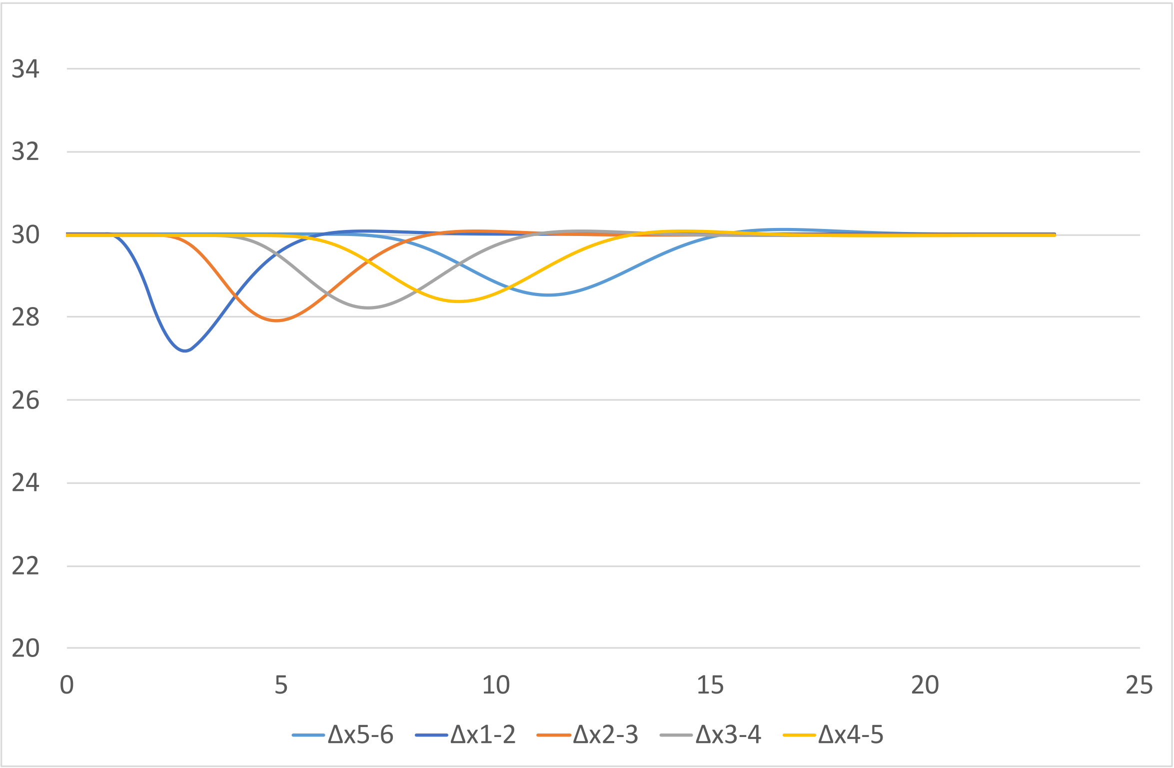
Stability analysis

Local Stability: the response of a following vehicle to a fluctuation in the motion of the leader vehicle directly in front of it.

Asymptotic Stability: how fluctuation in the motion of lead vehicle of a platoon, is propagated through a series of vehicles.

