PTV GROUP

the mind of movement

ANALYSIS OF SHOCKWAVES ON MOTORWAYS AND POSSIBILITY OF DAMPING BY HIGHLY AUTOMATED VEHICLES

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AGENDA

1. Definition of Shockwaves
2. Charactristics of Shockwaves
3. Software Environment and Calibration Process
4. Highly Automated Vehicles
5. Results
6. Evaluation Framework
7. Conclusions

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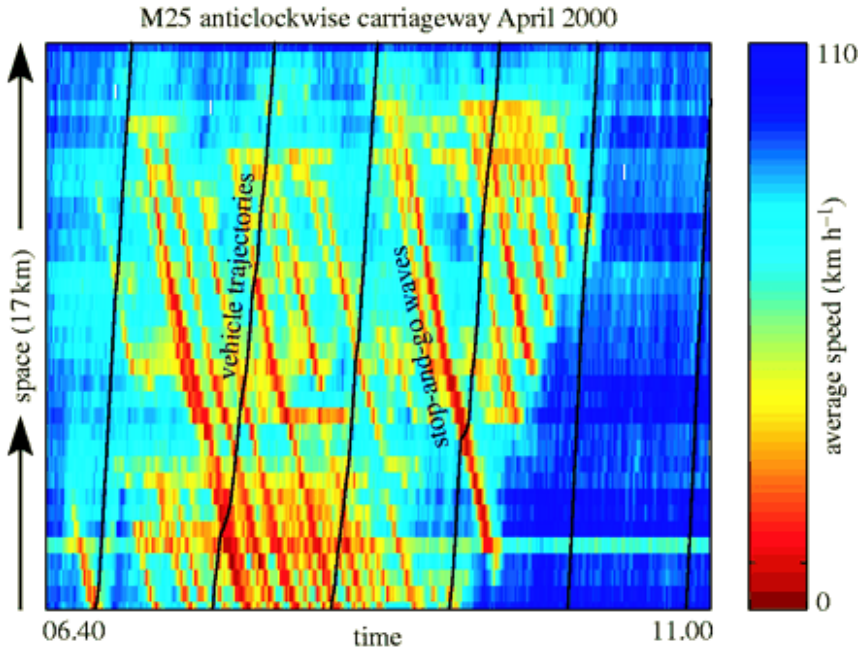
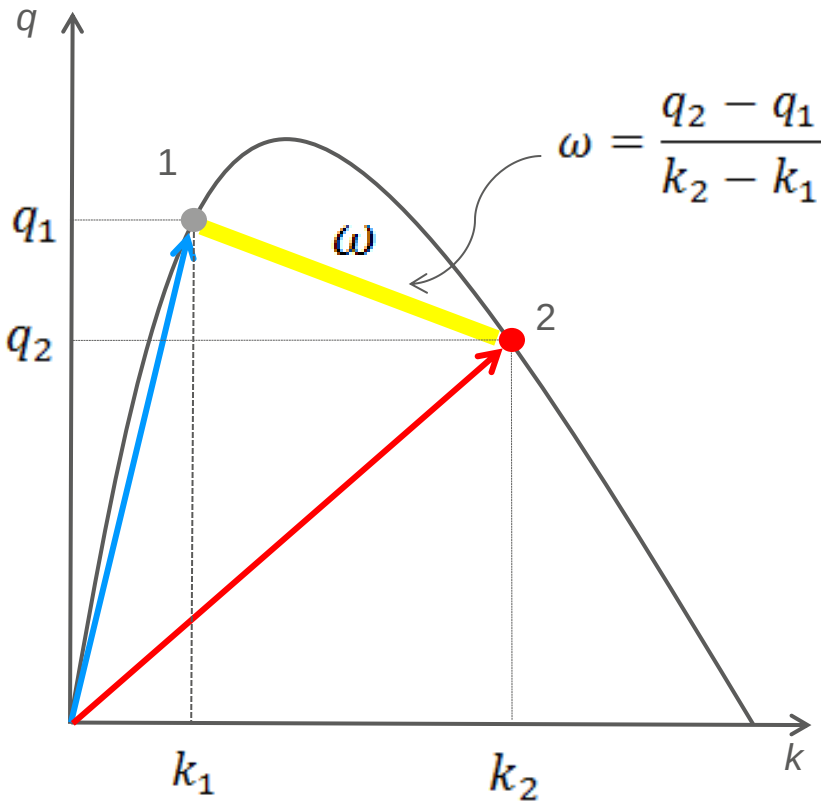
DEFINITION OF SHOCKWAVES

