Technical & Traffic Results
Motorway Chauffeur

L3Pilot Final Event

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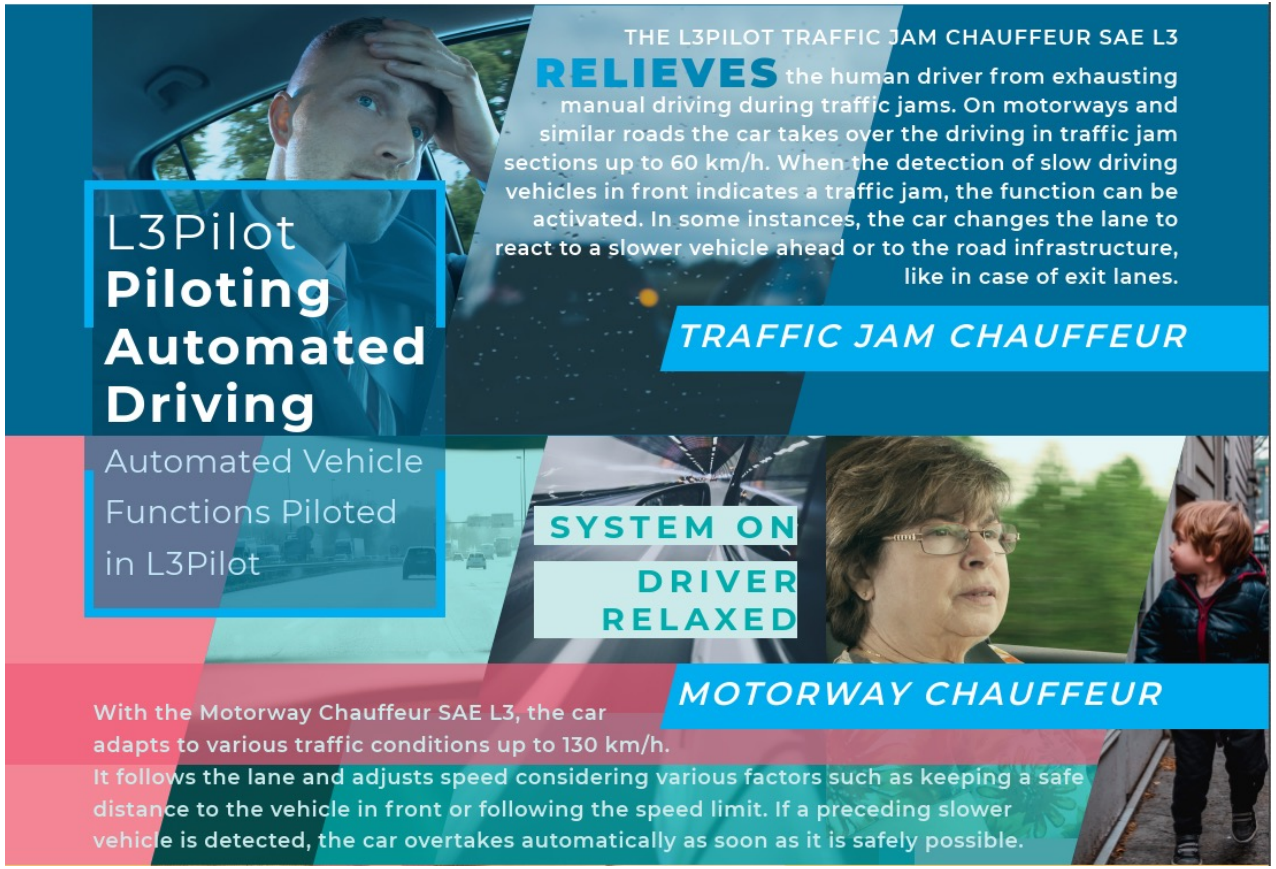
WIVW GmbH



Motorway chauffeur is also called motorway ADF.

Motorway - Database

Trip based information

N=5,276 trip sections

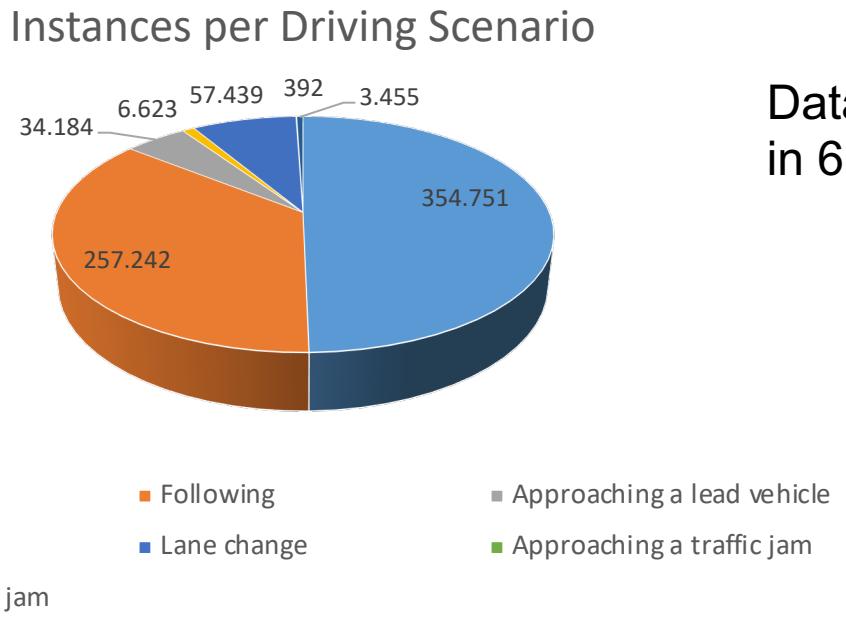
Filtering of short trips:
min(duration)=5 min
N=4,198 trip sections

