Automated driving in microscopic traffic simulation

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CTR Day - 2024

Background

- Automated driving systems (ADS) are expected.
- Road authorities concerns about traffic performance.

Research questions

- How to model automated driving in microscopic traffic simulation? — Modeling
- How will mix traffic affect transportation systems? — Impacts

Why mixed traffic?

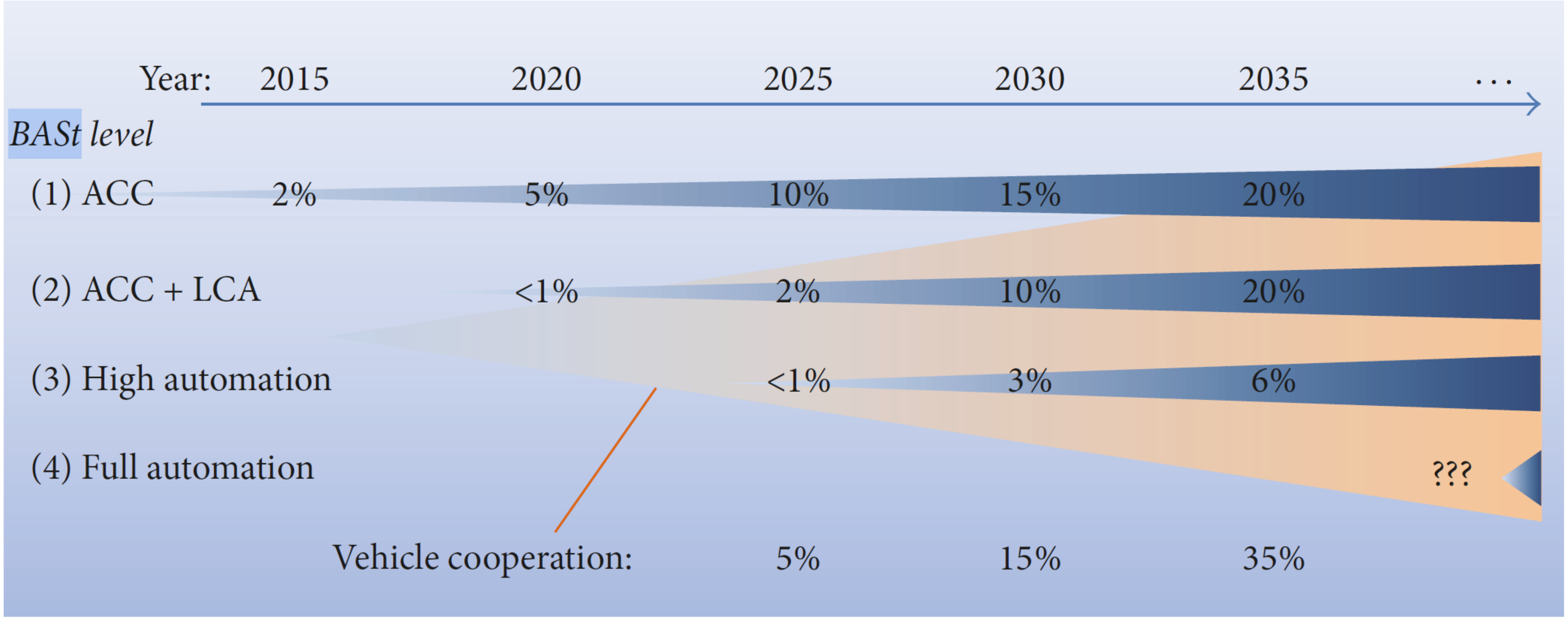
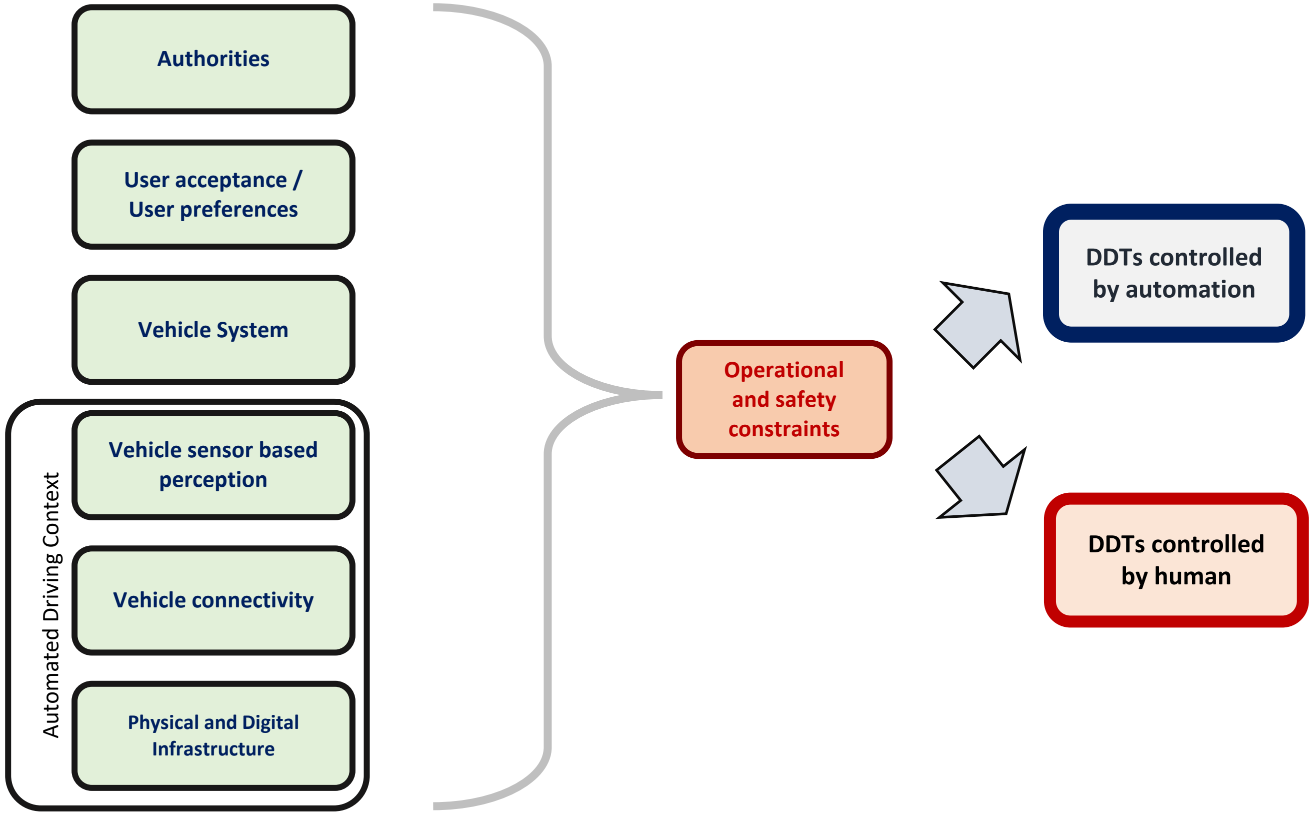


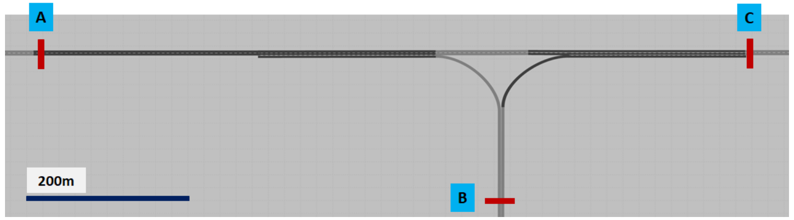
FIGURE 1: Estimated automated vehicle share on roads.