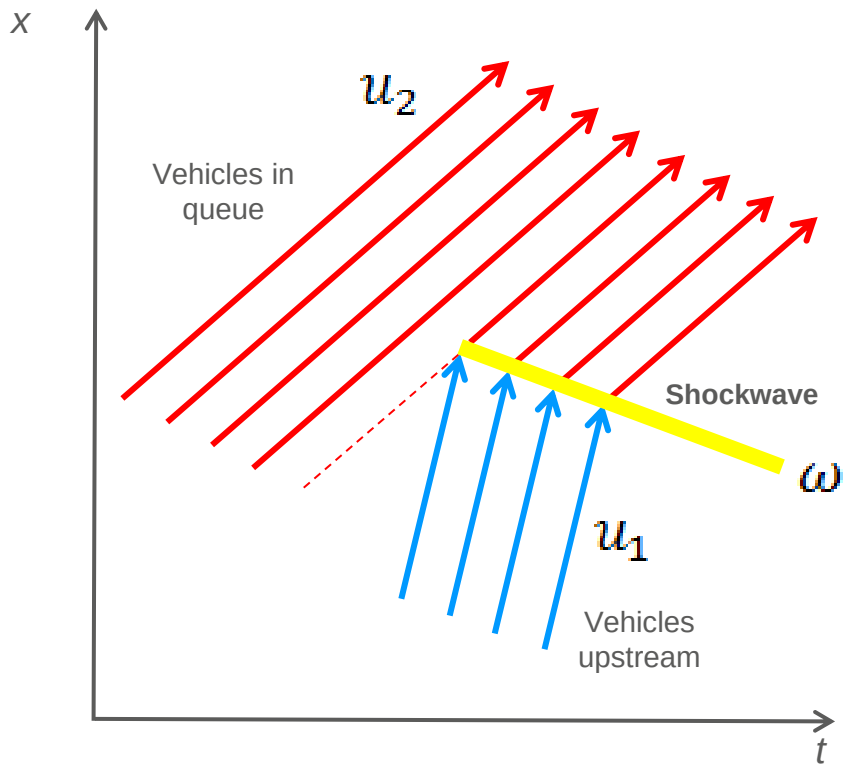
- A boundry in traffic stream that demarks a discontinuity in flow-density domain
- Points in space and time at which vehicles change their speed abruptly