Scenario based information

N=719,362 driving scenarios

Filtering of too short scenarios:
For most scenarios min(duration)=2 sec
N=605,031 driving scenarios

Scenario database



Data from 11 pilot sites in 6 countries

List of research questions - selection

Research question	Main indicator
What is the impact on longitudinal vehicle dynamics?	Longitudinal acceleration (ax)
What is the impact on lateral vehicle dynamics?	Lateral acceleration (ay)
What is the impact on lane keeping?	Position in lane
What is the impact on the driven speed?	Speed (v)
What is the impact on the frequency of driving scenarios?	Frequency of driving scenarios
What is the impact on car following behaviour?	Time-headway, time-to-collision

Detailed results for all research questions can be found in D7.3

Presented analysis

This presentation focuses on scenario based indicators.

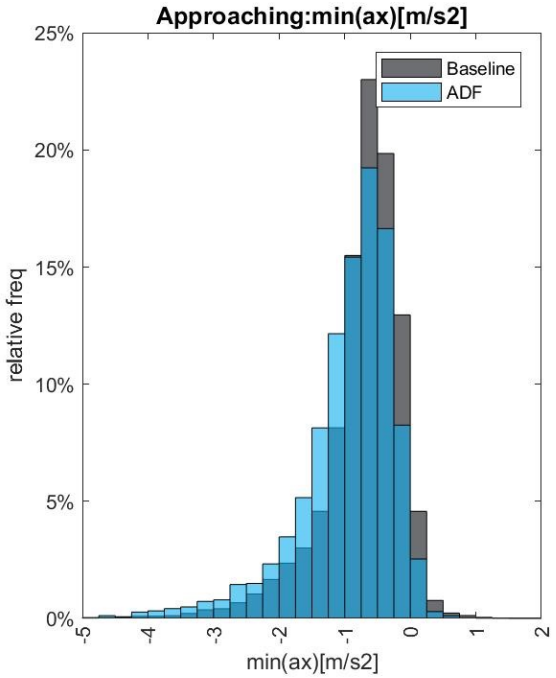
Per scenario type and indicator,

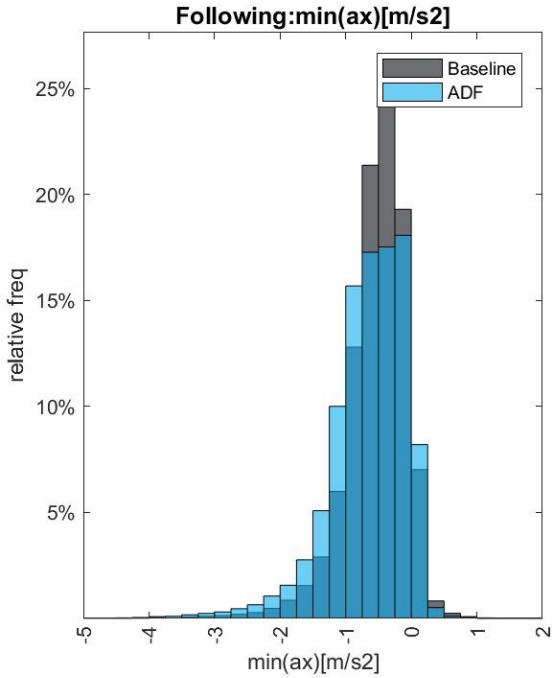
- driving behaviour while driving with the ADF active is compared to baseline driving.
- This is done with non-parametrical Mann-Whitney-U tests.

Results are presented based

- on histograms and
- information on effect sizes (Cohen's D.
- For non-significant effects, effect sizes are set to zero.