Source: Calvert et al. (2017) – Will automated vehicles negatively impact traffic flow?
In: *Journal of Advanced Transportation*

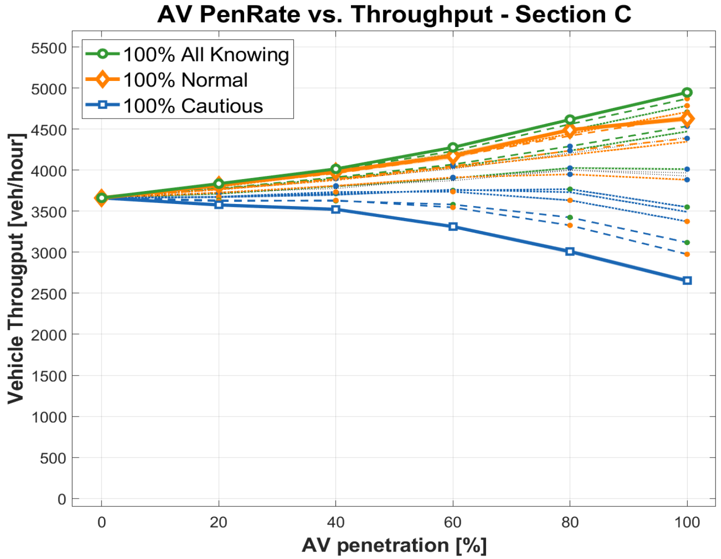
State of the practice - Modeling



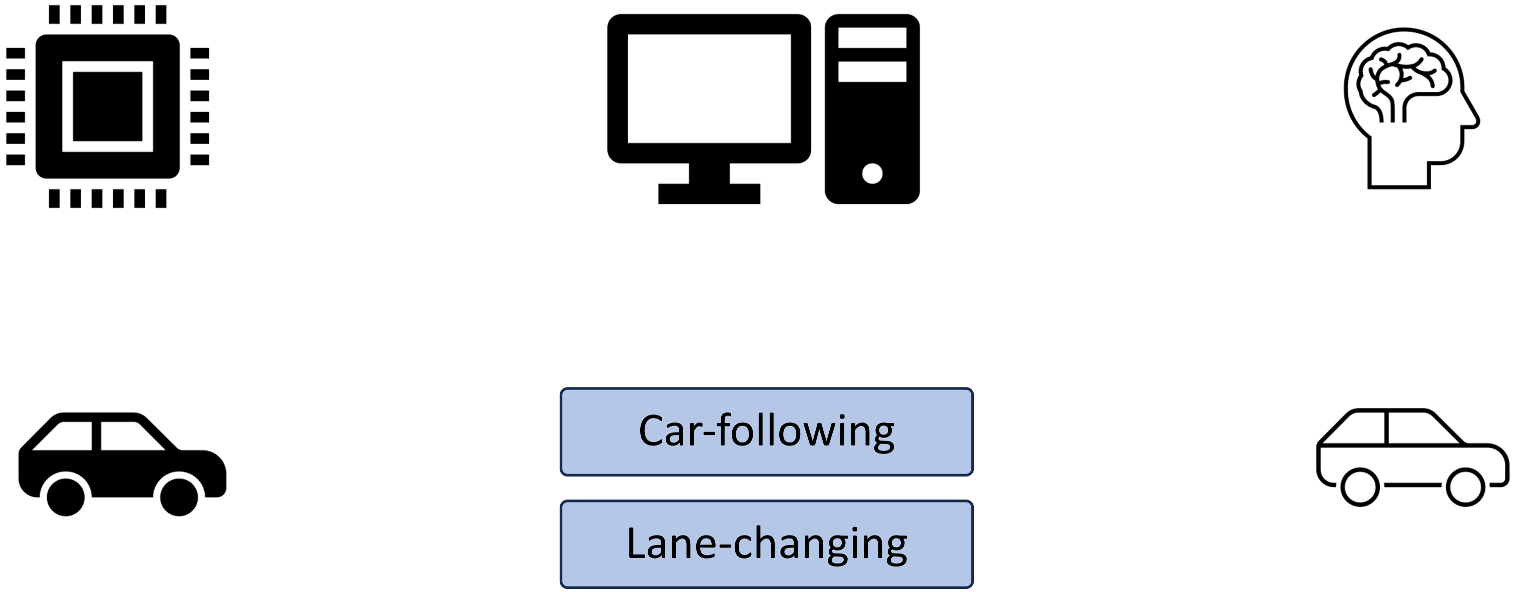
State of the practice - Impacts



- PTV Vissim
- Wiedemann 99 car-following model



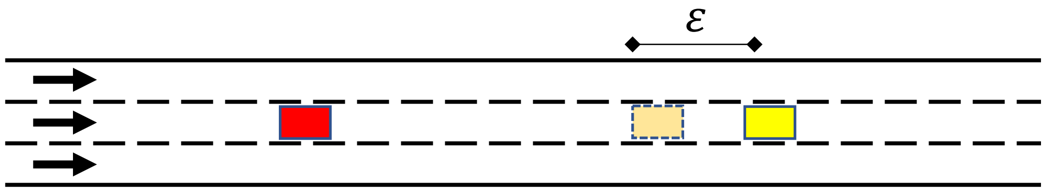
Microscopic driving models



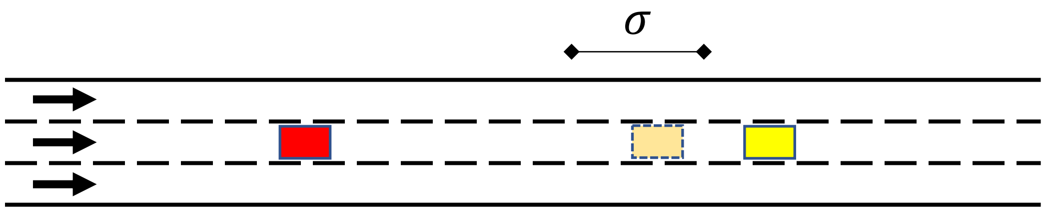
Perception errors

$$f_{err}\ (d,v) = \varepsilon(d) + W_{trans} * (\sigma(d,v))$$

Accuracy



Precision



Postigo et al. (2023) – Modeling perception performance in microscopic simulation of traffic flows including automated vehicles
2023 IEEE 26th International Conference on Intelligent Transportation Systems