http://rsta.royalsocietypublishing.org/content/366/1872/2017

SPEED OF SHOCKWAVE

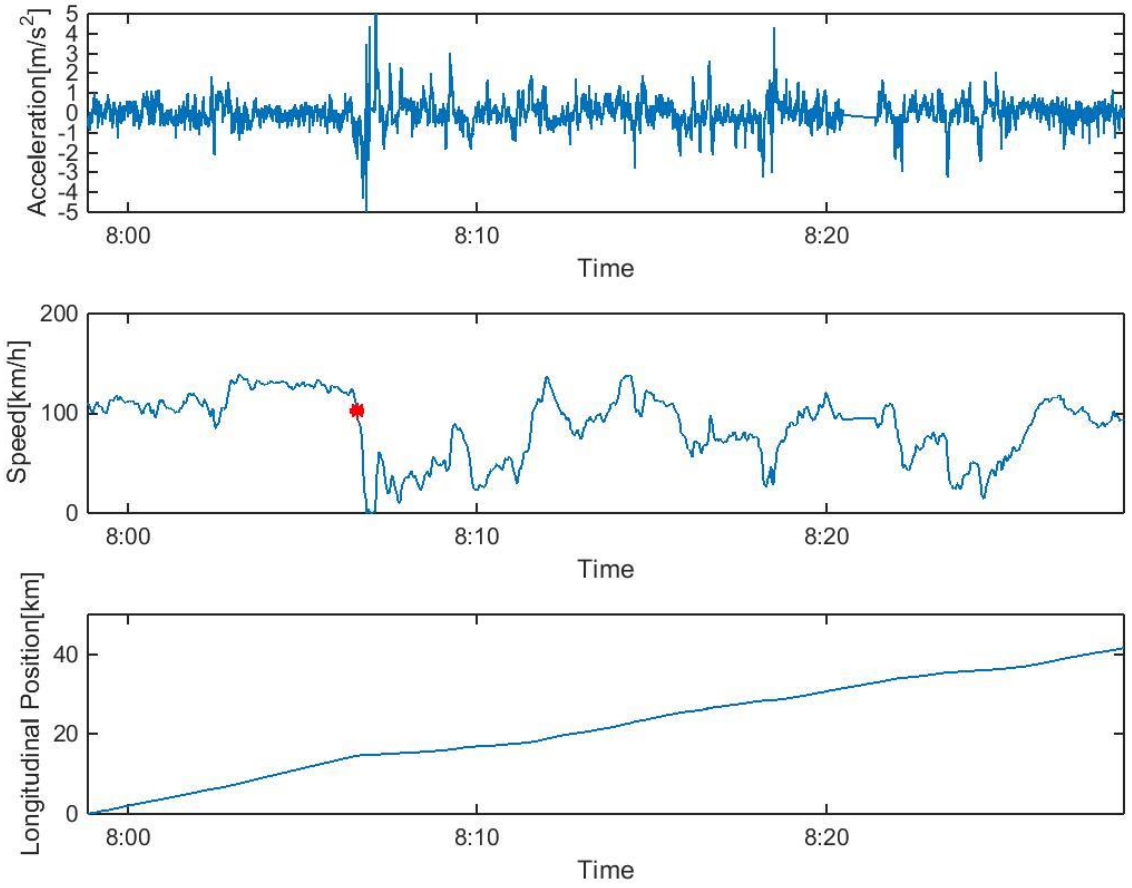




SIM^{TD} PROJECT

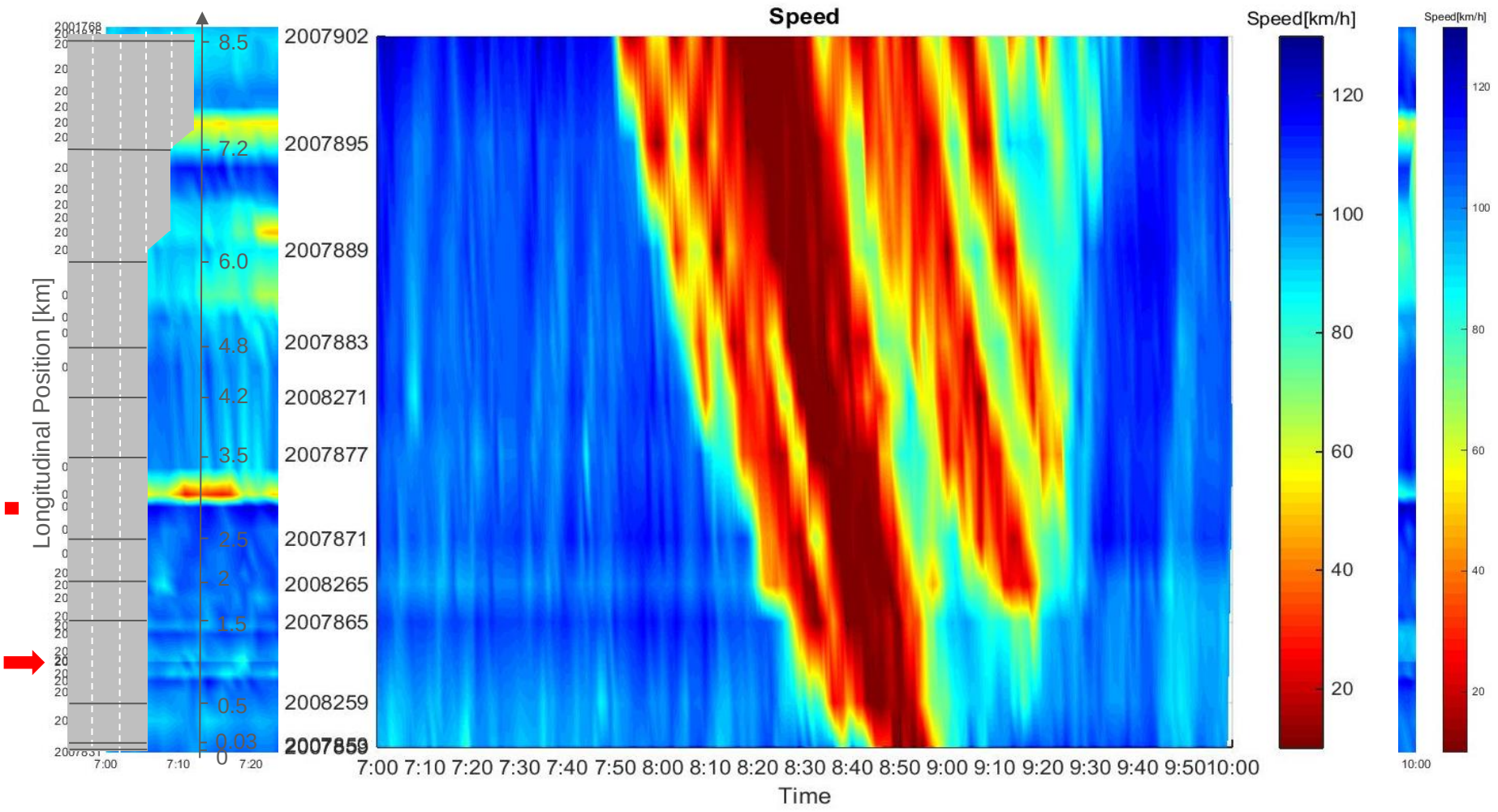
www.simtd.de

MICROSCOPIC CHARCTRISTICS OF SHOCKWAVES



Trajectory vehicle #500 on 28.11.2012