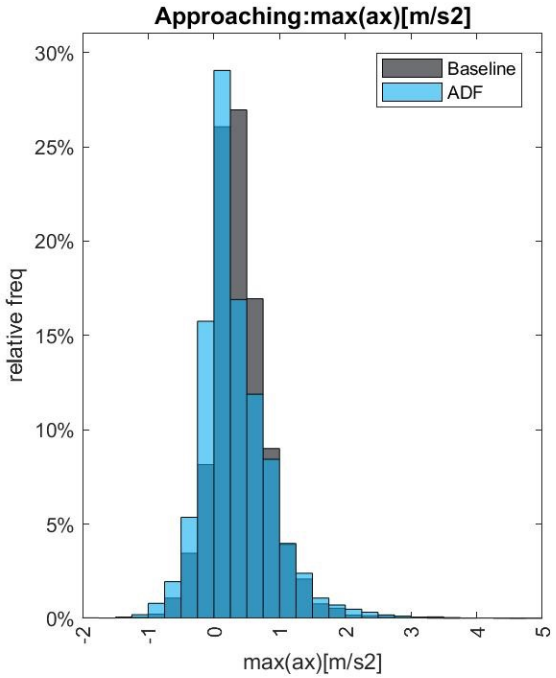
What is the impact on longitudinal vehicle dynamics? Minimum longitudinal acceleration

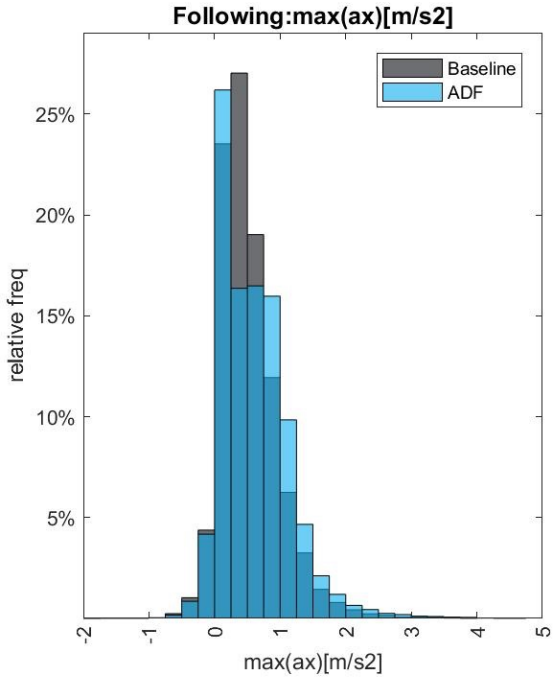




During following and approaching the ADF decelerates more than a manual driver.

What is the impact on longitudinal vehicle dynamics? Maximum longitudinal acceleration





During following the ADF accelerates more, during approaching less than a manual driver.

What is the impact on longitudinal vehicle dynamics? Overview effect sizes

Research question	Performance indicator	Uninfluenced driving	Following	Approaching lead vehicle	Cut-In	Lane change	Approaching traffic jam	Driving in traffic jam
What is the impact on longitudinal vehicle dynamics?	min(ax)	0.09	-0.22	-0.30	-0.29	-0.16	0.35	0.21
	max(ax)	-0.21	0.15	-0.14	-0.08	-0.37	0	-0.73
	sd(ax)	-0.21	0.18	0.18	0.25	-0.04	-0.34	0

In most scenarios, the ADF decelerates more strongly than during manual driving.

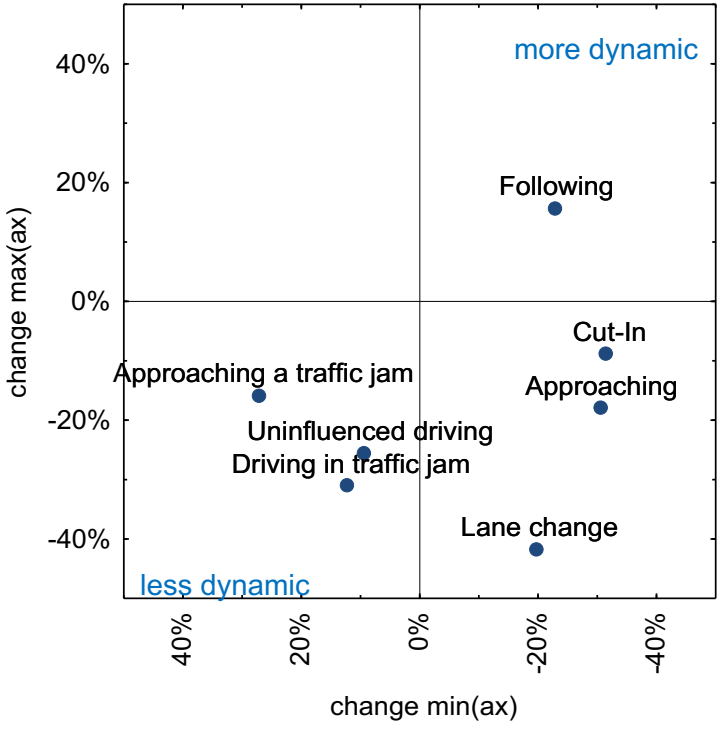
In most scenarios, the ADF accelerates less strongly than during manual driving.

As a consequence, results on the variation of longitudinal acceleration are mixed.

