Perspectives on an ALKS model in SUMO

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SUMO User Conference, Berlin, Germany

15 May 2024

DLR

Short agenda

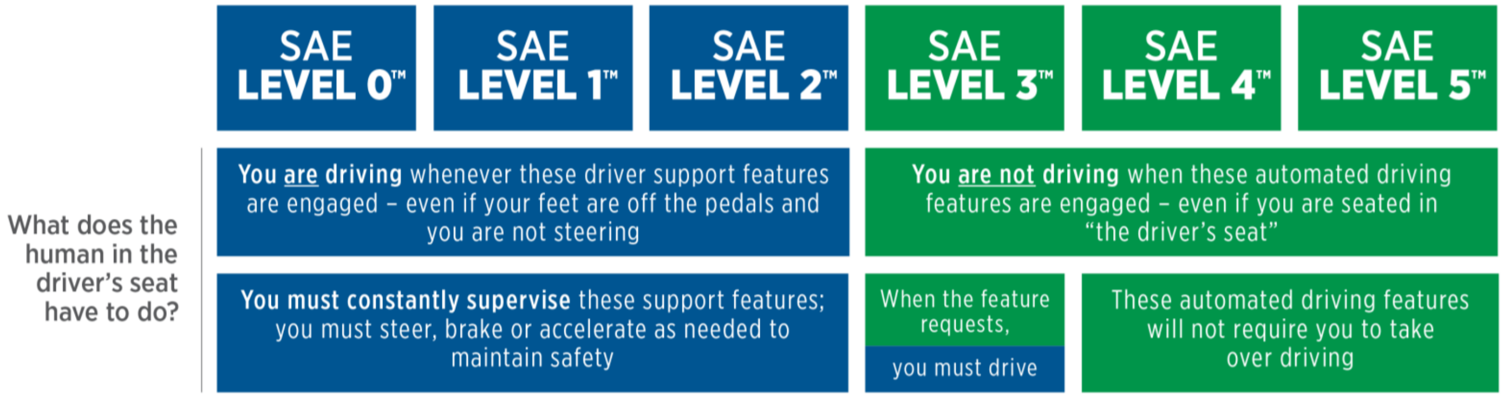
- Introduction about ALKS
- Partial reproduction of UN Reg. No. 157
- Conclusions & Outlook

Introduction

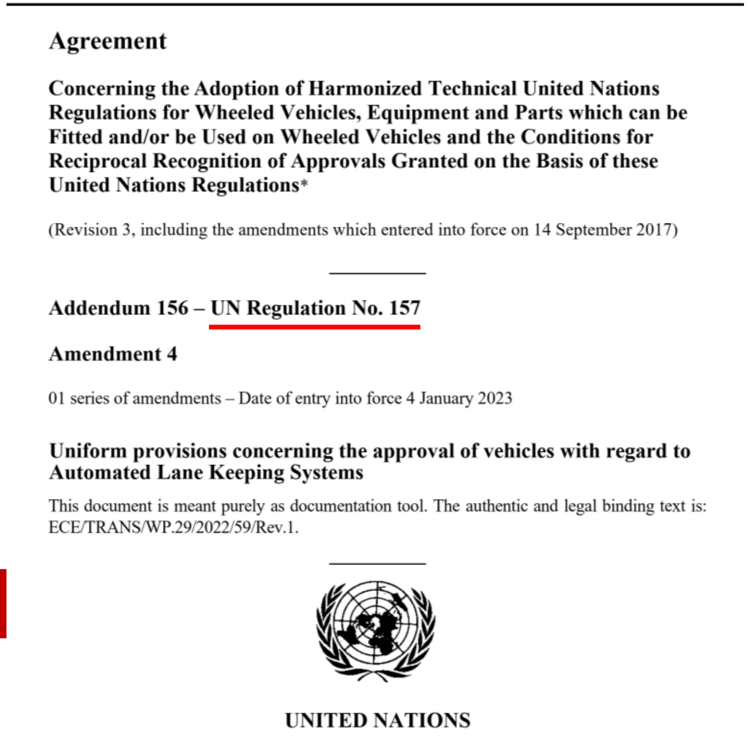
Source: German Aerospace Center

ALKS = Automated Lane Keeping System

- ALKS: essentially level 3 automated driving



https://www.sae.org/standards/content/j3016_202104



Agreement

Concerning the Adoption of Harmonized Technical United Nations Regulations for Wheeled Vehicles, Equipment and Parts which can be Fitted and/or be Used on Wheeled Vehicles and the Conditions for Reciprocal Recognition of Approvals Granted on the Basis of these United Nations Regulations*

(Revision 3, including the amendments which entered into force on 14 September 2017)

Addendum 156 – UN Regulation No. 157

Amendment 4

01 series of amendments – Date of entry into force 4 January 2023

Uniform provisions concerning the approval of vehicles with regard to Automated Lane Keeping Systems

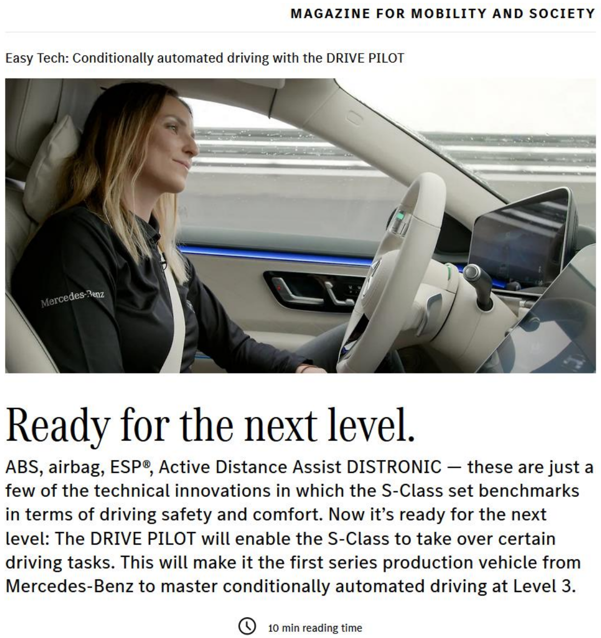
This document is meant purely as documentation tool. The authentic and legal binding text is: ECE/TRANS/WP.29/2022/59/Rev.1.

UNITED NATIONS

- Reg. 157 lays down safety requirements

https://unece.org/transport/documents/2023/03/standards/un-regulation-no-157-amend4

ALKS: about to enter the market



MAGAZINE FOR MOBILITY AND SOCIETY

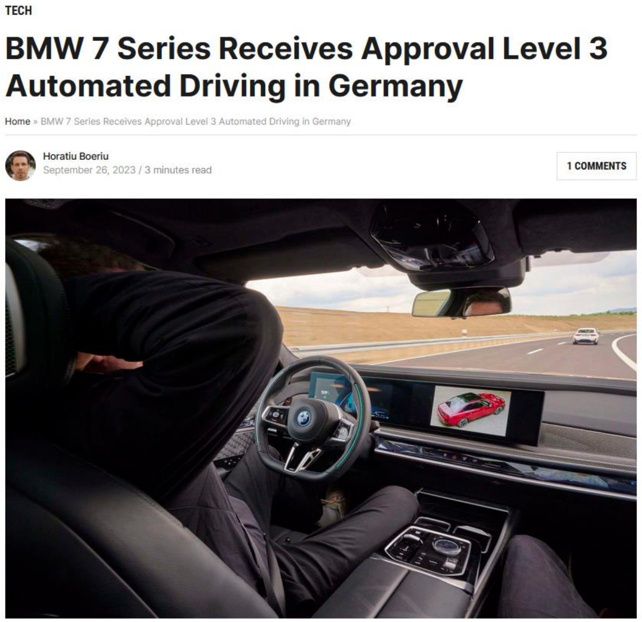
Easy Tech: Conditionally automated driving with the DRIVE PILOT

Ready for the next level.

ABS, airbag, ESP®, Active Distance Assist DISTRONIC — these are just a few of the technical innovations in which the S-Class set benchmarks in terms of driving safety and comfort. Now it's ready for the next level: The DRIVE PILOT will enable the S-Class to take over certain driving tasks. This will make it the first series production vehicle from Mercedes-Benz to master conditionally automated driving at Level 3.