$C = 0.5,\ \tau = 1sec$ | $C = 0.8,\ \tau = 1sec$ | $C = 1.1,\ \tau = 1sec$

$\Delta x(t)$



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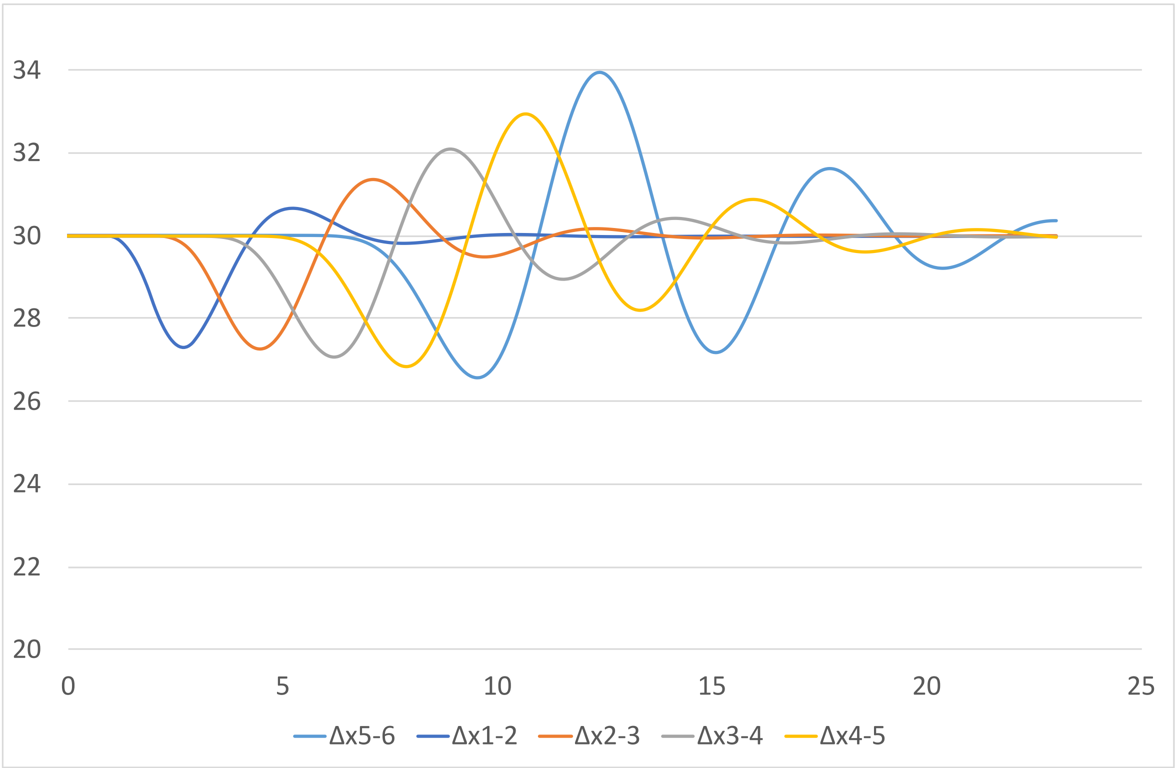

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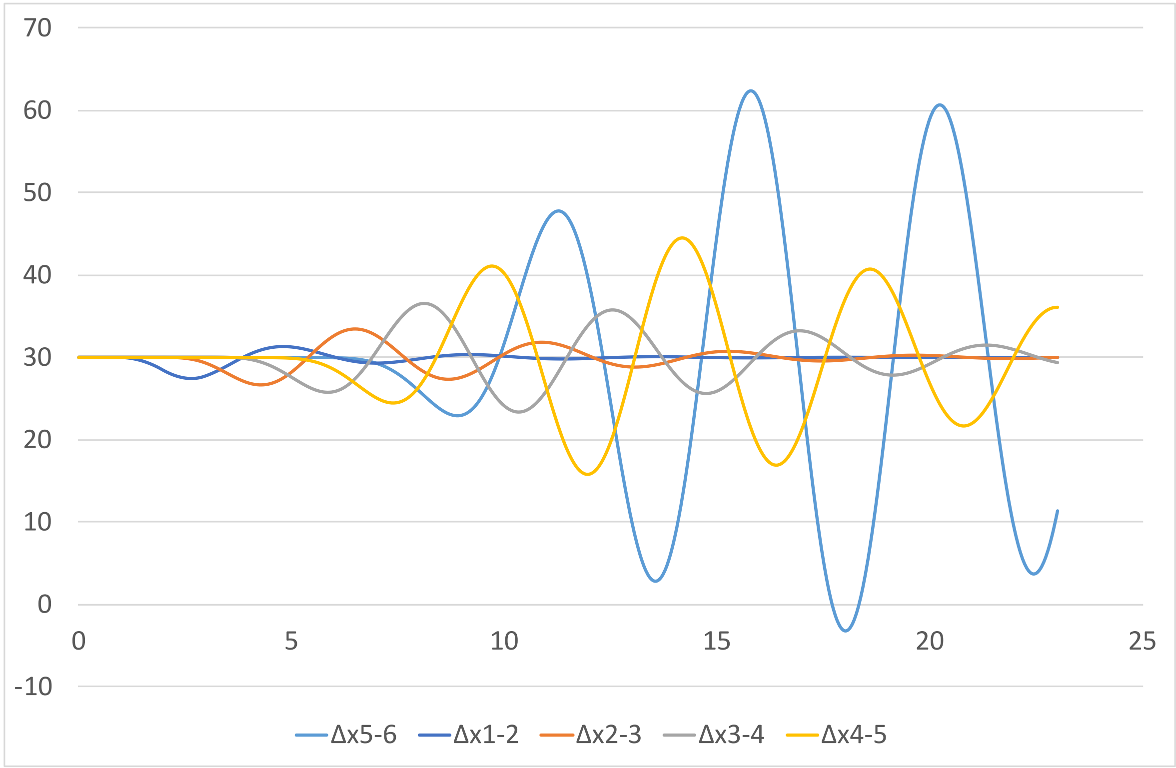