Simulation experiment - IDM

	P1 – Human [1]	P2 – ADS [2]
Desired acceleration – a	1.0 m/s2	1.0 m/s2
Desired deacceleration – b	2.75 m/s2	2.75 m/s2
Desired time gap – T	1.2 s	1.2 s
Free accel exponent – delta	4	25
Min. gap – So	2.0 m	2.0 m
Desired speed - Vo	25 m/s	25 m/s
Error Correlation – Tw	20s	500s

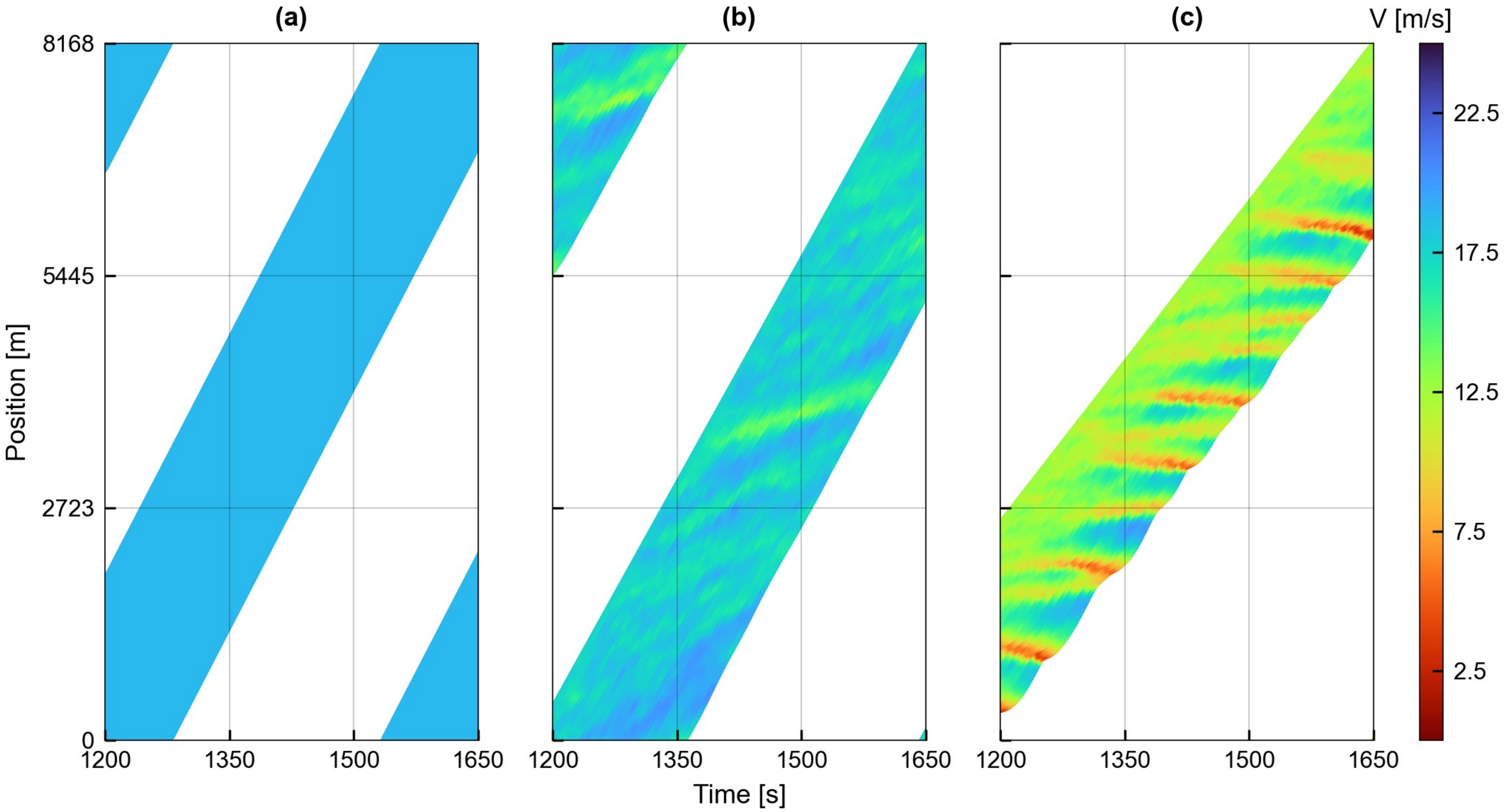
$$\dot{v} = a * \left(1 - \left(\frac{v}{V_o}\right)^{\delta} - \left(\frac{S^*}{S}\right)^2\right)$$

$$S^* = S_o + max\left\{\left(0, vT + \frac{v\Delta v}{2\sqrt{ab}}\right)\right\}$$