10 min reading time

https://group.Mercedes-benz.com/company/magazine/technology-innovation/easy-tech-drive-pilot.html



TECH

BMW 7 Series Receives Approval Level 3 Automated Driving in Germany

Home » BMW 7 Series Receives Approval Level 3 Automated Driving in Germany

Horatiu Boeriu
September 26, 2023 / 3 minutes read

1 COMMENTS

https://www.bmwblog.com/2023/09/26/bmw-7-series-receives-approval-level-3-automated-driving-in-germany/

→ Motivation: Can we have an ALKS model in SUMO?

Short summary of UN ECE Reg. 157

- Not a nice read!
- operational speed up to 60 km/h
  (theoretically up to 130 km/h, if system MRM lane change capable)

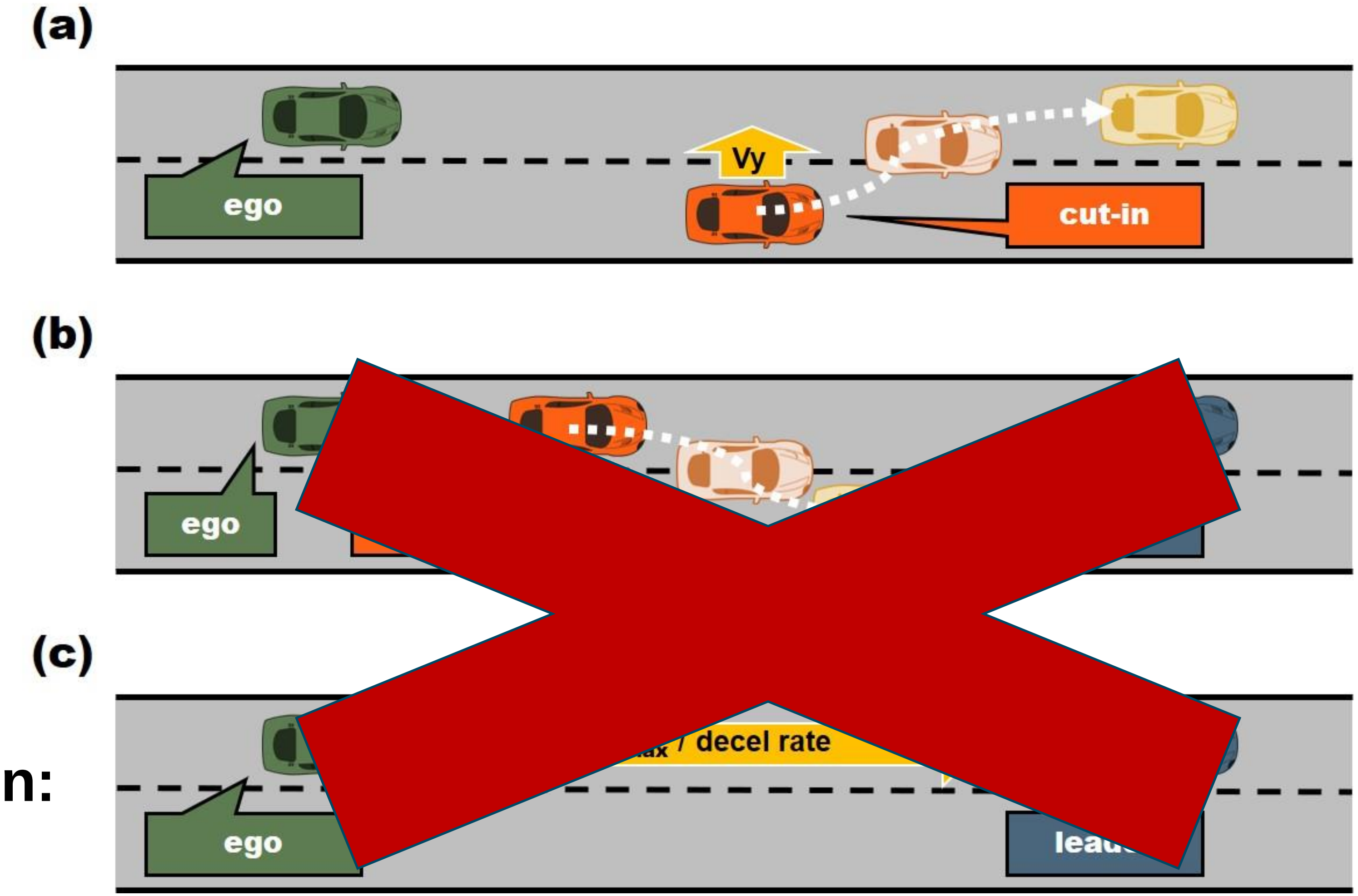
- so-called “performance models“ (= cf models):
  - Regulation 157
  - CC human driver
  - FSM

Three “traffic critical scenarios”

Cut-in:

Cut-out:

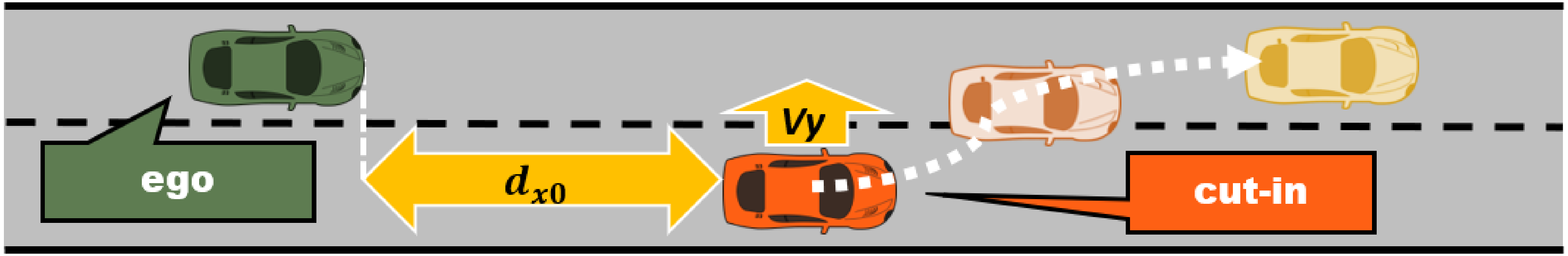
Deceleration:



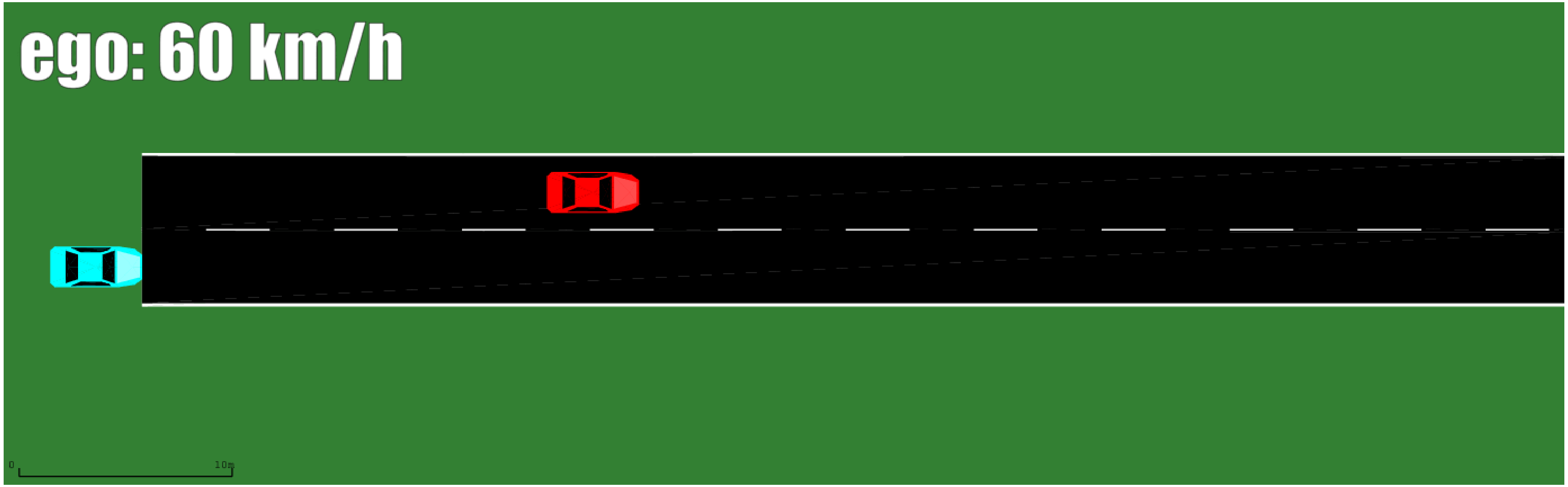
Notation

- V_y: lateral speed of challenger (speed jumps from 0 to V_y)
- d_{x0}: initial distance between front of ego and back of challenger