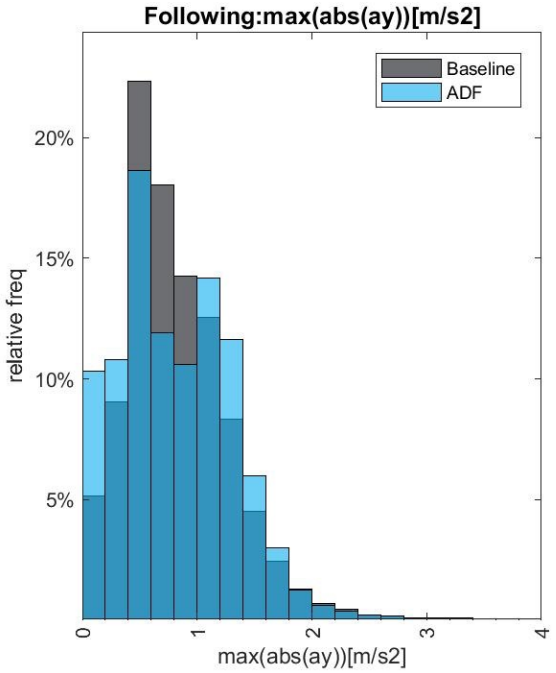
What is the impact on longitudinal vehicle dynamics?

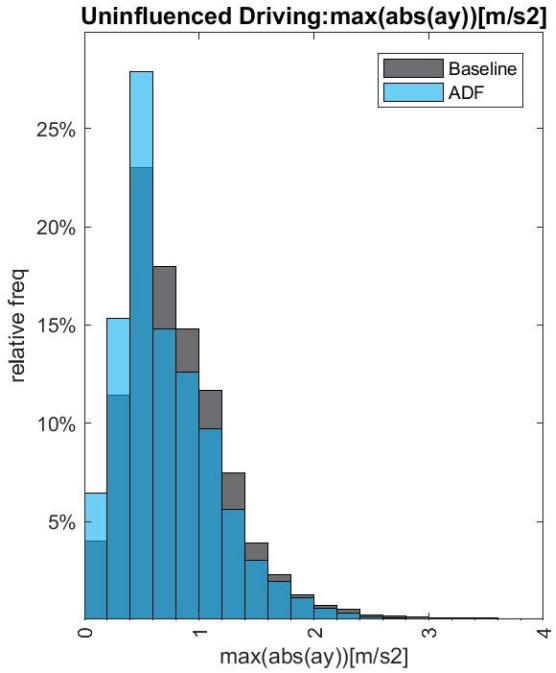
The results on vehicle dynamics are mixed:

- With ADF, the vehicle **accelerates** less strongly during all scenarios except following.
- For **deceleration** results are mixed.
- For more dynamic scenarios (cut-in, approaching, lane change), ADF **decelerates** more strongly than manual drivers.



What is the impact on lateral vehicle dynamics? Maximum absolute lateral acceleration





During following and uninfluenced driving, lateral dynamics are reduced while driving with the ADF.

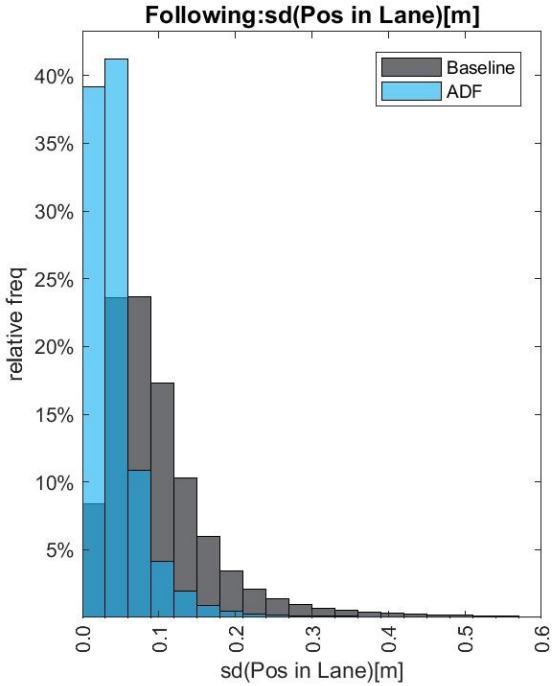
What is the impact on lateral vehicle dynamics? Overview effect sizes