MACROSCOPIC CHARACTRISTICS OF SHOCKWAVES

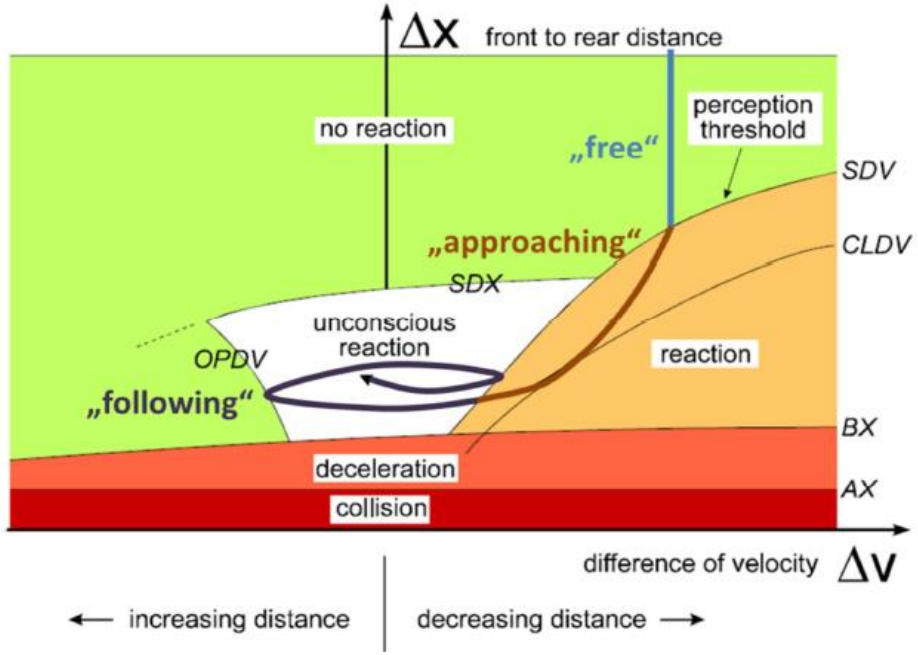


Space-time A5 South

MODEL ENVIRONMENT

Simulation Software: PTV Vissim 7

Psycho-physical car following model



Car following logic and driving states (Vissim Manual,2013)

Wiedemann 99:

$$ABX = AX + (bx_{add} + bx_{mult} * z) * \sqrt{v}$$

ABX: Minimum desired following distance

CC0: Desired rear bumper to front bumper distance between stopped cars

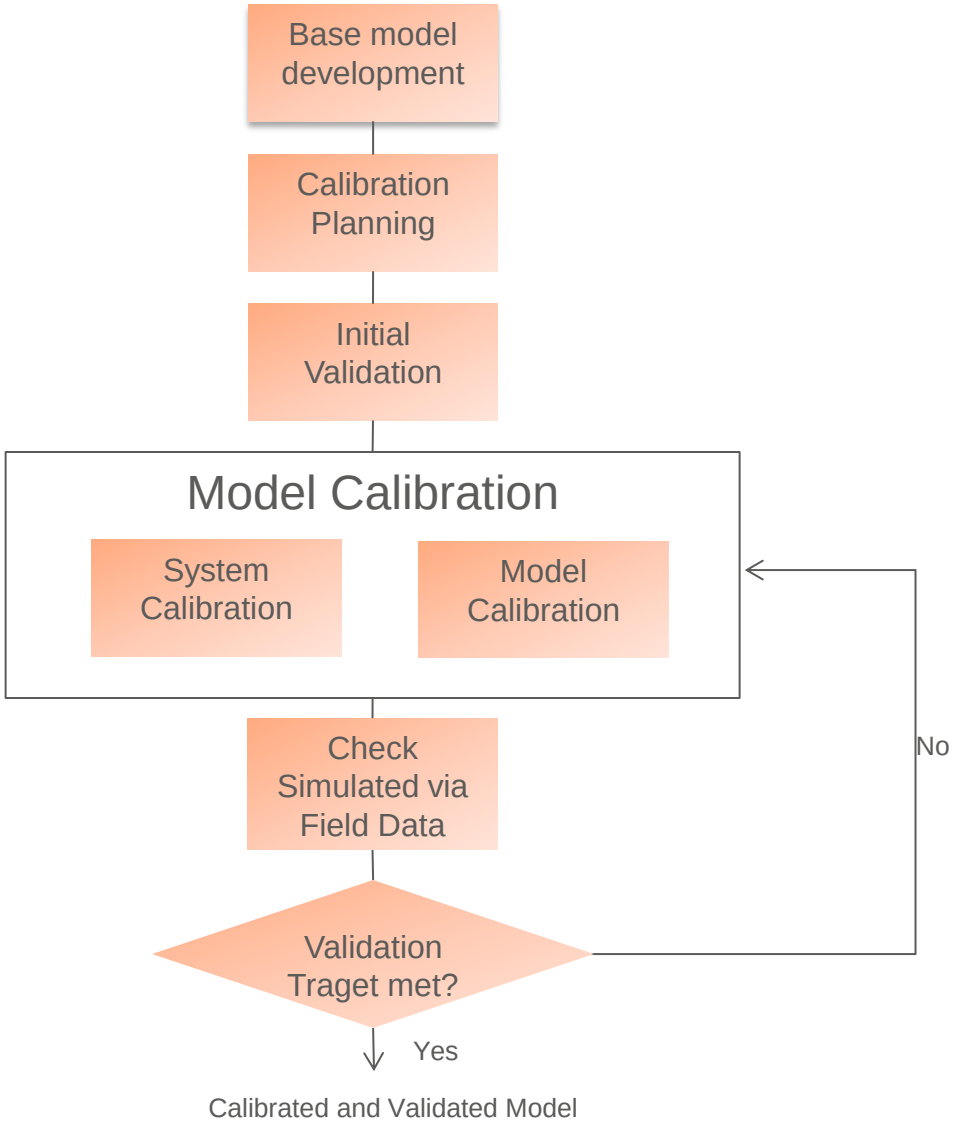
CC1: Time (in seconds) that the following driver wishes to maintain a certain speed