- $d_y = 1.6m$ (fixed): lateral distance between left side of challenger and right side of ego
- ℓ_e, ℓ_c (fixed): the lengths of the two vehicles

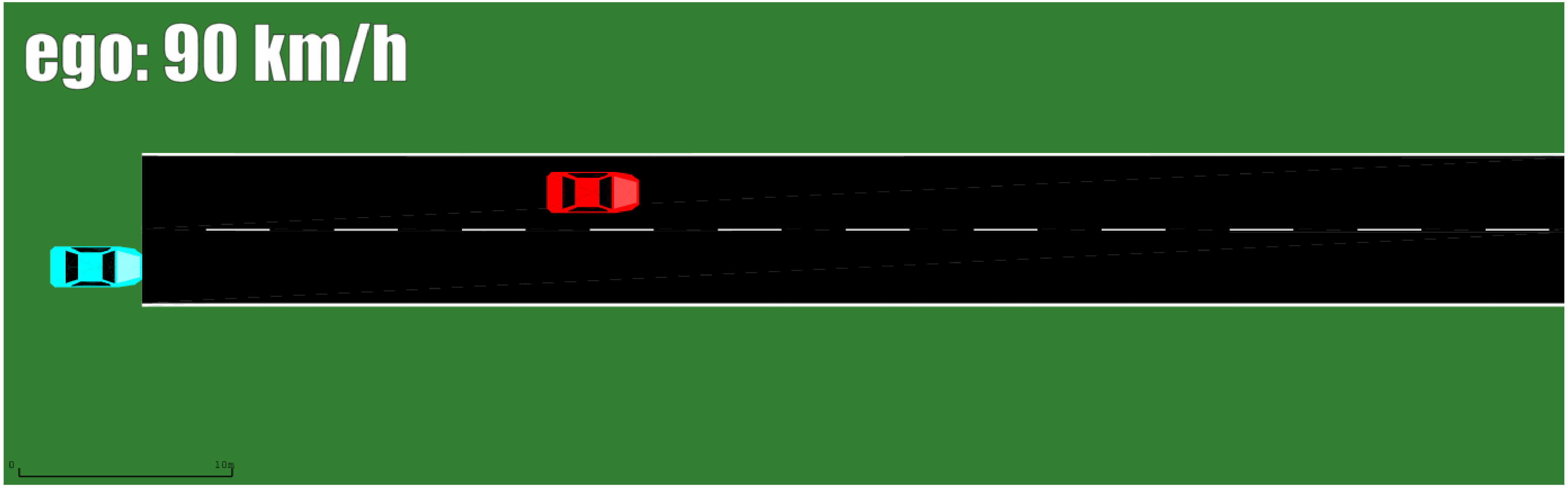


Most interesting: cut-in

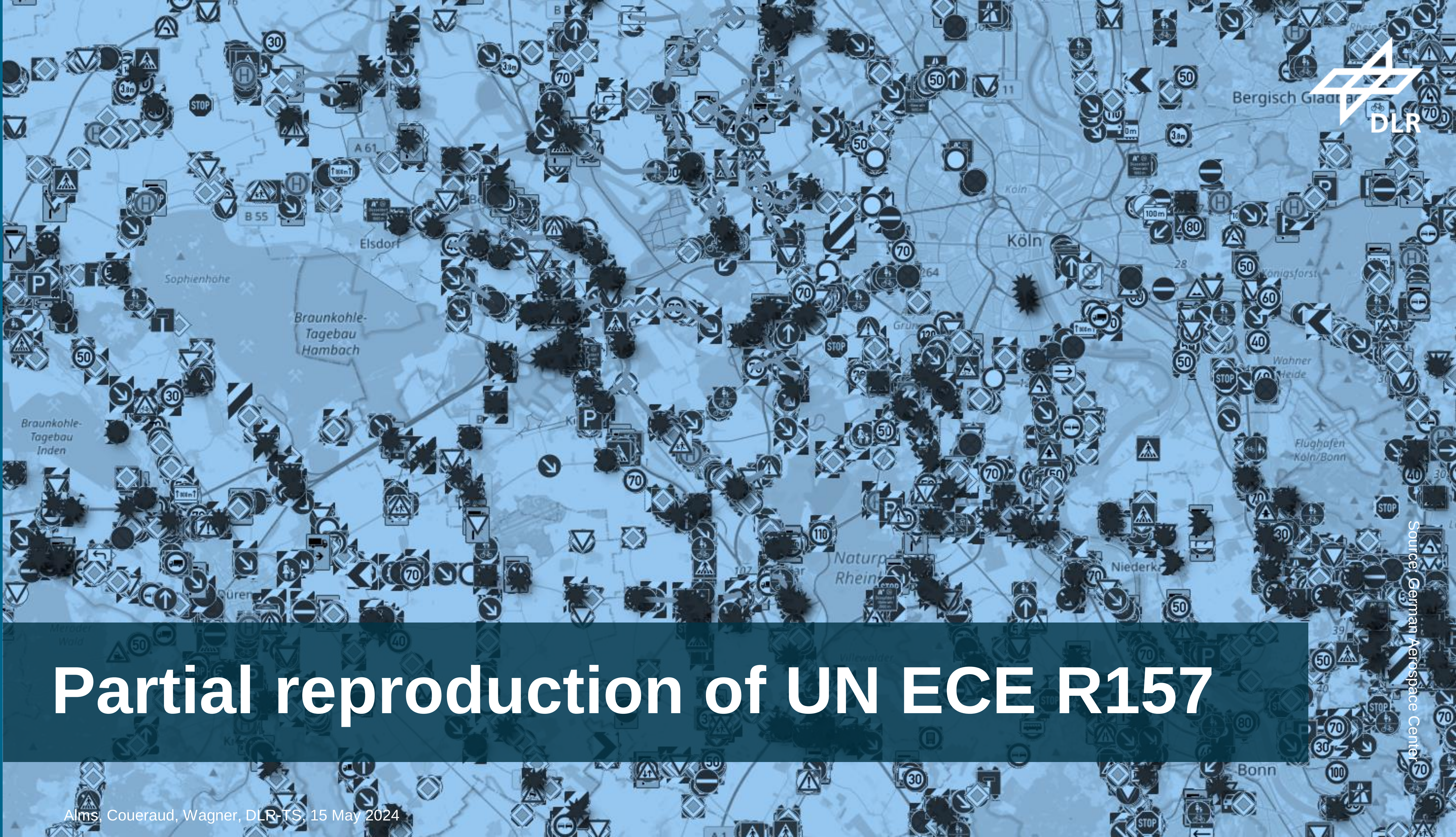


V_y= -1 m/s, d_{x0} = 19m, $V_{challanger}$= 30 km/h

Most interesting: cut-in



V_y= -1 m/s, d_{x0} = 19m, $V_{challanger}$= 30 km/h



Partial reproduction of UN ECE R157

Source: German Aerospace Center

Two step analysis:

1. Reproduce collision classification from R157

2. Comparison of models provided by the JRC repository:
   https://github.com/ec-jrc/JRC-FSM/tree/main

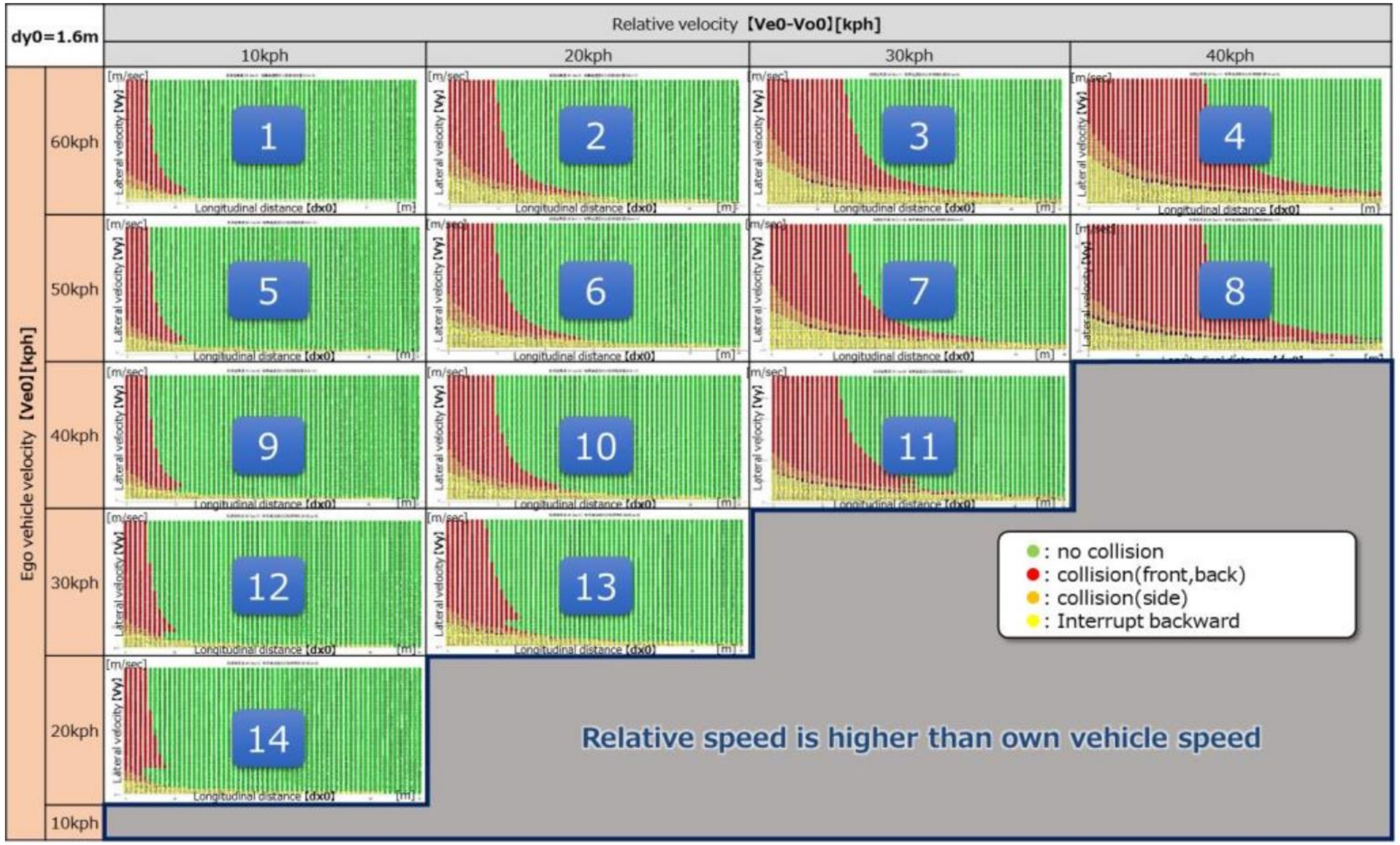
JRC = Joint Research Center of the European Commission

see also:

Mattas et al., Driver models for the definition of safety requirements of automated vehicles in international regulations. Application to motorway driving conditions. Accid. Anal. Prev. 2022, 174, 106743.

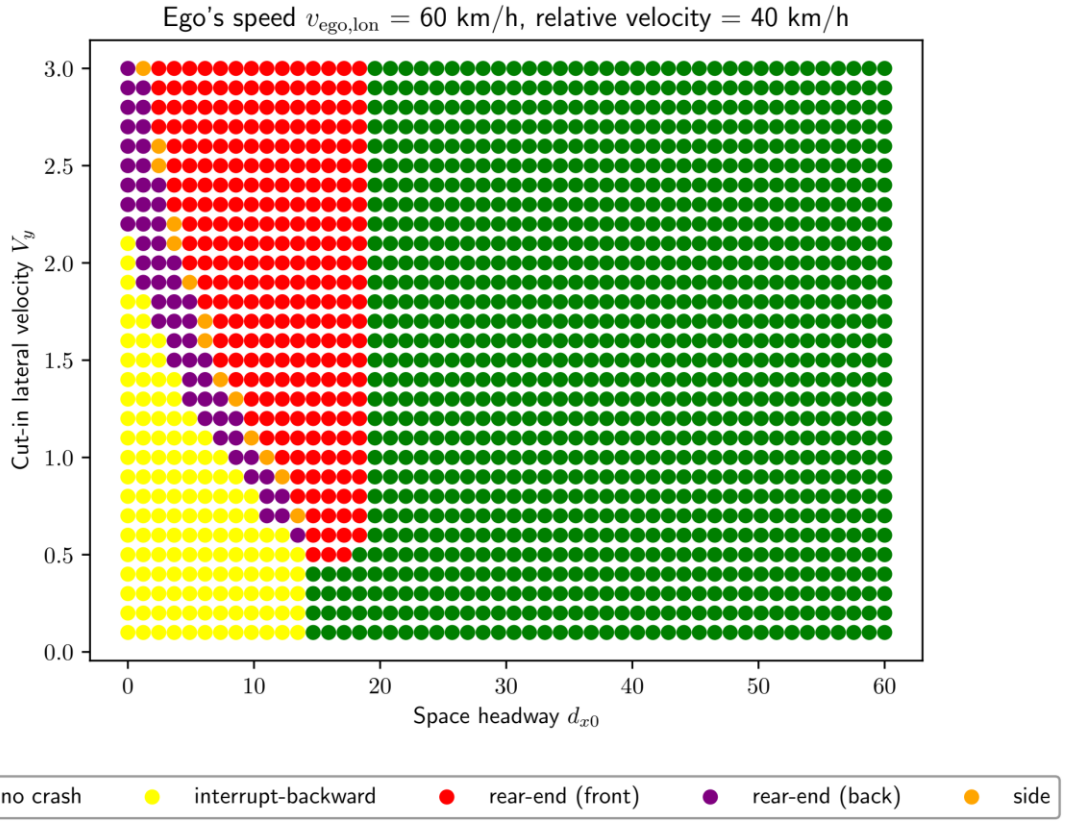
Two step analysis:

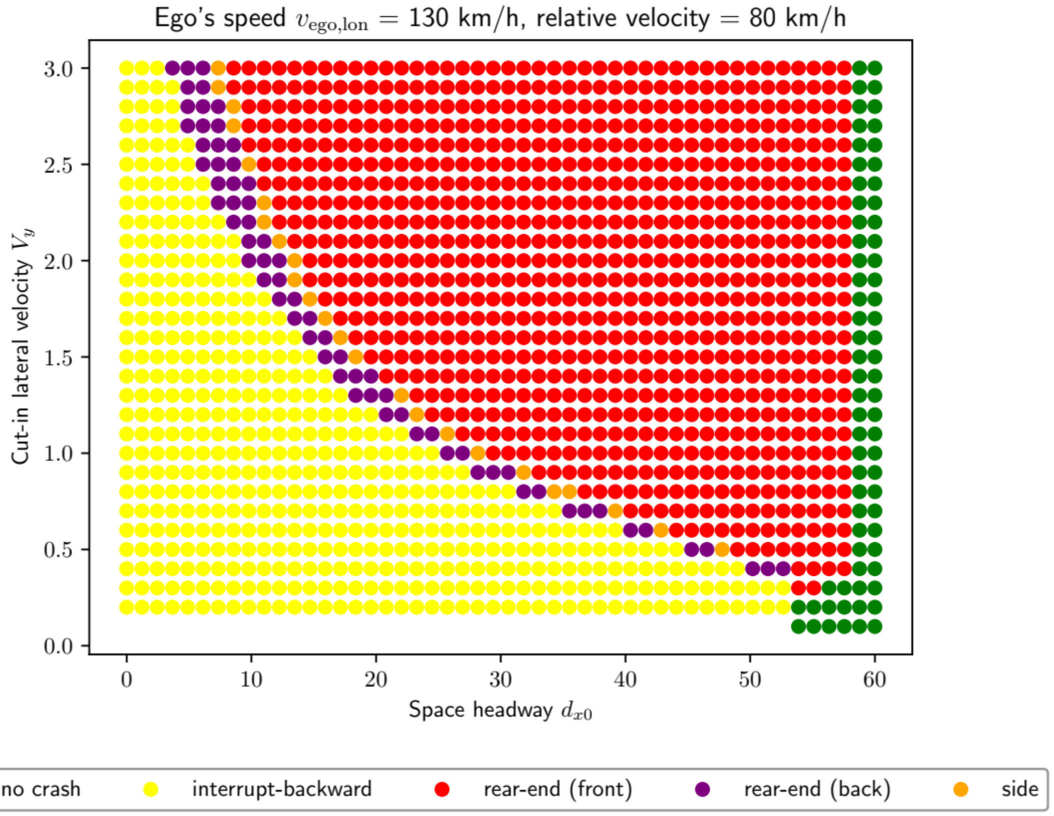
1. Reproduce collision classification from R157: e.g. Figure 7, Annex 3