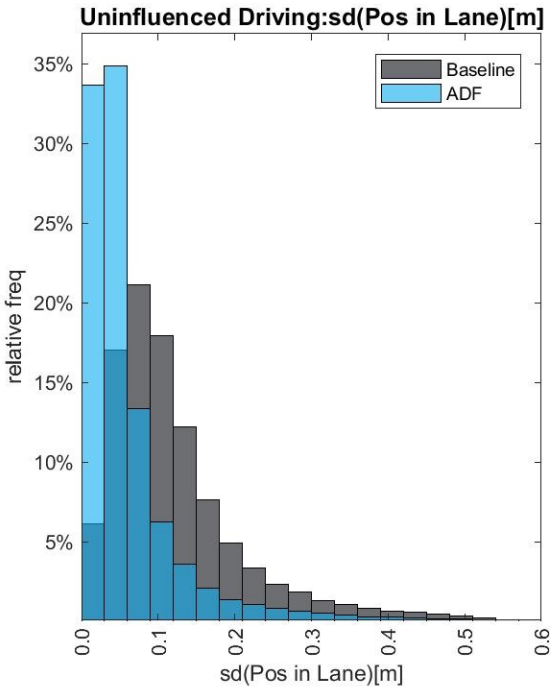
Research question	Performance indicator	Uninfluenced driving	Following	Approaching lead vehicle	Cut-In	Lane change	Approaching traffic jam	Driving in traffic jam
What is the impact on lateral vehicle dynamics	max(abs(ay))	-0.14	0.00	-0.21	-0.39	0.18	0	-0.39
	sd(ay)	-0.15	0.12	-0.17	-0.44	0.29	0	-0.34

In all scenarios except lane changes, lateral acceleration is reduced while driving with the ADF.

The variation of lateral acceleration is mostly reduced while driving with the ADF.

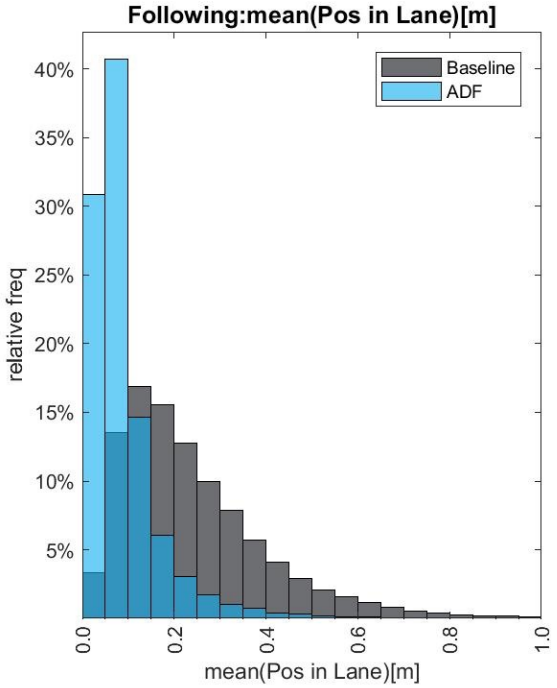
What is the impact on lane keeping?
Standard deviation of lane position

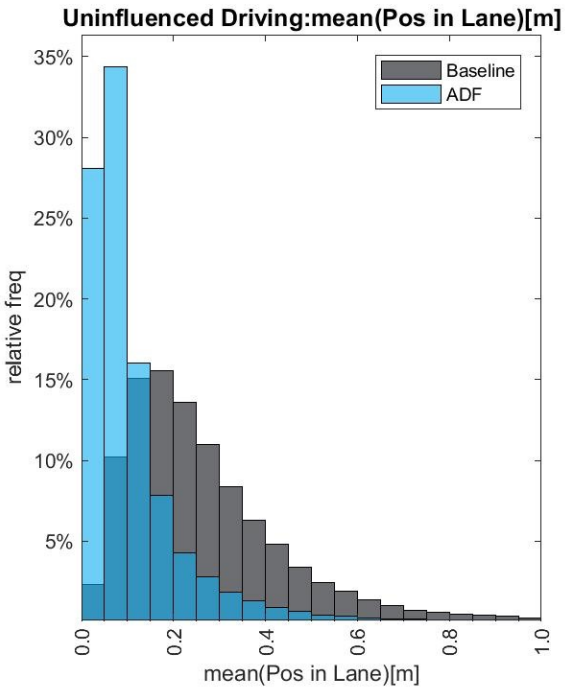




During following and uninfluenced driving, the vehicle moves less in its lane while driving with the ADF.

What is the impact on lane keeping?
Average position in lane





During following and uninfluenced driving, the vehicle drives closer to the lane centre while driving with the ADF.

What is the impact on lane keeping?
Overview effect sizes

Research question	Performance indicator	Uninfluenced driving	Following	Approaching lead vehicle	Cut-In	Lane change	Approaching traffic jam	Driving in traffic jam
What is the impact on lane keeping?	m(lat Pos)	-0.94	-1.28	-0.76	-1.16		-1.19	-0.10
	sd(lat Pos)	-0.71	-0.94	-0.60	-0.68		-0.46	-0.32

With ADF, there is less variation in the lane and average position is closer to the centre of the lane. This is stable across scenarios.

Across scenarios, both indicators show large effect sizes. The difference between ADF and baseline is about 50% of baseline values.