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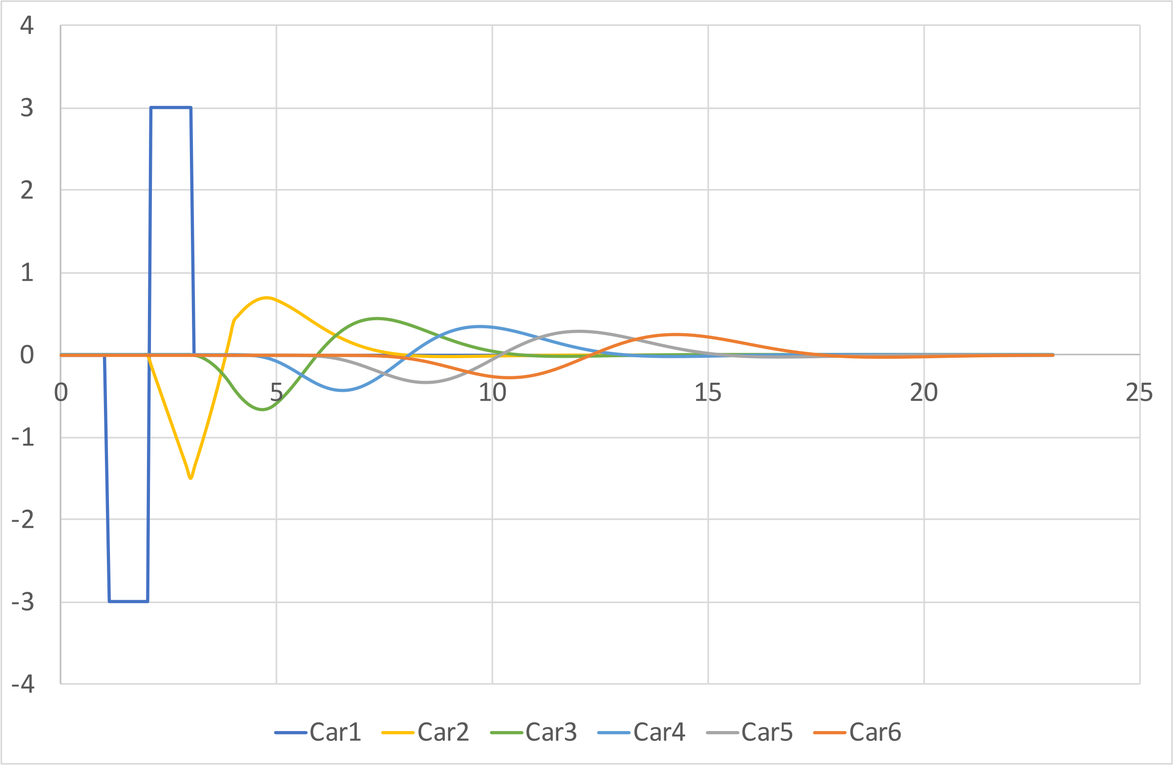
a(t)