v: Speed of the slower vehicle [m/s]

z: A value of range [0,1], which is normally distributed around 0.5 m with a standard deviation of 0.15 m

AX: Average desired distance between two cars in a standstill condition.

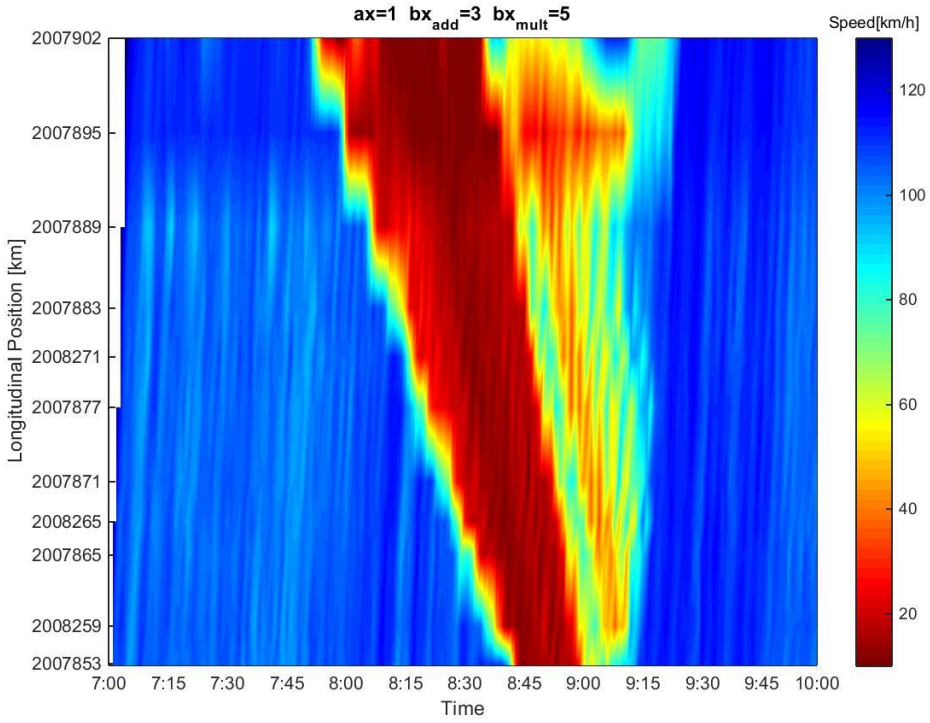
CALIBRATION PROCESS



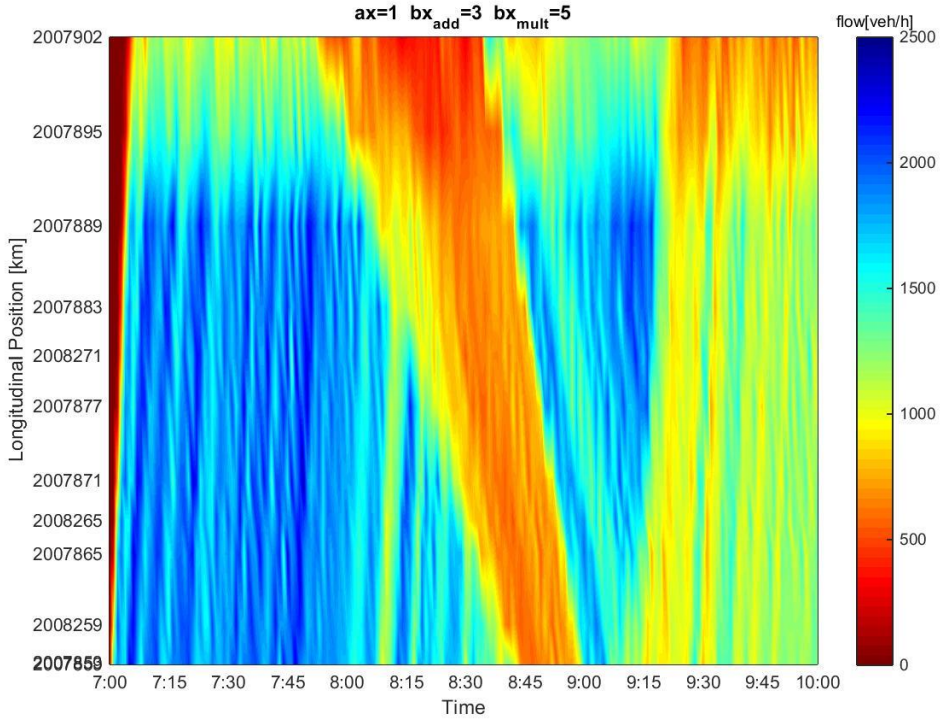
CALIBRATION RESULT

Parameter set with minimum root-mean-square deviation:
ax=1 bx_{add}=3 bx_{mult}=5