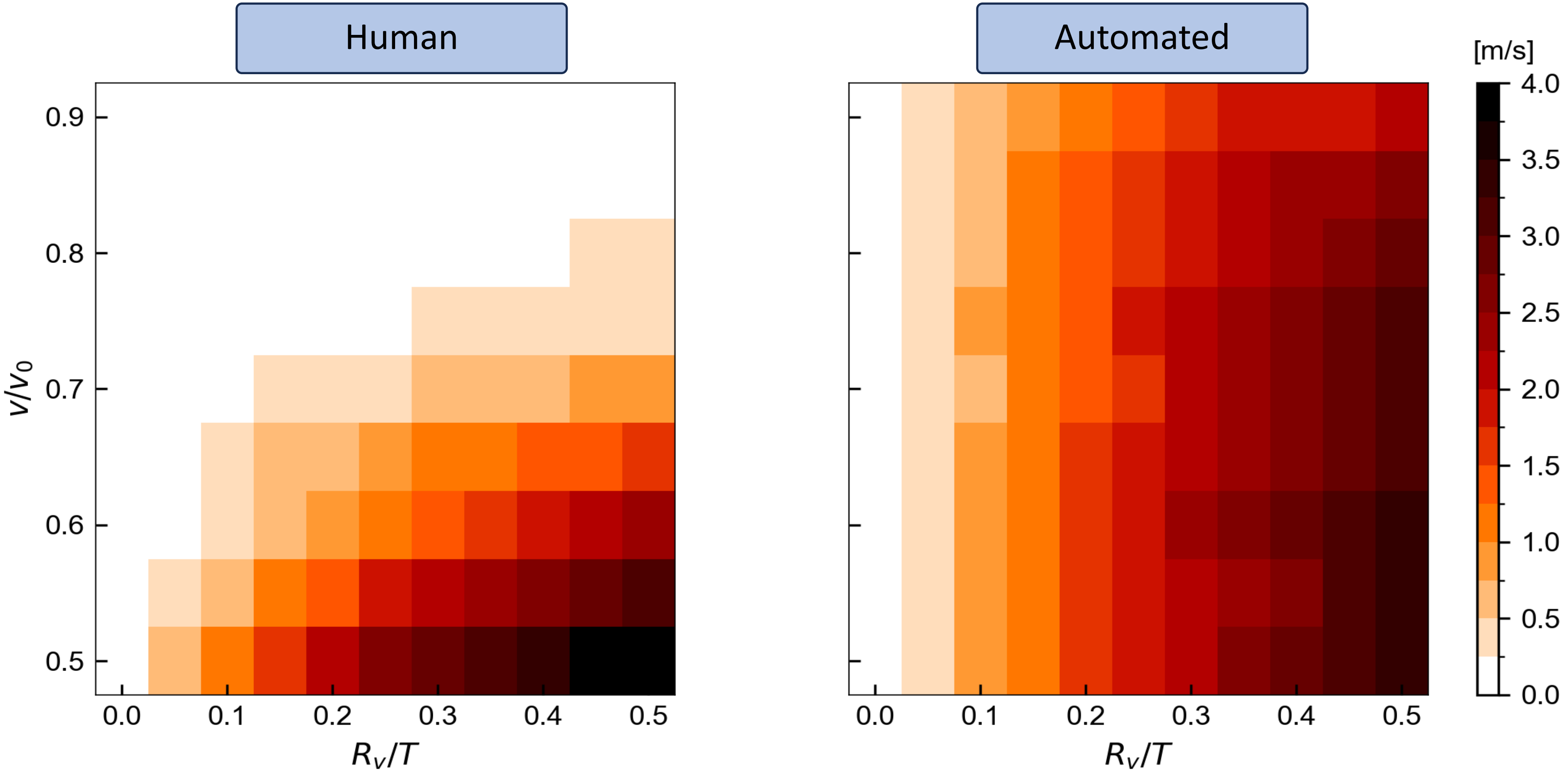
References:

[1] : Zhu et al. 2018, Pourabdollah et al. 2017, Treiber et al. 2000,
[2] : De Souza et al. 2020, Gunter et al. 2019

Effects on traffic flow dynamics (I)

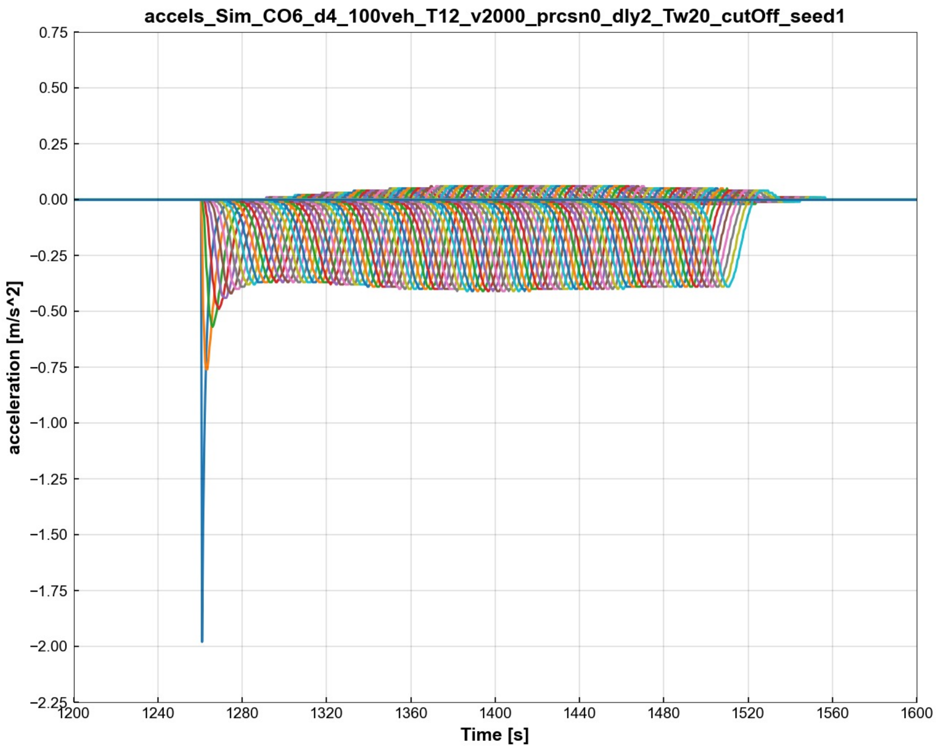


Effects on traffic flow dynamics – Free crusing

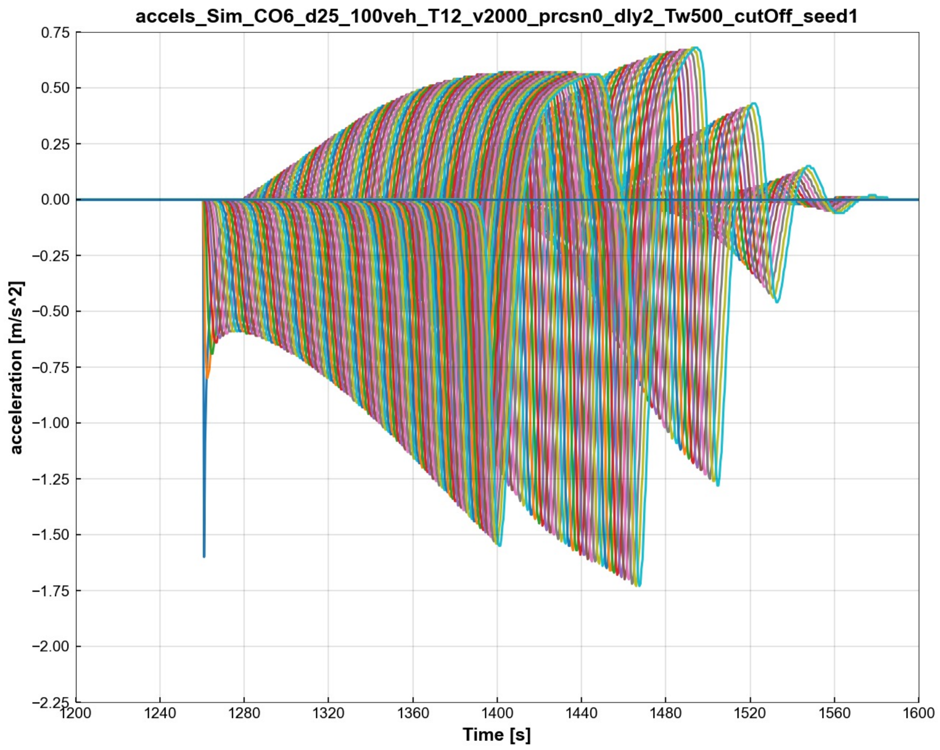


Effects on traffic flow dynamics – Cut in (I)