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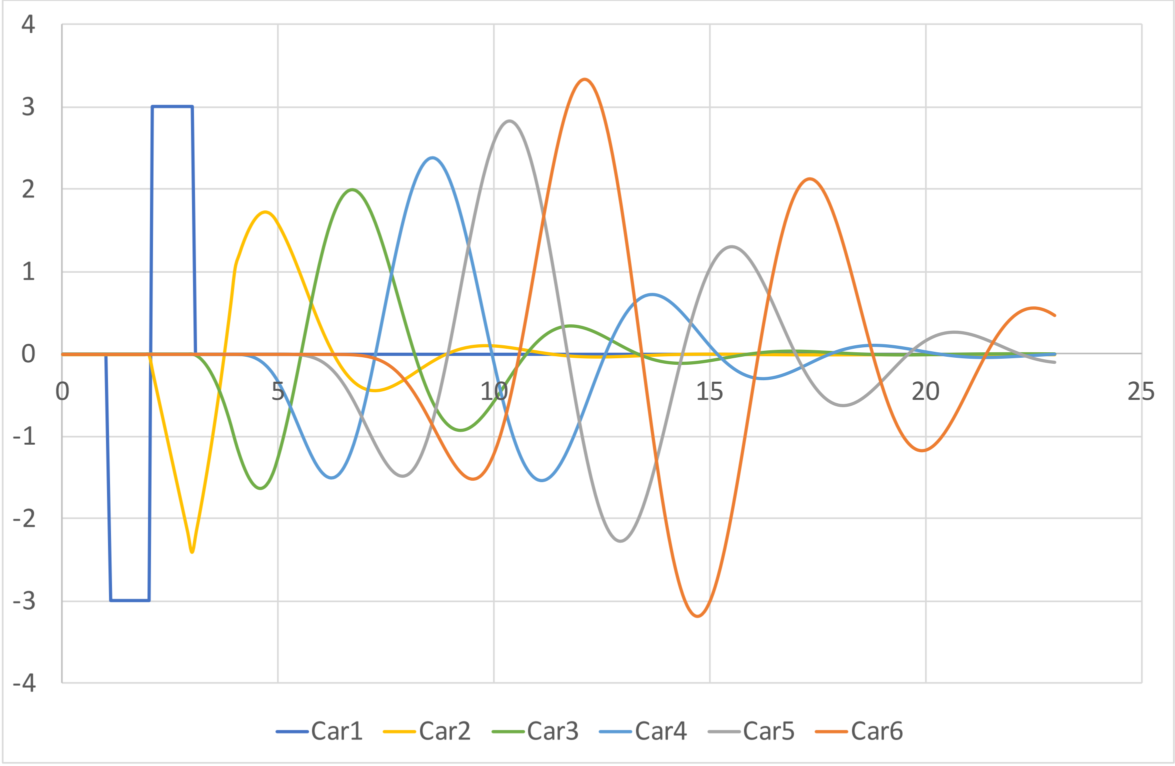

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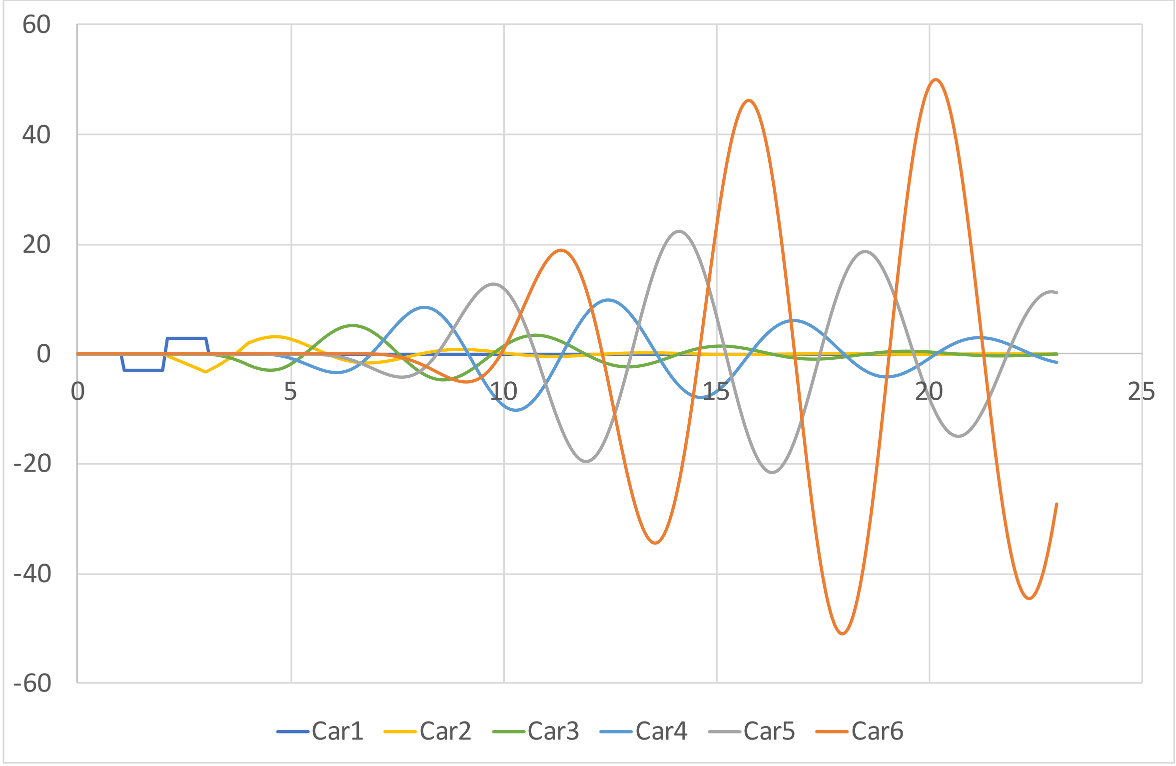