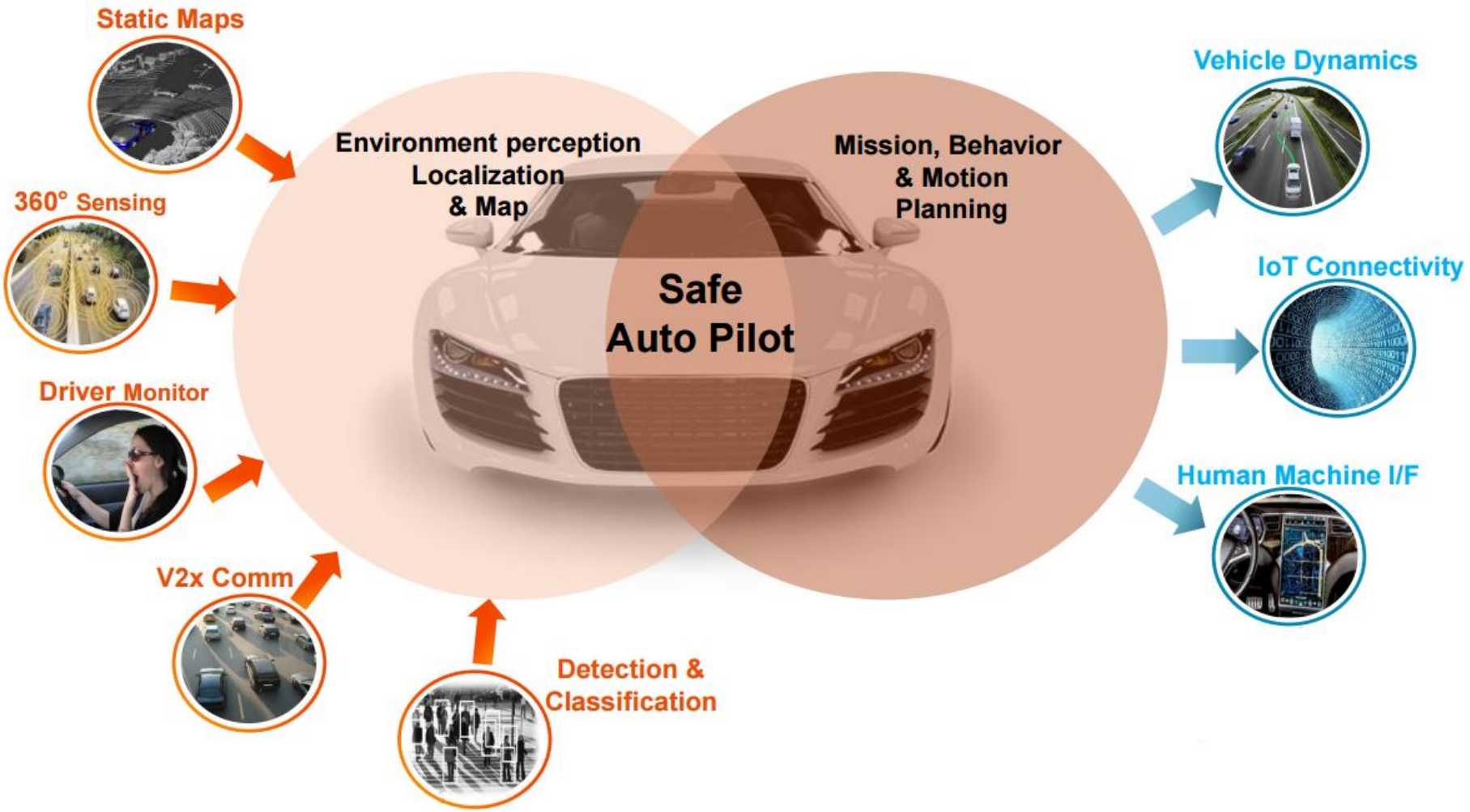
Speeds



Flows



HIGHLY AUTOMATED DRIVING



HIGHLY AUTOMATED VEHICLES

Simulation Parameters:

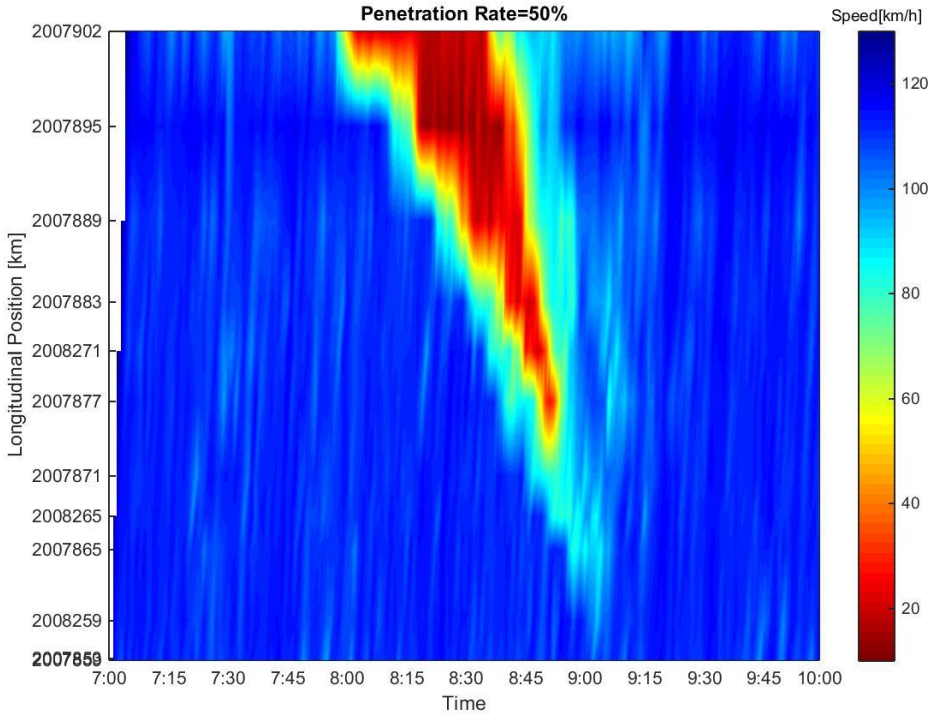
- Homogenous driving behavior
- Shorter headways than conventional vehicles
- Shorter reaction time to acceleration and deceleration
- Higher desired acceleration and lower desired deceleration
- More cooperative in lane changing