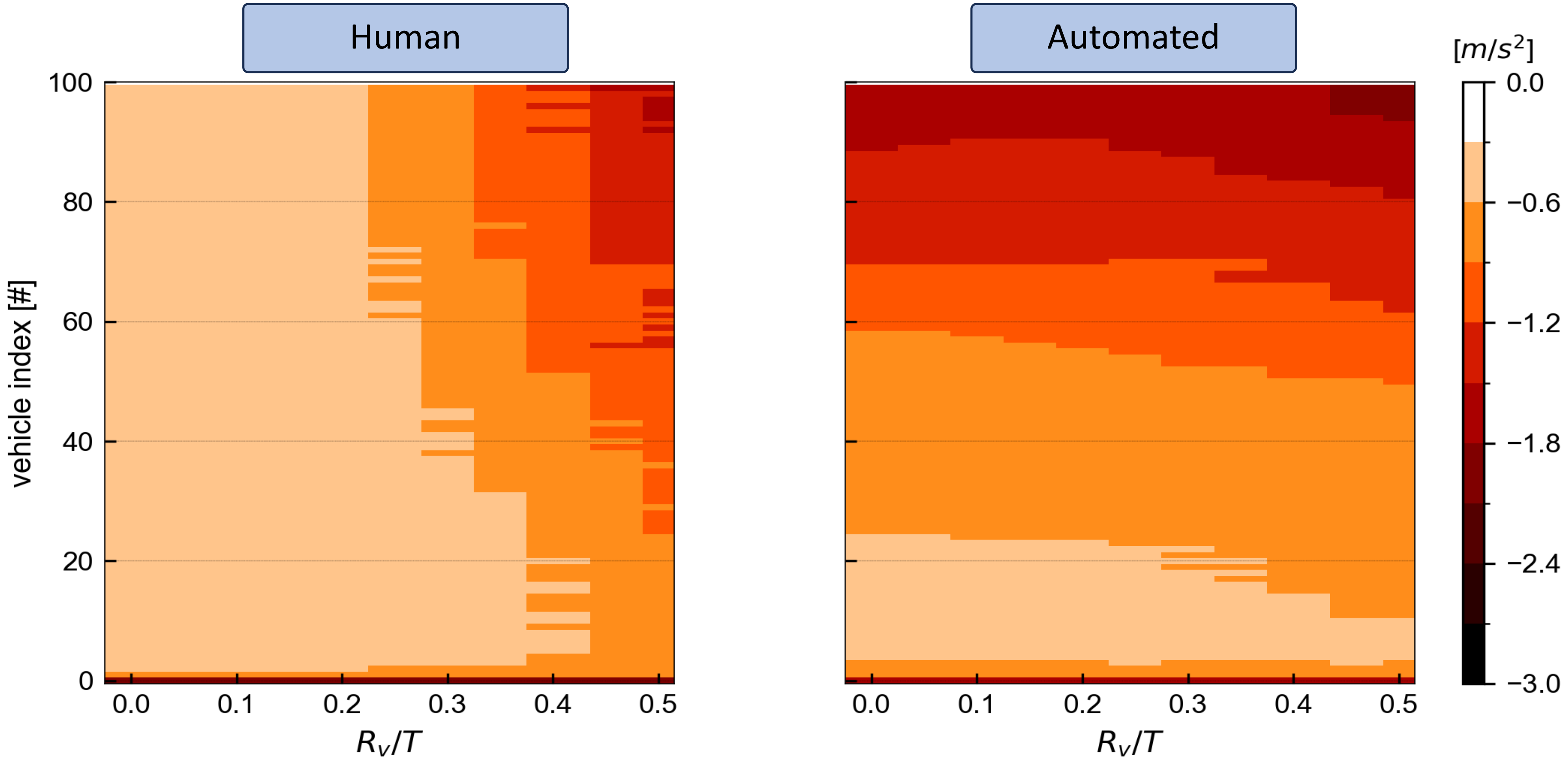
Human



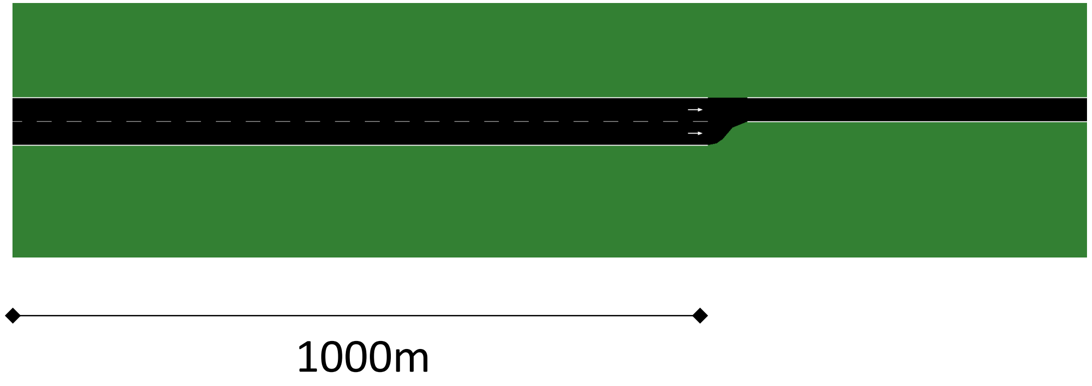
Automated

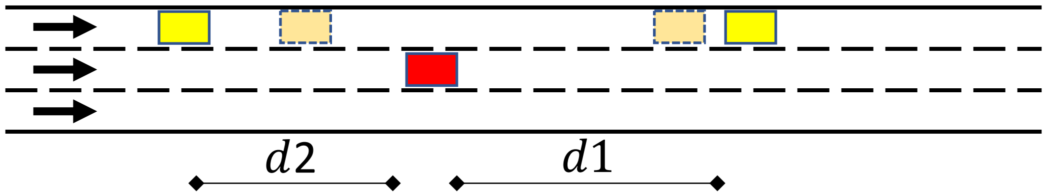


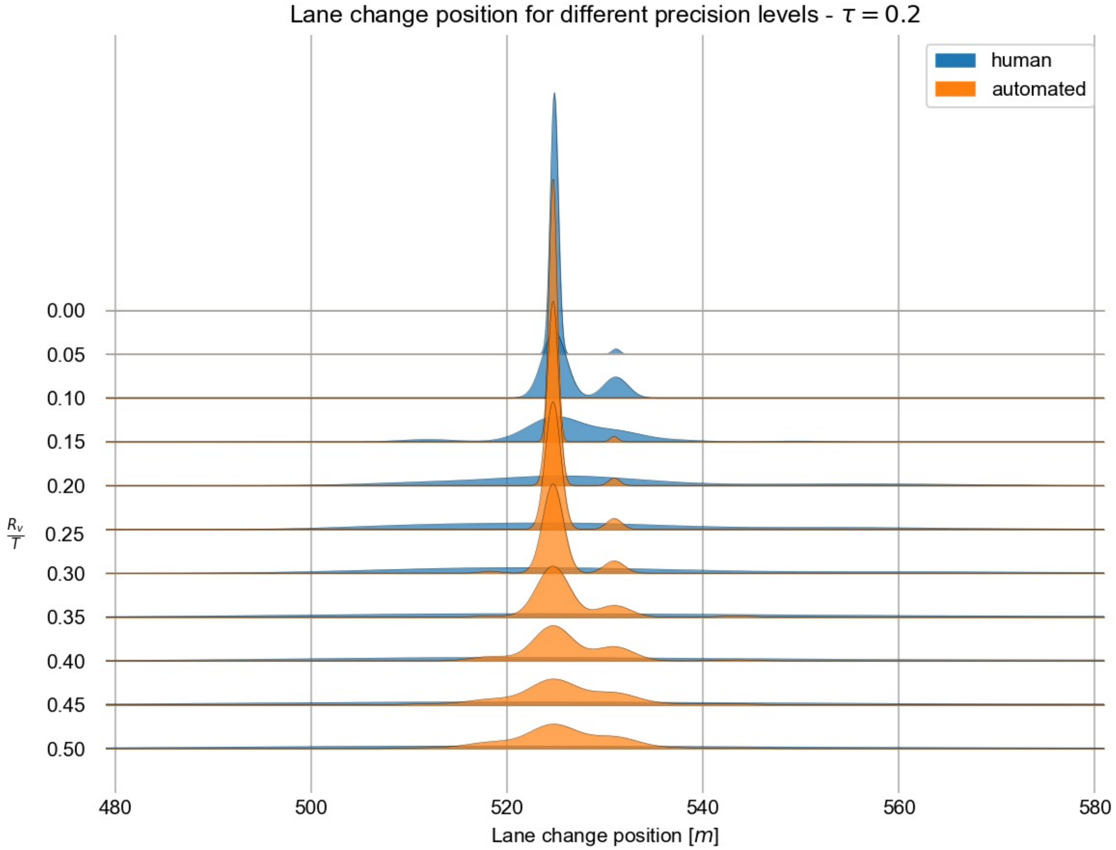
Effects on traffic flow dynamics – Cut in (II)



Lane changing







Conclusions and next steps

Modeling

- The perception performance is a key point of difference between automated and human driving.
- The simulation experiment shows that the common assumption of perfect perception misses potential drawbacks such as a reduced road capacity or reduced traffic safety.