1. Collision classification with SUMO

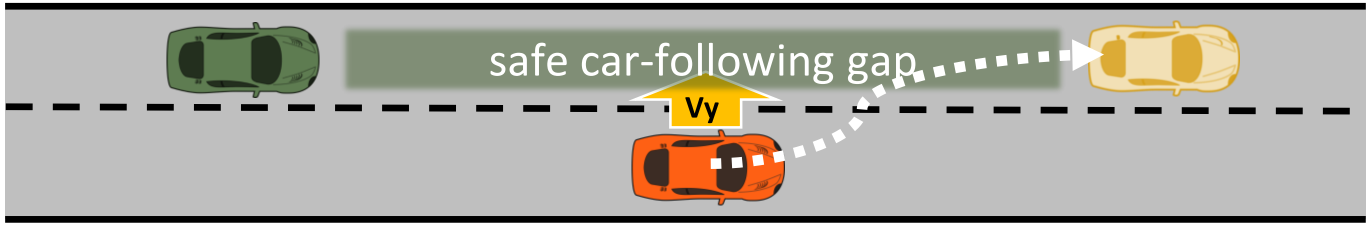
Two example outputs with simple continuous lane-change model:





SUMO's lane-change mechanism explained

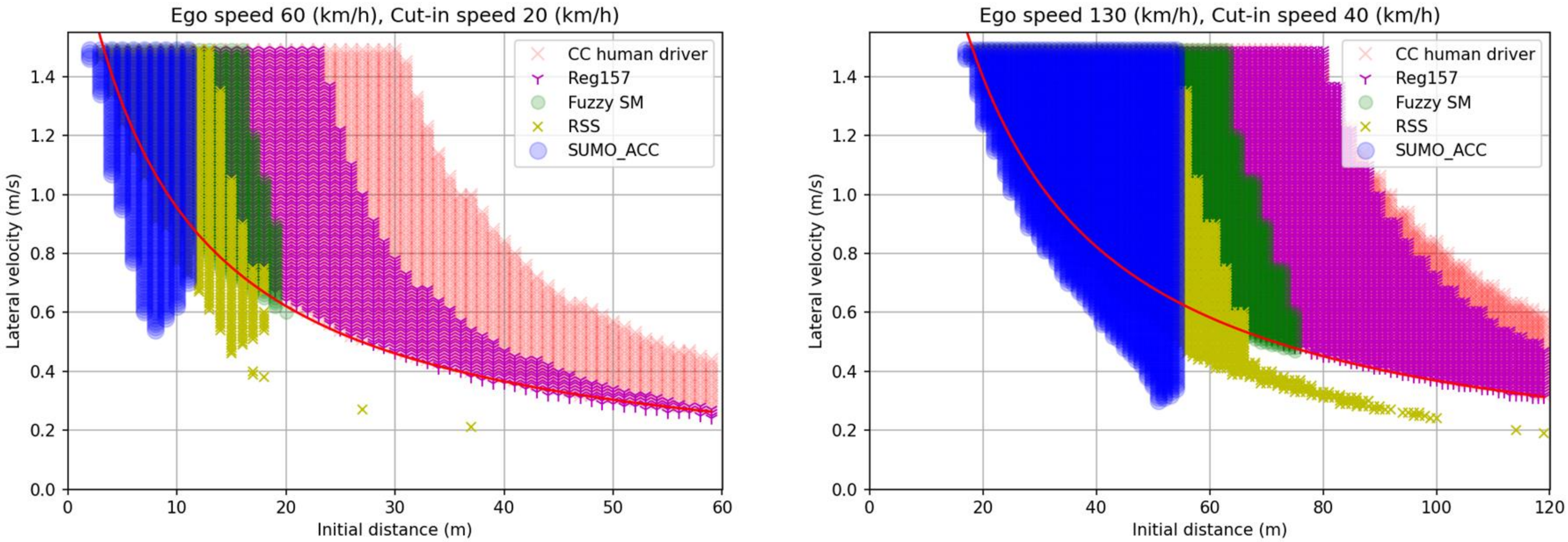
- note: default lane change is instantaneous (not applicable here)
- simple continuous lane change model with lateral velocity
  - SUMO' lane change model reserves a corridor for lane changes to ensure safe gaps



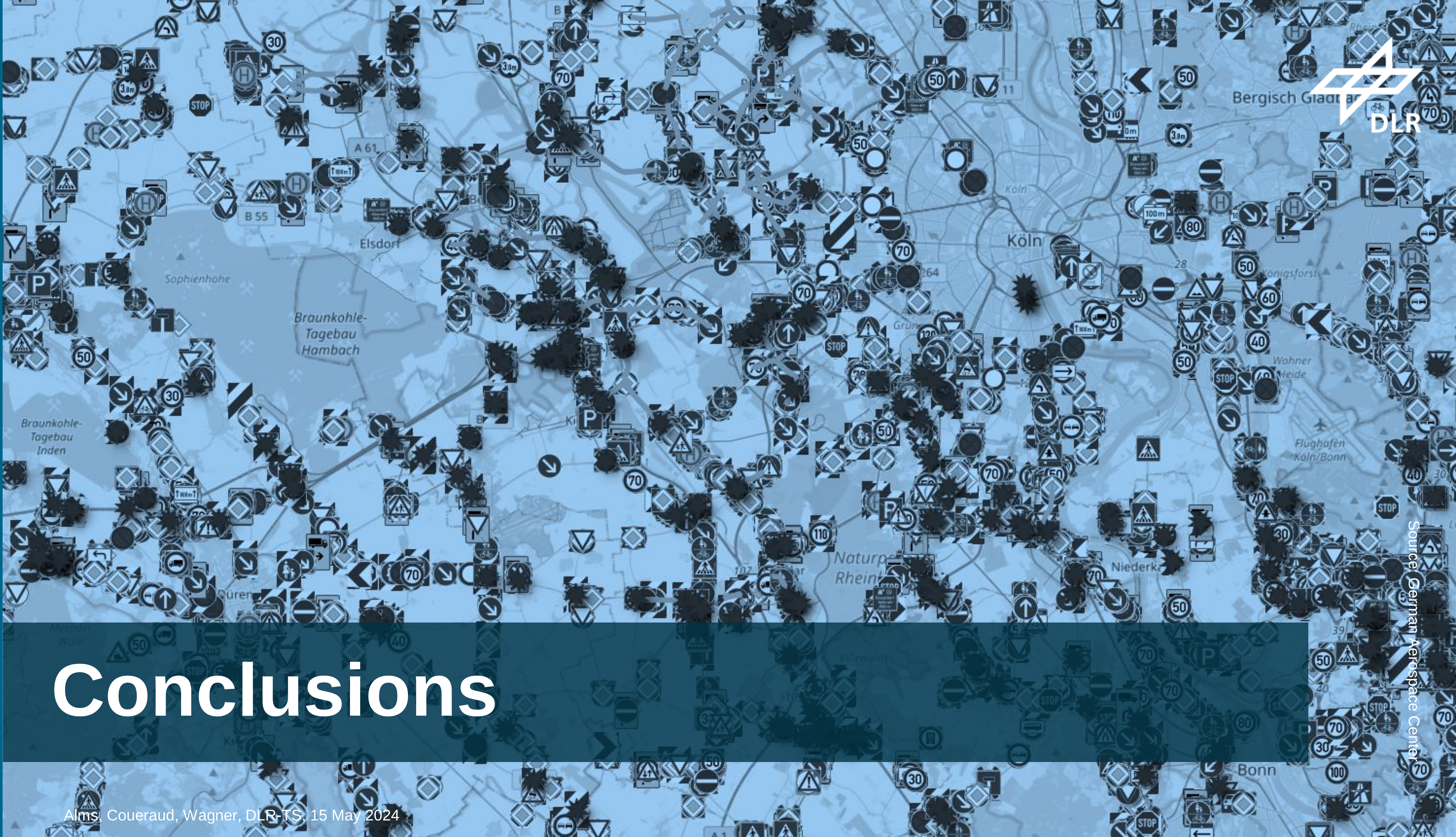
→ leads to immediate reaction by ego vehicle