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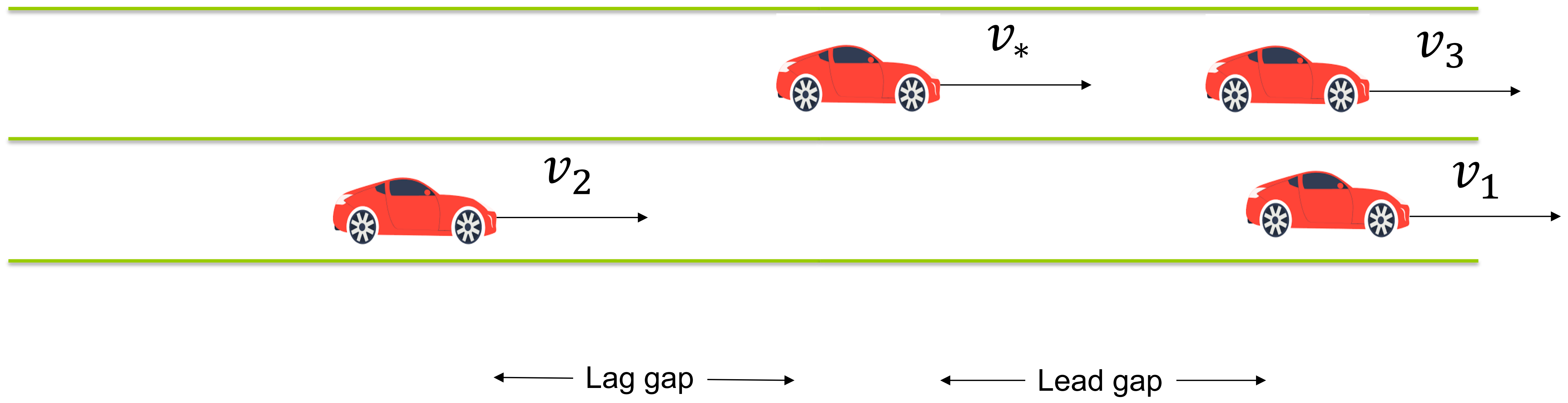
Lane changing models

Process:

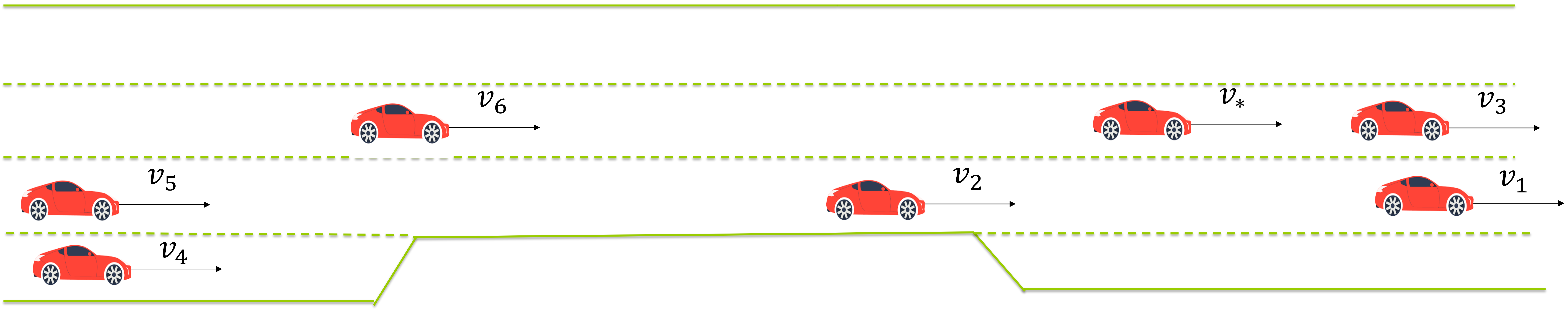
- Vehicles evaluate lead and lag gaps in adjacent lanes
- Decide if the existing gaps are acceptable