- The explicit modeling of the perception enables a wider range of assumptions to study mixed traffic in microscopic traffic simulation.

Impacts

- Next is to study the impacts of mixed traffic using the proposed modeling approach.
- Heterogeneity of human and automated vehicles to be included in a motorway environment.

Thanks for your attention!

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Accuracy (i)

$$f^{\Omega}(d,v) = \boldsymbol{\varepsilon^{\Omega}(d)} + W_{trans} * (\sigma^{\Omega}(d) + \sigma^{\Omega}(v))$$

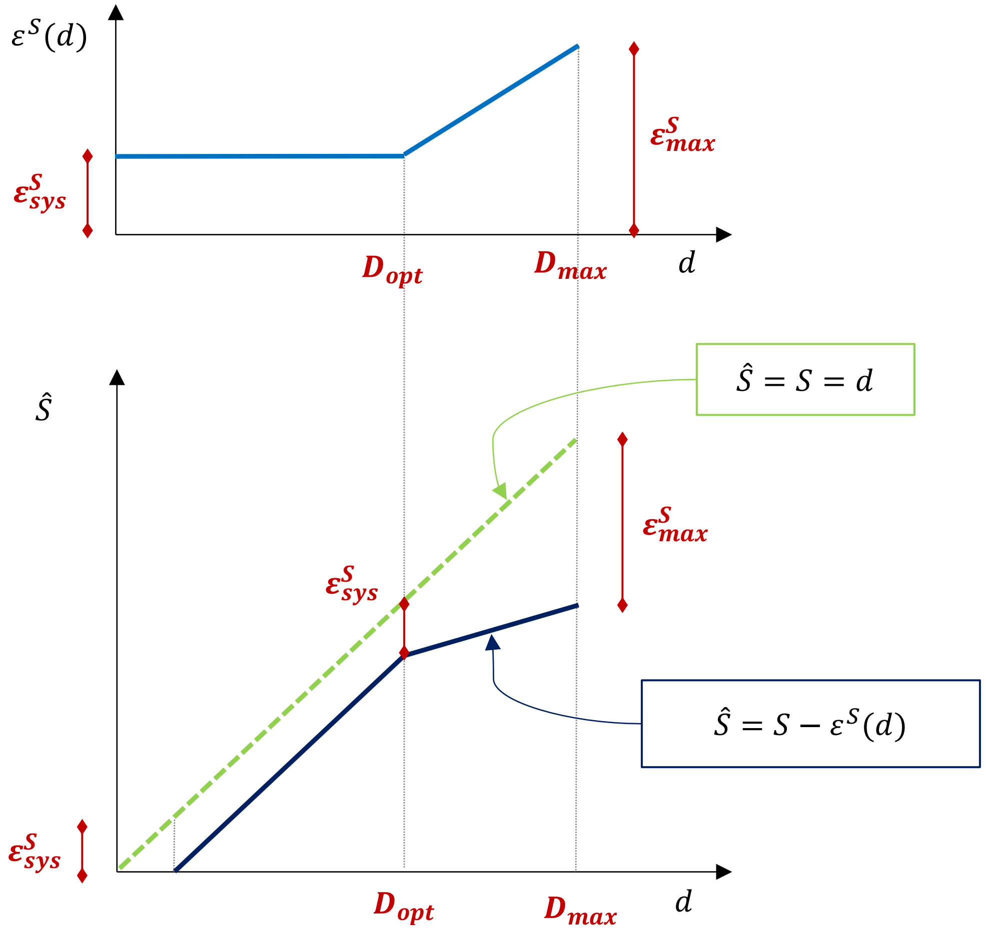
$\boldsymbol{\varepsilon^{\Omega}(d)}$ - *Parameters :*