What is the impact on driven speed?
Challenge

Challenge:

Driven speed is strongly impacted by speed limit

Speed limit is linked to region / test site

- Analysis per speed limit would reduce size of database and split data per test site / region

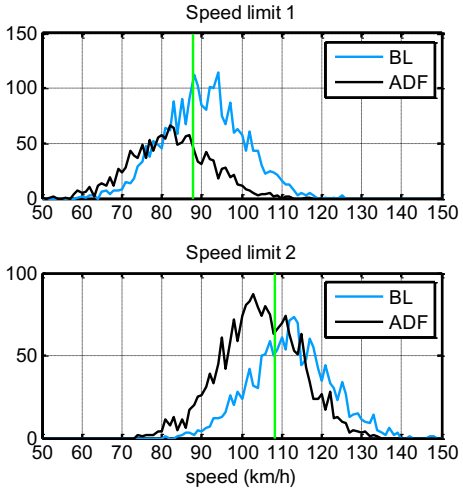
Solution:

Standardisation of measured speed per speed limit

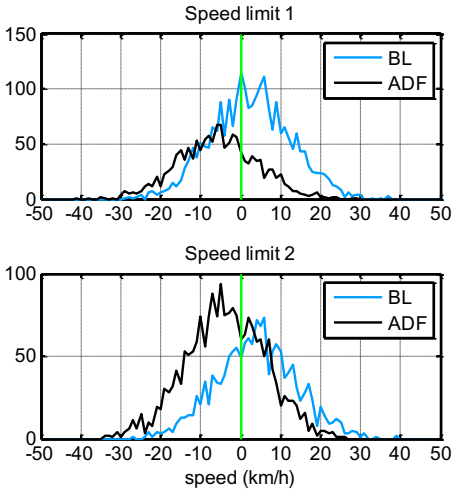
- Information on lag is removed from the data
- Information on shape of distribution and differences between conditions is kept

What is the impact of ADF on driven speed? Artificial example for standardization

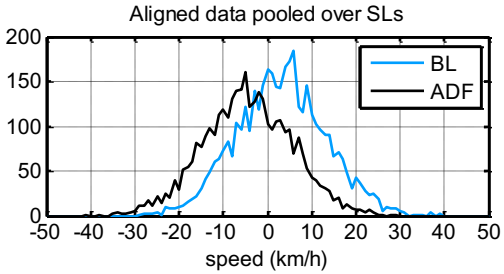
Data per SL
(medians = green line)



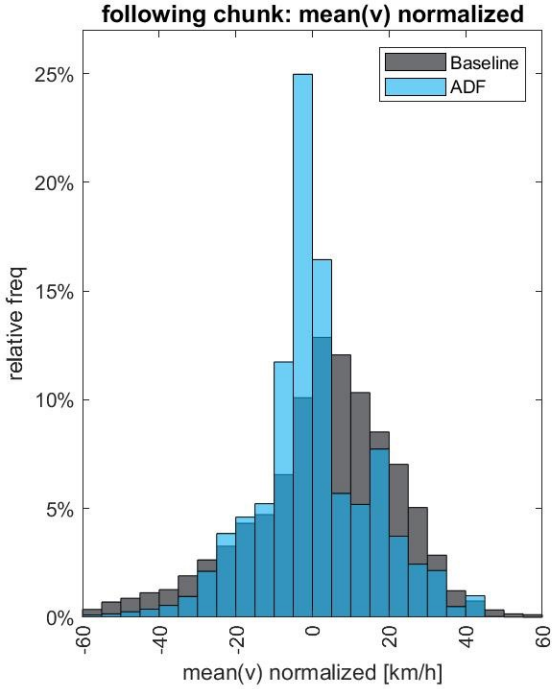
For each SL:
Align on medians

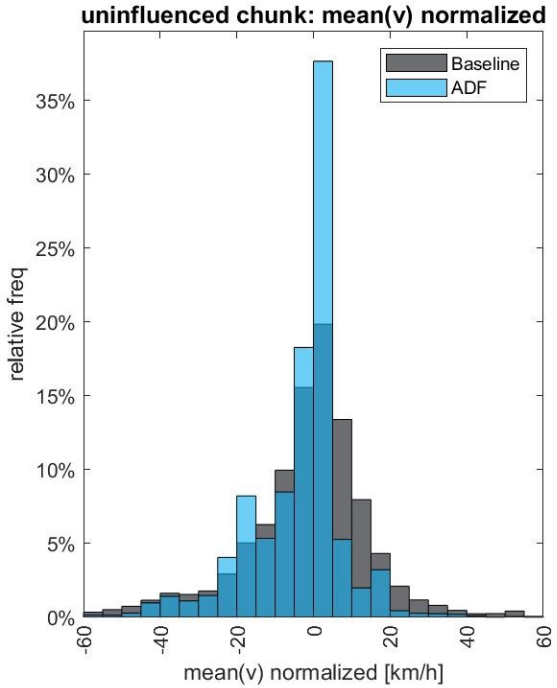


Pool aligned data
over all Speed Limits



What is the impact on driven speed?
Mean speed





During following and uninfluenced driving, average speed is reduced with ADF.