→ deceleration to ensure safe gap is overridden by lc model

2. Model comparison



→ **Delayed detection and reaction by the other models lead to curved collision pattern**



Conclusions

Source: German Aerospace Center

Partial success, but…

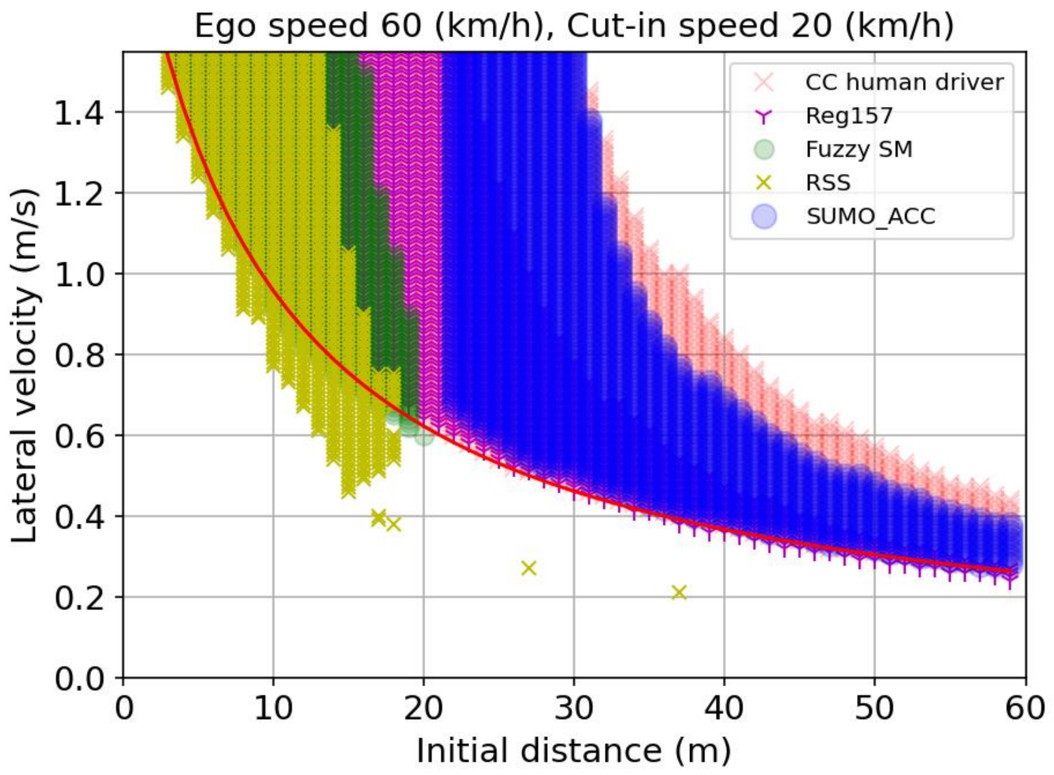
- sublane model probably better suited for further developments (wait for next slide…)

final remarks:

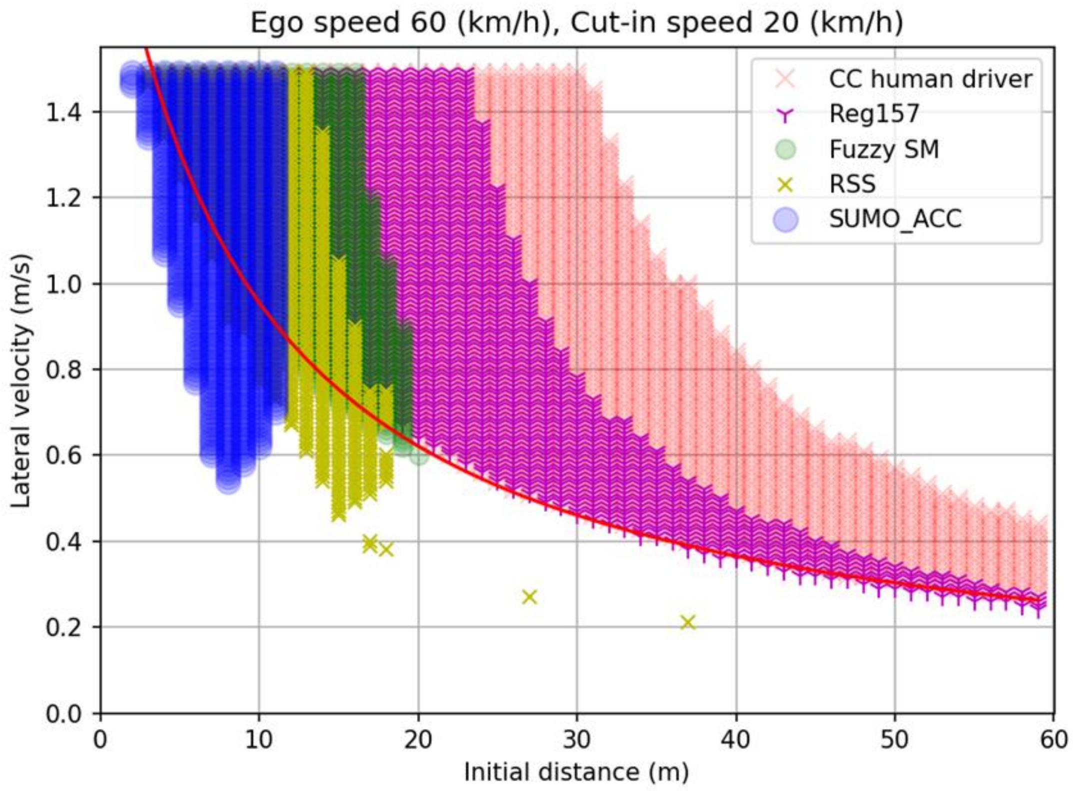
1. UN ECE R157 maybe a bit feeble:
   seems easy to implement better / safer models
2. Further questions regarding string stability and capacity:
   - (relatively large) headway $\tau = 1.6s$ as minimum required
   - current ACC systems prone to show string instable platoon behavior
   (**OpenACC JRC database**: https://data.jrc.ec.europa.eu/dataset/9702c950-c80f-4d2f-982f-44d06ea0009f)

Outlook: deploying the sublane model (work in progress)

sublane model



continuous lane change model



Imprint

Topic: ALKS for SUMO

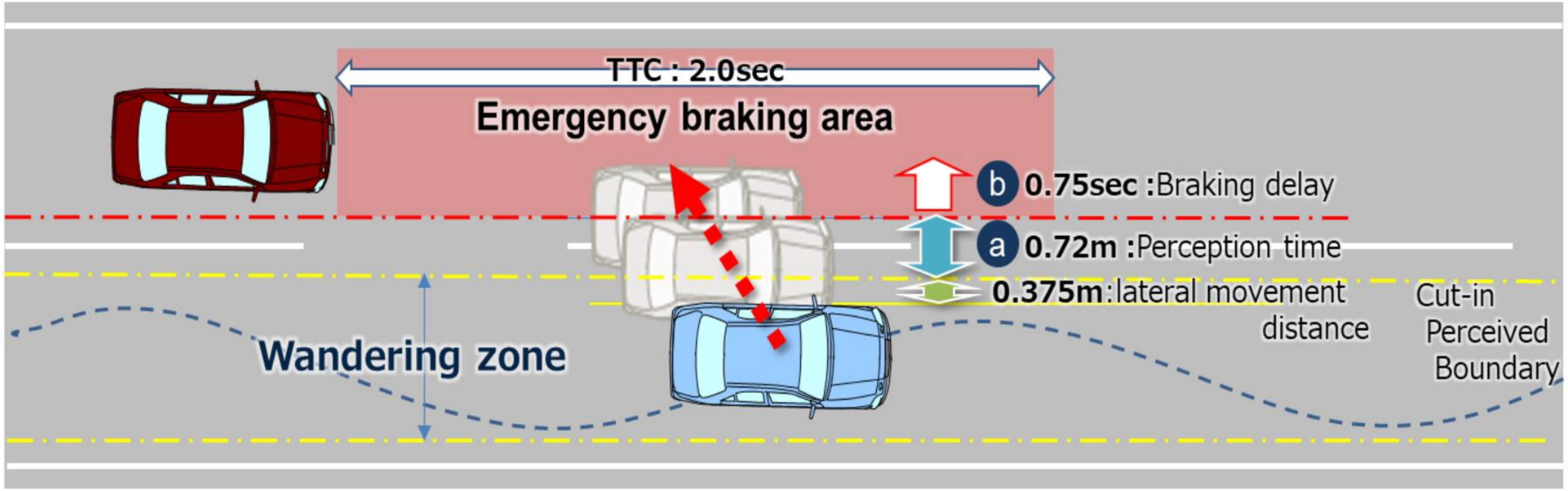
Date: 14 May 2024

Author: Robert Alms, Peter Wagner

Institute: Institute of Transportation Systems, DLR, and TU Berlin, Dynamic Modelling and Control of Transportation Systems