http://next.mercedes-benz.com/

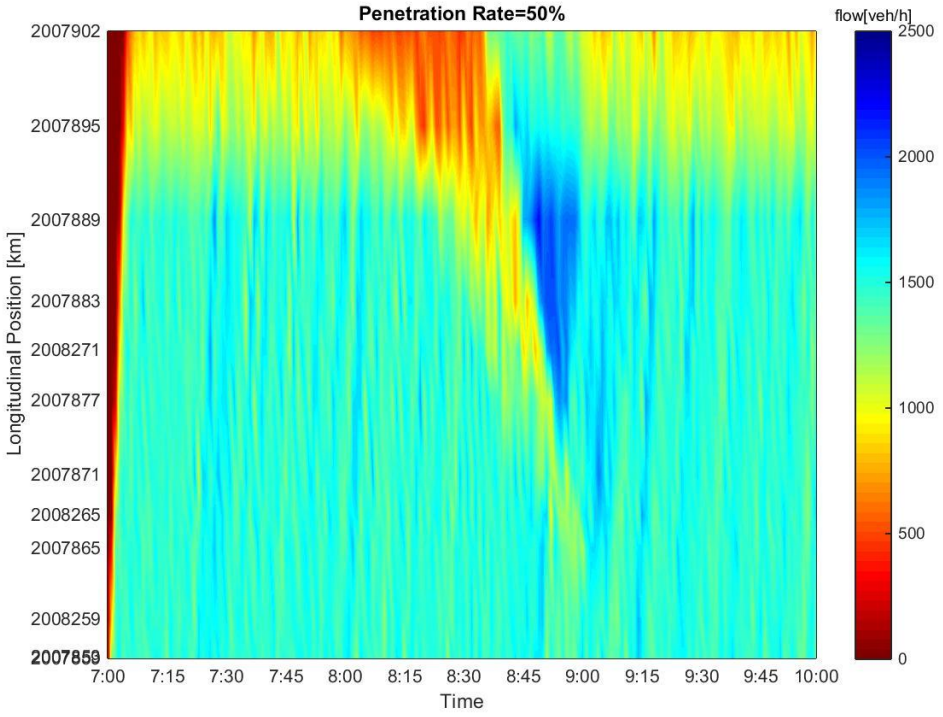
RESULT: AUTONOMOUS DRIVING

- Penetration rate of 50%

Speeds



Flows



EVALUATION FRAMEWORK

Network Indicator

I. Average Network Speed

1. $$V_k = \frac{\sum_{i=1}^{180} Speed_i * flow_i}{\sum_{i=1}^{180} flow_i}$$

2. $$V_{network} = \frac{\sum_{k=1}^{12} V_k}{12}$$

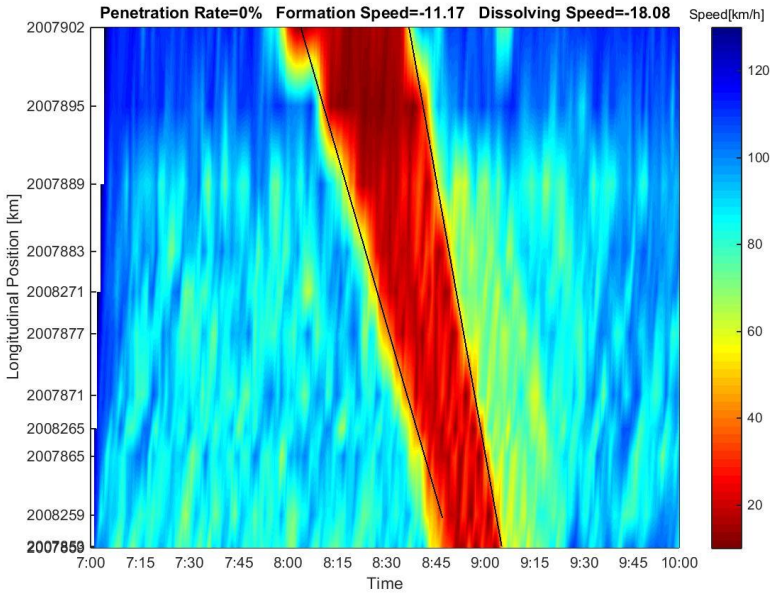
V_k	Weighted average of the detector
i	Minute from the beginning of simulation
$Speed_i$	Speed recorded by detector k at the minute i
$flow_i$	Flow recorded by detector k at the minute i

EVALUATION FRAMEWORK

Shockwave Indicator

I. Propagation Speed: Detection of upstream front of congestion

II. Dissolving Speed: Detection of downstream front of congestion



PERFORMANCE: AVERAGE NETWORK SPEED

Penetration Rate	Average Speed [km/h]	Percentage Change
0 %	83.22	-
5 %	84.10	1.1 %
10 %	85.92	3.2 %
20 %	90.76	9.1 %
50 %	105.60	26.9 %
100 %	112.30	34.9 %

PERFORMANCE: PROPAGATION SPEED

Penetration Rate	Shockwave Propagation Speed [km/h]	Percentage Change
0 %	-11.17	-
5 %	-10.49	-6.1 %
10 %	-10.17	-9.0 %
20 %	-8.78	-21.4 %
50 %	-6.26	-44.0 %
100 %	-4.81	-56.9 %

CONCLUSIONS

- Possibility of simulation of the HAVs within the fleet and observe their effect on traffic flow in different traffic situations
- As the penetration rate exceeds 20 %, considerable changes can be observed
- Higher penetration rates lead to the suppression of shockwaves
- The dissolving speed of the congestion was not adressed by highly automated vehicles

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