What is the impact on driven speed?
Overview effect sizes

Research question	Performance indicator	Uninfluenced driving	Following	Approaching lead vehicle	Cut-In	Lane change	Approaching traffic jam	Driving in traffic jam
What is the impact on speed?	m(v)	-0.12	-0.13	-0.26	-0.24		-0.25	0
	max(v)	-0.14	-0.15	-0.25	-0.20		-0.33	-0.41

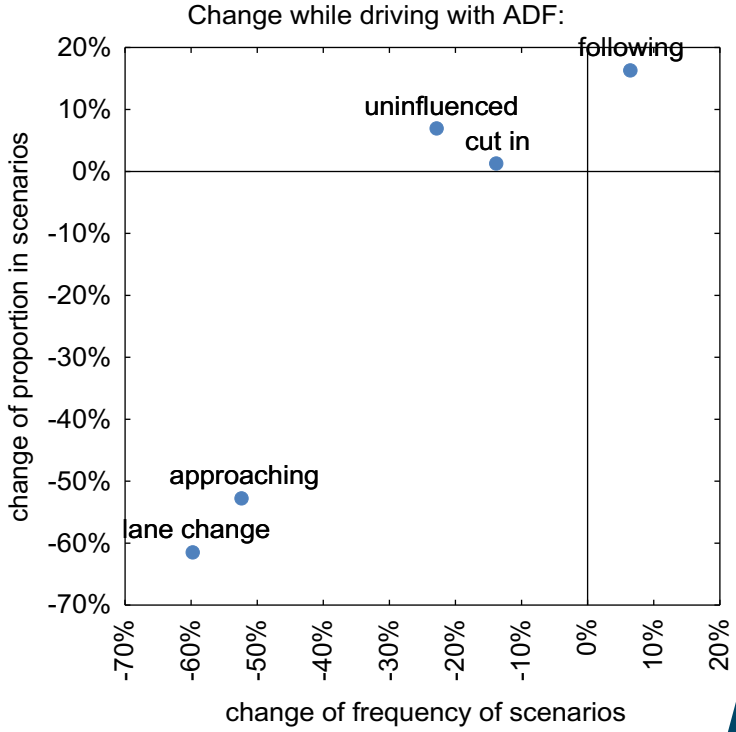
Across scenarios, speed decreases with ADF.

This is the case for average speed and for maximum speed.

What is the impact on the frequency of driving scenarios?

With ADF there is

- A reduction of lane changes by 60%
  - Here it has to be kept in mind that some of the tested ADFs did not support automated lane changes
- A reduction of approaching scenarios by more than 50%
- An increase of time spent in following & uninfluenced driving



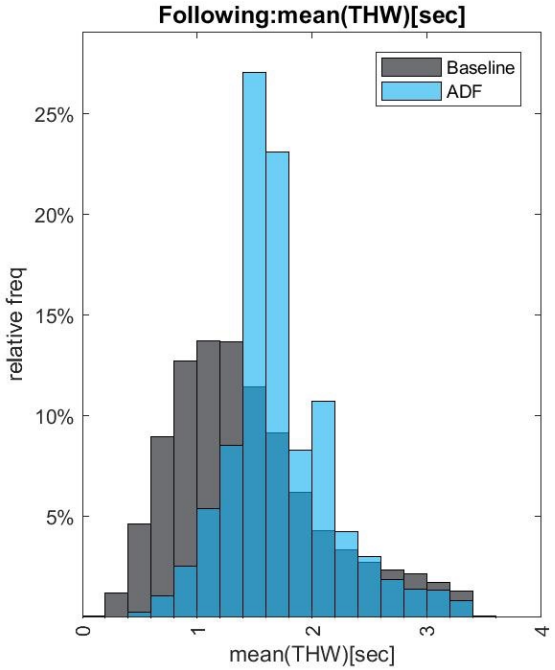
What is the impact on the frequency of certain events? Overview effect sizes

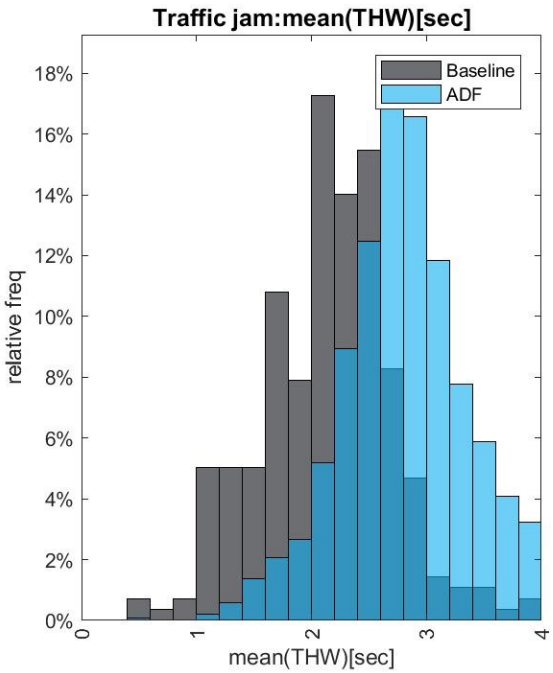
Research question	Performance indicator	Uninfluenced driving	Following	Approaching lead vehicle	Cut-In	Lane change	Approaching traffic jam	Driving in traffic jam
What is the impact on the frequency of events?	N(scenario/h)	-0.48	0.08	-1.01	-0.13	-1.08		
	%scenario	0.11	0.20	-0.94	0.01	-1.19		

With ADF, driving is less dynamic and more lane-bound.