$\varepsilon_{sys}^{\Omega}$: Systematic, persistent or minimum error

$\varepsilon_{max}^{\Omega}$: Error at maximum detection range

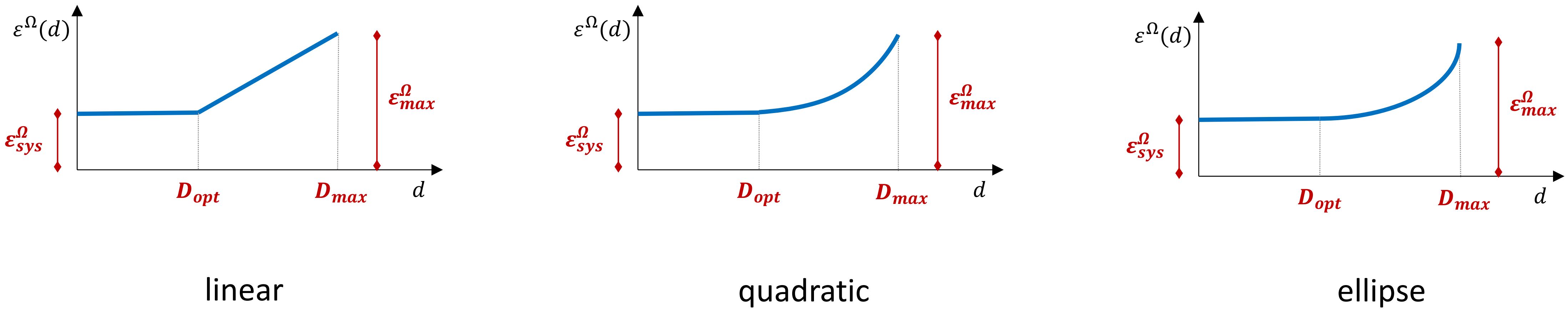
D_{opt} : Optimal operational range

D_{max} : Maximum detection range



Accuracy (ii)

$$f^{\Omega}(d,v) = \boldsymbol{\varepsilon^{\Omega}(d)} + W_{trans} * (\sigma^{\Omega}(d) + \sigma^{\Omega}(v))$$



Precision (i)

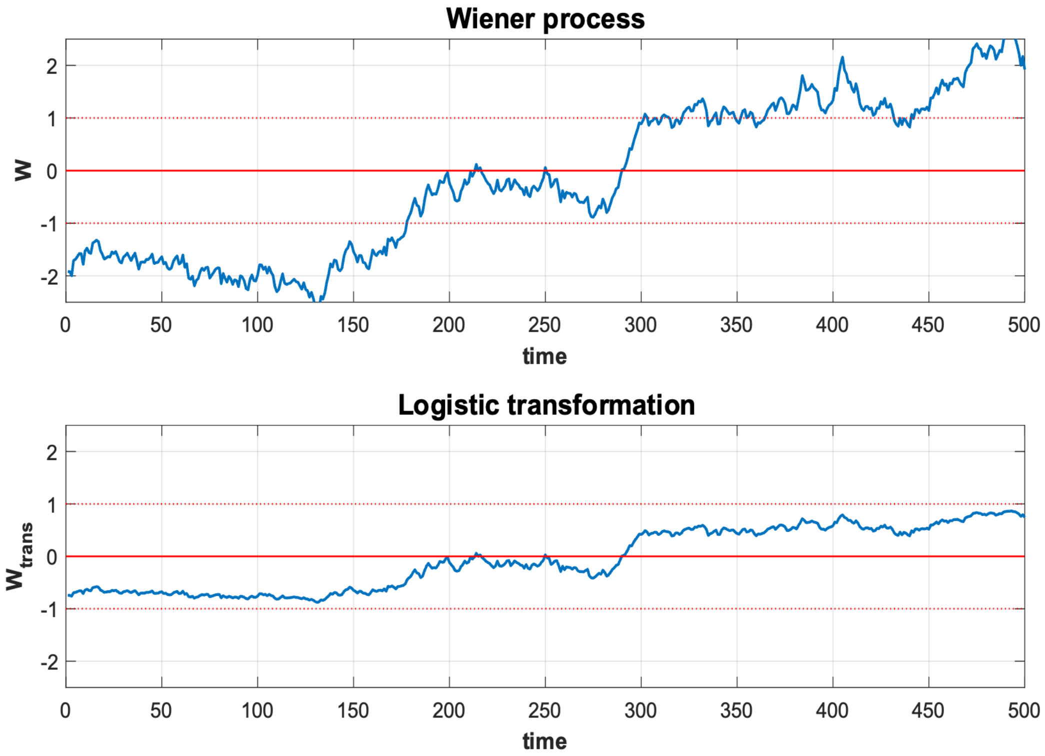
$$f^{\Omega}(d,v) = \boldsymbol{\varepsilon}^{\boldsymbol{\Omega}}(\boldsymbol{d}) + W_{trans} * (\sigma^{\Omega}(d) + \sigma^{\Omega}(v))$$

$$\boldsymbol{W_{trans}} \in [-\mathbf{1}, \mathbf{1}]$$

$$\boldsymbol{W_{trans}} = \frac{\mathbf{2}}{\mathbf{1} + \mathbf{exp}(-\boldsymbol{W})} - \mathbf{1}$$

$$W(t+\Delta t) = \begin{cases} \eta, & initial \\ \exp\left(-\frac{\Delta t}{\tau}\right) * W(t) + \eta\sqrt{\frac{2\Delta t}{\tau}}, & otherwise \end{cases}$$

$\eta \in N(0,1)$
τ: Time-window correlation



Precision (ii)

$$f^{\Omega}(d,v) = \boldsymbol{\varepsilon}^{\boldsymbol{\Omega}}(\boldsymbol{d}) + W_{trans} * (\sigma^{\Omega}(d) + \sigma^{\Omega}(v))$$