Delayed response by ALKS performance models

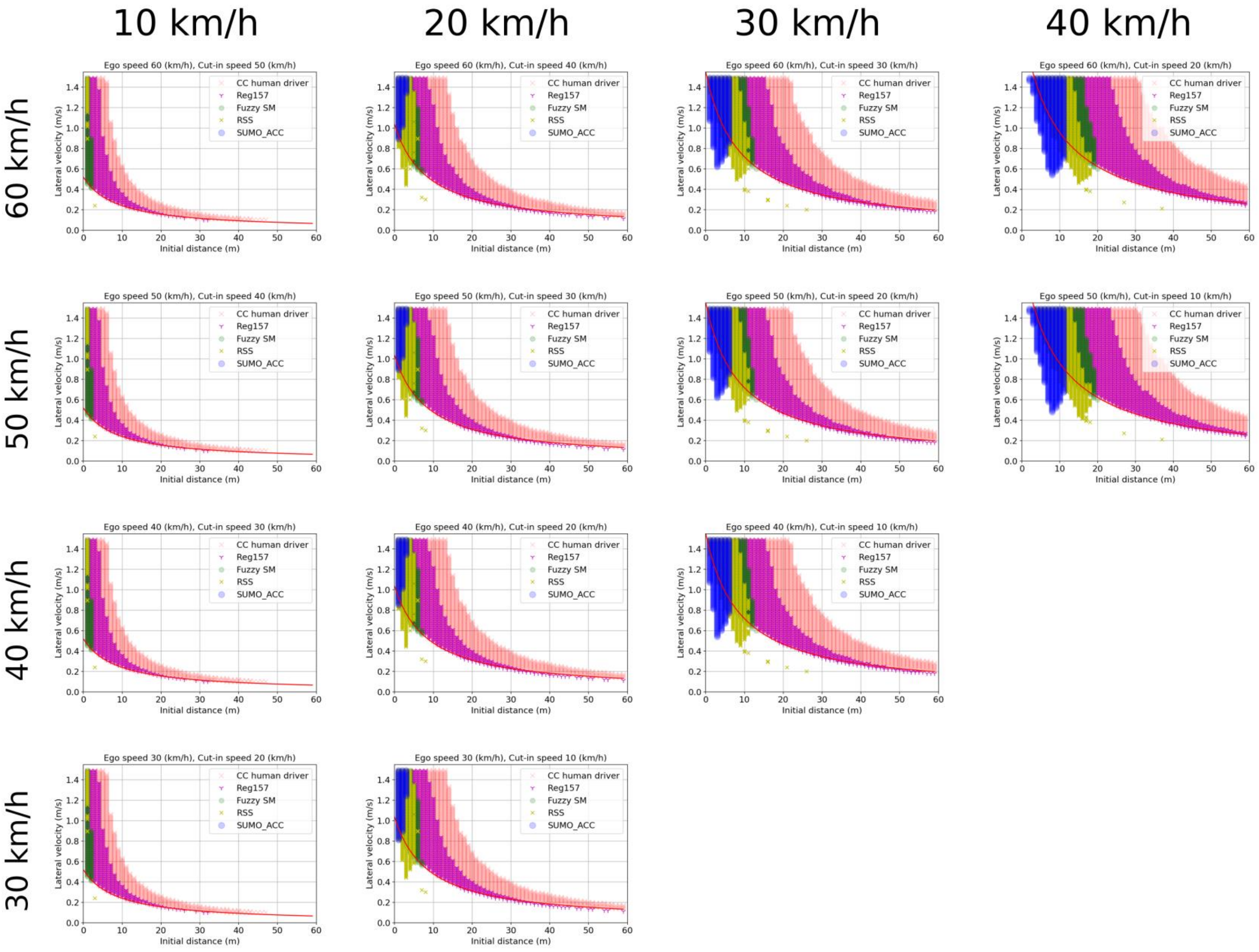
Driver model for the cut-in scenario



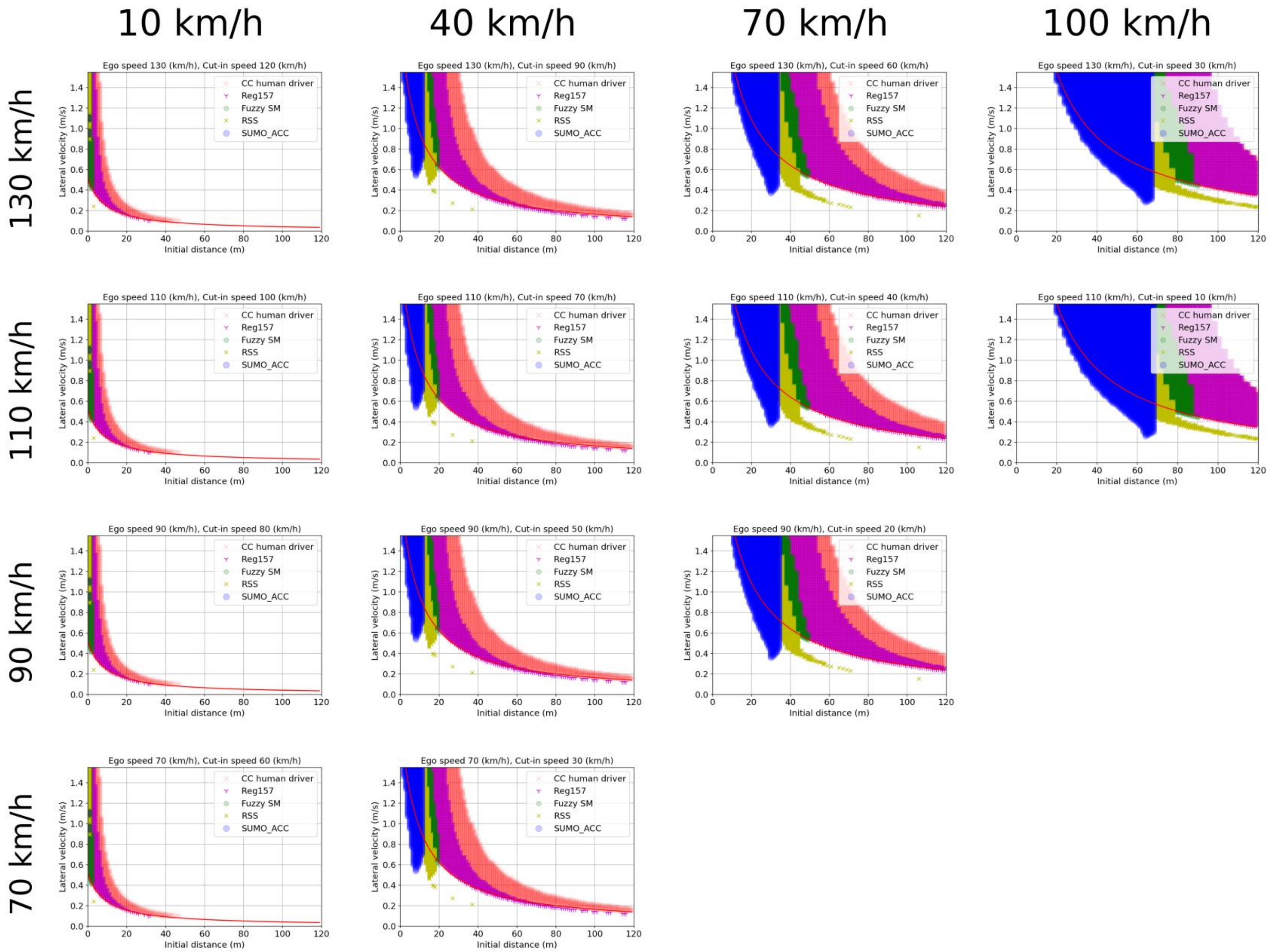
source: R157, Fig. 2, p.42

The red line…

- boundary between interupt backwards and side collision under the assumption, that both vehicles keep their speeds (no reaction!);
- ➔ connects initial distance d_{x0} (and speed difference Δv) determining overtaking time t_x to the time needed for the challenger to move lateral the distance d_y to tackle the ego from the side, t_y
- May write down an equation $t_x = t_y$, where $t_x = \ d_y/V_y$ and $t_x = (d_{x0} \ + \ell_c \ + \ell_e)/\Delta v$
- And then end up with: $V_y = \frac{d_y}{d_{x0}+\ell_c+\ell_e} \Delta v$;
- ➔ if lateral speed V_y is smaller than the expression on the r.h.s., then the challenger is too slow and ends up behind the ego.