Other than expected, cut ins are not more frequent with ADF.

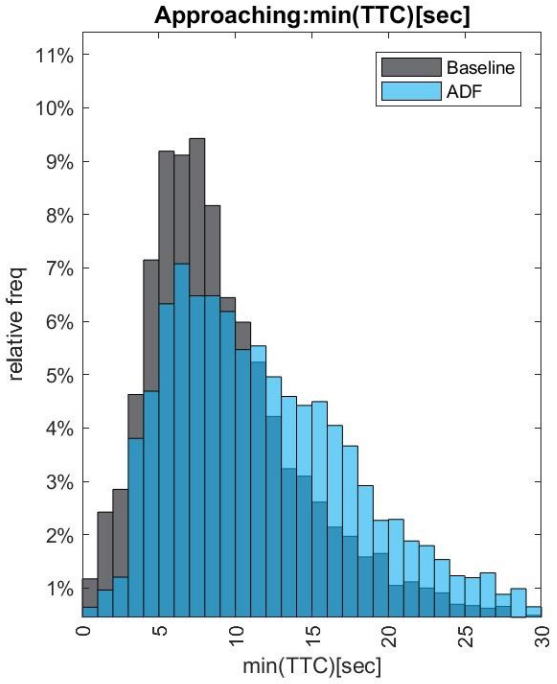
What is the impact on car following behaviour? Average time-headway

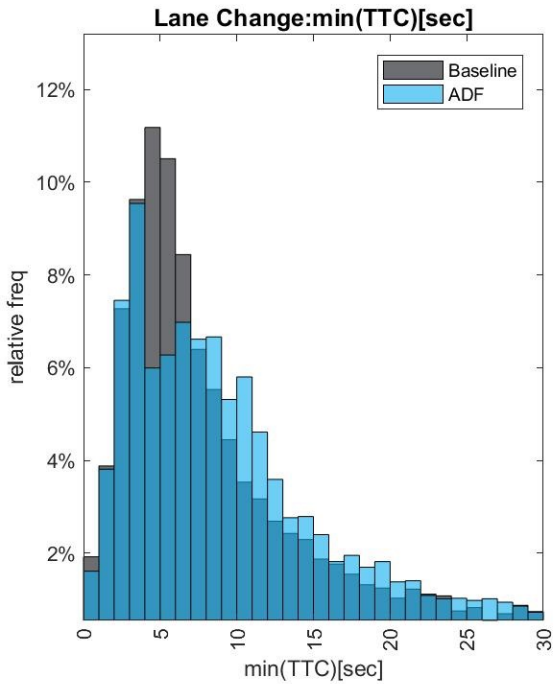




During following and in traffic jams, average time-headway is larger with the ADF.

RQ-T12: What is the impact on car following behaviour?





Across driving scenarios, minimum time-to-collision to the lead vehicle is larger while driving with the ADF.

RQ-T12: What is the impact on car following behaviour? Overview effect sizes

Research question	Performance indicator	Uninfluenced driving	Following	Approaching lead vehicle	Cut-In	Lane change	Approaching traffic jam	Driving in traffic jam
What is the impact on the distance to the lead vehicle?	m(THW)		0.53					0.66
	min(THW)		0.51	0.54	0.17	0.33	0.40	0.34
	min(TTC)		0.49	0.30	0.26	0.08	0.41	0.41

With ADF, distance to the lead vehicle is increased.

This is stable across scenarios.

List of research questions - Summary

Research question	Result
What is the impact on longitudinal vehicle dynamics?	Results on longitudinal dynamics are mixed across driving scenarios
What is the impact on lateral vehicle dynamics?	During most scenarios lateral dynamics are reduced with the ADF.
What is the impact on lane keeping?	Lane keeping is more stable with the ADF.
What is the impact on the driven speed?	With the ADF, speed is lower.
What is the impact on the frequency of driving scenarios?	With the ADF, there are less lane changes and the vehicles is approaching other vehicles less often.
What is the impact on car following behaviour?	With ADF, distances to the lead vehicle are larger.

Conclusions

Results are derived from a large database, using data

- from 11 motorway ADFs
- collected in 6 European countries under varying conditions.

Overall, results indicate a safer driving style while driving with the ADF.

Across scenarios, with ADF

- Distances to the lead vehicle increase
- Lane keeping becomes more stable
- Speed decreases

Driving with the ADF seems to be more lane-bound (at least for the tested ADFs).

Results on vehicle dynamics are mixed between driving scenarios.

Thank you for your kind attention.

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