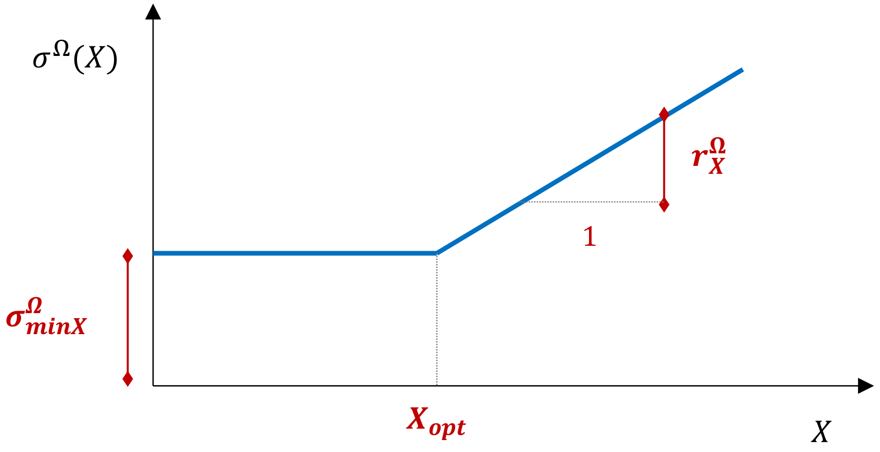
$\mathrm{X} = \{d, v\}$

$\boldsymbol{\sigma}^{\boldsymbol{\Omega}}(\boldsymbol{X})$ - *Parameters :*

σ^{Ω}_{minX} : Minimum variation or noise

r^{Ω}_{X} : variation increase rate

X_{opt} : Optimal operational range

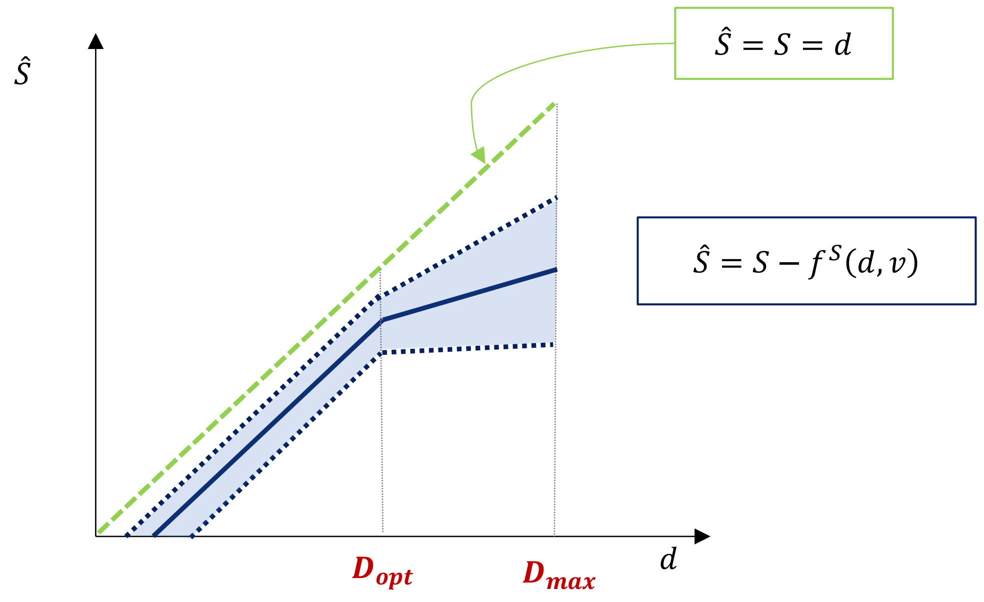


Accuracy and precision

Parameters :

$\varepsilon_{sys}^{\Omega}$	: Systematic, persistent or minimum error
$\varepsilon_{max}^{\Omega}$	: Error at maximum detection range
D_{opt}	: Optimal operational range
D_{max}	: Maximum detection range
σ_{minD}^{Ω}	: Minimum distance variation or noise
r_{d}^{Ω}	: Distance variation increase rate
σ_{minV}^{Ω}	: Minimum speed variation or noise
r_{v}^{Ω}	: Speed variation increase rate
V_{opt}	: Optimal operational speed
τ	: Time-window variation correlation

$$f^{\Omega}(d,v) = \varepsilon^{\Omega}(d) + W_{trans} * (\sigma^{\Omega}(d) + \sigma^{\Omega}(v))$$

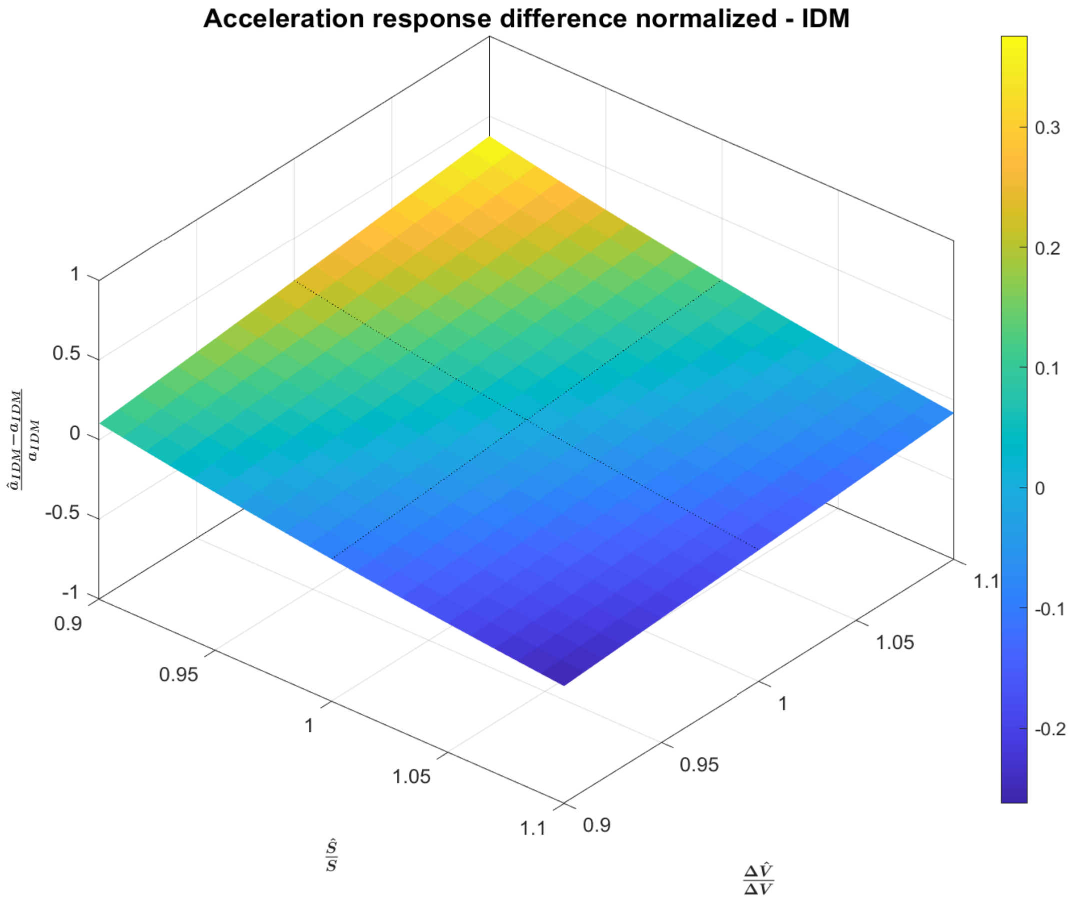


Intelligent driver model (IDM) sensibility

$$\dot{v} = a \cdot \left(1 - \left(\frac{v}{V_o}\right)^{\delta} - \left(\frac{S^*}{S}\right)^2\right)$$

$$S^* = So + \max\left\{\left(0, vT + \frac{v\Delta v}{2\sqrt{ab}}\right)\right\}$$

a = 1 m/s2
S = 65 m
v = 25 m/s
Vo = 25 m/s
Delta V = 5.55 m/s



Change in fundamental diagram (IDM)

Vo = 19.45 m/s

$$S = Se(v) = \frac{so + vT}{\sqrt{1 - \left(\frac{v}{Vo}\right)^{\delta}}}$$

$$\rho = \frac{1}{S}$$

$$Q = \rho * V$$