10 km/h
20 km/h
30 km/h
40 km/h
60 km/h
50 km/h
40 km/h
30 km/h
Ego speed 60 (km/h), Cut-in speed 50 (km/h)
Ego speed 60 (km/h), Cut-in speed 40 (km/h)
Ego speed 60 (km/h), Cut-in speed 30 (km/h)
Ego speed 60 (km/h), Cut-in speed 20 (km/h)
Ego speed 50 (km/h), Cut-in speed 40 (km/h)
Ego speed 50 (km/h), Cut-in speed 30 (km/h)
Ego speed 50 (km/h), Cut-in speed 20 (km/h)
Ego speed 50 (km/h), Cut-in speed 10 (km/h)
Ego speed 40 (km/h), Cut-in speed 30 (km/h)
Ego speed 40 (km/h), Cut-in speed 20 (km/h)
Ego speed 40 (km/h), Cut-in speed 10 (km/h)
Ego speed 30 (km/h), Cut-in speed 20 (km/h)
Ego speed 30 (km/h), Cut-in speed 10 (km/h)
CC human driver
Reg157
Fuzzy SM
RSS
SUMO_ACC
Lateral velocity (m/s)
Initial distance (m)



10 km/h
40 km/h
70 km/h
100 km/h
130 km/h
110 km/h
90 km/h
70 km/h
Ego speed 130 (km/h), Cut-in speed 120 (km/h)
Ego speed 130 (km/h), Cut-in speed 90 (km/h)
Ego speed 130 (km/h), Cut-in speed 60 (km/h)
Ego speed 130 (km/h), Cut-in speed 30 (km/h)
Ego speed 110 (km/h), Cut-in speed 100 (km/h)
Ego speed 110 (km/h), Cut-in speed 70 (km/h)
Ego speed 110 (km/h), Cut-in speed 40 (km/h)
Ego speed 110 (km/h), Cut-in speed 10 (km/h)
Ego speed 90 (km/h), Cut-in speed 80 (km/h)
Ego speed 90 (km/h), Cut-in speed 50 (km/h)
Ego speed 90 (km/h), Cut-in speed 20 (km/h)
Ego speed 70 (km/h), Cut-in speed 60 (km/h)
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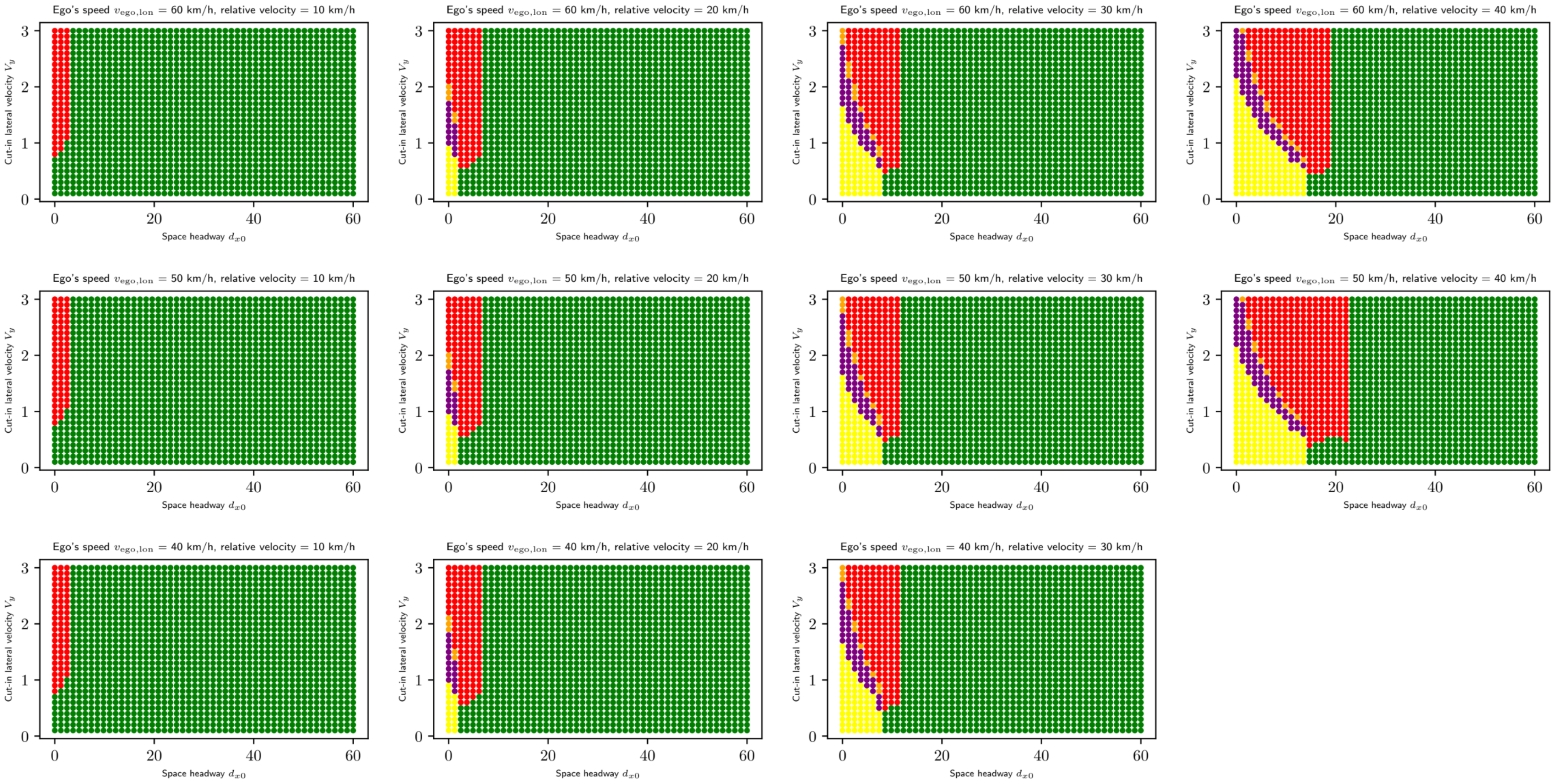
Lateral velocity (m/s)
Initial distance (m)


Ego's speed $v_{\mathrm{ego,lon}}$ = 60 km/h, relative velocity = 10 km/h
Ego's speed $v_{\mathrm{ego,lon}}$ = 60 km/h, relative velocity = 20 km/h
Ego's speed $v_{\mathrm{ego,lon}}$ = 60 km/h, relative velocity = 30 km/h
Ego's speed $v_{\mathrm{ego,lon}}$ = 60 km/h, relative velocity = 40 km/h
Ego's speed $v_{\mathrm{ego,lon}}$ = 50 km/h, relative velocity = 10 km/h
Ego's speed $v_{\mathrm{ego,lon}}$ = 50 km/h, relative velocity = 20 km/h
Ego's speed $v_{\mathrm{ego,lon}}$ = 50 km/h, relative velocity = 30 km/h
Ego's speed $v_{\mathrm{ego,lon}}$ = 50 km/h, relative velocity = 40 km/h
Ego's speed $v_{\mathrm{ego,lon}}$ = 40 km/h, relative velocity = 10 km/h
Ego's speed $v_{\mathrm{ego,lon}}$ = 40 km/h, relative velocity = 20 km/h
Ego's speed $v_{\mathrm{ego,lon}}$ = 40 km/h, relative velocity = 30 km/h
Cut-in lateral velocity V_y
Space headway d_{x0}