Types of lane changing actions

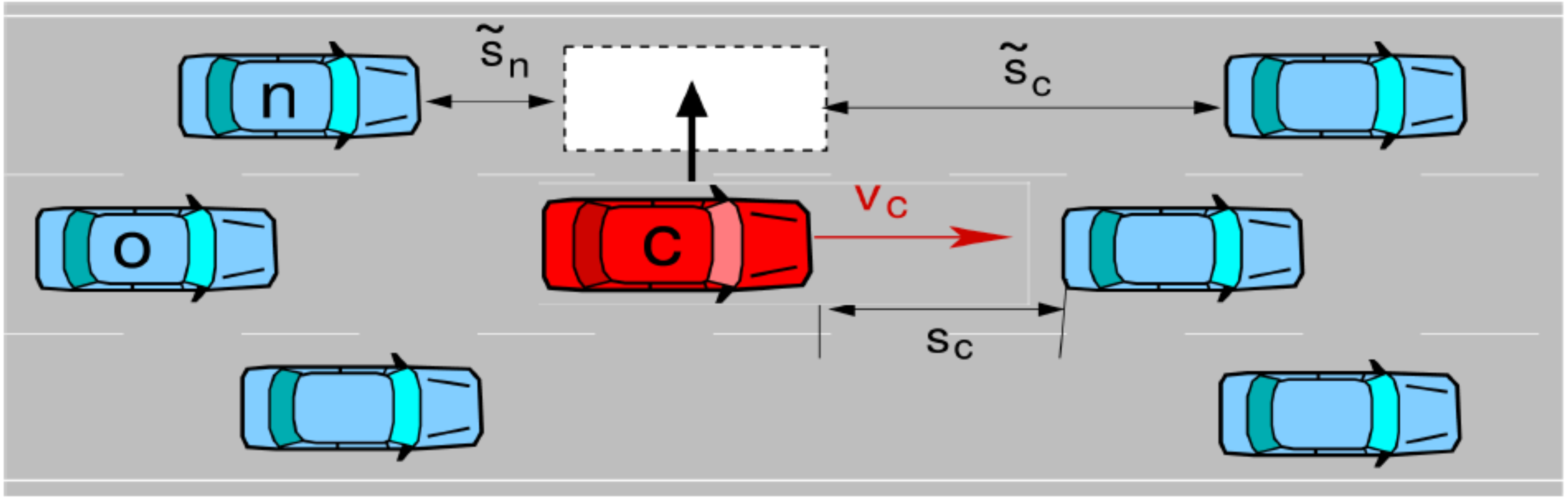
EPFL

- Mandatory: A vehicle is obliged to change a lane (e.g. on- or off-ramps)
- Anticipatory: A vehicle changes a lane to anticipate congestion downstream
- Discretionary: A vehicle decides to change a lane to be better off
- Cooperative: A vehicle changes a lane to help others



An example of a lane-changing model

EPFL



Builds on a car following model with an acceleration function

$$\frac{dv_\alpha}{dt} = a^{\text{mic}}(s_\alpha, v_\alpha, \Delta v_\alpha)$$

Safety criterion

$$\tilde{a}_n \geq -b_{\text{safe}}$$

Incentive criterion

$$\underbrace{\tilde{a}_c - a_c}_{\text{driver}} + p\big(\underbrace{\tilde{a}_n - a_n}_{\text{new follower}} + \underbrace{\tilde{a}_o - a_o}_{\text{old follower}}\big) > \Delta a_{\text{thr}}$$

M inimizing

O verall

B raking decelerations

I nduced by

L ane changes

Kesting, Treiber, Helbing, 1999

Summary